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The Fauna and Geography of the Maldive and Laccadive Archipelagoes

Being the Account of the Work carried on and of the Collections made by an Expedition during the years 1899 and 1900

Edited by

J. STANLEY GARDINER, M.A.

Fellow of Gonville and Caius College and late Balfour Student of the University of Cambridge.

VOLUME I. PART II.

With Plates VI—XIII and Text-Illustrations 24—40

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Reports.

Reports.

AMPHIBIA AND REPTILIA.

By F. F. Laidlaw, B.A. (Cantab.), *Demonstrator in Zoology at the Owens College, Manchester.*

With the single exception of *Lygosoma albopunctatum* every specimen contained in the collection belongs to a species which is abundant in Ceylon and in many cases through the Oriental region (e.g. *Hemidactylus frenatus*, *Typhlops braminus* and *Rana tigrina*). *Lygosoma albopunctatum* has not so far as I am aware been recorded from Ceylon. One or two species are characteristic Singhalese forms, viz. *Aspidura trachyprocta* and *Nicoria trijuga*. It is evident then that the reptilian fauna of these islands shows the closest connection with the fauna of Ceylon, and this is what one would expect, when the political and commercial dependence of these islands upon Ceylon is taken into consideration[1].

I have not been able to compare the specimens of *Bufo melanostictus* with a series from elsewhere. The differences between the two varieties, spoken of below (p. 120), though slight are yet sufficiently well-marked to attract attention.

So far as I can discover no account has hitherto been given of the herpetological fauna of the two archipelagoes. In the following list I have referred only to Boulenger's British Museum Catalogues, but another account of all the species may be found in the same author's volume on the Amphibia and Reptilia in the "Fauna of British India."

I take this opportunity of thanking Mr Boulenger for his assistance in naming some specimens, and I am much indebted to Mr Stanley Gardiner for asking me to describe his collection.

AMPHIBIA.

Fam. **Ranidae.**

1. *Rana tigrina* Dana.

Rana tigrina, Boulenger, *Cat. Batr. Sal.* p. 26 (1882).

A single female, a perfectly typical example of the species, from Minikoi, Laccadives. Range from the Philippine Islands and China to Ceylon.

[1] [The close connection with Ceylon is probably a growth of quite recent date. The principal trade relations of the 16th, 17th and 18th centuries were with the south-west coast of India. There has always been until recent years constant intercourse both with Arabia and Malaysia as well. Ed.]

Fam. **Bufonidae.**

2. *Bufo melanostictus* Schneid.

Bufo melanostictus, Boulenger, *Cat. Batr. Sal.* p. 306 (1882).

Several specimens of this toad were obtained by Mr Stanley Gardiner, two at Hulule, Male Atoll, the rest at Maradu in the Addu Atoll. The two former differ from the rest of the specimens in having the skin of the back distinctly less warty and the interorbital space perfectly smooth. The measurements of the largest individual (from Hulule) are as follows:—

Snout to vent	48 mm.
Thigh to knee	10 mm.
Knee to ankle	18 mm.
Ankle to end of 4th toe	28 mm.

The species is widely distributed in the Oriental region, ranging from China and the Philippine Islands westwards to Ceylon and India. It has also been introduced into Mauritius.

REPTILIA.

Order Lacertilia.

Fam. **Geckonidae.**

1. *Hemidactylus frenatus* (Schleg.).

Hemidactylus frenatus, Boulenger, *Cat. Liz.* I. p. 120 (1885).

This widely distributed animal is evidently abundant throughout the Maldives and in Minikoi. Thirty-four specimens were obtained from 14 different localities extending from Minikoi to Addu Atoll. The species ranges from Ceylon and the islands of the Indian Ocean to China, the islands of the Western Pacific, and to St Helena.

2. *Hemidactylus gleadovii* Murray.

Hemidactylus gleadovii, Boulenger, *Cat. Liz.* I. p. 129 (1885).

Four geckoes from Hulule, Male Atoll, are to be referred to this species. The largest specimen, a female, has the following measurements:

Length of head	13·5 mm.
„ „ body	28·5 mm.
„ „ tail (regenerated)	29 mm.

Of the two males one has a series of 12 preanal pores, while the other has no fewer than 30, but in other respects does not differ from the first.

The species is found in India, Ceylon, S. China and Burmah.

Fam. **Agamidae.**

3. *Calotes versicolor* (Daud).

Calotes versicolor, Boulenger, *Cat. Liz.* I. p. 321 (1885).

This lizard appears to be very abundant in the Maldive Islands. Twenty-seven specimens, mostly quite young (measuring from 20 mm. to 25 mm. from the tip of the snout to the root of the tail), were obtained at the following localities: Goidu. Goifurfehendu Atoll. Hulule, Male Atoll, Fainu, N. Mahlos Atoll, Maduwari, S. Mahlos Atoll, and Maradu, Addu Atoll.

The largest individual, a male from Goidu, measured 65 mm. from the tip of the snout to the vent. The lateral scales in the small specimens are much more strongly keeled than in the more mature individuals. In fact the larger a specimen the smoother its lateral scales.

The species ranges from India and Ceylon to China and Siam.

Fam. **Scincidae.**

4. *Lygosoma albopunctatum* (Gray).

Lygosoma (Riopa) albopunctatum, Boulenger, *Cat. Liz.* III. p. 309 (1887).

This small skink is plentiful in the islands and 14 specimens were obtained in Minikoi, Laccadives, at Mahdu, S. Mahlos Atoll, Limbo-Kandu and Inguradu, N. Mahlos Atoll, Manadu, Miladumadulu Atoll, and Hulule, Male Atoll. The specimens are considerably smaller than the type, an average specimen measuring as follows:

Length of head	6 mm.
„ „ body	24 mm.
„ „ tail	40 mm.
„ „ fore-limb	5 mm.
„ „ hind-limb	8 mm.

The species inhabits India, Burmah and the Malay Peninsula.

Order OPHIDIA.

Fam. **Typhlopidae.**

5. *Typhlops braminus* (Daud).

Typhlops braminus, Boulenger, *Cat. Snakes*, I. p. 16 (1893).

This species occurs all over the Oriental region and in S. Africa. The collection contains two specimens from Minikoi, Laccadives, and a third from Manadu in Miladumadulu Atoll. The Minikoi specimens measure 128 mm. total length by 2·75 mm. diameter of body (colour black-brown) and 132 mm. by 2 mm. (colour light brown), while the Manadu specimen measures 172 mm. by 4 mm. (colour grey-black).

Fam. **Colubridae.**

6. *Aspidura trachyprocta* Cope.

Aspidura trachyprocta, Boulenger, *Cat. Snakes*, I. p. 313 (1893).

A single specimen from Male, Male Atoll. The species is otherwise peculiar to Ceylon.

7. *Lycodon aulicus* (Linnè).

Lycodon aulicus, Boulenger, *Cat. Snakes*, I. p. 352 (1893).

The two specimens, which are from Hulule, Male Atoll, both belong to var. *A*, which is peculiar to Ceylon and S. India. The species ranges as far as Timor and Celebes.

8. *Hydrus platurus* (Linnè).

Hydrus platurus, Boulenger, *Cat. Snakes*, III. p. 267 (1896).

A single specimen belonging to var. *E*. The species inhabits the tropical waters of the Indian and Pacific Oceans.

Order Chelonia.

Fam. **Testudinidae.**

9. *Nicoria trijuga*, var. *thermalis* (Lesson).

Nicoria trijuga, var. *thermalis*, Boulenger, *Cat. Chel.* p. 122 (1889).

Seven specimens from Hulule, Male Atoll. The largest measured 118 mm. and the smallest 68 mm. along the carapace. This variety of the species has been introduced into Diego Garcia, Chagos Archipelago, but is otherwise peculiar to Ceylon.

Fam. **Chelonidae.**

10. *Chelone mydas* (Linnè).

Chelone mydas, Boulenger, *Cat. Chel.* p. 180 (1889).

11. *Chelone imbricata* (Linnè).

Chelone imbricata, Boulenger, *Cat. Chel.* p. 183 (1889).

Both this and the last species are of universal distribution in tropical and sub-tropical seas, and are exceedingly numerous in the Maldives and Laccadives.

LEPIDOPTERA.

By Ed. Meyrick, B.A. (Cantab.), F.Z.S.

The collection includes 67 species, of which one cannot safely be identified. Almost all the others—probably all but one—occur also in India or Ceylon. The solitary exception is *Notarcha penthodes*, a representative form which in Minikoi replaces the common and widely distributed *N. multilinealis*. The only other species not actually known to me as occurring in India or Ceylon is *Eucosma leucaspis*, but the Indian *Tortricina* are little studied, and it will probably be found to occur there.

Fam. **Arctiadae.**

1. *Celama squalida* Stgr. Minikoi, 1.
2. *Utetheisa antennata* Swinh. Hulule, 11.

Fam. **Caradrinidae.**

3. *Polytela gloriosae* F. Minikoi, 1.
4. *Melanchra consanguis* Gn. Minikoi, 1.
5. *Caradrina obtusa* Hamps. Minikoi, 1; Hulule, 1.

Fam. **Plusiadae.**

6. *Hydrillodes lentalis* Gn. Minikoi, 13.
7. *Simplicia robustalis* Gn. Minikoi, 2; Hulule, 1.
8. *Hypena indicatalis* Walk. Minikoi, 4.
9. „ *jussalis* Walk. Hulule, 2.
10. *Grammodes mygdon* Cr. Minikoi, 12; Hulule, 1.
11. *Ophiusa coronata* F. Minikoi, 1.
12. „ *metaspila* Walk. Minikoi, 5.
13. *Plusia permissa* Walk. Minikoi, 1; Hulule, 4.
14. *Leocyma sericea* Hamps. Minikoi, 8; Hulule, 6.
15. „ *cygnus* Walk. (?) Minikoi, 1, but in too poor condition to identify certainly.
16. *Hyelopsis signifera* Walk. Minikoi, 1; Hulule, 2.

Fam. **Hyblaeidae.**

17. *Hyblaea puera* Cr. Hulule, 8.

Fam. **Ocneriadae.**

18. *Euproctis varians* Walk. Minikoi, 12.

Fam. **Sterrhidae.**

19. *Leptomeris aspilataria* Walk. Minikoi, 6.
20. " *actuaria* Walk. Hulule, 1.
21. " *caesaria* Walk. Hulule, 1.
22. " *addictaria* Walk. Minikoi, 1.
23. *Anisodes annulifera* Hamps. Hulule, 1.

Fam. **Geometridae.**

24. *Eucrostis rectifasciata* Hamps. Hulule, 1.

Fam. **Selidosemidae.**

25. *Ascotis boarmiaria* Walk. Minikoi, 11.
26. *Hyperythra lutea* Cr. Hulule, 1.

Fam. **Sphingidae.**

27. *Cephonodes hylas* L. Minikoi, 1.
28. *Macroglossa sitiene* Walk. Minikoi, 6.
29. " *gyrans* Walk. Hulule, 4.
30. *Deilephila theylia* L. Minikoi, 8; Hulule, 6.

Fam. **Nymphalidae.**

31. *Anosia plexippus* L. Hulule, 1.
32. *Vanessa montana* Feld. Hulule, 1.
33. " *cardui* L. Hulule, 1.

Fam. **Satyridae.**

34. *Mycalesis mandata* Moore. Hulule, 7.
35. " *polydecta* Cr. Minikoi, 9; Hulule, 1.

Fam. **Lycaenidae.**

36. *Spalcis epius* Westw. Minikoi, 12.
37. *Zizera gaika* Trim. Minikoi, 2; Hulule, 7.
38. *Catochrysops osiris* Hopff. Hulule, 7.

Fam. **Papilionidae.**

39. *Papilio hector* L. Hulule, 3.

Fam. **Hesperiadae.**

40. *Baoris colaca* Moore. Minikoi, 39; Hulule, 7.

Fam. **Phycitidae.**

41. *Canthelea lateritialis* Walk. Minikoi, 1.
42. *Melathrix praetextella* Christ. Hulule, 2.

Fam. **Pyraustidae.**

43. *Schoenobius immeritalis* Walk. Hulule, 1.
44. *Nymphula depunctella* Gn. Hulule, 1.
45. *Leucinodes orbonalis* Gn. Minikoi, 1.
46. *Pleonectusa admixtalis* Walk. Minikoi, 11; Hulule, 16.
47. *Epichronistis acrospila* Meyr. Minikoi, 13; Hulule, 12.
48. *Molybdantha tricoloralis* Z. Minikoi, 5; Hulule, 3.
49. *Hydriris ornatalis* Dup. Minikoi, 3.
50. *Ischnurges gratiosalis* Walk. Minikoi, 24, a local form having the yellow ground of forewings less obscured with rosy suffusion than usual; Hulule, 4, normal.
51. *Phakellura indica* Saund. Hulule, 1.
52. *Margaronia suralis* Ld. Minikoi, 13, a local form having the discal black dots always obsolete on upper surface; Hulule, 12, normal.
53. *Margaronia bivitralis* Gn. Hulule, 1.
54. *Omiodes niphealis* Walk. Minikoi, 59; Hulule, 7.
55. „ *diemenalis* Gn. Hulule, 8.
56. *Hymenia recurvalis* F. Minikoi, 1; Hulule, 1.
57. *Conogethes suralis* Walk. Minikoi, 2.
58. *Notarcha penthodes* n. sp.

Differs from *N. multilinealis* Gn. only in having on both wings a sharply defined dark fuscous terminal fascia from apex to tornus, cut by pale streaks on veins.

Minikoi, 5 specimens; this is clearly a representative form of *N. multilinealis*, and I can detect no difference whatever except in the character given; yet since this character is conspicuous and apparently constant, and I have never met with it elsewhere, I think the facts are best exhibited by giving the form specific rank; no doubt it is a case where opinions may vary.

59. *Notarcha multilinealis* Gn. Hulule, 18, normal.

Fam. **Pyralididae.**

60. *Endotricha mesenterialis* Walk. Minikoi, 1; Hulule, 2.

Fam. **Thyrididae.**

61. *Striglina scitaria* Walk. Minikoi, 16; Hulule, 3.

Fam. **Pterophoridae.**

62. *Sphenarches caffer* Z. Hulule, 1.

Fam. **Heterogeneidae.**

63. *Natada sericea* Hamps. Hulule, 9.

Fam. **Epiblemidae.**

64. *Eucosma leucaspis* n. sp.

♂ 14—15 mm. Head, thorax, and abdomen dark fuscous, abdomen sometimes yellowish towards base beneath. Forewings moderate, elongate, posteriorly dilated, costa gently arched, apex obtuse, termen bowed, vertical; grey, slightly purple-tinged, strigulated with dark fuscous; upper half of central fascia blackish, moderately broad, oblique, followed by a triangular white costal patch extending to beyond $\frac{3}{4}$ of costa, tinged posteriorly towards costa with rosy-ochreous, its discal angle truncate and indented by a short blackish strigula; costal edge from central fascia to apex blackish, with pairs of white strigulae; beyond this patch a blackish blotch, semicircular above, not reaching costa, suffused beneath; ocellus including three longitudinal blackish marks, its posterior edge indicated by grey-whitish suffusion. Hindwings dark fuscous.

Minikoi, 3 specimens.

Fam. **Tortricidae.**

65. *Adoxophyes euryomis* n. sp.

♂ 17 mm., ♀ 19—20 mm. Head and thorax ochreous, palpi rather long. Abdomen pale ochreous, in ♂ with very long anal and genital tufts. Forewings moderate, oblong, costa strongly arched towards base, then straight, apex obtuse, termen slightly sinuate-bowed, vertical, costal fold of ♂ very broad, reaching from base to middle of costa; light yellow-ochreous, more or less tinged or sprinkled irregularly with reddish-brown; markings reddish-fuscous, edged with pale strigae; edge of basal patch indicated by an irregular streak from $\frac{1}{4}$ of costa to $\frac{2}{5}$ of dorsum, angulated below middle; central fascia from before middle of costa to before tornus, narrow, rather irregular, abruptly quadrangularly dilated posteriorly below middle; a curved irregular streak from before $\frac{3}{4}$ of costa to near termen above tornus, confluent beneath with a slender subterminal streak rising from a small spot on costa before apex. Hindwings rather light ochreous-fuscous, costa broadly ochreous-whitish.

Minikoi, 16 specimens; Hulule, 7. Occurs also in India.

Fam. **Plutellidae.**

66. *Simaethis submarginalis* Walk. Hulule, 4.

ECHIURIDEA.

By A. E. Shipley, M.A., *Fellow and Tutor of Christ's College, Cambridge, and University Lecturer in the Advanced Morphology of the Invertebrata.*

(With Plate VI.)

The collection of Echiuroids from Minikoi and the Maldive Islands contained few species and few specimens. Obviously they are shy animals and easily elude the search of the collector. Six species in all were found represented by some seventeen specimens. At Minikoi but two specimens of *Thalassema diaphanes*, one very small, and one specimen of *Thal. moebii* were taken. The Maldive Island specimens were, with the exception of the *Bonellia*, all taken at Hulule on the Male Atoll; they include examples of *Bonellia viridis*, *Thal. diaphanes*, *Thal. erythrogrammon*, *Thal. moebii*, *Thal. semoni* and *Thal. vegrande*. It is noticeable that all the species belong to the two genera of Echiuroids which are frequenters of the warm and temperate seas. The plate which accompanies this paper contains four coloured sketches, drawn by Mr C. Forster Cooper, accurately representing the hues of the living animals.

I have not thought it worth while to take up space by repeating the lists of literature given in my paper "On a Collection of Echiuroids from the Loyalty Islands, New Britain and China Straits, with an attempt to revise the Group and to determine its Geographical Distribution," published in Willey's *Zoological Results*, but under each species I have given a reference to the page of that article, upon which the literature will be found.

I. Genus BONELLIA Rolando.

1. *Bonellia viridis* Rolando.

Shipley. Willey's *Zoological Results*, Part III. 1899, p. 341.

A single medium-sized specimen of a blackish green colour, very dark.

Locality. Maduwari, S. Mahlos Atoll, Maldive Islands; found in the lagoon reef but never seen elsewhere in the Group. It is a widely distributed species, occurring in the Mediterranean and Adriatic and off Norway. Dr Willey collected it at the Loyalty Islands and saw specimens of it in the D'Entrecasteaux Group. It also occurs off the Australian and British New Guinea coasts.

II. Genus THALASSEMA (Gaertner) Lamarck.

2. *Thalassema diaphanes* Sluiter. (Plate VI, fig. 2.)

Shipley. Willey's *Zoological Results*, Part III. 1899, pp. 336 and 346.

A single specimen, 2·5 cm. long, from Hulule. Greatest breadth 8 mm. The animal was curved and the skin of the outer curvature was remarkably thin. The contents of the alimentary canal was in very obvious pellets, as is usually the case in this species. Another bottle containing three specimens from the same locality was labelled "in *Halimeda* masses." Two specimens, one very small, were taken at Minikoi. The smaller was taken "from lagoon sand between the roots of a branching *Porites*," the larger from "sand under stones of reef-flat"; when living this specimen had a proboscis, which when expanded reached a length of 2·7 cm. and its body was nearly as long.

Locality. Hulule, Maldive Islands and Minikoi, Laccadive Islands. This species has previously been described from the Bay of Batavia and from off Pigeons' Island, New Britain.

As this is the first mention of Hulule I insert here a note drawn up on the spot by Mr Stanley Gardiner on the Echiuroids of that locality:—

"*Thalassema* alone occurs. There seem to be three species, which live in and under the stones of the boulder zone, east and west. A fourth small species—perhaps different—light green colour, rather transparent (*Thalassema diaphanes* A. E. S.)—is found in *Halimeda* masses, but otherwise we have not found any except in the above positions. They are far more numerous to the east. The two specimens of the large species (*Thalassema erythrogrammon* A. E. S.) were obtained under a large stone on sand, close to inside of boulder zone to east. They live quite well for 20 to 30 hours in water in a covered basin, and kill best for museum purposes by very slowly adding dilute Chromic Acid. Alcohol sooner or later causes collapse, however slowly the anaesthesia is performed."

3. *Thalassema erythrogrammon* Max Müller. (Plate VI, fig. 1.)

Shipley. Willey's *Zoological Results*, Part III. 1899, p. 347.

A single, very large specimen whose dimensions, judging from a life-size sketch made by Mr C. Forster Cooper of the living animal, were:—length of body 39 cm., length of proboscis 11 cm., greatest width of body 4 cm. The posterior end of the body, which is very rugged and pitted, extended some 4 cm. from the extreme end. The specimen preserved in spirit which reached my hands had contracted to about one quarter of the above length. The proboscis, which was extremely contracted and had broken off the body, was but 3 cm. long, and was all bunched up like an acorn in outline.

The colour of the animal differs but little from what has hitherto been described. The ventral surface of the proboscis was yellow with a thin violet stripe as is usual. The fourteen longitudinal muscles were of a purplish red hue with greenish interspaces, and the posterior pitted portion was violet. The animal as Mr Cooper described it "pulsated horribly," and as the contractions passed along the body the areas, which coincided with the point of intersection of the longitudinal and transverse muscles, swelled up into prominent, light-pinkish knobs.

The alimentary canal was full of pieces of coral rock, some of considerable dimensions. Mr J. Stanley Gardiner has been good enough to examine a small specimen of the contents of the intestine and has kindly furnished me with the following list of its varied components:—

"One piece of *Madrepora*, end of a branch, corallum not at all worn down, 13 mm. long by 6·5 mm. in diameter, spines etc. still perfect and cells full of animal tissues: five pieces of *Pocillipora*, the largest 14 × 10 mm.: fragments of *Distichopora*: Lamellibranch and Gastropod shells, two of the latter perfect, apparently having recently contained the living animals: leaves of *Halimeda* and similar Algae in great numbers: Millepore and *Polytrema* fragments: *Calcarina* and other Foraminifera: one Polyzoon fragment: a little bunch of Hydroid remains. The rest of the sample was sand composed mainly of fragments of any of the above.

"The contents appear to indicate that the animal may browse directly on sedentary animals and plants besides taking in sand quite, as it were, passively."

A second specimen from the same locality was too macerated for accurate measurements but it was certainly not smaller than the above.

Locality. Hulule, Male Atoll, Maldive Islands. This is not far from the centre of the known area of distribution of the species, which extends from New Guinea to the Red Sea and as far south as the Isle of Bourbon.

4. *Thalassema moebii* Greef. (Plate VI, figs. 3, 3 *a*, 3 *b*.)

Shipley. Willey's *Zoological Results*, Part III. 1899, p. 350.

One specimen, 6 cm. long, 1 cm. in diameter. In the living specimen the proboscis was almost as long as the body, but it contracted to one-fifth the body length in dying. The three nephridia were crowded with eggs. Mr Cooper's sketch faithfully reproduces the greyish-yellow passing into violet colour of the animal with its violet stripes running spirally round the body. Another bottle contained six specimens, taken at the same place as the above. This contains a label recording that the specimens were found under stones. A second specimen, from Minikoi, was found "in sand under a loose stone of the boulder zone."

Locality. Hulule, Maldive Islands and Minikoi, Laccadive Islands, also recorded from Mauritius, Upolu and Amboyna.

5. *Thalassema semoni* Fischer. (Plate VI, fig. 4.)

Shipley. Willey's *Zoological Results*, Part III. 1899, p. 351.

A single specimen, 3 cm. long and 7 mm. broad at its broadest. The proboscis much shrunk, but in life as long as the body. The characteristic spiral funnels of the two pairs of nephridia were very evident.

Locality. Hulule, Maldive Islands, also recorded from Amboyna.

6. *Thalassema vegrande* Lampert.

Shipley. Willey's *Zoological Results*, Part III. 1899, p. 352.

Two specimens of this species were taken at Hulule. In many specimens of the Echiuroids collected on this expedition the proboscis had parted from the body but it had always been carefully preserved. In this case there was no trace of proboscis on the animal or loose in the bottle. The specimens were slightly shorter than those hitherto described but the skin seemed much contracted and was not so thin and papery as the latter.

Locality. Hulule, Maldive Islands. This species has also been described from the Philippines and from Rotuma.

EXPLANATION OF PLATE VI.

All the figures represent the life-size of the animals each with its proboscis in a state of moderate expansion. The figures were drawn by Mr C. Forster Cooper and represent the natural colour of the living animals.

FIG. 1. *Thalassema erythrogrammon* Max Müller.

FIG. 2. *Thalassema diaphanes* Sluiter.

FIG. 3. *Thalassema moebii* Greef. Fig. 3 *a* represents the proboscis of this species when contracted and Fig. 3 *b* represents the tip of the same when expanded.

FIG. 4. *Thalassema semoni* Fischer.

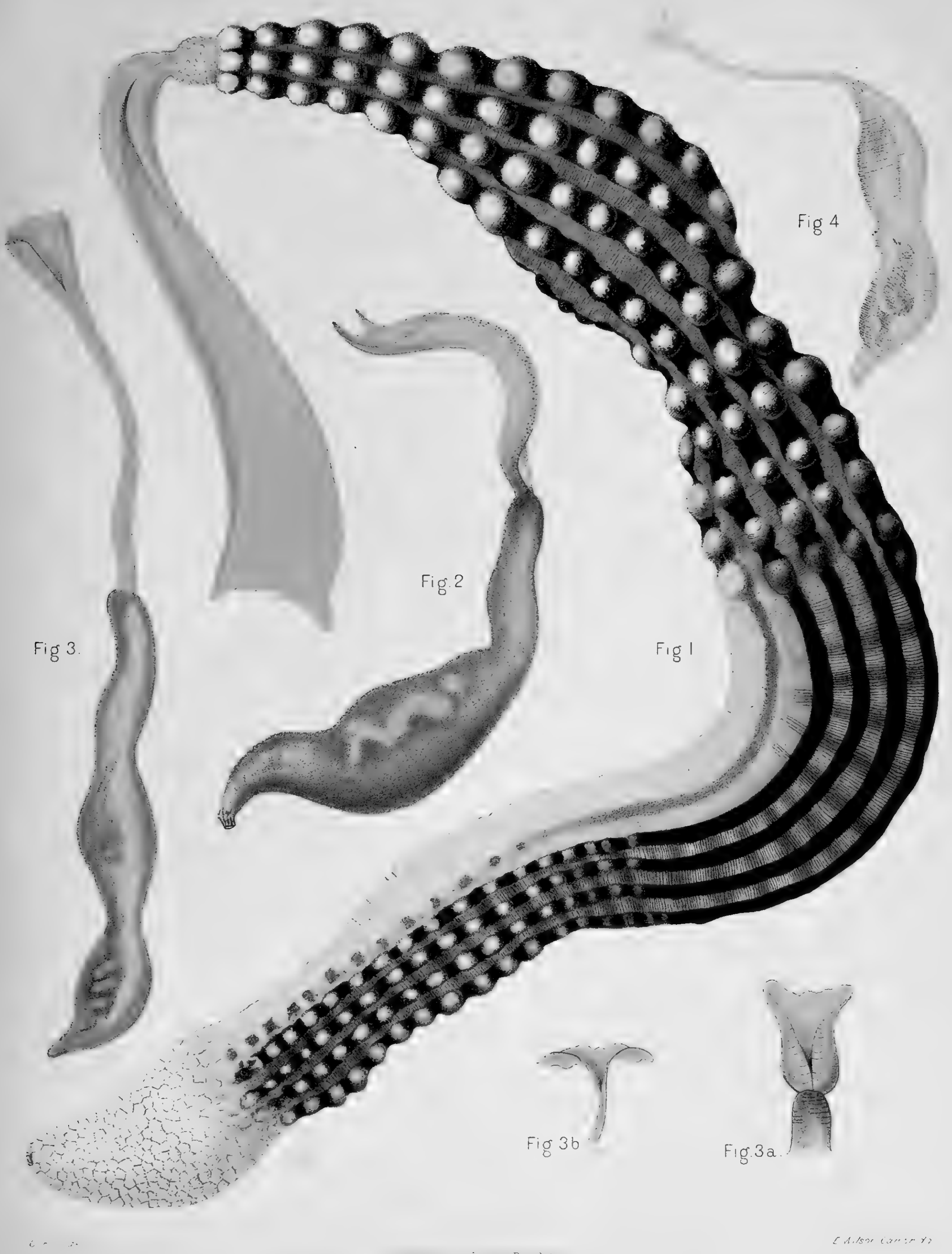


Fig 4
Fig. 2
Fig 3.
Fig 1
Fig 3b
Fig. 3a.

SIPUNCULOIDEA,

WITH AN ACCOUNT OF A NEW GENUS LITHACROSIPHON.

By A. E. Shipley, M.A., *Fellow and Tutor of Christ's College, Cambridge, and University Lecturer in the Advanced Morphology of the Invertebrata.*

(With Plate VII.)

The collection of Sipunculoidea brought back from the Maldive and Laccadive Islands by Mr J. Stanley Gardiner's Expedition was a rich one. It comprised the following nineteen species belonging to six different genera, one of which I take to be new, and many species were represented by numerous specimens:—*Aspidosiphon steenstrupii* Dies., *A. truncatus* Kef., *Cloeosiphon aspergillum* Quatrefages, *Lithacrosiphon maldivense*, n. sp., *Phascolosoma dissors* Sel. and de Man, *Phas. lobostomum* Grube, *Physcosoma agassizii* Kef., *Phys. asser* Sel. and de Man, *Phys. dentigerum* Sel. and de Man, *Phys. lacteum* Sluit., *Phys. nigrescens* Kef., *Phys. pacificum* Kef., *Phys. pelma* Sel. and de Man, *Phys. rüppellii* Grube, *Phys. scolops* Sel. and de Man, *Sipunculus billitonensis* Sluit., *S. cumanensis* Kef., *S. indicus* Peters, *S. vastus* Sel. and Bülow. Of these species all but five, *A. truncatus*, *Lith. maldivense*, *Phascolosoma lobostomum*, *Physcosoma lacteum* and *Phys. nigrescens*, were found at Minikoi in the Laccadives and all but four, *Phas. dissors*, *Physcosoma dentigerum*, *Phys. pelma*, and *S. billitonensis*, were found in the Maldives. Thus ten species were common to the two groups of islands.

On the whole the collection bears out the remarks made on the occurrence and distribution of the members of the group in Willey's *Zoological Results*, Part II. 1899, p. 151 and at the end of my paper "On a new species of *Phymosoma*, etc." in *Quarterly Journal of Microscopical Science*, XXXII. 1891.

The account of the new genus will be found at the end of this memoir.

In the following notes on the several species I have not attempted a complete bibliography, but I have mentioned the latest paper available in which the species in question is dealt with. The abbreviations are in all cases those suggested by Dr Sharp in the *Zoological Record*.

I. SYSTEMATIC ACCOUNT.

I. Genus ASPIDOSIPHON Grube.

1. *Aspidosiphon steenstrupii* Dies.

Shipley. Willey's *Zoological Results*, Part II. 1899, p. 153.

Many specimens found by breaking up the coral and stone masses. The specimens varied a good deal in size; the larger examples had the characteristic chalky deposit on the anterior shield.

Locality. Minikoi, Laccadive Islands and Naifaro, Fadifolu Atoll, where it was dredged at a depth of 12—20 fathoms, also recorded from the Philippines, from Mauritius, and from Lifu, Loyalty Islands.

2. *Aspidosiphon truncatus* Kef.

Shipley. Willey's *Zoological Results*, Part II. 1899, p. 154.

A few specimens, all small, were taken at Hulule, Male Atoll.

Locality. Hulule, Male Atoll in the Maldives, also known from Sandal Bay, Loyalty Islands, Mauritius and from Panama.

As this is the first mention of Hulule, Male Atoll, I subjoin some notes made by Mr Stanley Gardiner on the spot with reference to the Sipunculoids of the reefs around that island.

"The Sipunculoidea were not by any means numerous, though a large number of small specimens were obtained from the clumped tops of *Halimeda* masses. A few were taken from some beach-sandstone masses near the village, and a few were secured by breaking up rock masses. A small semi-transparent form was found in sand of the boulder zone occasionally; and two large specimens were in a hole under the rock of the south islet. The "vembol" (*Sipunculus indicus*) is numerous in the sand, but hard to obtain perfect.

"It is remarkable as compared with Minikoi that in the sand under overturned coral masses no Sipunculoids occur, nor under the stones of the spits of the various islands."

II. Genus CLOEOSIPHON Grube.

3. *Cloeosiphon aspergillum* Quatrefages.

Shipley. *P. Zool. Soc. London*, 1898, p. 471.

Numerous examples found living in the coral rocks to a depth of 9 fathoms.

Locality. Minikoi, Laccadive Islands, and from Maradu, Addu Atoll and Hulule, Male Atoll in the Maldives and dredged at a depth of 12—20 fathoms in a passage at Fadifolu in the same islands, previously recorded from many islands in the Pacific and Indian Oceans.

III. Genus LITHACROSIPHON, nov.

4. *Lithacrosiphon maldivense*, n. sp. (*vide* p. 137).

IV. Genus PHASCOLOSOMA S. Str. (F. S. Leuckart) Sel. and de Man.

5. *Phascolosoma dissors* Sel. and de Man.

Selenka. *Die Sipunculiden*, 1883.

Several specimens were found by breaking up the corals and stone masses from the outer reef. These specimens correspond with Selenka and de Man's species *Phas. dissors* in having strongly-bent hooks arranged in numerous rows, large papillae on the body and two retractors. The specimens are however longer than the specimens described by previous authors, reaching 3 cms. in length, and the relative proportion of breadth to length is different. This latter factor depends however on the state of the contraction of the muscles and must vary from time to time. The retractors are very powerful muscles, and in almost all the specimens collected by Mr Gardiner the body-wall had ruptured and the retractors with part of the viscera had protruded.

Locality. Minikoi, Laccadive Islands. Described also from the West Indies.

6. *Phascolosoma lobostomum* Grube.

W. Fischer. *Abh. Ver. Hamburg*, XIII. 1895, p. 14.

Many specimens of a species which closely corresponds with *Phascolosoma lobostomum* Grube.

Locality. These were dredged at depths between 6 and 20 fathoms at Hulule, Male Atoll, in the Maldives. This species has previously been described by Fischer from Somoa (? Samoa).

V. Genus PHYSCOSOMA.[1]

7. *Physcosoma agassizii* Kef.

Shipley. Willey's *Zoological Results*, Part II. 1899, p. 155.

This species was taken out from the coral rock in which they live.

Locality. Minikoi, Laccadive Islands, Goidu, Goifurfehendu Atoll and from Maduwari, South Mahlos in the Maldives and from Hulule, Male Atoll, in the same Islands. Two specimens found together with the second collection of *S. vastus.* The species, which is very near to *Phys. scolops* Sel. and de Man, has been recorded from the eastern Pacific from Puntarenas to Esquimault, and recently from near the mouth of the Congo, from Ponapé, one of the Carolines, and from Lifu in the Loyalty Islands.

8. *Physcosoma asser* Sel. and de Man.

Shipley. Willey's *Zoological Results*, Part II. 1899, p. 155.

One specimen was found in association with *S. vastus*, and two more under the growing coral at the extreme edge of the reef, where there was no sand.

Locality. Minikoi, Laccadive Islands; a second collection was dredged at a depth of 30—36 fathoms at South Nilandu, in the Maldives, and at 35 fathoms at Kolumadulu, in the Maldives, and at a depth of 40 fathoms at Mulaku in the same Islands. This species extends across the Indian Ocean from New Britain and the Malay Straits to Mozambique.

[1] The following is taken from Dr F. A. Bather's article on Echinoderma in the *Zoological Record*, 1900, pp. 77 and 78. I am indebted to the author for sending me a proof of the article. "*Prophymosoma*, nom. nov. pro '*Phymosoma* Ship[l]ey, récemment proposé pour des Holothuries,' non Haime; LAMBERT (187) p. 54. [*Phymosoma* is not Shipley, but Quatrefages, not a Holothurian but a Gephyrean; the name *Physcosoma* is already proposed for it by Selenka (*Zool. Anz.* XX. p. 460, 1897), but objected to by Spengel (*Zool. Anz.* XXI. p. 50, 1898) because *Physchiosoma* was used by Brera, 1811, presumably in error for *Physcosoma*. But since Selenka gave *φύσκων* as the derivation of his name, it should have been spelled *Physconosoma*, a form not liable to confusion with any name derivable from *φύσκη*. *Prophymosoma* is therefore a syn. of *Physconosoma*.]"

The reference to LAMBERT (187) is "Étude sur quelques Echinides de l'Infra-Lias et du Lias," *Bull. Soc. Yonne*, LIII. 1re semestre, pt. 2, Jan. 1900.

9. *Physcosoma dentigerum* Sel. and de Man.

Shipley. *P. Zool. Soc. London*, 1898, p. 471.

A few examples taken from borings in the coral rock.

Locality. Minikoi, Laccadive Islands, also recorded from Funafuti, Rotuma and the Philippines.

10. *Physcosoma lacteum* Sluit.

Sluiter. *Natuurk. Tijdschr. Nederl. Ind.* XLV. 1885, p. 507.

Two specimens which, though I failed to find the area of irregularly scattered hooks intercalated between 80 and 30 complete rows of hooks as described by Sluiter, in other respects seem to belong to this species.

Locality. Hulule, Male Atoll, previously recorded from the Malay Peninsula.

11. *Physcosoma nigrescens* Kef.

Selenka. *Die Sipunculiden*, 1883.

Three examples of this coral-boring form were taken at Inafuri, Goifurfehendu Atoll. It is a variable species, several local varieties having been recorded.

Locality. Inafuri, Goifurfehendu Atoll, also recorded from the Fiji Islands, Funafuti, the Philippines, Mauritius, and the Red Sea.

12. *Physcosoma pacificum* Kef.

Shipley. *P. Zool. Soc. London*, 1898, p. 470 and Willey's *Zoological Results*, Part II. 1899, p. 156.

One example from Minikoi was found under the same conditions as *S. vastus*, and several others were obtained under growing coral masses in the lagoon sand, principally under branching *Porites* and *Madrepora*, also found boring into coral rocks.

Locality. Minikoi, Laccadive Islands, from Hulule, Male Atoll and from Naifaro, Fadifolu Atoll, and from Goidu, Goifurfehendu and from Maradu, Addu Atoll, in the Maldives.

This species extends from the Red Sea through the Indian Ocean to the Pacific. Mr Gardiner had already taken it at Rotuma and Funafuti. Dr Willey found it at Uvea, Loyalty Islands and in Blanche Bay, New Britain.

13. *Physcosoma pelma* Sel. and de Man.

Selenka. *Die Sipunculiden*, 1883.

One specimen, small and difficult to recognize. It was of a dense black colour which must have been due to the action of the preservative reagent, as it is described in Mr Gardiner's notes as transparent when alive. It was found amongst the castings of a large species of *Ptychodera* on the lagoon flat.

Locality. Minikoi, Laccadive Islands.

The species is also recorded from the Philippines, Java and Mauritius.

14. *Physcosoma rüppellii* Grube.

Selenka. *Die Sipunculiden,* 1883.

A few specimens taken out of the coral rock, into which they had bored, at Minikoi and three specimens—also boring forms—taken at Goidu, Goifurfehendu Atoll, in the Maldives. The circular muscles of these had contracted so strongly in the anterior third of the body that the appearance of a very distinct tail was produced such as was described by Lankester in his genus *Golfingia.*

Locality. Minikoi, Laccadive Islands and Goidu, Goifurfehendu Atoll, in the Maldives, previously recorded from the Red Sea.

15. *Physcosoma scolops* Sel. and de Man.

Shipley. *P. Zool. Soc. London,* 1898, p. 470 and Willey's *Zoological Results,* Part II. 1899, p. 156.

The specimens of this species were found in the sand under stones in the boulder zone, most in the large island and at Wiringili; some were taken out of coral masses dredged up from a depth of six or nine fathoms, and others in a passage at Suvadiva Atoll at a depth of twenty fathoms.

Locality. Minikoi, Laccadive Islands, and Suvadiva Atoll in the Maldives.

Like *Phys. pacificum* and *Phys. asser* this species stretches from the Pacific Ocean to the coast of Africa. A few species were found at Minikoi in the same locality as *S. vastus, Phys. asser* and *Phys. pacificum.*

VI. Genus SIPUNCULUS L.

16. *Sipunculus billitonensis* Sluiter.

Sluiter. *Natuurk. Tijdschr. Nederl. Ind.* XLV. 1885, p. 487.

Shipley. Willey's *Zoological Results,* Pt. II. 1899, p. 157.

One example only and this differed externally from the specimens, of what I take to be the same species, brought home by Dr Willey. The large black spots were missing, and the anus was not so prominent. The animal was quite 20 cms. long when stretched out. The retractors were inserted very far forward about 3 cms. from the anterior end of the animal, the head of which however was retracted. Thus the proportion of the retractile part of the body to the non-retractile or trunk is much smaller than is usual in the genus.

Locality. Minikoi, Laccadive Islands, also from East Indies and Loyalty Islands.

17. *Sipunculus cumanensis* Kef.

Shipley. Willey's *Zoological Results,* Pt. II. 1899, p. 157.

A large collection of beautifully preserved specimens belonging to Selenka and de Man's variety *vitreus,* many with the introvert and head fully extended. The animals were captured near the south-west end of the Island of Minikoi, where they were found living in the sand under stones. Mr Gardiner notes "these forms are found quite free-living, but often one or two project from the stones, having apparently taken up their abodes in natural hollows. One can usually see whether they are present or not under a stone, as, if they are, there are considerable sand-castings over and around it. I at first thought that these must be due to some other animal, but found later that, if there is one, there are usually about half-a-dozen under each stone." A further collection was made from "the sand of the lagoon mostly by Wiringili Island" and another belonging to the variety *opacus* from under overhanging, branching *Porites* and *Madrepora*, amongst the lagoon sand. A fourth collection was taken amongst the Maldive Islands, in shallow water at Goidu, another at Hulule, Male Atoll, and yet another collection at Maduwari, South Mahlos, in the Maldives. The body-cavity of one specimen, I opened, was lined by a remarkable fibrous meshwork, which lay inside the longitudinal muscles and seemed tough and resistant.

Locality. Minikoi, Laccadive Islands, and Maduwari, South Mahlos, Hulule, Male Atoll, and Goidu, Goifurfehendu Atoll, Maldive Islands, also recorded from Blanche Bay, New Britain, and the Isle du Phare, Nouméa, from the Philippines and from Venezuela.

18. *Sipunculus indicus* Peters.

Selenka. *Die Sipunculiden*, 1883.

Two specimens, one mutilated and the other 47 cm. in length, from Minikoi, and others from the Maldives. It is described as "living in 'the sand' of the lagoon-flat in long holes open to the surface. It is called by the natives 'vembolu.' The native method of catching them is to push a long thin stick into their holes. This penetrates the body of the animal and by this means the beast is held firm whilst it is being dug out by the hands. It is then by means of the stick turned completely inside out, and in this condition is stuck on a stick and used as bait for day fishing in the lagoon."

Locality. Minikoi, Laccadive Islands, from Hulule, Male Atoll, and from Goidu, Goifurfehendu Atoll, in the Maldives.

The species is recorded from Mozambique.

19. *Sipunculus vastus.* Sel. and Bülow.

Shipley. *P. Zool. Soc. London*, 1898, p. 469 and Willey's *Zoological Results*, Pt. II. 1899, p. 158.

Locality. Several specimens of the variety *albus* were taken "from sand under stones of the boulder zone" at Minikoi, "mostly from the part between the large island and Wiringili." Found together with *Phys. pacificum.* Others were taken from Hulule, Male Atoll, and a few young forms at Naifaro, Fadifolu Atoll.

The species is recorded from Mauritius, Jaluit, Rotuma, Funafuti, Pigeon Island in New Britain, Lifu in the Loyalty Islands, and the Isle of Pines in New Caledonia.

Other specimens of this species were "obtained under upstanding dead coral masses of the outer reef at the base of the beach. These are parts of the solid reef, which have been undermined by tidal action. They are bedded usually in sand rock, which easily disintegrates causing an accumulation of sand in which these forms live. With them Enteropneusta occur in considerable number but never in close proximity. Often under a raised block Sipunculoids alone are found on one side and *Ptychodera* on the other." The two varieties which in the account of Dr Willey's Sipunculoids I distinguished as *S. vastus albus* and *S. vastus obscurus* were very marked and Mr Gardiner notes that some of the former were translucent whilst others were opaque, a condition possibly depending on the state of the contraction of the muscles. He notes that they take no part "in the disintegration of the rock. It was most noticeable that while the coral masses were bored into by various forms of Sipunculoids, the sand rock everywhere was absolutely free from all living organisms."

II. ON THE NEW GENUS LITHACROSIPHON (Plate VII.).

LITHACROSIPHON nov. gen.

Lithacrosiphon maldivense nov. sp.

A very peculiar form of Sipunculoid was represented in this collection by a single specimen. It was 3 cm. long and averaged about 4 mm. in breadth. The great peculiarity of the animal is that the anterior end of the body is armed with a solid conical cap of hard, calcareous (?) matter. This cap has the shape of the 'sugar-loaf' astrakan hats sometimes worn in Turkestan. The ventral outline of the cap, which runs from the apex to the point where the introvert opens, is straight and in a line with the general surface of the body, but dorsally the surface of the cap slopes down at a sharp angle with the ventral surface to just above the position of the anus. The straight ventral edge of the cap is 3 mm. long, the sloping dorsal edge 5 mm., the width of the cap at its widest, i.e. just where it is inserted into the body, is 3 mm. The cap is borne by a pad of skin, which forms the anterior end of the body, and into which the longitudinal muscles of the body-wall are inserted; this pad is almost transverse to the long axis of the body, but slopes a little from the anteriorly placed orifice of the introvert to the slightly more posteriorly placed anus. The hinder half of the stony cap is of the same deep chestnut colour as the body, and it has the appearance of being covered by a thin extension of the skin, but the anterior pointed half is naked, white and almost glistening.

The cap exhibits a certain laminated structure probably due to lines of growth. If found fossil, it could easily be taken for the end of a belemnite.

The general colour of the animal varies in the specimen, which had been preserved in spirit, from a deep chestnut-brown at the two extremities of the body to a greyish yellow in the middle where the skin becomes sufficiently transparent to show the bundles of longitudinal muscles. Anteriorly the skin, surrounding the base of the cap, is raised up into very numerous tubercles, some of which are arranged somewhat symmetrically round the orifice of the introvert and around the anus. The latter opening is a transverse slit and slightly elevated. The skin is thick and tuberculated for about the anterior sixth of the body, but it gradually thins and loses its tubercles and becomes transparent. In my specimen this is the stoutest part of the body, but outline counts for little in a Sipunculoid. Posteriorly the skin again becomes dark and opaque and covered by brown patches; the skin however hardly thickens, and there is no sign of any posterior shield, such as is so characteristic of the genus *Aspidosiphon*.

The internal anatomy is simple. The introvert in the specimen is fully retracted, and measures from the anterior end to the position of the head about 1 cm. in length. The two ventral retractor muscles—there are only these two—do not continue to surround the oesophagus, which with the dorsal vessel stand out from the muscles posteriorly. For about half their length the two muscles are fused, but their hinder halves, separated and spread out in a fan-shaped manner, fuse with the fourth to about the twelfth or fourteenth longitudinal muscles counting from the nerve-cord. I was unable to detect any signs of reproductive organs at the base of these muscles.

The longitudinal muscles split and anastomose very freely. In the centre of the body there are some 26—28 strands, but the number diminishes at each end. The circular muscles are also divided into strands and do not form a continuous sheath. Posteriorly there are a number of other small ridges, which cross the skin transversely. These appear to be due to the wrinkling of the peritoneal lining of the skin. A well marked muscle attaches the posterior end of the coiled intestine to the skin.

The nephridia are conspicuous. Their external and internal openings are far forward on the level with the anus or just behind it. They extend over more than half the length of the body, and are slightly crinkled and very uneven in diameter throughout, small irregular swellings being followed by constrictions.

The alimentary canal stands clear of the retractor muscles comparatively soon, though, as fig. 5 shows, anteriorly it is completely surrounded by them. When it leaves them it passes into the thin-walled intestine, which makes some ten or twelve coils. From this the rectum runs first as a fine tube and then as a more capacious one to the anus. As the sections through the oesophagus show, the lining epithelium is ciliated and thrown into ridges, which form as it were the roots of the tentacles.

In the single specimen at my disposal the introvert was completely retracted, and the only way to determine the presence or absence of hooks and the number of tentacles was to cut serial sections through this part of the body. This I proceeded to do, but unfortunately the presence of sand in the introvert materially interfered with the sections until the level of the head was reached.

Hooks are present and in extraordinary numbers. They are arranged in closely adpressed rings, and are compressed against each other so that the bases of contiguous hooks are in contact. Each hook has two points, and the base of each is slightly corrugated. The hooks are but slightly chitinized, very thin and under the microscope appear light yellow. Among the hooks are scattered—I could make out no order—numerous small processes such as are figured on Plate VII. fig. 7, *ch. p.* At first I took these for the bases of the hooks cut across, but on the whole I am inclined to regard them as cuticular products, homologous with but not analogous with the hooks. I have described similar but much larger structures in *Sipunculus australis* Kef.[1], and they probably represent the "zähnchen" of Selenka's Monograph. The number of rings of hooks is unknown; the very short piece of the introvert—about 1 mm.—which I cut contained some forty to fifty rows, and, if they be continued along the introvert, there are probably at least some hundreds.

The mouth is semi-circular and ciliated. Dorsal to it is a small bunch of tentacles, exactly how many I could not make out but should think about eight or ten. The nerves from the brain to these tentacles are very conspicuous. These tentacles are either very

[1] Willey's *Zoological Results*, Part II. 1899, p. 156.

short or very retracted; they form a small lophophore overhanging the mouth dorsally. In section each is roughly triangular, and besides the nerve each is provided with an extension of the blood sinus which lies round the brain. A similar sinus occupies much of the ventral lip, whose margins are, I judge, not broken up into tentacles. These sinuses aid in extending and keeping tense the tentacles and lip, when the introvert is everted.

In the hollow of the lophophore lies a short channel, the "cerebral organ" of Ward[1]. This is shown in Plate VII. fig. 11. It is short and leads to the two eyes.

The brain is compact, slightly hollowed ventrally by the blood sinus which on this surface closely ensheaths it. In the main the ganglion-cells form a dorsal cap. It gives off ventrally the usual circumoesophageal commissures and anteriorly the conspicuous nerves to the tentacles and lower lip.

The eyes are conspicuous, lying on the anterior surface of the brain, where that organ still retains its primitive connection with the ectoderm. Each consists of a cup-shaped pigmented layer of cells, densely black in colour; the little space surrounding the convex side of these cups, seen in Plate VII. fig. 11, is continuous with the cavity of the cerebral organ mentioned above.

The systematic position of this Sipunculoid is a matter of some interest. Its structure resembles that of the genera *Aspidosiphon* and *Cloeosiphon* much more closely than it does that of any other genus, and it resembles *Aspidosiphon* much more nearly than it does *Cloeosiphon*. It however differs from *Aspidosiphon* in the two most important features which characterize that genus. There are no anterior or posterior shields at all, but the anterior shield may perhaps be represented by the pad which bears and secretes the stony cap; if this be so, it may be noticed that this pad is more directly in a plane transverse to the long axis of the body than is that of any *Aspidosiphon* I have ever seen. The animal may be an abnormal form of *Aspidosiphon* but I doubt it. If it represent a true genus, this genus is one of the most easily recognized of all the Sipunculoids, even when the introvert is retracted. In many cases it is not possible at first sight to be sure whether one is dealing with a *Sipunculus*, a *Phascolosoma*, a *Phascolion* or a *Physcosoma*; but no one could make a mistake about this new form. For these reasons I have ventured to establish a new genus although I fully recognize the temerity of such a proceeding when there is only one specimen to deal with. The beginning of the generic name I suggest indicates its stony cap, the end its nearest allies amongst the Sipunculoids.

LITHACROSIPHON nov. gen.

A Sipunculoid with a solid, conical, stony anterior end to its body. The stony cap borne on a pad, and showing traces of a laminated structure. No posterior shield.

LITHACROSIPHON MALDIVENSE nov. sp.

Longitudinal and circular muscles in bundles, the former of 26—28 strands which anastomose freely. Two retractors arising near posterior end. Spindle muscle present. Very numerous rows of slightly chitinized hooks. The hooks in each row two-pointed and very

[1] *Bull. Mus. Harvard*, XXI. 1891, p. 143.

numerous. Intestine in about 10—12 coils, no diverticula on rectum. Tentacles few and short. Two conspicuous eyes.

Locality. The single specimen was procured by breaking up a large coral mass, dredged from 25 fathoms at Miladumadulu in the Maldive Islands. It is worth noting that the undoubted head-quarters of the genus *Aspidosiphon* is in the Indian Ocean.

EXPLANATION OF PLATE VII.

b = brain.
ch. p = chitinous process on introvert.
d. v = dorsal blood vessel.
e = eye.
i = intestine.
int = introvert.
l = base of lophophore.
l. l = lower lip.
n = nerves.
oe = oesophagus.
p = pad which secretes stony cap.
r = rectum.
r. m = retractor muscles.
sp. m = spindle muscle.
v. n = ventral nerve cord.

FIG. 1. Side view of *Lithacrosiphon maldivense* Shipley, × 2, showing the appearance and the colour of the specimen preserved in spirit.

FIG. 2. Dorsal view of the head × 4, showing the white calcareous cap, the sheath which surrounds its base, the tubercles on the skin, and the anus.

FIG. 3. Ventral view of the head × 4, showing the orifice of the introvert and the other structures mentioned under Fig. 2.

FIG. 4. Side view of the head × about 4·5, showing the profile of the calcareous cap.

FIG. 5. The body of the animal laid open by a dorsal incision to show the internal organs, × 2.

FIG. 6. One of the chitinous projections found amongst the hooks of the introvert, highly magnified.

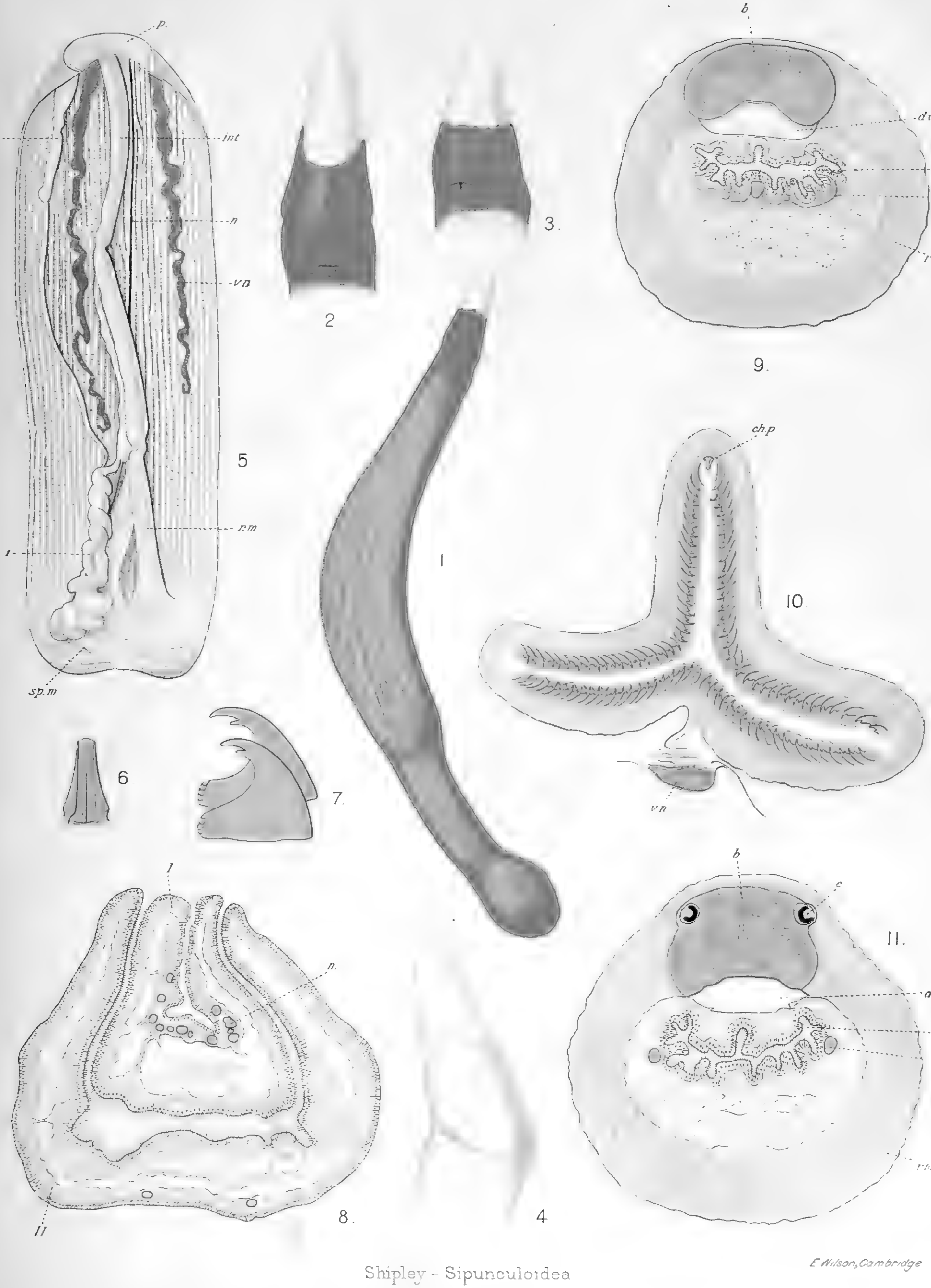
FIG. 7. Two of the hooks of the introvert, highly magnified.

FIG. 8. Transverse section through the semi-circular mouth, showing the base of the lophophore and the lower lip, each with nerves coloured yellow and blood sinuses white, highly magnified.

FIG. 9. Transverse section through the posterior half of the brain and through the ventral half of the circumoesophageal nerve-ring, both coloured yellow.

FIG. 10. Transverse section through the retracted introvert and the ventral nerve cord. The introvert had contracted into a three-ridged tube. The hooks and nervous system are coloured yellow. One of the chitinous projections is shown.

FIG. 11. Transverse section through the anterior half of the brain showing the eyes; the two halves of the circumoesophageal cord are shown on each side of the oesophagus.



Shipley - Sipunculoidea

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LAND AND FRESHWATER MOLLUSCA.

By Edgar A. Smith.

The small collection obtained by Mr Stanley Gardiner's expedition is of special interest as being the first made in these islands. As far as I can ascertain, not a single land or freshwater shell has hitherto been recorded from these localities.

The present collection comprises eight land and two freshwater forms from the Maldives and four terrestrial species from the Laccadives, three of which are included among those from the Maldives. The latter group, judging from the collection at hand, does not possess a single indigenous species, all the forms occurring either on the Indian Peninsula or in Ceylon or other localities. The single species (*Sitala vagata*), described as new from the Laccadives, will in all probability eventually be found on the mainland of South India.

The following table shows at a glance the distribution of the species recorded:—

	India	Ceylon	Other localities
Succinea vitrea[1]	×		
[2]*Sitala vagata*[3] n. sp.			
Euplecta indica	×		
Xestina bombayana	×		
Rhachis punctatus[1]	×	×	Zanzibar, Mozambique
Opeas gracilis[1]	×	×	Sumatra, Java
[2]*Tornatellina manilensis*			Philippine and Natuna Is.
[2]*Melampus castaneus*			Christmas Is., Samoa, Hawaii.
Leptopomoides halophilus		×	
Melania tuberculata	×	×	Africa, Madagascar, Mauritius, Syria, Persia, Arabia, Siam, Java, Australia, &c.
Cyrena ceylonica		×	

In the "Introduction" to this work (p. 7) Mr Gardiner refers to the introduction of many plants by foreign vessels. Doubtless from time to time communication with the

[1] From both Maldives and Laccadives.

[2] Not yet known from India or Ceylon.

[3] From Laccadives only.

mainland is effected by native craft, which might very easily transport the few molluscs, that occur on the islands.

1. *Succinea vitrea* Pfeiffer.

Succinea vitrea, Pfeiffer, *Monog. Helic.* vol. IV. p. 810; Hanley, *Conch. Ind.* pl. LXVIII. figs. 2, 3; Sowerby, *Conch. Icon.* vol. XVIII. pl. III. fig. 20.

Hab. Fainu, North Mahlos Atoll; also Minikoi, Laccadive Islands.

This species was originally described from the neighbourhood of Calcutta, and it also occurs at Bombay. It is scarcely separable from *S. crassiuscula* Benson, another Indian form.

2. *Sitala vagata* n. sp.

Testa obtuse turbinata, minute perforata, tenuis, dilute fuscescens, lineis incrementi tenuissimis obliquis striata, striisque spiralibus minutis supra et infra sculpta; spira mediocriter elata, ad apicem obtusa; anfractus quinque convexi, regulariter accrescentes, ultimus ad peripheriam acute angulatus, infra convexiusculus, antice haud descendens; apertura oblique lunata; peristoma tenue, margine columellari albo, supra paulo dilatato et reflexo, umbilicum partim obtegente.

Diam. maj. 3 millim., min. $2\frac{3}{4}$, alt. $2\frac{1}{2}$.

Hab. Minikoi, Laccadive Islands.

The spiral striation is excessively fine and only visible under a strong lens. This species probably occurs on the Indian Peninsula, although I cannot identify it at present with any known Indian form.

3. *Euplecta indica* (Pfeiffer), var. *malabarica*.

Helix indica Pfeiffer: Reeve, *Conch. Icon.* vol. VII. pl. LXXXIII. fig. 448; Hanley, *Conch. Indica*, pl. LV. fig. 10.

Euplecta malabarica n. subsp., Blanford, *Proc. Malac. Soc.* vol. IV. p. 250, pl. XXV. fig. 5.

Hab. Fainu, North Mahlos Atoll (Gardiner); Malabar Coastland (Blanford).

A smaller form than the type of *indica*, with a more conical spire, more convex whorls, and stronger and more granose sculpture. *Helix shipleyi* Pfr. is another variety of this species.

4. *Xestina bombayana* (Grateloup).

Helix bombayana, Grateloup, *Actes Soc. Linn. Bordeaux*, vol. XI. p. 406, pl. I. fig. 1 (1839): Pfeiffer, *Conch. Cab.* p. 327, pl. CXXX. figs. 4—5; Hanley, *Conch. Ind.* pl. XXIX. fig. 5; Deshayes, *Hist. Nat. Moll.* vol. I. p. 181, pl. 69 I, fig. 5.

Helix belangeri, Reeve (non Deshayes), *Conch. Icon.* vol. VII. pl. CCVI. fig. 1457.

Nanina bombayana, Tryon, *Man. Conch.* series 2, vol. II. p. 80, pl. XXIII. fig. 43 (copy of Reeve).

Hab. "Fainu, North Mahlos, also Male, North Male Atoll, but nowhere else in the group" (Gardiner).

The specimens from the above localities agree in all respects with those from the mainland of India, whence they have probably been transported by human agency. In the present species the concentric or spiral striation upon the upper surface is very faint, and scarcely visible to the naked eye. In *X. vitellina* Pfeiffer, which should, I think, be considered a variety, it is rather more distinct. In other respects I can detect no difference.

Helix belangeri Deshayes, united with this species by Blanford[1], appears rather different.

The shell described and figured in the *Voyage aux Indes orientales*, p. 413, pl. I. figs. 1, 2, 3, is almost double the size of average examples of *bombayana* and very different in form. The sculpture upon the upper surface also is finer than in the shell depicted by Deshayes.

5. *Rhachis punctatus* (Anton).

Bulimus punctatus Anton: Reeve, *Conch. Icon.* vol. V. pl. LXV. fig. 452; Pfeiffer, *Conch. Cab.* ed. 2, p. 229, pl. LXII. figs. 22—24; Hanley, *Conch. Ind.* pl. XX. fig. 10.

Hab. Turadu, Heddufuri, Cumfinadu, and Mahdu, all South Mahlos Atoll; Fainu, North Mahlos Atoll; Hulule, North Male Atoll; also Midu, Addu Atoll: Minikoi, Laccadive Islands.

This species is widely distributed in India, being recorded from near Calcutta, Poona, Bombay, Benares, Trichinopoly, Orissa, etc., also Ceylon, Zanzibar and Mozambique.

During aestivation it might easily be transported almost any distance attached to grasses or herbage of any description, hence its wide distribution. The Maldive specimens are quite normal in every respect.

6. *Opeas gracilis* (Hutton).

Bulimus ? gracilis ? Hutton, *J. Asiatic Soc. Bengal*, vol. III. pp. 84, 93 (1834); Reeve, *Conch. Icon.* vol. V. pl. LXIX. fig. 495; Pfeiffer, *Conch. Cab.* ed. 2, p. 79, pl. XXI. figs. 18 and 19; Hanley, *Conch. Ind.* pl. XXIII. fig. 4.

Hab. Heddufuri and Mahdu, South Mahlos Atoll; Fainu, North Mahlos Atoll; Hulule, North Male Atoll; also Midu, Addu Atoll: Minikoi, Laccadive Islands.

Widely distributed in India, Burmah and Ceylon, also recorded from Sumatra, Java and Borneo. The species of *Opeas* and some allied genera are notorious for their wide distribution, and it is evident that they are capable of surviving transportation for long distances. The eggs, imbedded in earth attached to plants, might very easily be carried from place to place.

[1] *Proc. Malac. Soc.* vol. IV. p. 245.

7. *Tornatellina manilensis* Dohrn.

Tornatellina manilensis Dohrn, *Mal. Blätt.* 1863, vol. x. p. 160; Pfeiffer, *Monog. Hel.* vol. VI. p. 264.

T. natunensis Smith, *Ann. Mag. Nat. Hist.* 1894, vol. XIII. p. 458, pl. XVI. fig. 7.

Hab. Hulule, North Male Atoll.

I cannot distinguish the few specimens from the above locality from this Philippine form. Other examples were described from the Natuna Islands under the name of *T. natunensis.*

8. *Melampus castaneus* (Mühlfeldt).

Melampus castaneus Mühlfeldt: Pfeiffer, *Mon. Auric.* p. 30, for synonyms and references; Smith, in British Museum *Monog. Christmas I.* p. 58, pl. VIII. fig. 18.

Hab. Inguradu, North Mahlos Atoll, on the shore.

This species occurs at Christmas Island, also the Samoan and Hawaiian Islands—and doubtless in many intervening localities. Other species of *Melampus* also have a very extended range.

9. *Leptopomoides halophilus* (Benson).

Cyclostoma halophilum Benson: Pfeiffer, *Conch. Cab.* ed. 2, p. 241, pl. XXXI. figs. 29—31.

Leptopoma halophilum Reeve, *Conch. Icon.* vol. XIII. pl. VIII. fig. 49: Hanley, *Conch. Ind.* pl. CXLII. fig. 4.

Hab. Heddufuri, South Mahlos Atoll; Fainu, North Mahlos Atoll; Midu, Addu Atoll.

A few specimens from the above localities appear to be inseparable from this species. They are smaller than Ceylonese examples and may not be full-grown. Being in fresh condition they exhibit a few spiral lirae, which apparently become worn away or very indistinct with age. Most specimens are of a brownish horn-colour with a single reddish line below the periphery. Occasionally this line is above the periphery, or it may be entirely absent. The Ceylonese specimens are generally of a richer brown colour and inclined to be longitudinally streaked. They also exhibit a pale zone above the infraperipheral line, a feature sometimes observable in the shells from the Maldives.

10. *Melania tuberculata* (Müller).

Melania tuberculata Reeve, *Conch. Icon.* vol. XII. pl. XIII. fig. 87; pl. XVI. fig. 110.

Hab. A freshwater pool, Hulule, North Male Atoll.

Brot[1] gives the following distribution of this well-known species. N.E. and W. Africa, Madagascar, Mauritius, India, Ceylon, Syria, Persia, Mesopotamia, Arabia, Siam, Java. It also occurs in Australia. Only young examples, about 16 mm. in length, were obtained at the Maldives.

[1] *Conch. Cab.* ed. 2, p. 247: also for synonymy and references.

11. *Cyrena ceylonica* (Chemnitz).

Venus ceylonica Chemnitz, *Conch. Cab.* vol. VI. pp. 280, 333, pl. XXXII. fig. 336: Philippi, *Abbild.* vol. III. p. 108, pl. III. fig. 3 (*Cyrena*): Sowerby, *Conch. Icon.* vol. XX. pl. XIX. fig. 111 (*Cyrena*).

Hab. A large freshwater lake, surrounded by mangroves, in the centre of Landu, Miladumadulu Atoll[1].

The species of this genus are generally found near the coast, often buried in the mud of mangrove-swamps. The single specimen from the above locality does not present any characters, which will separate it from the Ceylon form. The outline of most species of *Cyrena* is subject to considerable variation, and as the colour and sculpture of the periostracum are very similar in many of the so-called described species, their identification becomes exceptionally difficult.

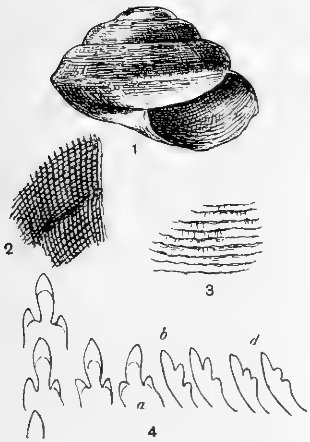


FIG. 24. 1. Shell. 2. Sculpture of upper surface—growth lines 19 to $\frac{1}{100}$ of an inch. 3. Spiral lines on lower surface 9 to $\frac{1}{100}$ of an inch. 4. Radula: *a*. 6th admedian tooth; *b*—*d* laterals.

NOTE ON KALIELLA OR SITALA VAGATA.

Since I described this species, Colonel Godwin Austen has kindly examined the radula. He observes—"I have now come to the conclusion that it is nearer to *Kaliella* than any group I know—both in the general form of the teeth and formula,

K. vagata	Type of *Kaliella*
32–6–1–6–32	26–7–17–26
38–1–38	33–1–33

The admedian teeth are all alike, with a long central tooth, with large side cusps, on a quadrate basal plate. The lateral teeth are tricuspid, becoming very minute on the margin. The sculpture of the shell is not as in the typical *Kaliella*, which is finely lirate transversely, but the transition to a decussate or papillate surface cannot count for much."

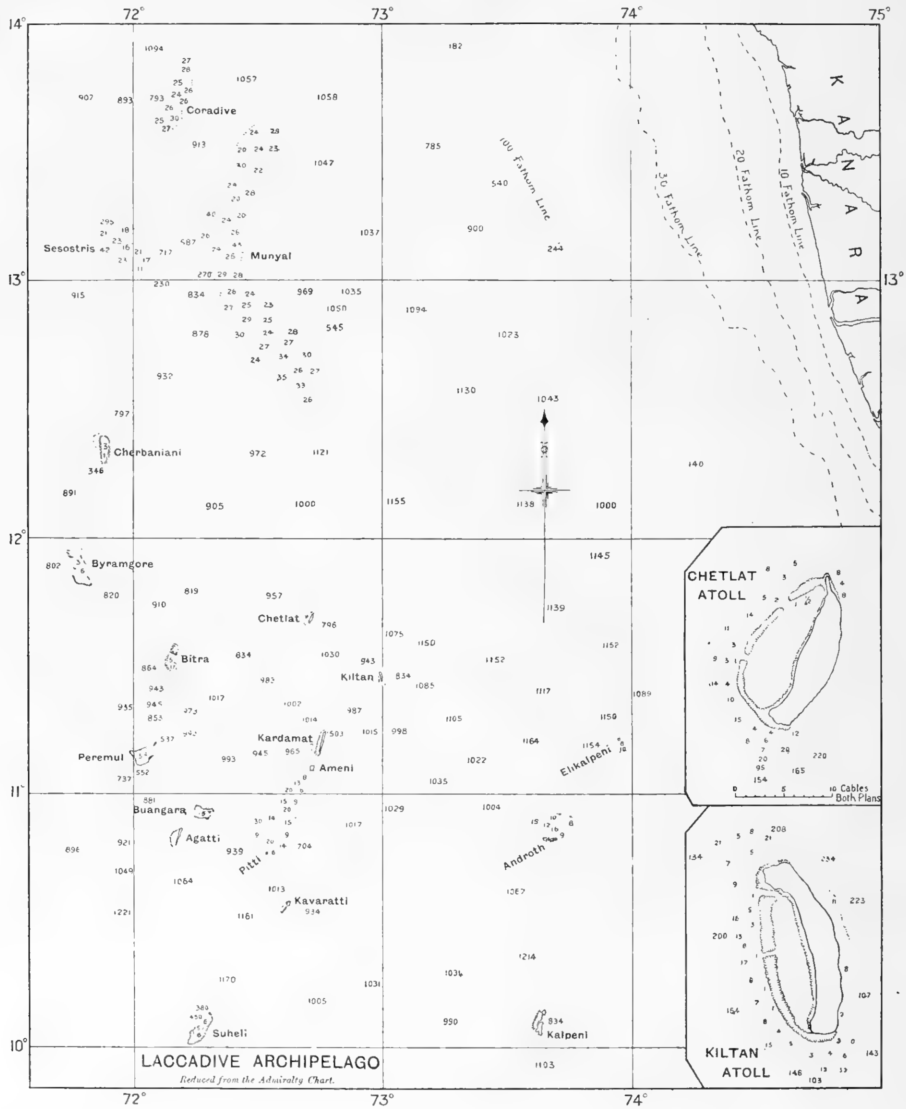
[1] [The animal is very rarely found, even in this locality. Although similar pools are by no means uncommon in the Maldive Group, the natives elsewhere did not recognize the shell. ED.]

THE MALDIVE AND LACCADIVE GROUPS, WITH NOTES ON OTHER CORAL FORMATIONS IN THE INDIAN OCEAN (*continued*).

By J. Stanley Gardiner, M.A., *Fellow of Gonville and Caius College, and Balfour Student of the University of Cambridge.*

(With Plates VIII.—XII. and Figs. 25—33.)

CONTENTS.


72°
73°
74°
75°
14°
13°
12°
11°
10°
Coradive
Sesostris
Munyal
100 Fathom Line
30 Fathom Line
20 Fathom Line
10 Fathom Line
KANARA
Cherbaniani
Byramgore
Chetlat
Bitra
Kiltan
Kardamat
Peremul
Ameni
Elikalpeni
Buangara
Agatti
Pitti
Androth
Kavaratti
Suheli
Kalpeni
CHETLAT ATOLL
10 Cables
Both Plans
KILTAN ATOLL
LACCADIVE ARCHIPELAGO
Reduced from the Admiralty Chart.

To face p. 147

of Reef-building Corals and Nullipores—Oceanic Shoals and Deep-Sea Corals —Intermediate depth Corals—Depth of Lagoons—Currents—The Topography of the Banks—The Reef-Platform—Conclusions.

(*To be continued.*)

CHAPTER V.

THE MALDIVE AND LACCADIVE ARCHIPELAGOES.

THE Maldive and Laccadive archipelagoes form a long, narrow belt, extending due north and south from the level of the Kanara coast of India in lat. 14° N. to Addu Atoll in lat. 0° 40′ S. (fig. 3). The Laccadives form the north part of the line down to lat. 10° N., and consist of a series of isolated islands and banks, mostly of small size, extending between longs. 71° 40′ and 74° E. The Maldives commence in lat. 7° 10′ N., and then form a definite sequence of large banks between longs. 72° 30′ and 73° 40′ E. Intermediate to the two groups in lat. 8° 20′ N. lies the isolated bank of Minikoi, distant 111 miles from the nearest Laccadive shoal and 71 miles from Ihavandifolu, the most northern Maldive reef. It hence does not belong much more to one archipelago than the other.

The contour lines are not accurately known for the two series of shoals, but it is probable that their common bank has nowhere a greater depth than 1200 fathoms. In the "Nine" and "Eight Degree" Channels on either side of Minikoi soundings of 1195 and 1179 fathoms are recorded, and in the "Equatorial Channel" separating Addu and Suvadiva 1027 fathoms. A bight of deeper water runs up between the bank and the Indian and Ceylon coasts, 1345 fathoms being obtained in lat. 10° N. A depth, however, of 1000 to 1100 fathoms everywhere separates the Laccadives from India, and there is no trace in any part of any connection with the mainland by a series of shoal-patches or otherwise (Plate VIII.). The least depths, 1047, 1037 and 1094 fathoms, are found between the Bassas de Pedro (Munyal) and the coast, distant 117 miles. The breadth between the 100 fathom lines is only 36 miles, and the channel accordingly is comparatively narrow. A possible connection is hence suggested, whereas the narrowness of the channel is really due to the fact that the two archipelagoes lie north and south, while the Western Ghats and the Indian coast extend north-north-west and south-south-east. The channel is further reduced by the increase in the distance of the mud line at about 85 fathoms from south to north along the west coast of India, the regular and customary increase in approaching the head of any bay.

The 2000 fathom line (fig. 3) closely approaches the south coast of Ceylon, and thence runs up slightly towards Cape Comorin. Between the latter and Minikoi the depth is about 1550 fathoms, the 2000 fathom line passing right across to the Maldives, which it probably closely follows southwards at a distance of 30 to 40 miles outside the banks. Off the south of Addu it may be expected to be a little more remote, and thence it extends up nearer to the west side of the Maldives, becoming somewhat more distant from the Laccadives and the Indian coast towards the head of the great bay between India and

Arabia. There is one sounding of 1977 fathoms to the south-west of Suvadiva at 30 miles distance, and there are two west-north-west and west-south-west of Minikoi of 2120 and 2220 fathoms, each at about 100 miles.

I. The Laccadive Archipelago[1]. (Plate VIII.)

If Minikoi be left out of consideration, this group consists of seventeen banks, round each of which the 100 fathom line is continuous. Of these ten have more or less ring-shaped reefs or are atolls, one is almost completely covered with a surface reef with land, two are large banks with one or more surface reefs and traces of the ring condition, and the remainder are completely submerged banks. Elikalpeni, Androth, Kalpeni and Suheli are outliers, all probably separated by over 1100 fathoms from one another and the rest, which with the possible exception of Kavaratti are included within a common 950 fathom line.

Of the atolls, Kiltan, Chetlat and Kavaratti are perfect, of oval-shape, lying almost north and south. They resemble Minikoi in that their eastern reefs are largely covered with land, while their western are awash. Kalpeni[2] has the west reefs bare, but islands for 4 out of 7 miles, the length of the bank, along its eastern face. Agatti bank has two atolls. Agatti itself, almost exactly resembling Kavaratti to the south, separated by a bank at a depth of 7 to 10 fathoms from a northern atoll, with three islands on its eastern reefs. The lagoons of the above are extremely shallow, having only about 3 fathoms of water, and their passages lie to the north or west. Of the other ring-banks Cherbaniani is perfect, with 3 fathoms of water in its lagoon, sand-banks on the north and east sides, and a few coral rocks at the south end, a single passage to the south-east. Suheli to the north is also perfect with islets north and south-east, lagoon 6 fathoms and passages north-west.

Bitra has one island north-east, passage close to same and lagoon 5 fathoms. Byramgore and Peremul are less regular, the circumscribing reef of the former being very imperfect, except to the south; their lagoons are much broken by coral patches, between which 5 to 7 fathoms are found. Kardamat is an atoll either in a late or an early stage. Its reef is 5 miles long by $2\frac{1}{4}$ broad, lying nearly north-by-east and south-by-west; a narrow island

[1] In considering this group my sources of information were in the first place the "West Coast of Hindustan Pilot, 1893," pp. 365—373, and "Malabar" by William Logan, Collector (who visited the south islands attached to Calicut in 1869 and again in 1887), vol. II. pp. cclxxv—cccii, 1887. I was subsequently through the courtesy of the Chief Secretary to the Government of Madras allowed to examine in his office at Madras a large number of reports on the islands, some unpublished. I have also made use of native sources of information to check and extend the above accounts.

[2] I have already referred to the effect of the hurricane of 1847 (p. 21), which was most destructive on this island, reaching it at high tide. The following account shows how the sea may attain access to any low island, and, if the conditions of the region are suitable, its complete erosion might rapidly follow. "The sea rose and flooded the whole but across the narrower part of the mainland; it seems to have had tremendous velocity. All the trees, with the very soil, and between 50 and 60 houses were washed into the ocean with upwards of 200 persons." "Across the broader parts of the island the water was not so destructively rapid, but so complete was the inundation that the first impression of the islanders was that the whole shoal had sunk." "The storm lasted for about an hour in all its violence." "Out of upwards of 105,000 full-grown coconut trees, the number before the storm, 768 only are now standing." ("Proc. Board of Revenue, S. Canara, Aug. 2nd, 1849," quoted in *Malabar*, vol. II. p. ccxcix.) In the same storm enormous quantities of loose coral appear to have been swept back from the shores into the *totam*, or hollowed-out planting land. A large part of the seaward beach was swept almost bare of loose coral masses, which were deposited at the south-east corner of Kalpeni island, forming a bank 60 feet wide by 12 feet high above the low tide level. This naturally suggests that a large part of the rocky areas of all these islands might have been formed in a similar way, but in reference to Minikoi I have carefully and at considerable length shown the grounds on which I base my view that that island, and by inference probably all these islands, owe their origin directly or indirectly to some change of level (Chap. III.).

4 miles long covers the eastern side of the reef, a kind of boat-channel, the incipient or the possibly former lagoon, separating it from the western reef.

Two of the submerged banks have land on their edges, Androth island resting on the south of a bank $11\frac{1}{2}$ miles long east and west by 6 broad, while Ameni and Pitti are at opposite ends of a bank 26 miles long, extending north-north-east and south-south-west. Both banks have traces of the atoll-shape, Androth having 16 fathoms in the centre and 7, 10 and 15 on the edge, and Pitti 26 fathoms in the centre, 9, 6, 8, 20 and 9 on the rim. Elikalpeni, north-west of Androth, is nearly round, 4 miles in diameter, depth irregular, average 8 fathoms, least 6 fathoms. The remaining banks lie all to the north of the group, and are much larger, Munyal being 71 miles long by 7—14 broad, Sesostris 15 by 8 miles, and Coradive 20 by $5\frac{1}{2}$ miles. Sesostris has numerous soundings, indicating patches growing up, and some trace of a rim in soundings of 11, 15, 17 and 12 fathoms on the circumference, the general depth being about 23 fathoms. Coradive averages 26 fathoms in depth and Munyal 28 fathoms; both are somewhat irregular but a less depth than 20 fathoms is not found on either. All three are charted as covered with sand, decayed coral and broken shells.

A few points are of particular interest as bearing on the general question of the formation. In the first place practically all land lies on the eastern or leeward side of the reefs, the group being completely exposed to the gales of the south-west monsoon, while it must be largely protected by India from those of the north-east. The present contour of the land throughout the group would hence seem to be really due, as at Minikoi, to elevation and subsequent erosion, the latter having completely removed all save traces of the land from the western reefs. A few of the smaller islands are mere sand-cays, but the larger are to seaward covered with loose coral-blocks on a substratum of coral limestone; the seaward beach is usually steep, with pinnacles and masses of the same rock extending out on to the reef, wherever it forms a reef-flat. Against the lagoon the islands have been very considerably broadened by sand blown up from the beach, and some probably owe the greater part of their breadth to this source.

The larger islands of the Laccadives have a steep slope close along their eastern faces, in effect have no definite reef-flat, indeed not as much reef as is found at Minikoi between Mou-Rambu and Kodi points (fig. 6). In contour all the surface reefs have the usual gradual slope outwards for a certain distance, passing into a steep commencing at 20 to 30 fathoms, a considerably less depth than is customary off exposed reefs. All have a greater distance to the commencement of the steep off their western than their eastern faces, and this is the more especially marked where long stretches of land occur. Off the west side the steep seldom commences within 250 or 300 yards of the edge of the reef, more often averaging 400—500 yards, while to the east it is seldom off islands more than a cable (100 fathoms) from the actual shore. Off Chetlat, Kalpeni and Kardamat the 100 fathom line is in places within 150 yards of the land, and the shelf may be little marked, the slope commencing from the reef itself. I shall have further occasion to discuss the meaning of this diversity, but, considering the presence of definite windward and leeward reefs in the Laccadives, I may here point out that it seems to indicate a real relationship between the slope and the wave, current, and tidal actions, in effect to suggest a connection between the line of the steep and the mud-line off continental lands.

There are no dredgings over the submerged banks which show their formation. The bottom on Elikalpeni can be clearly seen, and is covered with sharp coral rocks. On Androth and Pitti also the coral is visible, and is building up circumscribing reefs. The natives do not visit the northern banks, and so less is known about them. If they were fairly level, they might conceivably be deemed to be washing away, but they vary in depth to such an extent (Munyal 14 in 34 fathoms), that there can be little reasonable doubt but that they too are in places being built up by corals and other organisms to the sea level. Growing coral is very seldom obtained by any sounding apparatus, while decaying coral (which abounds, wherever there is growing coral) is readily secured; hence no reliance can be placed on the recorded presence of the latter, as showing the real character of the bottom in any particular place. A further feature is the very marked steep round all these banks, seeming to be in many places absolutely precipitous. To a less extent the same is a feature of all the Laccadive banks, and is especially noticeable as the fall off some seems to extend from about 25 fathoms to 400 or 500 fathoms, or even more.

II. The Maldive Archipelago. (Plates IX. and X.)

In discussing the question of the formation of the Maldives it is necessary to consider the Archipelago in three main divisions, Addu, Suvadiva, and the main group. The two former differ so greatly both from one another and the remaining banks that they require separate consideration. They are divided by relatively broad channels both from one another and the rest of the group, so that their conditions of wind, rain, and currents are not the same. The changes going on in them differ materially as compared with the other banks, and indeed they would appear almost to have been formed quite independently of the more northern shoals.

Addu (fig. 25) differs from all the other banks of the Maldives and Laccadives in its more perfectly-typical atoll-form. Being 10 miles in maximum length east and west by 6½ miles north and south, its encircling reefs are about 20 miles long, of which at least two-thirds are covered with land. The greatest length from reef to reef of the atoll is at the north end, and on this as base the reefs to the south form a rough semicircle. In this there are two passages to the south and south-east—both with shoals growing up—except for which practically the whole reef is crowned with land, only narrow gaps separating the different islets. To the north the reef runs so as to form a

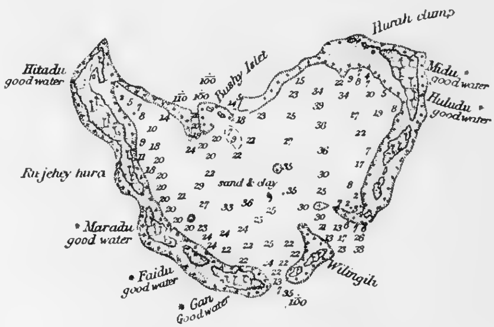


Fig. 25. Addu Atoll (*from the Admiralty Chart*). Scale 4 miles to 1 inch.

bay, which has at its head two narrow passages; these seem to have been considerably filled up since the survey was made in 1835, and are never now used by the islanders for their vessels. The north reef itself is narrower and almost bare, two islets being found on the patch of reef between the passages, and a few others extending out along the reef for about a mile from Midu at the north-east. The chart has in the lagoon a patch of soundings of 34 to 39 fathoms, but our deepest sounding was only 31 fathoms, and soundings around the position marked 39 fathoms only yielded 27 to 30 fathoms. The lagoon, instead of being fairly open, is now near the circumscribing reefs, especially north-east and north-west, much filled in by coral shoals. Indeed ships cannot now approach within one and a quarter miles of the head of the north-west horn of the lagoon, which is represented as open in Moresby's chart. The land too has very greatly changed, and the seaward edge of the reef, particularly round the semicircle to the south and at the two horns (north-east and north-west), has grown considerably outwards. It is mainly in the filling in of its lagoon and its topography that the atoll differs from the rest, but its varied conditions will be more particularly considered in the Appendix to this paper.

About Fua Mulaku in lat. 0° 18′ S. I have no particular information, not having been able on account of the heavy gales to land on it. It is an island, surrounded by a reef-flat, occupying the northern three-fifths of a bank, $3\frac{1}{2}$ miles long by $1\frac{1}{5}$ broad. The bank to the south is covered with coral rocks, and has 5 to 8 fathoms of water. The shoal is said to have practically no reef-platform, but to slope almost precipitously off the whole bank except to the south. The island does not appear to be materially eroding. It is in the centre naturally hollowed out to form a large freshwater pool of inconsiderable depth.

Suvadiva atoll[1] lies between the Equator and lat. 1° N., and is 43 miles long from north to south by 35 miles from east to west, covering an area of over 800 square miles. The bank is nearly completely surrounded by reef, outside which a typical reef-platform, wherever we could see, appeared to exist. The circumscribing reef has about 40 passages into the lagoon of the atoll in a length of 130 miles. Many of these are extremely narrow, two only being over half a mile in width; six have depths of 30 to 36 fathoms, five of 20 to 29 fathoms, and ten of 10 to 19 fathoms. The shallower passages in particular, but to a certain extent all, seem to have narrowed somewhat as compared with the chart, but none appeared to have actually closed up, nor have any fresh ones formed. In most cases the narrowing has been due to the outgrowth of the reefs on either side, but at the same time there may have been a decrease in depth as well. Further, it was remarkable that some of the reefs have grown out horns into the lagoon by the passages, a condition not found on any other bank[2]. The islands form a series along the east, south and south-west sides of the atoll, the north and north-west parts of the encircling reef being almost bare. The larger are generally formed of rock on their seaward face and sand against the lagoon. Parts of the encircling reef are double, with pools in the centre, having a few fathoms of water. This is especially the case to the south-west, but between Nadalle and Hondedu, where we particularly examined the reef, many of the pools have come into communication with the lagoon of the atoll, the reef between having been wholly or in part removed. The lagoon is open and very free from reefs. In a traverse round the whole of the lagoon, while dredging, we carefully examined as many of the reef-patches as possible. While locating seventy-two marked in the chart, we only failed to find two, and we observed only three new shoals. Most of the deeper patches marked with a few fathoms of water are now definite surface reefs. The reefs surrounding Hatedu, Labadu and Noorbhai islands have grown out somewhat, while a shoal near Budu has been incorporated into its reef. The

[1] For chart see Appendix.

[2] The decrease in width of the passages was particularly marked on each side of Kudu and Nilandu in the east reef and between Gan and Gaddu to the south-east. The outgrowth of reefs into the lagoon was observed on each side of Nilandu and to the south of the passage between Kondai and Diyadu. For further particulars and chart see Appendix.

patches generally did not, however, appear to have greatly changed in size, but some had subdivided themselves into two or more separate masses. The lagoon islands are undoubtedly all washing away, and none are now inhabited. The majority seemed to be of sand formation, surrounded by rather rocky reef-flats. In the depth of the lagoon our soundings showed an increase varying from 1 to 4 fathoms towards the centre of the atoll, but there did not appear to be any general change near the encircling reefs. The shoals almost uniformly reach the surface, or within 2 or 3 fathoms of the same; they have precipitous walls from about 5 fathoms in depth down to 20 or 25 fathoms, where they tail off in an area covered with rough, dead coral to the general depth of the lagoon in their vicinity. The bottom is in the shallower parts covered with sand, but over the centre and below 40 fathoms with fine mud. It was remarkable that the dredgings nowhere gave any signs of any shoals growing up, the bottom appearing in any one place to be almost a dead level. On the whole the atoll is scarcely at all changed since the survey, and the conditions are such that it is only after a minute examination that any deductions should be actually ventured upon. The atoll has reached an almost perfect state, and is of such extremely large size that it is quite probable that many of the changes, now going on, are quite secondary and not such as are taking place in the majority of atolls[1].

The remainder of the banks of the Maldives form a well-defined line of 325 miles in length without any breaks of really considerable extent. The line is single at either end, but it doubles itself in the centre and encloses a long narrow strip of water between its two series of shoals. There were no soundings in the original survey, which served in any way to show the topography and connections of the central reefs with one another, but we succeeded in running three lines across the basin as follows[2]:

1. Mawafuri, North Nilandu to the channel between Wattaru and Mulaku 157, 164, 176, 188 and 198 fathoms.

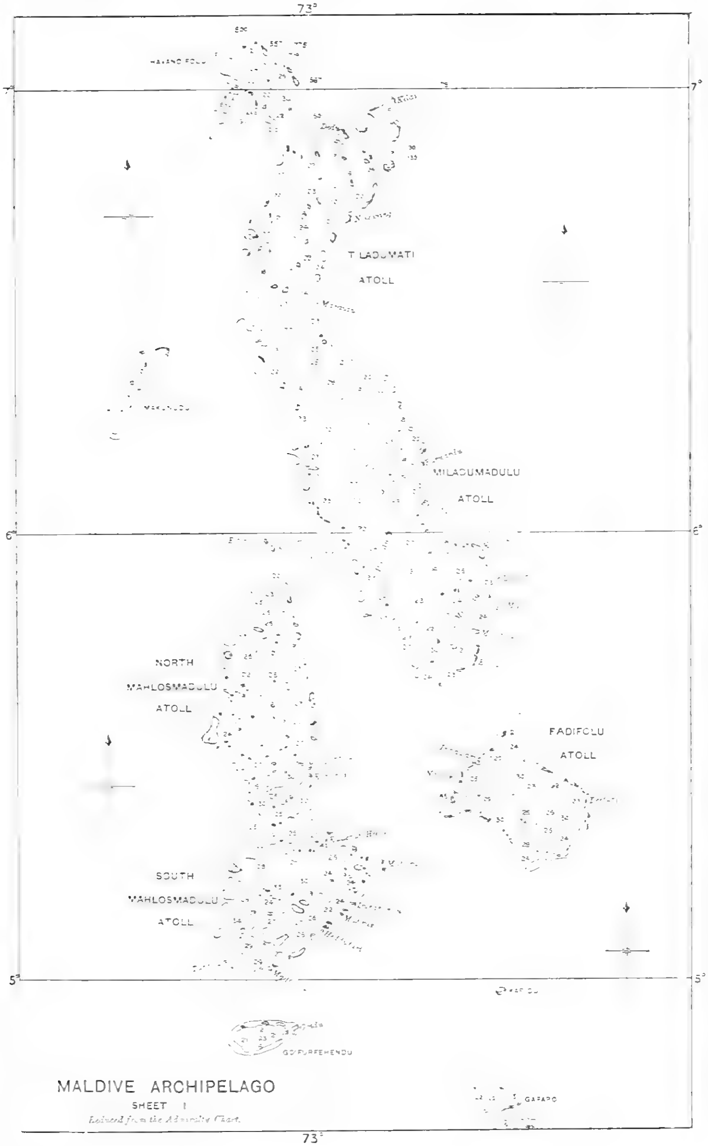
2. Felidu, the first sounding 5 miles and then a line 10 miles north of the last to the channel between North Nilandu and Ari 206, 201, 197 and 198 fathoms.

3. Mahiaddu, Ari diagonally across the basin to the channel between the two Male banks 188, 205, 205, 192, 162 and 186 fathoms.

In addition I ran a section out until a level bottom at about 165 fathoms was reached one mile to the west of Naifaro, Fadifolu, and there are a series of soundings in the chart between Ari and Rasdu and the latter and Toddu, showing a level bottom at about 150 fathoms. We also sounded some of the channels between the different banks, finding maximum depths of 270 fathoms between Kolumadulu and South Nilandu, 235 fathoms South to North Nilandu, 243 fathoms Mulaku to Wattaru, 260 fathoms Wattaru to Felidu, 198 fathoms North Nilandu to Ari (not quite in the centre) and 245 fathoms South to

[1] Throughout the course of the expedition I was assisted in all branches of the work by Mr Forster Cooper, whose observations relating to matters of fact I have in many places incorporated without special acknowledgment. I was greatly assisted in the work in Suvadiva and Addu by Capt. Molony, s.s. "Ileafaee," who paid particular attention to the locating of the various reefs and shoals in their lagoons.

[2] We used for sounding from the s.s. "Ileafaee" between the atolls and on Addu, Suvadiva and Nilandu banks a "Lucas" machine, kindly lent us by the Admiralty, Mr Lucas himself presenting us with 3000 fathoms of wire. The machine was not adapted to receive a belt from the steam-winch, so that the wire had to be hauled in by hand, an especially long and tedious process, as we had no detachable weights. While in the schooner an ordinary sounding line was generally employed, but for boat-work I more frequently used a loosely-spun cod-line with a 3 lb. lead, as recommended by Mr J. Y. Buchanan.

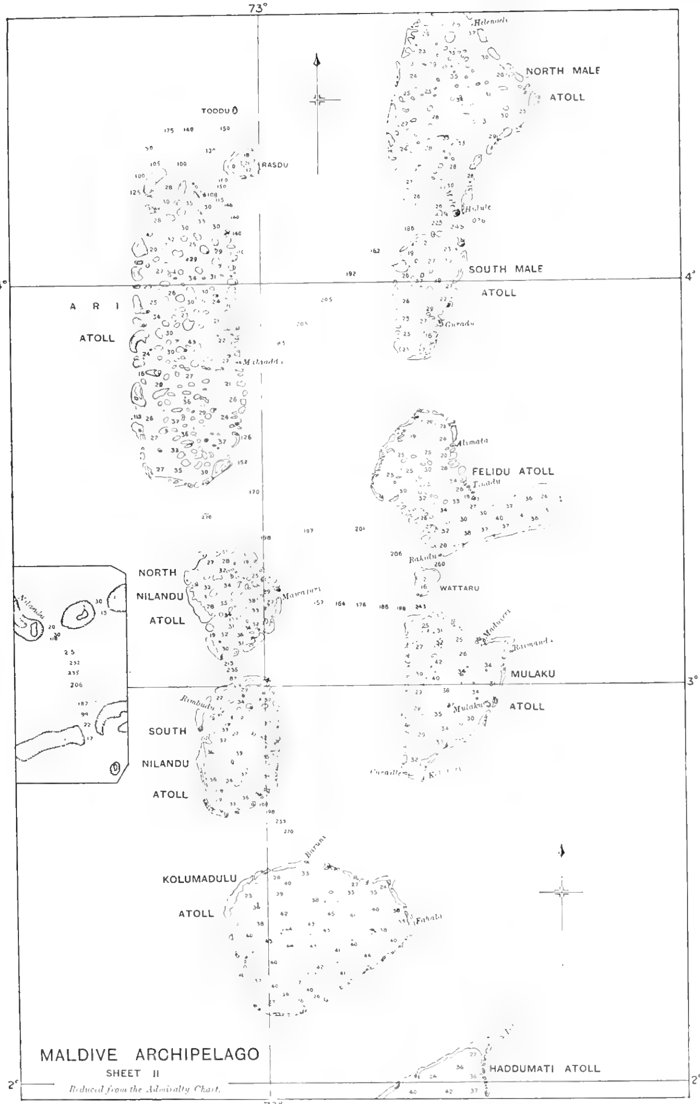


MALDIVE ARCHIPELAGO

SHEET I

Reduced from the Admiralty Chart.

To face p. 153



(Showing the lines of soundings run by the Expedition.)

To face p. 153

North Male. In the latter channel we carried the line out eastwards, getting 1030 fathoms two miles south-east of Hulule reef and about the same distance from the nearest reef of South Male. This is the sole sounding off the centre of the group, which at all suggests the contour of the bank as a whole. There may be opposite the passage, where the above

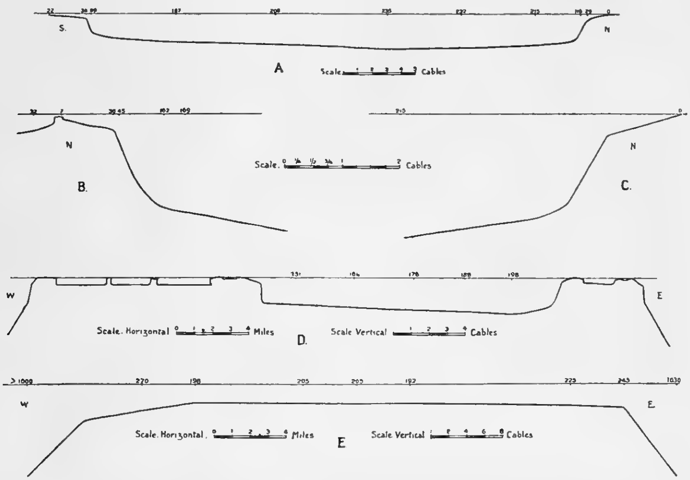


FIG. 26. *A*. Section across the passage between North and South Nilandu atolls. *B*. Section of slope to south of South Nilandu. *C*. Section to south of North Nilandu. *D* and *E*. Sections across the central basin, *D* being supposed to pass across two atolls, and *E* along two of the channels between the banks. (See Plate X.)

sounding was taken, a small bight of deep water, but from the analogy of other reefs it is probable that the 1000 fathom line approaches all the banks nearly as closely on their seaward sides. There are, however, a few soundings to the north, but here the conditions change somewhat owing to the approach towards continental land. A line to the south-west of Ihavandifolu shows a depth of 357 fathoms less than three-quarters of a mile from the reef, a gradual slope to 1000 fathoms at a distance of 5 miles, succeeded by a very much more gradual slope to the 2000 fathom line presumably in a further distance of 30 to 40 miles.

The trend of the Maldives is such that from Kolumadulu to Ihavandifolu it is almost certain that all must lie on the same plateau. The distances separating the banks are inconsiderable save the Kardiva Channel, running north-east and south-west, which between Fadifolu and Gafaro is 27 miles across and between Goifurfehendu and Ari 33 miles. The lines of the banks are, nevertheless, quite clear; indeed on the east side the island of Kardiva breaks the channel almost in the centre, and to the west Toddu stands out about 10 miles north of Ari. There is not improbably a great bight of deep water extending inwards for many miles from the west, and the whole plateau also may be deeper, but at the same time it is unlikely that the banks to the south and north are separated by any depth greatly in excess of that found in the central basin to the south or in the channels between the atolls. Haddumati to the south and Makunudu to the north-west may arise separately, but Ihavandifolu is almost certainly founded on the same bank, the single sounding, 601 fathoms, in the channel between it and Tiladumati lying considerably to the east of the narrowest part of the passage. The various banks, then, arise as so many plateaus from a common plateau, which has a general depth of about 200 fathoms. This plateau presumably includes on its surface all the banks between Kolumadulu and Ihavandifolu. It probably continues at about the same depth beneath the various banks, to seaward passing into the general slope off the reefs. In the channels, however, as soundings between the two Male atolls show, the depth increases gradually to seaward between the various banks.

In sounding we used the 28 lb. "Valve" leads of Admiralty pattern and the "Snapper," as made by the Telegraphic Construction and Maintenance Co. of Silvertown. The former leads failed on the great plateau to bring up samples of the bottom, and those procured by means of the "Snapper" were very meagre. In the passages between the banks the bottom was evidently extremely hard, only an occasional piece of dead coral being obtained. In the sections across the plateau it was generally similar, with, in places, very coarse sand of broken coral and shell fragments. Fine mud was obtained in the soundings of 205 fathoms due west of South Male, its deposition here being due probably to the protection afforded by that atoll to the east and Ari to the west. The behaviour of the lead in sounding especially in the channels left no doubt but that the current found on the surface extended to the bottom with at least as great force[1].

The banks have to seaward the regular characteristic platform, extending out from the reefs for a distance usually of about 300 yards with a gradual slope to 40 or 50 fathoms. This is followed by the "steep," which at about 150 fathoms passes into a more gradual slope, perhaps the original slope of the whole plateau. This depth though appeared to be very irregular even in a small area, off the south-east of North Male and the north-east of South Male varying between 120 and 180 fathoms. Off North Mahlos, however, the line seemed more regular, lying in three places between 140 and 150 fathoms. Towards the central basin of the plateau the reef-platform is much narrower, seldom exceeding 200 yards in breadth. The steep commences generally below 30 fathoms and the fall then is absolutely precipitous to at least 110 fathoms, the lead not resting anywhere. Of course over such an enormous area the variation in slope may be very large, but the platform appeared to be distinctly narrower and the steep more precipitous against the central basin. In the channels between the banks the platform is usually intermediate in breadth, but the steep commences at a shallower depth than on either side, and is almost perpendicular. In entering North Nilandu from the south the sounding machine near the stern of the s.s. "Ileafaee" recorded 118 fathoms, while the bottom could be seen over the bows of the vessel, a distance of less than 100 feet (fig. 26, *C*). In the Maimbudu passage of South Nilandu also the lead gave 162 fathoms, but when we had got in about 50 fathoms of wire the bows of the steamer drifted over a 6-fathom patch; the lead at the same time stuck in something on the slope and was lost (fig. 26, *B*). Off the south-east of Ari, east of Dungatee the lead hung for a moment at 32 fathoms, and then fell off to 114 fathoms, a fresh sounding a few yards further out giving 126 fathoms. The inner sides of all these atolls may be considered to be their leeward sides, as the force of the waves and currents

[1] When we were sounding in April, the currents were invariably setting from east to west, the wind being from the west and hence opposed to them.

against them must be largely broken by the banks of the opposite line. As such the great resemblance between their slopes and those to leeward of the Laccadive reefs is remarkable, the slopes to windward in both groups being approximately the same.

The different banks (Plates IX. and X.) present among themselves at the present day great diversity of form in their surface-reefs. The smaller have a well-marked ring-shape independently of their position in the group, but the smallest of all, Toddu, is merely a reef almost completely covered with land $1\frac{1}{2}$ miles long by 1 mile broad. Karidu is a little larger; the island covers the south half of the shoal, the north part having an enclosing reef and shallow lagoon. Wattaru and Rasdu are small round atolls about 4 miles in diameter; the former has one small passage and an open lagoon with 19 fathoms of water, while the latter has two broad passages and lagoon, 21 fathoms deep, much filled in by small reefs. Goifurfehendu and Gafaro are slightly larger, being 9 and 7 by 4 miles; like Wattaru they have each a single small passage and open lagoons, 22 and 23 fathoms deep. The rest of the banks are much larger, but, independent of other considerations, position seems to be a definite factor in assisting them to assume the atoll-shape. In this same quality they present great variation, differences which are strongest between those at the two ends of the series. To the north the Tiladumati-Miladumadulu bank, 87 miles long by 11 to 20 broad, has as a whole little semblance to an atoll. It indeed possesses merely a number of isolated reefs, by far the greater percentage crowned with land. Those on the edges of the bank tend to be rather more elongated than those in the centre, but it is only here and there that two or three lying together in close proximity form anything approaching a definite rim to the bank. The interior of the bank would be described as open. The reefs reaching the surface on it are few but relatively large, small patches such as are commonly found in reef-areas or atoll-lagoons being completely absent. Some of the reefs are themselves *faro*[1], or small atolls, with definite little lagoons, or *velu*[1]. The latter are usually shallow, seldom exceeding 10 fathoms in depth. Dureadu, however, in the centre of Miladumadulu is remarkable, being only one and a quarter miles in diameter but having 16 fathoms in its velu. The Mahlos bank has a more definite series of reefs on its rim, large faro to the west but small isolated masses to the east and south. It has no central basin, the whole of the inner part being much broken and filled up with reefs awash, many small, indeed mere patches. Fadifolu is much smaller and has a well-defined rim to the east, little broken up, and a series of patches to the west. The lagoon is much more open than the last and to the south-east is almost clear of reefs.

The banks of the eastern series as compared with Mahlos have progressively southwards better-defined rims and more open lagoons. North Male is clearly marked off on all sides by a series of large faro, mostly elongated in the direction of the rim of the whole bank. Its lagoon has small areas with numerous little patches of reef, but mostly it is open,

[1] The technical term *atoll* is derived from the Maldivan *atolu*, signifying a province for governmental purposes. There are 13 of these in the Maldives, and many consist of the islands on separate banks, most of which have distinct encircling series of reef reaching the surface. Many of the individual reefs are themselves ring-shaped with pools of water several fathoms deep in their centres. There are obvious disadvantages in using diminutives of the terms *atoll* and *lagoon* as applying to such. They are situated on shallow banks, and many are actually larger than some of the isolated ring-shaped reefs of the Pacific, which arise separately in the deep basin of that ocean. I therefore propose to borrow further the Maldivan terms, *faro* and *velu*, the former signifying such a small ring-shaped reef of an atoll or bank and the latter its central basin. I further, following the Maldivan use of the term *velu*, apply it to deep pools even in the long, linear, circumscribing reefs of many of the banks, as I conceive that such pools have in all these reefs on banks the same mode of origin.

studded with relatively large reefs, themselves usually faro. South Male is very similar but much smaller. Many of the circumscribing reefs are narrower and without velu. Felidu is enclosed by linear reefs or small patches with little velu and narrow passages between. Where the passages are few, the lagoon is almost free from reefs, but where numerous very patchy. Mulaku taken as a whole is still more enclosed, and the lagoon is more open; its shoals are however mostly smaller than in the lagoons of the more northern banks. The circumscribing reefs still have linear velu stretching along them, but they do not at all approach the ring condition.

In the western line Ari is intermediate to some extent between Mahlos and North Male, having a well-defined rim of large faro to the west and south with a series of reef-patches and small faro to the east. A few parts of the lagoon are filled in with small reef-patches, but generally the latter is studded with faro or relatively large reefs. North and South Nilandu have still numerous passages but are more definitely circumscribed by elongated faro than North Male. The north atoll might be placed in the series between North and South Male, the south one between the latter and Felidu. Both have open lagoons with few but relatively large reefs.

The series ends in a typical atoll, Kolumadulu, which save for its greater size, being 26 miles in diameter and covering about 430 square miles, differs in no respect from those found elsewhere in the Pacific and Indian Oceans. It has a long linear circumscribing reef with only 17 passages, most of which are very narrow. The reef itself is in few places more than three-quarters of a mile in width, and, where it is as much, it is either crowned with land or has a pool of deep water in the centre. The lagoon is relatively open, a circumstance due not in any way to a decrease in the number of shoals, but to the latter being of small size, mostly indeed mere patches. Haddumati lastly is very similar, but if possible still more perfect in shape. Its reefs generally are, except where covered with land, narrow with no trace of velu, and there are only six passages, mostly very small, into the lagoon.

A most important point of difference from north to south lies in the gradual increase of the banks in depth, but whether this be correlated with their position or with the perfecting of the atoll-form is not quite clear. The small banks, having relatively a greater amount of reef around them, would naturally be expected to be shallow, as is indeed the case. The large banks admit of a direct comparison, and this shows an irregular increase from Tiladumati to Kolumadulu. In that Ari and the two Nilandu are fairly open banks, and yet have soundings of 36 to 38 fathoms, and the two Male atolls less depths the increase might at first sight seem to be a function of the position. But if Felidu be examined, its greatest depth (41 fathoms) is in the south-east horn, which is almost completely enclosed by reef, while its greatest depths in the northern more open part do not exceed 30 fathoms. Generally indeed in examining all the banks it will be seen that the greatest depths are towards the centre and in the most enclosed parts of the lagoon. It will then be clear that the depth is rather a function of the state of perfection of the atoll-condition than due to the position of the banks. Size is undoubtedly a factor of importance, but the conditions, which govern the depth, are certainly the same as those which give rise to the atoll.

Another notable variation is found in the extent to which land is distributed on the reefs in the centres of the banks. Here again the atoll-condition is probably the determining factor, but the question is greatly complicated by the fact that the shoals in the circumscribed lagoons are mere small patches of reef, at most a few hundred yards across, while the reefs on the open banks are often a mile or more in diameter. I shall have occasion later, in describing the changes and conditions in North Mahlosmadulu to discuss the meaning of this difference in the size of the interior reefs, but I may here point out that many of the interior islands of the northern banks are situated on the smallest rather than the largest of the lagoon shoals. There are, in fact, even in the most perfect atolls of the Maldives, numerous shoals quite as large as those which support some of the central islands on the open banks. Hence both the smallness of the lagoon shoals and the absence of land would seem to be determined by the atoll-form. In Tiladumati-Miladumadulu there are 65 reefs on the centre of the bank, of which only one has no land. In North Mahlos the percentage, if the "jungle" of reefs in the centre be omitted, would be in favour of those which have land, but in South Mahlos it is the other way. North Male, Ari and the two Nilandu have islands, but they are relatively few in all these banks. South Male and Felidu have islands only near passages or where the banks are open, and there are none in Mulaku, Kolumadulu and Haddumati save one in each atoll, situated right in a passage. Four are known to have existed in Fadifolu of which Moresby found two in 1834; none now occur. The tendency for these islands to exist near passages is important as pointing to the possibility of the currents and general change of water in the lagoons having a determining influence.

Lastly as to the land on the rim-reefs of the banks it is noticeable that it lies rather on the east than the west side in all without determination of their position or form. In Tiladumati-Miladumadulu and North Mahlos every rim-reef of the east side has land, while in the former ten out of thirty-one and in the latter seven out of sixteen on the west side are devoid of such. Fadifolu is to some extent peculiar, but the character is well-marked in all the other banks. It might be pointed out that the strongest and heaviest winds and seas are from the westward rather than the eastward. These might be expected either to pile up coral and so form land, or perhaps, if land already exists, to wash it away. The former supposition is untenable in view of the absence of land, and the latter is largely discounted by the fact that Felidu and Mulaku, which must be to a large extent protected on their west sides by the opposite series of banks, are by far the best examples of the absence of land on the western reefs. The presence of land would seem then to have been determined on the formation of the group.

Each bank, visited by us, in a measure exhibited different changes and conditions, in some one point appearing clearer than in others. It is impossible to give a succinct idea of the extent of the changes and of the varying characters without tracing them particularly, each in the bank which shows it best. North Mahlos[1] however shows most of the points and so may be taken as an example in the next chapter.

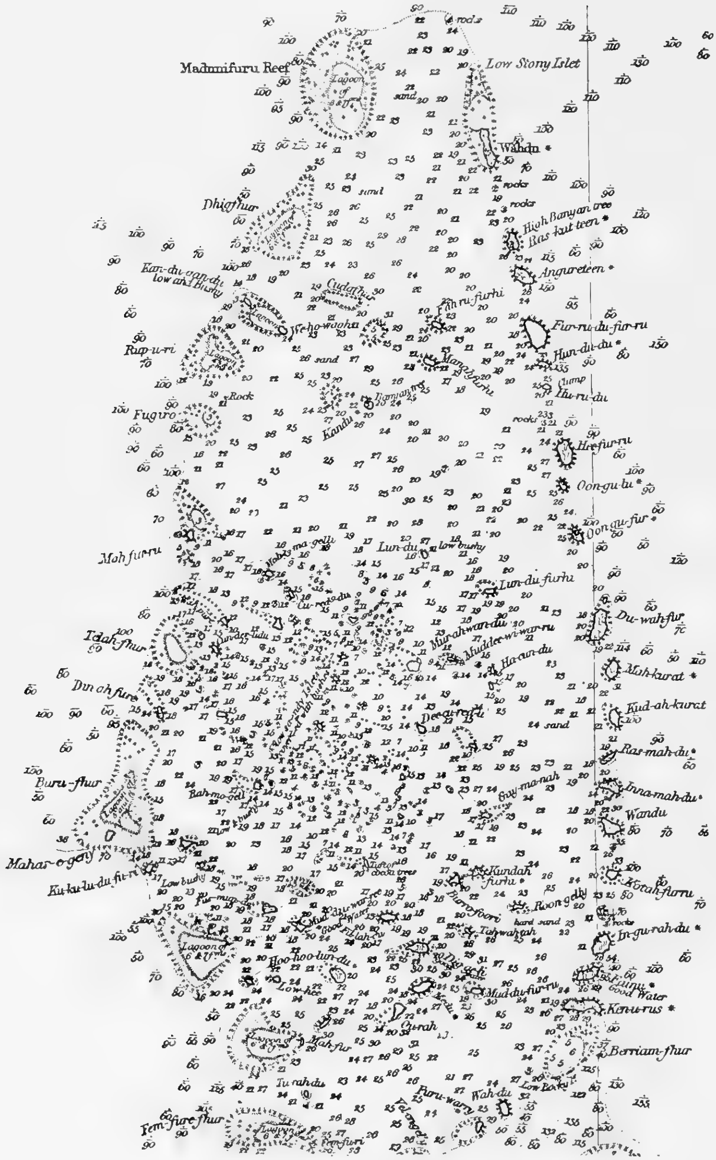
[1] In this bank I visited all the rim-reefs of the western side except the two southern. On the east side I saw Fainu, Kenurus, Inguradu, Raskatteen and Wahdu, most of the rest being visited by Mr Forster Cooper. In addition I crossed the atoll in six levels, and cruised in and out between the central reefs and islands.

CHAPTER VI.

North Mahlos Bank. (Plate XI.)

Mahlosmadulu is divided by deep channels into three banks, each of which has signs of an approaching atoll-condition in series of circumscribing reefs. To the north of the whole bank and separated from it by a deep channel, 2½ miles wide, with no bottom at 100 fathoms, lies a small reef having at its opposite ends the two islands of Ettingili and Alifuri (Plate IX.). The north bank or North Mahlos is 34 miles long by 13 broad in the centre, and extends almost as an oval from north to south. At the south end the Moresby channel, 2 miles broad and 125 fathoms deep, separates it from a central smaller bank, Mid Mahlos, triangular in shape and pointed to the west. This again is separated by a channel of 110 fathoms, less than 1 mile broad, from the South Mahlos bank, 19 miles from north to south by 22 miles from east to west. The three banks from north to south cover areas respectively of about 320, 35 and 270 square miles.

There is no evidence to show clearly whether the three banks of Mahlosmadulu were originally formed as distinct upgrowths, or whether they became disunited from one another as their development proceeded. The probabilities incline to the second alternative, but the point is one which requires to be considered rather in connection with the next chapter. The gross and minute characters of the reefs over the whole Mahlos bank are so uniform, that it is obvious that all must have been formed contemporaneously and are closely connected. The reefs on both sides of the three banks merge into one another in such a manner that any original separation into smaller banks seems impossible. The whole bank would be subjected to the same monsoon currents, which in this position set almost east and west. Moreover—and this is probably of greater importance—the tidal wave which travels along the lines of latitude and extends to the bottom of the ocean, would be resolved into current on meeting a ridge extending north and south such as the Maldives. As the banks grew up on the ridge the rate and hence force of the current would naturally be much accentuated. The two channels in Mahlosmadulu are in the position where this current would act with greatest effect, in that the bank forms a very open bay to the west and there is to the east an inlet, right opposite the deep passage between Miladumadulu and Fadifolu. That the current may be of very considerable force was clear on Nov. 29 and 30, 1899, when after fine, almost calm weather we found it in the deep channels between the three parts of Mahlos varying between 5 and 6 knots per hour. On the following day in the three shallow passages between Inguradu and Berriam-faro the current set constantly to the west, and at no state of the tide was less than 2 to 3 knots. *In accordance with all our experience in the Maldives the current must extend to the bottom*



NORTH MAHLOS BANK

From the Admiralty Chart. Scale 4 miles to 1 inch.

of these channels with as great force as in the surface waters, and I consider that they have probably been cleared out and owe their origin to this cause.

The general character of the whole bank may be seen by reference to the charts, but after this premiss I return to the consideration of the changes that are going on more particularly in North Mahlos, as also in all parts of the whole Mahlos bank (Plate XI. and fig. 32). Land is found on all the rim reefs of the east side, on some of the central reefs, and a few of the west reefs. The question as to whether this land owes its formation to elevation or to other causes is of great importance in view of Professor Agassiz's work on the coral reefs and islands in various parts of the West Indies and of the Pacific Ocean[1]. The question of elevation and, if found, of its amount can only be discussed in reference to those parts of the land which are formed of coral rock, since sand may be piled up to a considerable height by the wind. No part of the rock at the present day, so far as I have seen in the Maldives, exceeds a height of 12 feet above high tide or 17 feet above the reef-flat, which everywhere shows the approximate level of the low tide. Sand does not, it is true, generally reach as great a height, but here and there dunes are found which greatly exceed it[2]. The island of Maregiri in North Mahlos (fig. 32) is an example, having a general level of 14 to 15 feet above the reef-flat with dunes of 30 feet or more. The whole island, as far as could be seen, is formed of sand with lines of sand-rock in the western beach. It is situated in a whirl of waters, and its reef is fully exposed to the south-west monsoon. The origin of the land in the first place is probably to be traced to the piling up of sand on a flat reef owing to these causes. Some of the dunes were evidently only the formation of the last south-west monsoon, many of the tree-stems being buried for 6 or 7 feet in the sand. Much of the latter will doubtless be levelled down, and spread over the land, but some will remain. A fresh monsoon will heap up more sand in the same places, and in this way permanent mounds will be formed, and the whole island raised in height.

The rim islands of the east and south sides of the whole Mahlos bank have usually at their seaward ends belts or areas of recent coral rock, but this character is much less

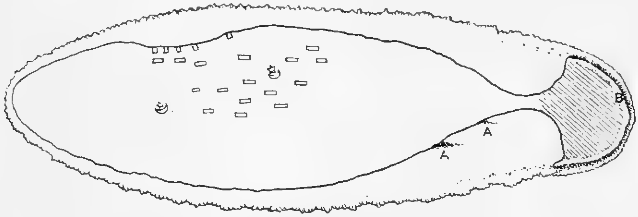


Fig. 27. Kenurus Island. The rocky area of the land is shaded; the sandy area is, as in all these figures, left unshaded. *AA*. Lines of beach-sandstone. *B*. High ridge above the beach formed by piling up of coral-blocks.

marked on the east than the south side. In Kenurus (fig. 27) the east end is formed entirely of coral rock, while the land behind is built up of sand alone. The island is

[1] *Vide* "The Islands and Coral Reefs of Fiji," *Bull. Mus. Comp. Zool. Harvard*, vol. XXXIII. 1899, and numerous other papers.

[2] The question is not complicated, as in the Laccadives, by the artificial hollowing out of the islands for the purpose of forming planting land (*totam*). Among Maldivan people such hollowing out is only doubtfully found in Minikoi, where the race is largely intermingled with the Malabari. *Vide* p. 30.

$1\frac{1}{4}$ miles long by $\frac{1}{4}$ broad, and lies practically due east and west. It has two bays, one on each side behind the rocky area, which hence is connected by a neck with the rest. The foundation reef round the whole is roughly a narrow oval bluntly pointed at either end. In a section of the east end the reef may be seen to consist of a flat about 26 yards broad, outside which the reef-platform may be distinguished for an additional 150 yards, a very marked point of shallow water extending out seawards. The reef-flat has a very well-defined edge, a broken area with fissures extending in for half its breadth succeeded by an area covered with pinnacles and masses of recent coral limestone, most of which are completely washed by the waves at high tide. The beach behind is steep and reaches a height of about 13 feet above the flat. It is covered with rough masses of coral, which have evidently been separated out on the washing away of the coral rock on the flat outside, recently living coral blocks being practically absent. Limestone masses crop out to a height of 8 or 9 feet, but so far as could be seen all rock above this owed its formation to piling up by the waves. Indeed the latter have built up a ridge right round the east head to a height of 13 or 14 feet, the central part showing a level of 8 to 9 feet. The latter is formed entirely of rock, the surface of which may be quite smooth or covered with jagged coral masses, that have been worn out of the rock beneath by the erosive action of the rain. The reef broadens round both the north and south sides of the head to 40 or 50 yards, and then continues as a well-defined broad flat round the island. The masses and pinnacles are found right round the rocky area, and then continue along the reef-flats on both sides of the land. Round the south side they may be traced for half the length of the island, but on the north the rocks are fewer and do not extend for more than 200 yards west of the rocky area. Where masses are found on the reef at the present day land in all probability formerly existed. According to this view the original island of Kenurus would have been U-shaped, broader at the open base to the west but rounded off and solid at the point to the east. The coral rock can be seen just as decidedly as at Minikoi to have owed its position to a change of level, so that there must have been here a U-shaped reef open to the west. Perhaps the inner part of the U may have been filled in with a sand-flat before elevation, but after the latter change there was a considerable piling up of sand, which extended the land for some distance beyond the open mouth of the original reef. Indeed the west end of the present island of Kenurus is even now growing out into the lagoon by the same means, an eddy due to the meeting of the currents on either side of the reef washing up the sand. The whole beach round the rocky area is washing away, the process being most rapid along its north and south sides. Two lines of beach sand-rock, running out into the water on the south side of the neck, show that the sand once continued out as far as the reef and that the bays were formed on its washing away. Along the rest of the north and south shores there is little or no change, the only washing away being to the south-west. Even there it appeared to be a temporary effect, due to the last south-west monsoon, and seemed on Dec. 2 to be being obliterated by the north-east.

The other islands of the east rim usually have traces at least of the rocky area at their seaward ends in pinnacles and masses of limestone, but whether there is a definite rocky area of the land depends on how far the island is distant from the seaward edge of its reef. Fainu for instance has no rocky area at all, the edge of the reef being about 250 yards from the beach. A zone of pinnacles on the reef to the east and north-east alone shows the former rocky area. The island, however, has at first sight the appearance of a rocky shore, as the beach south and east is clothed with sandstone. At the east end this runs out into four ridges, two dipping to the north and two to the south, showing periods of rest while the land was being washed away. The method of erosion is plain to the south, where the waves have undermined the rock for 3 or 4 feet. The sea washes up under the masses at low tide with each wave, and has further in many places eaten through the rock above, forming blow-holes which spout after every breaker. A block finally gets broken off, and then is quickly removed. The other sides of the island show loss in fallen coconuts and other timber, and, indeed, the whole island is slowly disappearing now that it has lost its protecting rocks.

Inguradu is intermediate to Fainu and Kenurus, having a small rocky island to the north-east, connected by a ridge of rocks to the main island. The reef off the smaller island is only about 20 yards broad, but off the east end of the main island it is 80 to 100 yards. The beach above it is for the most part covered with loose masses of rock, piled up for a height of 9 to 10 feet above the reef-flat, which itself is covered with pinnacles and masses of the rock. The latter extend round the north and south sides of the island on the reef, and connect with a series of similar rocks in one part of the beach of the west end, which is evidently now washing away. The original reef before elevation would hence appear to have been nearly circular, perhaps partially filled in in the centre with sand.

Indeed every island of the east rim appears to have had at one time a fringe of rocks round its east end, which fringe has been or is now being eroded away. The topography of the present islands depends on how far this fringe continued round on their north and south reefs and on the extent of its erosion in each case. The sandy area behind it was apparently due in some to an elevated sand-flat, but principally to the protection it afforded so as to allow the heaping up of sand by the wind and waves. As a general rule the breadth of the rocky area to the east did not exceed 150 yards, narrowing westwards both along the north and south sides of the reef. Its extensions did not usually meet one another on the west end of the reef, but it has been seen in Inguradu that they closely approached one another. Hurudu (fig. 28) shows a step further, a chart made by Mr Forster Cooper, showing that the island was completely encircled by coral rock. The island before elevation was an almost flat reef at the low tide level—the west end slightly lower—700 yards in diameter with a pool of water of about 4 feet deep in the centre. On elevation the rock began to be washed away on all sides except the west, where some sand was heaped up. In the latter position trees began to grow on the sand, but the sand itself has now been largely removed, and the rock crops out in the base of the beach and forms a line in the land 20 to 60 yards further back. Along the south and south-east sides a coarse beach-rock also has formed of coral and fragments out of the limestone, joined together by carbonate of lime deposited from the sea-water. Wahdu and Berriam are now the only reefs on the east side of the bank that are definite faro (small atolls with lagoons or velu). The former has a rocky island

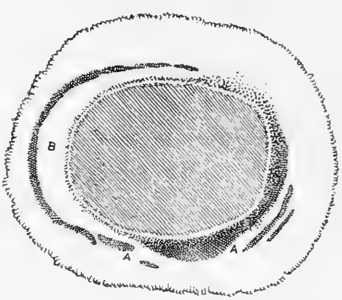


FIG. 28. Hurudu Island. The rocky area of the land is diagonally shaded. *AA*. Lines of coarse coral rock at base of beach. *B*. Sand area. (*From a sketch-map made by Mr Forster Cooper.*)

to the north and a sandy island to the south, with pinnacles along its east side; its lagoon is 8 fathoms deep. The other has a line of rocks along its east and south sides, really elongated islets without vegetation; its lagoon is $5\frac{1}{2}$ fathoms deep.

Of the islets on the reefs of the west rim all are situated towards the inside of the reef and are of sand formation with the exceptions of Cooper Island on the Wa Faro reef (fig. 29) and Kandu-Gandu. In speaking of the former island the natives term it "hura," a name applied to any large mass of rock, standing on a reef, washed over by tides of exceptional height, such as the islands of Berriam. However, Cooper Island (fig. 29) has now become covered with coconut and pandanus trees, shrubs, &c. The method by which the sea has been shut off from it is clear. The waves and tides began to eat into its sides with the result that small masses gradually got broken off and were deposited round the rock as a wall. Between them a little sand found a resting-place, with fragments of pumice, &c. Occasionally at first a higher tide would break through this rampart, and strew its masses over the whole surface of the land for some distance from the sea. Rain action eroded the surface and dissolved out masses of coral, so that the ground even in the centre of the island became covered with loose stones. Sand, further, was blown into the centre, and thus the land was made suitable for plants. The island at the present day is washing away on all sides except perhaps to the east, where a spit of small stones has been heaped up for 336 yards out from the beach; here the waves round the island meet one another and, after forming an eddy, pass on over the reef. The island to the west has now a broad reef-flat with numerous masses of limestone, its inner part against the land forming a rough zone like that to the south-east of Minikoi. South and north the reef has the same characters, but on all sides there is a broad flat outside the outermost pinnacles, the greater part of which has probably been formed by the outgrowth of the reef subsequent to the elevation of the land. The rock also stretched to some degree along the sides of the faro, but there was no heaping up of sand between its horns as on the east side of the bank. The reason of this is probably because of the exposed position of the reef as compared with those of the east rim, and perhaps also to a lesser original height of the rocky area, on this side the limestone being seldom more than 6 feet above the low tide limit.

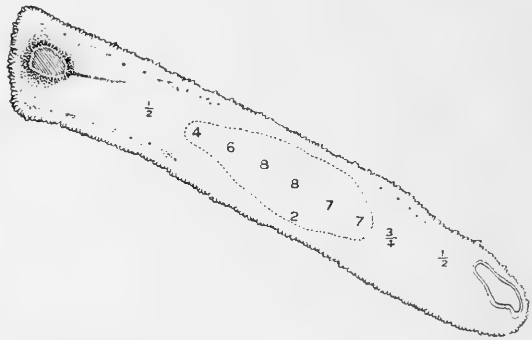


Fig. 29. Wa Faro, showing Cooper Island (rock) to the west and Wa Island (sand) to the south-east. (Soundings in fathoms.)

The limestone throughout North Mahlos is similar to that found at Minikoi, but it has in its composition more sand and broken fragments, fewer large coral masses, and fewer nullipores. *Many of the corals in the limestone being entire and absolutely in the positions in which they were originally growing, there can be no question in respect to the elevation.* The change of level would seem to have been less than at Minikoi by a few

RAISED ROCKS AT MADUWARI

To face p. [illegible]

feet, but it is difficult to decide whether there may not have been more action by rain in North Mahlos. It is possible also that the reef may have been more perfect before elevation at Minikoi than in Mahlos. It has been suggested to me too that the elevation at the two places need not have been contemporaneous, but this view I must absolutely reject. The elevation is found regularly around the tropical belt of the Pacific and Indian Oceans, and has probably not been due to an actual upheaval. It was rather, I think, dependent on a change of level in the ocean, brought about by the attraction of the water towards continental land and to the south polar region. On this view it is quite probable that there may be a real difference in different parts of the Maldives and in the Laccadives. The maximum height of the rock above the reef-flat is 9 feet in Mahlos, but in Miladumadulu it reaches 11 feet, and in Minikoi it is about 13 feet (p. 29). In Hulule, Male atoll, it is only 6 to 7 feet, and in Suvadiva and Addu 5 to 6 feet. Thus there would seem to be a real lessening of elevation to the south. The rainfall, it is true, also increases to the south, and perhaps accounts for some of the difference, but I would still consider that the greater part is really dependent on a less change of level.

It remains now to consider the actual changes of the reefs and land since the change of level took place. In this connection it is necessary to call attention to the much steeper slope for the first 150 fathoms to seaward of the east reefs as compared with that off the west reefs. The character of the latter reefs is the same as those to the west of Minikoi and to the west of Funafuti[1]; the growth of all reef-building organisms—corals and nullipores—extremely vigorous and little or no sand. It is to be remembered also that the east side is protected to some extent by the neighbouring bank of Miladumadulu, the dirt from which must be injurious. The comparison of these reefs is hence with those to the south-east of Minikoi and off the east of the main island of Funafuti atoll. At the same time there can be no doubt, but that all the reefs are growing out on their seaward faces, and it may be assumed that such growth has been general at some time in the past off all the reefs on all sides, independently of any loss or other action that may be going on at the present time. The formation of the sandy areas of the islands may have been partially due to the elevation of flats within the original reefs as already mentioned, but is everywhere, I consider, mainly to be accounted for by the heaping up of sand by the winds and waves. The sand itself varies in coarseness, but none has the muddy character often found in sand-flats, nor could I find in it any traces of worm-tubes, branching nullipores and other organisms, which might be expected to have left some remains.

That some of the original reefs were small faro, before they were elevated, is quite clear from the appearances of Raskateen and Hurudu, but the most striking case in the whole of Mahlos lies in Maduwari, almost its most southerly island (Plate XII. and fig. 30). The reef is about $1\frac{1}{4}$ miles long at its south or seaward side, the breadth of the bank being rather less. The island lies along the south side of the reef, and to the north of it is a sand-flat with about 4 feet of water at low tide, bounded by a surface reef. The south beach of the island is rocky, with two or three rows of pinnacles on the reef-flat. Above the beach is a rocky belt, which extends around the east and west ends of the island.

[1] *Vide* "The Coral Reefs of Funafuti, Rotuma and Fiji," *Proc. Camb. Phil. Soc.*, vol. IX. pp. 417—503 (1898).

At the west end this belt runs out into a horn, and its continuation is shown by a series of rocks which form a line round the sand-flat, the only open part, never at any time enclosed by such rocks, being to the north-east. The central part of the island is entirely of sand-formation and now washing away. In the past it was clearly formed by the piling up of sand through the north-east opening, a horn now extending in this direction. Between the sand and rock a narrow pool was enclosed, stretching right along the island from east to west, represented now by a mangrove swamp with a pool of water (barachois or kuli) to the west. The line of rocks around the sand-flat is not situated on the reef itself, which is formed of great coral colonies with deep pools and channels of water between, but well within it. The reef is such as is growing up anywhere within the bank, and of recent formation, while these rocks are undoubtedly the remains of the original reef which was elevated. Their foundation is a flat of rock, fairly bare of mud and sand, so that corals may grow on it. The masses stand up to a height of 7 or 8 feet on this. They are formed of coral rock of recent formation, and are undermined and pitted all over. In the drawing (Plate XII.) the end 48 feet of the longest mass (66 feet) is represented; its top is never covered even at the highest tides. Here is an undoubted case of an island having originally been a nearly-closed crescentic reef. Its old lagoon was largely if not completely filled in with sand, but, owing to the erosion of the rocky protective part, most of this has now been removed. The reef has grown out on every side, and a pool is being formed in the centre by solution, the old reef having been dissolved away to a depth of a few feet.

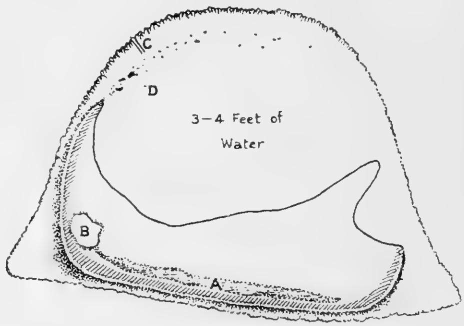


Fig. 30. Maduwari Island and reef. The rocky area is diagonally shaded. *A.* Mangrove swamp. *B.* Pool of water or kuli. *C.* Boat-channel through reef. *D.* Rocks represented in Plate XII.

In North Mahlos there is no case of any island which so strikingly tells its own history, but there are many similar islands and reefs to the east of Miladumadulu. Yet the islands of the east side of North Mahlos show stages in the washing away of the land and the formation of great broad pools between it and the reef. Round Hurudu and Raskateen the reef closely fringes the land. Inguradu has a sand-flat to the north-east, just covered with water at low tide. Kenurus has a broad sand-flat on either side of the neck and a pool to the north-west, each slightly hollowed out below the level of the reef-flat. Fainu has a channel 3 feet deep along the whole of the north side, and off Rasmadu a similar one extends nearly completely round the land. Duwafuri has the channel cut across in places by lines of beach sandstone but otherwise perfect, varying up to 2 fathoms in depth in a pool to the north-west. Wahdu again has a great broad flat to the west with 1 to 2 fathoms or more of water, but this reef shows a much later stage in the presence of a deep velu (8 fathoms) in the centre. Nevertheless only a tendency to form deep pools of water *pari passu* with the washing away of the land is clear.

The changes taking place are better exemplified on the reefs within the bank, where series may be found from reefs almost completely covered with land to typical faro. The land in this situation was all formed by sand, most of it probably heaped up by the waves, but some perhaps elevated. Every island now shows washing away, but its rate is neither necessarily nor generally the same on every side of any island, and in places there may even be an extension of the land. Limbo-Kandu has a barrier of sand above a steep beach, heaped up behind to a height of 12 feet and surrounding a central flat 5 to 6 feet lower. Around it is found a bare reef with a rather indefinite flat, sloping very gradually from the base of the beach, the 1 fathom line being 30 yards distant to the south and about twice as far to the north. Off the north and east of Cunderudu the reef is similar, but rather broader and with a definite flat; around the south-west end however it is 70 yards to the edge of the reef-flat, and a boat-channel is enclosed with 2 to 3 feet of water, 30 yards broad. Meda is very similar, its boat-channel extending only along the north side with about 3 feet of water. The reef round Mudduwari (fig. 31) is 180 yards distant on its west side and 70 yards on the east; the boat-channel continues right round the whole island, with 3 feet of water on the east side and, according to the natives, more than a fathom on the west. Hoohoolundu, Ourah and Fusmundu all show an increased distance between the reef and the land, and large pools on their west sides, where the erosion has been much the greatest. The latter island is situated on the extreme east end of the reef, and the washing away seems to have been entirely at the west, where the pool is 1½ to 2 fathoms deep. Fahrifuri is similar, the reef being 600 yards distant to the west-north-west and enclosing a pool of 3 fathoms in depth. With the increase of the distance of the reef from the land the channel has become a definite little lagoon or velu, and the reef a faro. That the islands on each of the above reefs extended over the greater parts of their surfaces there can be no doubt. In many places, stretching across the boat-channels, one finds masses and lines of beach-rock, which have not been washed away, and in some these or coral masses occur on the inner parts of the flats of the reefs. A small island on the reef at Mudduwari (fig. 31) has only within man's memory been cut off from the land, and at Fusmundu and Fahrifuri isolated rocks may be seen round the greater part of the velu. Wakaru is especially interesting as—the original island was a great religious centre—the natives have preserved records of it for the last 150 years. It had at one time three mosques, to which pilgrimages were made. The island was densely inhabited and of considerable size, covering the most of its shoal. In Moresby's chart it is seen to the north of Mudduwari and Filladu, and marked as having a "tuft of cocoa trees," which *coconuts* were evidently of considerable size for the island to have been especially selected for notice. Now only a small sand-bank, covered over at high tide, is found on the east end, and the reef has become a definite faro with small velu. The three banks west and to the north of Limbo-Kandu have traces of the original land in a few rocks, covered over and protected by worm tubes, but otherwise are all faro. The last stages of all are visible in the faro of the west rim, but, before considering these, it is necessary to examine the reefs themselves further.

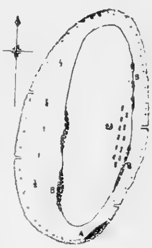


Fig. 31. Mudduwari Island and reef. *A.* Rocks with a few bushes on the reef. *B.* Areas of beach sandstone. (Soundings in fathoms.)

I have already mentioned the characters of the seaward reefs off the islands of the rim, but the reefs towards the lagoon are very different. In the first place the presence of nullipores as a factor in their formation may be practically neglected. The importance of these organisms, when present, in welding up the different coral colonies cannot be over-estimated. In effect they act as the ties which keep the whole together, so that it ultimately forms the apparently solid reef. In the case of Mahlos much of the so-called reef-flat round islands may have been part of the original raised limestone, but it is certain that no regular flat is now being formed without the cooperation of nullipores. The inner reefs are mere agglomerations, formed by the growths of various corals, their interstices in some measure filled in by *Halimeda* remains, coral and shell fragments and sand. The corals are bored into by sponges, algae, worms, etc., and killed at their basal ends, so that they are constantly breaking off or collapsing, only to become still more readily the prey of the borers, which riddle them through and through, so that they finally break down into small fragments and sand. The sand-feeding organisms are the last to act on the fragments. Holothurians, Enteropneusts and others swallow them, consuming their organic matter, ultimately to extrude them worn down into still smaller fragments. The carbonate of lime is dissolved and removed by solution, and the silica and other insoluble matters are left as a fine mud or clay. Currents further play their part, and indeed in North Mahlos no clay or mud is found, the whole of the bank being swept almost clean.

The breaking down of the surface of any lagoon reef, together with the coral growth, keeps its appearance almost constant, but the reef is seldom or never still. Its surface-flat is everywhere either growing outwards, or, owing to being broken down and eroded outside, retreating gradually, if the reef be a faro, on its velu. If the foundations for the flat are being built up outside, it naturally extends, but the corals of its inner part are killed by the fine mud, the product of the boring organisms, swept over from outside. A few colonies of *Porites* alone survive for some time, but even these finally go, dying as soon as mud begins to cling to them or silt them up. From the edge of reef-flat of any reef in the more enclosed parts of the lagoon of North Mahlos the bottom falls gradually to 3 or 4 fathoms, and then precipitously to some depth within 7 or 8 fathoms of the bottom in the vicinity. Far more of the coral from the reef above is swept outwards than over the reef and into its velu, if present; indeed the sandy flat, that is found commonly inside such reefs, is generally bare and devoid of fragments of dead corals, save of those few species which may very occasionally be observed growing in such positions. This being the case, it might be expected that these fragments would be swept back over the steep and so gradually extend the reef outwards on all sides. That this is often what happens is quite clear in some parts of Miladumadulu, but it depends on several factors, whether this is generally so in any atoll. The first in importance of these is the circulation of the water, which, if not free, will not remove by solution the excess of carbonate of lime thrown down by the organisms. Further the boring and sand-eating forms, which play a most important part, are not nearly so numerous in open as in enclosed lagoons. An example of such an enclosed bank is Addu, where in the lagoon the reefs are growing up, and sand, formed from them, is gradually raising the level of the bottom. As a contrast Haddumati and Kolumadulu have an ample supply of water, and the interior reefs save near passages have absolutely precipitous sides (on which the lead finds no resting-place) from 2 or 3 fathoms to near the bottom. At the foot of the steep are found masses of dead and decaying coral with a very occasional living colony, but on the steep itself there is no growth of coral nor of other organisms. In an open bank such as Miladumadulu there is no precipice, but merely a steep slope commencing at 6 to 7 fathoms and seldom exceeding 10 fathoms in height. On it may be seen from the surface masses of *Madrepora*, and dredges and trawls come up off reef after reef, either torn to pieces or nearly full of *Goniopora*, *Alveopora*, *Dendrophyllia* and other corals. Other organisms too are numerous; Alcyonarians and Gorgonians are constantly brought up, and the dead corals from the reef above are protected from solution by Polyzoa, Tunicata, *Polytrema*, and many other incrusting animals. A further character is that, from the edge of the reef-flat to the edge of the steep off such a reef, the whole bottom is covered with a dense grove of corals, while off a reef in Haddumati or an enclosed atoll this area is almost bare save for a few masses of Lobophytum and a little *Halimeda*.

In Mahlos both conditions are found at the present day, that of the enclosed lagoon in the central mass of reefs, and that of the open bank to the north round Limbo-Kandu and the neighbouring reefs. Round the latter reefs the slope is covered with corals and other organisms to a depth of about 6 fathoms, at which depth the steep commences only to fall to about 14 fathoms, being in some places scarcely defined at all. The reefs near Limbo-Kandu are undoubtedly extending outwards on all sides, but it is evident that the above island exercises a by no means helpful influence on its own reef, as the first slope from which the rate of the extension may be judged, is broader off the various faro in the vicinity, and the steep is less marked. In the "giri atiri" or "jungle of reefs" in the centre of North Mahlos the conditions are far otherwise. The steep is everywhere well-defined and the upper slope, until it absolutely passes into the flat, is as described above in closed atolls quite bare of corals. Any corals brought up from the base of the steep are bored into and rotten, and without any protecting organisms. Everything appears to be covered with a thin coat of slimy mud clinging to it, and the reef-flat above is sometimes undermined for a fathom or more. Here and there great masses of the reef have fallen—the sea has not the power within a bank to throw them back on to the reef as negro-heads[1]—and seem to be rotting away. The process is at the same time so slow that it is difficult to prove except by a series of most accurate observations through many years, that any reef is actually washing away, but *the general impression in the "jungle" is that the reef-flat is everywhere being driven back, and that the whole of its reefs are being removed.* I do not see that the characters of its reefs can be otherwise explained, and later I propose to show some definite evidence that there has been loss in the inner reefs of the western faro. The last stage in the history of a disappearing reef is its reduction to a mere little surface patch or series of patches, ultimately single coral heads, which sooner or later will themselves topple over, their basal mounds being subsequently reduced to the level of the floor of the bank. The topographical relations and depths between many of the shoals in the "jungle" show clearly their former connection in single reefs or faro. The last stages it must be remembered are necessarily much slower than the first, as with progressive destruction of the reefs more open conditions prevail, and there is less mud. Even a condition of stable equilibrium may be found, and this I deem to be the case in many of the more open, larger and more perfect atolls. In the smaller such a condition cannot be reached, and hence we find the open lagoons

[1] I restrict the use of the term "negro-heads" to large masses of the rock, which have been broken off the edge of any reef by hurricanes or heavy gales and thrown back on to the reef-flat. I never saw any such in the Maldives, though they were common enough on Fijian and other Pacific Ocean reefs.

of Goifurfehendu, Gafaro and Wattaru. In Fadifolu also there is a very marked destruction of the central reefs, and one even was found to have been resolved into a series of patches.

The reefs against the passages into any bank are subject to strong tidal and other currents, both in and out, which for all practical purposes reach the bottom, the friction being negligible. They hence experience a rapid change of water, which must be advantageous to their organisms, but against this the force of such strong currents and the mud they carry out of the bank must be injurious. Their slope is commonly gradual to about 6 fathoms and then precipitous to within 5 fathoms of the bottom. Where the reef projects as two points on each side of a passage, there is no doubt of what is happening. The edge of each reef is covered with nullipores, which for ever hold each inch they save from the sea. Only a few corals are found, but the slope in such a position in North Mahlos is less precipitous and nearly completely covered with nullipores, as deep as the eye can see. *There is no doubt in many places but that the encircling reef is closing itself up.* That this everywhere is the case in the Maldives, I cannot say, but it seemed to be the rule in every atoll we visited; in many passages we found no change, and in a few a possible compensation in an enhanced depth. Where there is a long passage between two reefs, as between Fainu and Kenurus, the nullipores are only found on the reefs at their seaward ends, and off the latter island there is a distinct shallow horn growing northwards closing the passage. The same is the case north of Inguradu, and Mr Forster Cooper noted it also in several of the other reefs of the east rim. On the west rim I found the channel much restricted between Ma-faro and Kuda-faro, and observed along the whole side the broader western ends of all the faro. Generally speaking, the reefs on either side of passages belong everywhere to the category of outgrowing ones, but it is only the very outer ends of these that can ever meet by the spreading of the reefs themselves. Here again, as the strength of the currents must increase, growth will be less rapid as the rim becomes more perfect. In Mahlos and Miladumadulu the outgrowth of points is quite clear, but in more perfect atolls no definite change could be proved. Even where found, it was never certain that it was a function of the last 60 years, as the tendency of the cartographers would have been to round off every point and reef.

There is also in some of the passages an upgrowth from the bottom, which assists materially in closing them up. In the chart of North Mahlos no less than 10 shoals or reef-patches, that have not quite reached the surface, are marked in the passages. These patches differ from those in the "jungle" in that they are the centres of vigorous organic growth. They are not gaunt rocks but hills, with steep though not precipitous sides, except perhaps towards the lagoon, and are covered all over with corals, nullipores, and other organisms. Of corals *Dendrophyllia*[1] abounds in all the passages, and dead corals are at once covered over with *Polytrema* and Nullipores (*Lithothamnion*). The passages are swept clean of all sand, but some coral must remain. In some of the passages of other banks we found fresh shoals that can hardly have existed before, but we did not examine the

[1] Dr MacMunn in a Report "On the Pigments of *Coenopsammia*, *Dendrophyllia* and *Heliopora*, etc." in the same Part of this Publication points out the presence of chlorophyll among the other pigments and discusses its meaning. Should the chlorophyll assist in the nutrition of the polyps of *Dendrophyllia*, its habitat in the passages should be an exceptionally favourable one owing to the constant change of water. The presence of a chlorophylloid pigment in the skeleton of *Heliopora*—hence completely outside the polyps—is of the greatest interest, and so far as I am aware without parallel in the animal kingdom.

channels into North Mahlos in view of such[1]. Soundings towards the inner sides of the passages yielded no results on account of the impossibility of comparison, and it was the same within the bank. Indeed, so far as they went, they only served to show that there is little or no change in either position. Bottom samples were never obtained in passages except by the dredge, but elsewhere the "snapper" gave occasional fragments of corals with coarse sand in a few places, the latter only in protected situations or near the centre of the bank. The bottom character generally can only be described in most situations as hard rock, the lead being repeatedly sent down with no result; tallow showed further a clean bottom in such positions.

The comparison of the present condition of the western faro with that of the chart is instructive (Plate XI. and fig. 32). On the whole the topography of Moresby's survey is so accurate that it is evident that the survey was an extremely careful one. From the fact that soundings are given in some of the lagoons and not in others, and that where depths are given from native report it is expressly stated, it is certain that Moresby's officers visited all those whose depths are recorded:—

Maregiri. Sand island with dunes 28 feet high, nearly triangular in shape with base to west-by-south and acute angle to east-by-north, the latter point growing out with no reef, west reef 110 yards broad, north and south 120 yards.

Bodu-faro. Sand island to south, elongated in an east and west direction, equivalent to the north half of the island represented in the Admiralty chart; sand bank covered by a few seedlings to the north-north-east. Lagoon or velu varying up to 12½ fathoms in depth, in size more than twice that shown on the chart, extending far up to the north end and down into the south-west horn. No surface-reef for 1½ to 2 miles along the middle of the east side, but a line of reef at 2 to 6 fathoms, less than 100 yards broad.

Dina-faro. Rock patch to the south of the west end, and sand island to the south-east, rapidly washing away, the north half of the island marked on the chart having disappeared but left traces in lines of beach-sandstone. Small velu, scarcely yet defined.

FIG. 32. Reefs of the western rim of North Mahlos, to show the present condition for comparison with Moresby's chart (Plate XI.). *Scale 4 miles to 1 inch, same as Plate XI.*

[1] The winds and currents were so strong during our visit to this bank that it was extremely dangerous to go to leeward (*i.e.* west) of the western faro. I went round Cooper Island in a small boat and took more than two hours in getting through the outer mile of the channel to the south on my return. In the passage south of Maduni-faro there were two points, apparently small reefs occasionally breaking, but the sea was running too high to allow of their examination.

Telin-faro. No islands. Velu 8 fathoms deep, much larger in every direction, the sand-flat and reef to west being about 400 yards broad. Opening into faro north-east, 1 mile broad with depths of 3 to 5 fathoms with in places 7 to 8 fathoms.

Wa-faro (fig. 29). Cooper Island of rock to the west, and Wa of sand to the east, the latter the north half of the island charted. Velu 8 fathoms deep, very well-defined, occupying the centre of the faro.

Kuda-faro. Sand bank on basis of coral rock east-north-east, 60 by 25 yards. Very small velu with 2 fathoms.

Ma-faro. Sand island to south covered with trees, quite inside the reef, the inner part of the island represented. Velu twice the size shown and 6 fathoms deep.

Fugiri-faro. Two small sand banks on west side. Velu somewhat enlarged, 4 to 5 fathoms in depth.

Ekuru-faro. Sand bank to north-east. Velu 5½ fathoms, slightly larger than represented.

Digu-faro. No land. Velu 6 to 7 fathoms, extending up to the north end. Reef otherwise no change, south and east less than 100 yards broad.

Maduni-faro. Sand bank to south and rocks round west side. Velu considerably larger north and west, 7 fathoms deep. Distinct point to the faro running out to the south, reef narrow to the east.

From the above comparison it will be seen that Dina-faro and Wa-faro have now definite velu, while none at all are charted (Plate XI.). Telin-faro and Bodu-faro show that there is a tendency for the different velu to come into communication freely with the general lagoon, and in reference to this point it is important to notice that they are situated against the most enclosed area of the western side. They may, accordingly, be fairly taken as showing the destruction of the reef in enclosed situations. The change in Bodu-faro is a most remarkable one and admits of no possible doubt, as there are in the chart (Plate XI.) on the east side soundings of 18, 15, and 18 fathoms against a reef and sand-flat half a mile broad, where none such now exists. The precipitous slope off these reefs towards the general basin was repeatedly noticed in our cruise, and shows that they tend to wash away on this side. The velu or lagoons have all markedly increased in size at the expense of the sand-flats. The latter are usually bare with less than 1 fathom of water, and at the sides of the velu fall very rapidly to their depths. There may be a few overhanging corals at the edge of any velu, but they are all in the centre bare and covered with sand. There is an ample change of water in them owing to the breakers, which pour over the reefs, and the enlargement of their velu everywhere I can only consider as being due to this cause, acting by means of solution. That this should produce the remarkable increase in depth, about which there can be no question, shows the great effect of the solution and currents, and clearly demonstrates how—starting from a single coral mass, which has grown up to the surface—by lateral extensions a definite atoll may be formed.

I do not wish to claim that North Mahlos alone will serve to demonstrate and much less that it will prove all the different points that I have endeavoured to bring out in this chapter, but I deemed it better to discuss as far as possible one bank alone, and to place in an Appendix an account of the conditions and changes found in other banks. I failed to find any evidence, indeed any indications whatever of any of the reefs of North Mahlos having at any time been joined together. There is no sign of a previous continuous reef having extended on any side. Indeed no one, who dispassionately considers the fact that the passages are in most cases as deep or deeper than the interior of the bank in their vicinity, can fail to see in this the strongest possible evidence against any such view. *Each large reef on the bank is a separate entity that has grown up and pursued its history by itself, influenced it is true by the reefs in its vicinity but never directly connected with them. It is only now that the bank is at all approaching the condition of the perfect atoll. Having seen how small faro may be formed from their earliest beginnings, we now see in North Mahlos the further fortune of such atolls, their joining together where possible to form long linear reefs with the loss perhaps of the whole inner part of their own reefs.* We find too in Mahlos different physical conditions, and the consideration of its reefs in different parts shows how they are affected, and points to some of the factors that must have been of importance in forming the lagoons of our perfect atolls. The bank, on which these reefs have been built up, was at some former time a plateau at a depth apparently of not more than 30 fathoms, and there must have been on its outer edge a special tendency of growth to have formed its existing series of reefs. When I say that it was a plateau, I am perhaps neglecting the "jungle of reefs" that is found in its centre. There is here a distinct decrease in the general depth of our bank, which from side to side in this situation would appear to have been dome-shaped. This "jungle" is, so far as I am aware, without parallel on any other coral bank of the Pacific or Indian Oceans, and is, I consider, entirely a local feature, complicating our problem. The history of the bank as a whole has been further confused by the elevation of some land, the wash from which must have profoundly affected the reefs round it and retarded their formation and growth. *That any rocky land has been formed save by this change of level is so far as I can see impossible, but many islets in the centre of the group have indubitably been washed up as sand-banks. With other larger sandy islands the origin is less clear, but it is singular that they all show erosion of their shores and some an extraordinary loss.* With the growing up of the rim the eddies and currents must be constantly profoundly changed, and it is to this that some islands owed their origin as perhaps they now owe their erosion. The differences between the east and west sides of the bank must be mainly due to the difference in force of the monsoons on the two sides. In the first place the stronger and more regular wash on the west as compared with the east side would tend to make its reefs larger and more defined. All these reefs had land, where rock masses are now found. This was much more rapidly washed away on the west than the east side. And, lastly, whereas the reef-platform is very narrow on the east side, it has on the west the regular slope off oceanic reefs. However interesting these considerations relating to the land may be, they nevertheless do not affect the general conclusions as to the growth and formation of atolls, of the which for further evidence I must refer to the Appendix.

CHAPTER VII.

The Formation of the Maldives and Laccadives.

In Chapter V. I indicated that our soundings showed that the main chain of the Maldive group lies on a relatively shallow plateau at a depth of about 200 fathoms. The chief problem that concerns us relates to the formation of this bank. There can be but little doubt that it is surrounded with precipitous walls or a steep slope for an additional 600 fathoms at least. Further there is indubitably a close connection between all the various banks of the Maldives and Laccadives, so that they would appear to have been built on the same set of foundations. Any explanation of the formation of one bank, then, must necessarily embrace those of all the others.

The topography of the central deep plateau appears to me to almost preclude the idea that it was formed on the subsidence of a large central island. There is no trace of any such movement continuing to the present day, the only recent change being that which formed the land, a change which must have been one of elevation if it was not due to an alteration in the level of the sea. Under the subsidence theory the existing reef-banks around the central basin would have owed their origin to the direct upgrowth of the fringing and at a later time the barrier reef of this central island. The various reef-banks would according to this view have been formed on the breaking up of the original reef, and the channels between the banks would represent its passages. Where there are a series of the latter opening into the lagoon of an atoll or barrier reef, the majority of such channels have depths less than that of the central lagoon. Indeed it is extremely rare for any of them to equal in depth the lagoon, into which they give entrance. It might hence reasonably be expected that some trace of the original reef would be found in the channels between the larger banks in decreased depths, but this is not the case. The shallower water lies in the centre of the plateau and the depth gradually increases in the passages. Again the peculiarly open condition of the central basin between the banks is of importance in respect to this same question. Either the land must be supposed to have been of extremely uniform height so that there were no eminences in the centre, on which reefs would have built up, or it must be maintained that the present banks represent the positions of the peaks of the land, and that the original land, owing to too rapid subsidence, failed to acquire a continuous reef. Under the latter conditions it would be probable that the valleys separating the mountains along the two chains would be of less depth than the great central valley, a second position which is not supported in any way by the soundings. Indeed it is largely a question of suppositions, and in the case of the Maldives there are required a series so great and complex as to afford strong presumptive evidence against the view that the present reefs are in any way the continuations of older barrier and perhaps fringing reefs. The original land would have to be regarded as a great plateau, which has sunk to or beyond its present depth. Even allowing that the average level of the whole plateau may have been considerably raised by any valleys having been filled in, it is surely remarkable that on a land site of 330 miles long by 70 broad, an area of about 12000 square miles, no single peak should have continued to exist to the present time. The subsidence theory, further, is absolutely incapable of affording any adequate explanation of the presence within the limit of the Maldive and Laccadive groups of such large atolls as Suvadiva and Kolumadulu, small atolls as Addu and Minikoi, open banks as Tiladumati and Mahlos, isolated reefs as Fua-Mulaku and Toddu, and finally submerged dome-shaped or flat banks as found in the north of the Laccadives.

The banks facing the central plateau drop almost precipitously to its level. It would seem hence that they were erected on it as their foundation, so that it will be necessary first to consider its formation. Two possibilities suggest themselves. The first is by direct upward growth on a deeper plateau, mound or series of mounds on the sea-floor, both by the agency of corals and sediment. This view I shall have occasion later on to discuss in some detail, but I must provisionally reject it here as affording in any way a sufficient explanation of the formation of such a great bank as our central plateau to a height of at deepest 200 fathoms from the surface. The second possibility lies in the cutting down of land above or below the sea by aerial, wave, current and tidal actions to such a depth, the detritus being supposed to have spread out and formed the plateau. First it is necessary to consider what evidence there is as to the depths to which currents extend and at which they, assisted by waves and tide, can move matter. There is very little doubt, but that currents may extend to considerable depths and sweep the ocean floor quite bare. Indeed wherever in the ocean a rocky bottom is found, its character is probably due to an ocean current. To quote Mr J. Y. Buchanan, "when the rocky bottom of the ocean comes up to moderate depths as in the oceanic shoals which I had the opportunity of examining in the s.s. Dacia in 1883, these currents and the tidal element in them are very evident. In archipelagoes like the Canary Islands, which are separated by channels having often a minimum depth of 1200 fathoms and more, the crests of these ridges are swept bare of sediment, and are hard rock, generally calcareous and manganiferous[1]." There is hence no inherent improbability in the original land or bank of the Maldives being cut down to a depth of 150 or even 200 fathoms. The position of the group too would be one eminently favourable to the action of the currents, the plateau rising abruptly and lying right in the middle of the Indian Ocean, fully exposed to the two monsoons. The tidal wave sweeps across the ocean along the lines of latitude, extending from the surface to the greatest depths. Meeting an obstruction, lying absolutely at right angles to its course and extending from the bottom at 2200 fathoms to within less than 200 fathoms of the surface, its energy would be dissipated in current which would be of such force that it alone would probably be quite sufficient to cause the washing down of the bank to its present depth. With such a current there certainly could not be in any case much deposition of sediment on so shoal a ridge. The general hard bottom found in our soundings can only be explained by the action of the currents, and on them lies, I consider, the solution of the question as to the formation of the foundations of the atolls and banks of the Maldives.

[1] "A Retrospect of Oceanography." *Report International Geogr. Congress*, London, 1895, p. 25. I may take this opportunity of expressing my indebtedness to Mr Buchanan for discussing this matter with me.

It is quite unnecessary to repeat the evidence and well-known views of Sir John Murray[1] and Admiral Sir W. L. Wharton[2] as to the action of marine currents in cutting down land and moving matter. Even by continental land where the action is that of currents due to the waves meeting an impediment, the shore platform tails commonly at 80 to 100 fathoms off in a steep, the product of the backwash (see Plate VIII.). That the currents are strong and extend to considerable depths is evident from my being able to accurately note their directions down to 150 fathoms off the reefs. It was quite evident too in my soundings that the current was nearly equally strong in the passages right down to the bottom[3].

Of what rock the original land or bank was formed is entirely a matter of theory and a question, to which the geological study of the Indian continent has so far yielded no clue. It may have been a series of volcanic erupted masses as Sir John Murray suggested. If one supposes that the eruptions were submarine, that in effect the mountains were chiefly masses of loose volcanic matter, it would be easy to imagine even a greater erosion than to 150 or 200 fathoms. Sir John Murray considers that all oceanic islands are volcanic, regarding all others such as New Zealand, Madagascar and Seychelles as continental lands. Yet I may point out that with regard to most groups of coral islands there is no direct evidence to show that their foundations are volcanic. If they are really so, as the mountains of volcanic chains vary greatly in height, there would, it is reasonable to suppose, be a stray peak or two—central cores of hard lava round the craters—still remaining in the Maldives and Chagos. Further, so far as the Maldives are concerned there is no trace of any corresponding activity in the Indian Peninsula. I am hence rather inclined to believe that there was a connection with the other banks towards Madagascar, in fact that these reefs show the positions of the mountains of a great continental land, which once joined Ceylon and Madagascar, but the greater part of which has in past time subsided to great depths and left no trace at the present day. The existence of such a land in the past too is absolutely required to explain the distribution of both animals and plants[4]. The current action would be, I consider, quite sufficiently powerful, aided in the first place by the disintegration of any subaerial land by heat, rain and other agencies, to cut down such a mountainous area, as I suppose to have existed, to the present level of our great Maldive plateau.

It may be contended and perhaps truly that the separate banks are the remains of some of the peaks; that Kolumadulu and Male perhaps were the sites of mountains, which were cut down to a depth of 20, 40 or even 60 fathoms, and then built up by the reef-organisms to their present levels. I can scarcely regard this as probable on account of the great regularity of the common plateau and the regular precipitous slopes of the several banks on all sides. As already mentioned, there is no trace either of a central deeper valley nor of shallower valleys between the separate banks, the plateau being a

[1] *Proc. Roy. Soc. Edin.*, vol. x., p. 507 et seq.

[2] *Nature*, vol. LV. p. 390.

[3] My friend Mr Cameron points out that the influence of the friction of the bottom on the tidal waves and currents may be neglected. Horace Lamb (*Hydrodynamics*, p. 543, 1893), after discussing the viscosity in periodic tidal force, summarised the matter as follows:—"This indicates how utterly insensible must be the direct action of viscosity on oceanic tides. There can be no doubt that the dissipation of energy by tidal friction takes place mainly through the eddying motion produced by the exaggeration of tidal currents in shallow water."

[4] *Vide* "The Anniversary Address to the Geological Society of London" by W. T. Blanford, F.R.S., February 21, 1890, pp. 58—69. It will be observed that, while rejecting the subsidence theory of Darwin as quite inadequate, I consider that the topographical conditions which made the formation of the coral reefs of this region possible, have probably owed their initiation to the sinking of a great continental land.

mound slightly domed in the centre and sloping outwards on all sides. The chief currents from west and east striking approximately in the centre of the plateau, the banks would not naturally be expected to have their long axes lying about north and south but rather more in the direction of the currents. This would of course largely depend on the topography of the original mountains, but the currents, having to cross the bank somehow, would on either side of the valleys at any rate tend to spread out the detritus from the land or bank and to broaden the north and south ends of the shoals in an east and west direction, a condition of which there is no trace in their present contours save perhaps in Felidu alone. Yet at the same time it is quite reasonable to suppose that the banks commenced to grow up before the channels between them attained their present depths. There may even have been a slight additional lowering of the plateau as a whole in depth. The washing away would naturally be slower with the deepening of any bank by reducing the force of the currents, but the upward growths of reef at various points would tend by providing obstructions to accelerate them. The hard bottom, found in the channels, shows that they are still current-swept. The summit of a bank formed by the washing away of land or shoal would be almost flat, and there would not be in any case the much steeper slopes towards the sides, as found in these passages. There is no means of estimating this erosion since the original foundations for the banks commenced to be laid, but it may perhaps be safe to infer from the lesser soundings obtained that about 160 fathoms was the original depth of the plateau.

My conclusion then is that an almost flat plateau at a depth of 160 *fathoms was at one time formed, and that on this the banks severally arose.* So far as sections have been run off atolls in the Indian and Pacific Oceans, there is in all a striking uniformity in slope, a gradual fall—that of the reef platform—to something under 50 fathoms, succeeded by a steeper drop to about 150 fathoms. The agreement in depth with our Maldive plateau suggests that this is the depth to which the oceanic currents have sufficient force to cut down the banks and prevent the fixation of the reef-building organisms, partially directly by their strength and partially indirectly by movement of mud and sand smothering them and preventing their growth[1]. Below this depth I consider that we have the volcanic basis of our banks, as Murray suggested; or, as I think, the remains of an ancient land. In commenting on the cutting down of land Sir A. Geikie postulated that the depth to which the currents would act "is probably nearly coincident with the lower limits of reef-builders." Depths approaching 150 fathoms were not however imagined by anyone, but with increase of knowledge the depth at which it is known that the organisms may dwell has gradually been further and further increased. It has been pointed out by myself and others that reefs are largely formed by calcareous algae (*Lithothamnion*), and that the corals, which cover the reefs, feed mainly by their commensal algae. It follows then that the limit in depth, at which these may exist, is probably dependent on physical questions, chiefly on the power of sunlight to penetrate sea-water, the temperature being assumed to be favourable. There are no absolute experiments on this point, but the results of dredging point to a depth of 150 to 200 fathoms as the effective limit to which nullipores can live.

[1] This may appear at first sight to be inconsistent with other views put forward in this paper. There is however a great difference between the deposition of sand and mud and its smothering action on corals. No sand is normally deposited on the reef-flat, but frequently off islands after a heavy gale or a change of wind large areas of corals on it are found to have been killed by the mud and sand clinging to the tissues and blocking up the mouth parts of the polyps.

The question as to the depth at which reef-corals occur is an important one, and one to which we devoted very particular attention. With open boats and a sailing vessel it was practically impossible to dredge the steep outer slopes of the reef so as to get any sample of the bottom. There was too no other ground in the Maldives with a depth of between 50 and 100 fathoms, so that necessarily our work was confined to depths below the lesser limit (*i.e.* 0 to 50 fathoms). The dredgings between 30 and 50 fathoms outside reefs were very few, but there were a large number in the passages of the atolls and a still larger number in the lagoons. Of the latter only those close to shoals (surface-reefs) would be expected to yield any evidence, since it is only in such positions that a hard rocky bottom, suitable for coral growth, is found. *Heliopora*[1] was obtained off Addu, growing apparently luxuriously at about 40 fathoms, but of genera of true corals at all important on the surface reefs in any region *Madrepora*, *Seriatopora* and *Pocillopora* alone were represented below 30 fathoms. It might possibly have been expected that only branching corals would have been obtained, and that no evidence would hence be forthcoming as to the real depth at which most reef-corals live. Yet in shallower depths colonies of massive species were not infrequently procured, and the characters of the growths of the above-mentioned genera afford the strongest possible deductive proof that reef-corals do not live below about 50 fathoms nor flourish 20 fathoms higher[2]. It was surely remarkable too that such branching corals as *Montipora*, *Porites*, *Pavonia*, *Psammocora*, *Mussa*, *Euphyllia*, etc. besides the hydrocoralline *Millepora*, all common enough on reefs, should not have been represented at all below 30 fathoms. The *Madrepora* secured belonged to finely-branching facies with light coralla, and only a single small piece of a delicate *Seriatopora* was procured. The *Pocillopora* afforded less definite evidence, several pieces of massive facies being brought up, though most colonies were finely branching. Yet compared with the large pieces of coarse *Pocillopora*, apparently of the same species brought from 20 fathoms, its growth is very evidently far from luxuriant at this depth. Dr Bassett-Smith's dredgings on the quite open Tizard and Macclesfield banks, in which he had the use of steam, support the same view, fragments of *Favia* and *Montipora* alone being caught up between 41 and 50 fathoms and only six so-called species from 31 to 40 fathoms[3]. At Funafuti eight dredgings 40 to 140 fathoms on the steep slope of the reef yielded no reef-corals, and with "swabs" 30 to 45 fathoms I only secured about 20 fragments of *Madrepora*, *Pocillopora*, *Stylophora* and *Porites*, with pieces of *Millepora* and *Heliopora*[4]. The characters of the specimens were the same as those subsequently procured in the Maldives, and they are scarcely such as characterise the corals that mainly build up the reefs as we find them in the present day.

It would seem to me then that about 30 fathoms is the extreme limit in depth of the growth of the effective reef-building corals. Our dredgings also brought out the fact that the luxuriance of growth of corals progressively increases as the water becomes shallower to within a few (3—6) fathoms of the surface. The formation of corallum in corals is, I consider, dependent on the excretion of ammonium carbonate, and is directly proportional to the amount of the metabolism. The latter, so far as the reef-forms are concerned, is

[1] *Vide* note on p. 168.

[2] This question will be better brought out and dealt with in the "Report on the Madreporaria," which I am now preparing. I may here mention that, with any genus or species of such corals, the skeleton decreases in density (*i.e.* specific gravity) with increase of depth. Branching forms too have finer and more delicate stems, consistent with the limits of variation found in any species. The polyps also have a tendency to be further distant from one another.

[3] *Ann. Mag. Nat. Hist.*, Nov. 1890.

[4] *Loc. cit.* p. 479.

mainly influenced by the amount of carbonic acid (CO_2) in the water, the circulation of the water, and the quantity and intensity of the light. Temperature is not a factor of vital importance in coral-reef areas. It undoubtedly assists the metabolism, but excess of heat appears to be practically unknown on reefs. I have measured in pools at Minikoi, abounding in corals, temperatures up to 133° F. at low tide; save that the corals tended to expand as soon as the colder tidal waters entered the pool, I could not subsequently see any difference in them to those completely covered with the sea water. So far as cold is concerned I have been unable to trace any death of reef-corals to this source, nor have I found any definite evidence of such recorded. In reference to the carbonic acid the "Challenger" results showed an excess in deep water over shallow, but in any case within 50 fathoms of the surface, well within the wave limits, there could not be much difference in this, the water thoroughly mixing. The real factor is the light, which to reach the commensal algae has to penetrate the tissues of the polyps as well as the water. An intense light is evidently required, and even on the Equator 30 fathoms is almost beyond its limits in the Maldives. On it depends mainly the metabolism, and our dredgings indicate that its action is not great and of little effect below 15 or 20 fathoms. Hence Darwin's conclusion "that in ordinary cases reef-building polypifers do not flourish at greater depths than between 20 and 30 fathoms and rarely at above 15 fathoms"[1] appears to be literally true and amply borne out by our results.

The accounts of nullipores, the depths at which they live, are extremely unsatisfactory, algae being generally much neglected by zoologists, to whom the practical investigation of coral-reef conditions and formation has been, by almost universal consent, relegated. My own investigations have not unfortunately been carried out on such a scale that I can give or indicate any answer to the question of the importance of these forms in building up a reef beyond a depth of 40 to 50 fathoms. To this depth nullipores certainly may and do grow against the open sea in great luxuriance. Their species or facies appear to be the same from the surface down to this depth, and there is no alteration in their texture, no decrease of specific gravity, so far as I could ascertain. At the same time their growth is always extremely slow as compared with corals, and they do not nearly so readily cover a vacant area. Only the smallest growths are found in the oldest cleared out boat-channels through the reefs to the shores of the islands of the different atolls[2], and where beacons or other fixed marks have been placed by the islanders on the reefs, they have not been in any case, that I saw, appreciably covered at their bases by nullipores, although these organisms may clothe the whole basal reef on which they are fixed. Their metabolism also like that of corals must decrease with greater depth, and, although they very certainly are an important contributory agency in building up banks from upwards of 200 fathoms, I must reject them absolutely as in any case capable alone of furnishing a sufficient amount of material to raise the foundations to sufficient depths for the reef-corals to take possession[3].

It remains then to consider what may be the chief contributory agents in building up our banks to the surface from their common plateau 150 or 200 fathoms below. In

[1] *Coral Reefs*, 3rd ed., p. 115 (1889).

[2] Most inhabited islands have one or two boat-passages through the reef around them communicating with the boat-channel inside, where it exists. These passages have by Maldivan law to be cleared out every three years from every scrap of coral or nullipore that may be growing in them, and they are inspected by Government officers to see that this is properly done. The coral, etc. obtained is either taken on shore to be burned into lime, or more often sunk in the lagoon of the atoll outside.

[3] The importance of nullipores is rather in consolidating the corals together. For this purpose they are especially efficient, since their skeletons are scarcely affected by boring organisms.

the first place I am convinced that in such shallow depths in an open ocean the calcareous remains of pelagic or of any free form of life could not to any large degree rest, on account of the tidal and oceanic currents, and hence it is to sedentary forms that we must look for an explanation. The latter has been, I believe, afforded by the discovery of deep coral banks in the Atlantic, of some of which Mr J. Y. Buchanan has given an account[1]. In my paper on Funafuti, Rotuma and Fiji I gave a number of quotations to show the vigorous growth of corals at considerable depths, but I did not then appreciate fully the effects of tide, current and wave actions. The banks, described by Mr Buchanan, appear to have been absolutely formed by these corals and to have been built up by them to comparatively shallow depths. Of the three banks described, the "Coral Patch" was of great interest, having an almost flat summit—least depth 435 fathoms—covered with living *Lophohelia prolifera* and surrounded by precipices from 550 to 850 fathoms. The "Seine bank" had broken coral with apparently some chlorophyllous organism on its summit at 86 fathoms, and the "Dacia bank," 49 fathoms in the centre, was slightly domed in shape with cliffs from 100 to over 300 fathoms. The deduction that the precipitous portions of these banks are formed by the dead coralla, the living polyps building on the dead "bones" of their parents, appears to me a perfectly legitimate and indeed the only possible one. The largest bank, the Dacia, is small as compared with the Maldive banks, being only 8½ miles in diameter. Yet in the same paper indications of similar larger banks in the Atlantic are given, and it appears to me quite reasonable to suppose that the separate Maldive banks were built up somewhat in the same way. The Maldive plateau being of long, narrow shape, of considerable size, at no great distance from continental land, and in the track of oceanic currents, would be affected differently to smaller banks. On the latter the conditions of food over the whole surface would be nearly the same, the organisms raining down on them fairly evenly from the water above. Such banks hence would be covered all over with corals, causing them to grow up nearly flat or slightly domed. On account of the direction of the Maldive plateau the currents would necessarily set right across it, and its sides accordingly, being best provided with food, should naturally be expected to grow up the faster. As they got higher and presented more obstructions, channels might well be broken through and further cleared out, giving rise to those found at the present day between the different atolls[2].

Nullipores, as the shoals approached the surface, would naturally become of increasing importance, but there is some evidence to show that the class of corals, that built up the banks, cannot live in shallow depths, though the precise cause of this is not clear. It may partially be temperature, though pressure is a probable contributory cause as well, since their distribution in depth is limited in temperate regions as well. The Seine bank was covered with broken and dead corals, and the Dacia was probably also, its surface evidently being very rough. Perhaps 50 fathoms or so is the limit of the upward growth of the deep corals. Possibly they build up until they are finally extinguished by the reef-corals. Whatever may be the case is immaterial, as there is a third class of corals that can live either on the reefs or near the surface, where there is little competition, but flourishes best at 30 to 50 fathoms. This class, as are the deeper corals, is not dependent on its algae for nutriment,

[1] "On Oceanic Shoals discovered in s.s. Dacia in October 1883." *Proc. R. S. Edin.*, vol. XIII. p. 428, 1885.

[2] As soon as the sides of the plateau commenced to grow up, mud would necessarily be swept over the central part of the plateau and would effectually kill any corals or other sedentary organisms. On account of the current being accentuated by the upgrowth of the sides, the channels would probably form at an early stage. The eddies, formed by the currents through the channels meeting in the centre of the plateau, might account for the shape of the banks.

and perhaps deserves a more precise notice here. Of first importance so far as massiveness is concerned may be placed *Heliopora*, which I obtained off Funafuti from the same depths. In all four dredgings outside Addu atoll it was obtained, and from the quantity procured seemed extremely abundant; it too was not bored into by organisms in any way. The genus is also found living in the lagoons of atolls in the Maldives, but I never saw it living on the reef-flat or outer slope to 15 fathoms. In the lagoons the colonies are closely packed with lamellae and stunted. Of true corals in this class (Madreporaria) many large masses of *Goniopora* and *Alveopora* of several species were brought up from the lagoons, and solitary corals were in places extraordinarily numerous. *Cycloseris* was found on nearly every bank, and in one of the north passages into Suvadiva atoll with 38 fathoms of water were trawled great masses of rubble, formed almost entirely of its dead coralla. The most important genus however was *Dendrophyllia*[1], of which a very dark green velvety species (*D. ramea*, sp. ?) formed great dense groves in nearly every passage into the interiors of the banks. We never obtained it below 45 fathoms, nor above 15, but between these depths, if the bottom was at all rocky, the dredges seldom came up without some of its branches. Many other corals could doubtless be added to this list, but the above seemed the most important forms in the Maldives, which might be expected to raise the reefs in their later stages, and afford foundations for the more vigorously-growing reef-species. In addition there is the increasing importance of the nullipores on increase of depth, and *Polytrema* and other Foraminifera also, with Mollusca and other forms doubtless assist. Perhaps indeed all these are unnecessary, but their enumeration serves to point out their possible economic position in the formation of the reef.

The next stage is dependent on the arrival of the larvae of the reef-building corals. Some fix themselves, and their resulting colonies soon commence to struggle with the possessors of the ground for supremacy. Their arrival is but slow, and at first they are probably spread out over the surface of the whole reef. As the shoal grows up oceanic and tidal currents over it become more definite. Its edges are more bathed than its central part and more oxygen, carbonic acid and food are carried to them. As a result the rims in particular soon send patches of reef up to the surface, to give rise finally to the perfect atoll through a series of changes, such as are sketched in my account of North Mahlos.

The depth, to which the shoal would be raised before the reef-corals obtained sway, would naturally to some degree vary in different regions with their diverse conditions, and on this in the first place would depend the depth of the subsequent lagoon. It is not until the rim becomes moderately perfect that the latter begins to be hollowed out by solution, and until then its depth in the centre depends on that of the original shoal. In this case Tiladumati-Miladumadulu and Mahlos might be expected to show these depths, *i.e.* 25 and 26 fathoms, while the atolls to the south demonstrate the increase of depth as the rim perfects itself. In this connection stress must only be laid on banks of considerable size, small ones having from the first more perfect reefs. The wave and current actions must be much less obstructed by small reefs, and hence there would be some considerable circulation of water over every part of them. They would then have been more covered over with reef-corals, and would accordingly, when they grew up, have shallower lagoons. The very smallest would have a solid, flat surface-reef with no lagoon at all. The larger atolls of this class probably include Goifurfehendu 23 fathoms, Rasdu 21 fathoms, Wattaru

[1] *Vide* note on p. 168.

18 fathoms, Makunudu 19 fathoms, and Ihavandifolu 28 fathoms, besides some of those in the Laccadives. Toddu, Karidu, and Fua-Mulaku, being smaller, have not yet attained by secondary means, *i.e.* growth outwards and solution of central parts, the atoll condition, and their reefs being still crowned with land will have to be reduced to the bare reef before they can do so.

This depth, about 26 fathoms, found in Tiladumati-Miladumadulu and Mahlos is the same also as occurs on many submerged banks. In the first place attention may be called to those in the Laccadives, as they have not yet begun to assume an atoll shape. Of these one is small and has only 6 fathoms of water, but the other three are much larger and have 23, 26 and 28 fathoms. Indirectly these banks too serve to give additional proof of the above theories. Being domed they cannot be submerged atolls. Considerable irregularity in depth strongly opposes the idea that they are still being cut down by the sea. Further they have apparently precipitous walls. If the encircling reefs of atolls do ever actually grow up directly from 40 to 50 fathoms, taking the depths of the lagoons of some, it is remarkable that these banks as yet show no signs of any such reefs. Turning to the shoals of the Pacific I may refer to those recently mentioned by Admiral Sir W. L. Wharton to the north of Fiji, five in number, with depths of 24 to 26 fathoms in their centres. The second largest of these, the Alexa bank, 18 by 9 miles, has a perfect rim 13 to 18 fathoms in depth. Speaker's and Pitt banks in the Chagos are also nearly comparable in size and have 24 and 22 fathoms. Many other similar shoals might be cited, but reference may be made rather to those which markedly differ. First Saya de Malha has a sounding of 65 on the centre but only 22 fathoms on the rim; yet the merest glance at the chart on p. 14 serves to show that it is in its foundations comparable rather to the great Maldive plateau than to its several banks. Great Chagos, Tizard and Macclesfield all have over 45 fathoms. The first is of great size (see p. 17), and all three have the rim though largely submerged far more perfect than that, for instance, of Tiladumati-Miladumadulu. The larger the bank the more tendency there is for the rim to grow up from a greater depth, as more food would reach the sides before the centre. However, as already remarked, the formation of each reef must be considered by itself in view of the physical conditions of its region. These may be expected to profoundly modify it, and probably are largely responsible for the variations that occur. In the above I have only tried to sketch the conditions which have been affecting the formation of the reefs in the Maldives. I would not necessarily apply them to all reefs, though I believe that in their main principles they will be found to be true also of the greater number in the Pacific and Indian Oceans.

I have already indicated under Mahlos the changes that take place to form an atoll, but a further reference is necessary to the enclosing or rim reefs. These may in the smaller banks almost grow up as such in the perfect state, more or less completely surrounding the lagoon. The relative length of the reef roughly varies inversely as the size of the bank, and the amount of water which must pass over it directly. Further, the greater part of the current, oceanic or tidal, may be diverted on either side of a small bank, whereas a relatively much greater amount of water, conditions of depth, etc. being the same, must pass over the encircling reef of a larger bank. Such being obviously the case it is apparent that the outfalls for the water may be relatively very much less numerous and smaller from small than large banks. Again, the amount of current will increase with the contiguity of other banks, and also if there is—instead of deep sea—shallow water, a ridge in fact on either side. The consideration of the current factor is, I believe, a most important one. It acts on coral growth in two ways, advantageously by constantly bringing fresh water and disadvantageously by sweeping sediment over the corals, by preventing fixation of the larvae, and, when strong, by stunting and even breaking the corals. On a bank at 25 to 30 fathoms patches all over the surface would commence to grow up, wherever the conditions might happen to be especially advantageous. A fairly definite rim might early be expected to show itself, but together with its growth there would be an increase of current over the bank. If the bank be small or isolated there might not be a sufficient increase to affect the growth of the rim as a whole, though some parts would possibly from the first be lower and, serving as outfalls for the water, form the passages. In this way atolls such as Addu and Goifurfehendu and others have probably been formed.

On the other hand, in atolls of the next size some part of the rim might be more perfect from the commencement, and in the central banks of the Maldives it would naturally be that on the east side of the east line of reefs and on the west of the west line, these sides being more exposed to the sea and hence to more favourable conditions. This is at once illustrated in the more perfect reefs of these two sides in Felidu, Mulaku, North and South Nilandu and Fadifolu atolls. Lastly over the largest banks of the central plateau the currents, both oceanic and tidal, must be from their position and size much stronger, and probably from the first in Mahlos and Tiladumati-Miladumadulu the corals could only build up patches of reef on the rim. The condition would remain open and shoals would grow up anywhere on the centre of the bank. Until the wall of the bank became fairly perfect each patch would behave as an isolated reef in the ocean, and by spreading out on all sides and becoming hollowed in the centre form an atoll. The rate at which this might occur would, as compared with an isolated reef in the ocean, be enormously increased owing to the shallow depth of the foundations on which the corals would spread out to almost any extent.

Of other atolls in the Maldives Kolumadulu and Haddumati are exposed both east and west to the full action of the sea, and are less enclosed than others by their neighbours. They only differ from Suvadiva in their smaller size, but the latter is still less contiguous to its fellows. The encircling reefs of these banks are fairly perfect, though they are broken by numerous passages into their lagoons. A study of their lines of circumscribing reefs shows that the conditions are not so simple as at first sight might appear, since they have a line of shallow pools along their centres. Either the rim grew up double—the conditions inside such large banks being supposed to be the same as outside—or the reefs were formed by the fusion of a series of faro. The first condition is conceivable and partially accounts for the outgrowth of the ring-reefs of Mahlos, but such growth only continues while the passages into the bank are numerous. Between these pools the encircling reef narrows somewhat, and its close examination shows that it was rather formed by the fusion together of an enormous number of little patches. For this fusion to have taken place on some banks, while the patches are still separate in so many others, the rim as a whole must have grown considerably and the passages been shallow, but then there is the elevation of the group, which with shallow channels may have been of great assistance. It is not necessary, however, that each passage should have had at least its present depth of water at all times; many are being filled up by coral growth, and it is more than probable that others, through which tide and current particularly sweep, may have been and are being cleared out and deepened.

It remains then to consider the reef-platform, which slopes gradually down to the commencement of the steep at about 40 fathoms. Why does not the whole grow up as a wall to the surface? To this question it is hard to give any answer on account of our ignorance of this slope, of what even its surface is like and what covers it. We are not in a position to theorise about it, but I should not suppose that the greater part of it came into existence contemporaneously with that of the foundation-bank. It is, so far as I am aware, a feature of all surface oceanic reefs in both the Pacific and Indian Oceans, and varies little in depth and breadth. There is no reason to suppose that the original shoals had any such tailing off. In the Maldives I did not particularly investigate this platform, but my soundings were sufficient to show that it is fairly regular on all sides of all banks save towards the interior of our plateau. In fact it was regular against all parts of the banks that were fairly freely exposed to the ocean. Off the west of Fadifolu I endeavoured for a short distance to place in both the 50 and 100 fathom lines. The two lines were generally separated from one another by no more than the length of my whale-boat, the slope from one to the other being certainly over 75°. I hence restricted myself to observing the 50 fathom line. It varied inside the banks from 50 to 300 yards from the edge of the reef-flat, in the majority of places being less than 100 yards. The steep generally commenced at about 20 fathoms, hence much below the depth usual outside atolls. This difference indicates that there is some action, much stronger outside the atolls, that forms this platform. This I conceive to be the current action, largely set up by the waves, and it is to it that I would look for an explanation of the shallow slope. The oncoming waves carry a large quantity of water against the reef, the most of which is thrown back in a deeper current, sweeping down the slope (see p. 24). The strength of this, weather conditions being constant, will depend on the exposure of the reef to the sea and on the height to which it rises in the water. For our purposes the reef may be assumed to reach the surface as in the Maldive banks. There is left then the question of exposure, which would naturally be much less on the inner sides of the banks. The outgoing currents would be less strong on the inner sides, and material would be carried out to a lesser depth than on the seaward sides. The quantity of lime thrown over the steep on the outer side would be very much greater than on the inner side. The depth at the edge of the reef-platform I would regard as the depth to which the current can sweep out the heavier masses of lime from the reef above. A considerable part of the reef to seaward might then have been formed of masses, piled up by this means. Against the deep channels between the several banks the strong currents would preserve for a long time the original, almost perpendicular slope, and from the lesser growth and protected situation within the bank the platform would be of less definite form and the original slope would be preserved. The Laccadive banks also support this view, in that the reef-platform on the west side of the reefs is of the regular slope and breadth, while on the east, which is protected by the Indian Peninsula, it is usually almost non-existent or else very narrow (Plate VIII.).

The matter in this chapter is, I fear, so extremely complicated on account of the varied conditions on the banks that it does not lend itself to the formulation of conclusions *in a brief set of words. I may, however, present some of my views as to the formation of the* *group in the pictorial method of expression by means of the accompanying diagrammatical section of the outside of a bank (fig. 33) as I suppose it to have been formed:—*

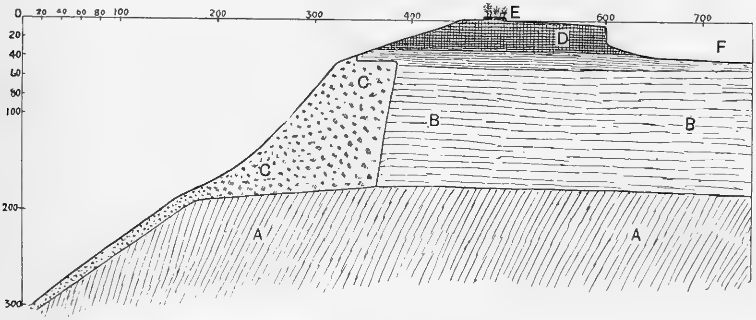


FIG. 33. *Scale in fathoms.*

A. *Basis of primitive rock, cut down by the action of the currents to this depth. This is deeper in the central basin of the plateau and in the channels between the several banks on account of additional erosive action since the latter commenced to grow up.*

B. *Upgrowth of a shoal by means of deep sea corals assisted somewhat by nullipores and other organisms. The more densely shaded area at the top shows the line in which the deep corals cease to grow and the reef forms commence; the reef, however, is in this part mainly built up by the intermediate depth corals and other organisms.*

C. *Outward extension of the reef by means of detritus, swept off the reef above by the currents.*

D. *Surface reef formed by true corals, nullipores, etc.*

E. *Land, formed by elevation or a change of level of the ocean.*

F. *Lagoon, formed partially by the more rapid growth of the organisms on the edge of the bank, building up an encircling reef, and partially by the subsequent solution of the central parts.*

(To be continued.)

ON THE PIGMENTS OF CERTAIN CORALS,

WITH A NOTE ON THE PIGMENT OF AN ASTEROID.

By C. A. MacMunn, M.A., M.D., etc.

(With Fig. 34.)

CONTENTS.

1. Coenopsammia willeyi (from Hulule)[1]. [Fig. 34.]

Alcohol extract of dried coral. Fig. 34. I.

When coarsely powdered and extracted with absolute alcohol and let stand for 24 hours, or longer, a greenish-yellow solution was obtained, which had a red fluorescence, and showed the spectrum of a *chlorophylloid* substance in solution, but no lipochrome bands. The bands in this alcohol solution read:—1st, λ 674 to λ 635, 2nd a faint band, λ 619 to λ 595. Traces of two other bands nearer the violet were also seen—in the green. Ether extracts the same colouring matter from the dried coral.

[1] [For description of the species see Willey's *Zoological Results*, Part IV. pp. 357 et seq. (1900). I have examined by sections the polyps of both species of *Coenopsammia* and the species of *Dendrophyllia*, whose pigments are reported upon in this paper. They have no commensal algae, such as are found in most reef corals, and I have been unable to find any algal matter in their coelentera. The specimens sent to Dr MacMunn consisted of the dried coralla with the animal part still remaining on the same. In some cases the corallum had been stained slightly by the diffusion of the pigment, which is situated in the external ectoderm alone.

Coenopsammia willeyi grows for the most part on the under-surfaces of the masses of the boulder zone, wherever there is a free circulation of water and no sand. Only one colony was found in Minikoi, but the species is fairly numerous throughout the Maldives in suitable positions. The colour when alive is a light, uniform, rather iridescent brick-red. Ed.]

On evaporating the alcohol solution to dryness on the water-bath, a residue partly brown and partly green was obtained, soluble in absolute alcohol, forming a dull green solution with a red fluorescence. In this solution the four bands referred to above were visible, but no lipochrome bands. The residue is also soluble in ether, in chloroform and in carbon disulphide, each solution showing the same chlorophylloid spectrum; the position of the bands varying according to the nature of the solvent.

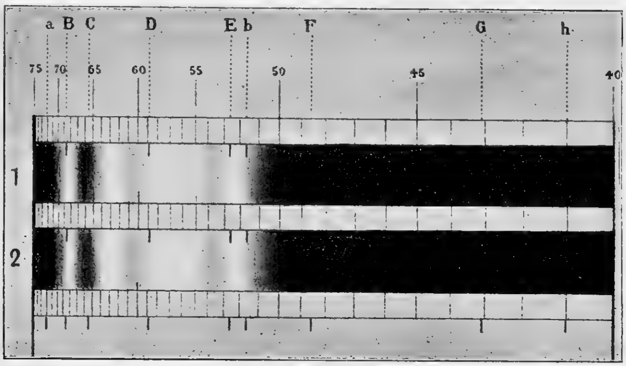


Fig. 34. Spectra of the pigments of *Coenopsammia willeyi*.
1. Alcohol extract of the dried coral. 2. Alcohol extract of the decalcified coral.

Pigments of the decalcified coral. Fig. 34. 2.

The coral was now decalcified by means of hydrochloric acid, at first of the strength of 1 to 4; afterwards the strong acid was added, from time to time, as required. When the lime-salts had been dissolved the soft brownish residue was washed with water until free from acid, on the filter paper. The wash water had a yellowish colour but showed no bands. The brownish acid-free pigmented substance itself gave no bands and was therefore free from polyperythrin.

The brown decalcified substance was then treated with absolute alcohol which soon assumed a deep yellow colour and had a red fluorescence, and showed the same chlorophylloid spectrum as the alcohol solution of the dried (undecalcified) coral itself. The solution showed four bands of which three read:—1st, $\lambda\,672$ to $\lambda\,639$, including shadings, dark from $\lambda\,670$ to $\lambda\,650{\cdot}5$, 2nd about $\lambda\,616$ to $\lambda\,595$, and 3rd about $\lambda\,545$ to $\lambda\,531$. *So that here the chlorophylloid pigment occurs united with lime-salts,* and no lipochrome could be detected.

Solution of pigment in NaHO.

Those portions of pigment of the decalcified corallum which were insoluble in alcohol were treated with caustic soda (weak). The solution on filtering had a reddish brown colour, but showed no bands, and absorbed the violet end of the spectrum. The addition of hydrochloric acid to this caustic soda solution causes partial precipitation of this pigment, and after filtering a brownish pigment is obtained. It is insoluble in ether, chloroform, alcohol, water or water acidulated with hydrochloric acid, but soluble in weak aqueous solution of caustic soda.

This pigment is evidently the main cause of the colour of the coral.

2. Coenopsammia nigrescens (from Hulule)[1].

An alcohol solution of the coarsely powdered coral was of a greenish-yellow tinge. In a layer of 10 centimetres deep a band could be seen in the red, due to a trace of a chlorophylloid pigment, and reading from λ 670 to λ 648. On evaporation on the water-bath a residue partly greenish-yellow and partly brownish was obtained, but this residue is more yellow (or reddish-yellow) than in the case of *C. willeyi*, and it is not wholly soluble in ether. The ethereal solution was reddish-yellow and left on evaporation a yellow residue soluble in the same solvents as in the case of *C. willeyi*.

Alcohol extract of dried coral.

The coarsely powdered coral was then after the alcohol extraction treated with dilute hydrochloric acid 1 in 4, then with the strong acid. On filtering off the soft decalcified coloured parts from the acid, the latter was found to have a reddish-yellow colour; this solution absorbed the violet end of the spectrum but gave no bands.

Pigments of the decalcified coral.

The soft pigmented parts of the decalcified coral were then washed free from acid and treated with absolute alcohol: but only a little pigment went into this.

This filtered alcohol extract had a greenish-yellow colour and did not show a noticeable red fluorescence, and did not give a band in red. It however strongly absorbed the violet end of the spectrum. On evaporating this solution an orange-coloured residue was left: partially soluble in ether and in chloroform, the solution showing no bands. That part of the pigment insoluble in these solvents was yellow. Here again the absence of a lipochrome was noticeable.

The decalcified coral after extraction with alcohol was now treated with caustic soda and water and filtered. The filtrate was of a reddish-brown colour and absorbed the violet end of the spectrum but showed no bands, nor were any visible on adding sulphide of ammonium.

Solution of pigment in NaHO.

Hydrochloric acid did not precipitate out this pigment to any marked extent even when added to excess. The little pigment precipitated out and filtered off was of a brown colour, insoluble in ether, chloroform, or absolute alcohol and soluble in weak acid and alkaline aqueous solutions.

Here again no polyperythrin was present.

3. Dendrophyllia ramea[2].

The dried coral was extracted with alcohol and yielded a yellow solution. This showed no absorption bands, nor had it a red fluorescence. It absorbed the violet end of the spectrum; in a deep layer at λ 480 completely. On evaporation a brownish, and in thinner parts a yellowish, residue was left. This was soluble in ether but

Alcohol extract of dried coral.

[1] [*Vide* Milne Edwards and Haime, *Cor.* III. p. 128. The species was only found in the Maldives. It occurs in the same position as *C. willeyi*, but is much less common. The colour, when alive, is a uniform, dull, cloth-black. Ed.]

[2] [All the specimens of *Dendrophyllia* appear to me to belong or closely approximate to this species (see Milne Edwards and Haime, *Cor.* III. p. 115). The species is very common in the passages of the atolls and banks in the Maldives from 15 to 40 fathoms. It also is found within the banks, wherever there is a sufficient current to keep the bottom fairly clear of mud and sand. The colour, when alive, is a somewhat iridescent black with very dark olive-green in the peristome, lighter immediately around the stomodoeum. Ed.]

not quite as soluble in alcohol; soluble in chloroform, forming a reddish-orange solution, and in carbon disulphide. In none of these solutions were any bands detectable. This residue (*quite free from any traces of alcohol*) became *redder* with strong nitric acid and with sulphuric acid, and *a marked red* with iodine in iodide of potassium solution. Hence this pigment is not a lipochrome.

Pigments of decalcified coral.

The coral was decalcified by means of hydrochloric acid as before. The acid however —differing in this respect from the above corals—took up some pigment, the solution after filtering being of a brown or reddish-brown tint. In this solution no absorption-bands could be seen: the violet end of the spectrum only being absorbed. If caustic soda be added in excess to this solution the pigment may be precipitated out.

The colouring matter seems mainly to occur in the superficial layer of the coral: as taught by the action of hydrochloric acid. The decalcified masses of pigmentary substance when examined in a compressorium showed no bands; hence no polyperythrin was present: they are black in thick, and brownish in thin layers.

The alcohol extract of decalcified coral.

By extracting the pigmented masses with alcohol a solution of a pale greenish colour was obtained which absorbed the violet end of the spectrum abruptly: no bands could be seen. On evaporation this left a yellow residue, which seemed to become brown by prolonged heating on the water-bath. Ether only took up part of this residue, leaving yellow flocks of pigment undissolved. This ether solution was yellow and showed a faint band at *D*; so that this pigment had changed by heating. This band read (about) from λ 580 to λ 615. On evaporating the ether a yellow and in part greenish residue was left: this was only partially soluble in chloroform, and this on evaporation left a residue partly yellow and partly dark brown. This residue was now only partially soluble in alcohol: so that the heating as stated had decomposed the pigment.

The residue left from the evaporation of this last alcohol solution became distinctly *red* with nitric acid, gave no distinct coloration with sulphuric acid, and gave a fine *brilliant red* with iodine in potassic iodide solution. This last reaction was very remarkable, and was yielded by both the brown and the yellow portions of the residue.

Solution of pigment of decalcified coral in NaHO.

Caustic soda in aqueous solution extracted—after the decalcified coral had been already extracted with alcohol—the dark pigment in considerable amount. The solution being almost black, but by transmitted incandescent (electric) light it appeared reddish or brown-reddish. In a deep layer this let through the red rays, in less deep the red and green, and in less deep still the violet end of the spectrum only was absorbed. No band was seen, nor on the addition of ammonium sulphide.

By adding hydrochloric acid to this solution to acidity a precipitate fell. This was filtered off and washed, and was of a brown colour: insoluble in ether, *soluble in alcohol*, insoluble in water, and soluble in aqueous solutions of caustic soda.

I stated above that hydrochloric acid extracted some dark pigment also from this coral which was partially precipitated by adding caustic soda to alkalinity. Now this latter pigment differs from that just described in some respects, as it is insoluble in alcohol, and *insoluble* in aqueous solution of caustic soda. Hence there appear to be two dark pigments colouring this coral; and no lipochromes are present in it.

4. Heliopora coerulea[1].

Alcohol extract of dried coral.

On extracting the coarsely-powdered, dry coral with alcohol a solution of a bluish-green colour was obtained which had a red fluorescence. This showed a band in the red from λ 670 to λ 644.

The solution was evaporated at the temperature of the air, and left a blue-green residue. Redissolved in absolute alcohol a blue-green solution was obtained, which had a red fluorescence and showed four absorption bands which read:—1st, from λ 674 to λ 635, including shadings, 2nd a shadow from λ 616 to λ 592, 3rd from λ 577 to λ 560? and 4th from λ 545 to λ 531. This spectrum denotes the presence of a chlorophylloid substance, but it was not accompanied by a lipochrome.

The pigment of the decalcified coral.

The powdered coral, already extracted with alcohol, was decalcified as before. The acid solution appeared blue but this was found to be due to particles in suspension —as it disappeared on filtering. On extracting the decalcified blue parts of the coral with rectified spirit a fine blue solution was obtained, like ammoniated sulphate of copper solution. This solution showed no absorption band, but transmitted the blue, green, and yellow of the spectrum and cut off a portion of the red end. Caustic soda discharged a part of the blue colour but did not destroy it.

A deep layer of neutral spirit solution of *helioporin*—as we may call it—more or less absorbed the red end of the spectrum up to and beyond the *D* line.

On evaporating such an alcoholic solution on the water-bath a blue residue was left. This was insoluble in ether, in chloroform, and in water, soluble in alcohol, but not as freely as before it was evaporated by means of heat. A further confirmation of the change undergone by the pigment in solution by heating was shown by the appearance of a band in red and one in the yellow at the *D* line. These bands reminded one of the chlorophylloid spectrum of the alcohol extract of the dried, undecalcified coral, and probably point to the connection between helioporin and this chlorophylloid pigment. Such a solution changed further on standing exposed to the air to a purplish tint, but still showed the two absorption bands referred to above.

Moseley, who first described this blue pigment of *Heliopora*[2], says that nitric acid destroys the blue colour of *Heliopora*. I found that nitric acid added to the alcohol solution made the colour more lavender, but did not remove it. Hydrochloric acid made the colour bluer. Caustic alkalies change the colour to a dirty green, as Moseley described. Here again no lipochrome bands could be detected.

This blue pigment decreases as the depth increases in which the coral lives; thus in the specimens sent me I found that the greatest amount of helioporin was present in specimens from the reef, which were coloured dark blue. Those dredged from a depth of 25 fathoms

[1] [In this case the pigment is situated in the corallum which is completely external to the living tissues. Most of the specimens, submitted to Dr MacMunn, had been cleaned by exposure for a long period of time to the sun and rain. The genus is found sparingly on the sand flats within the outer reefs of the atolls of the Maldives, and was obtained also in various dredgings between 25 and 45 fathoms. On the outer slope of Addu Atoll it seemed the most important reef builder at the depth of 40 fathoms. Ed.]

[2] *Quart. Jl. Micro. Sc.* vol. XVII. N. S. p. 2.

were much darker than those dredged from a depth of 40 fathoms, and what is of great importance, the side of the corallum next the surface, and therefore more exposed to sunlight, was a deeper blue than the opposite side.

5. Remarks on the Coral Pigments.

Of the above pigments some belong to those which may be called chlorophylloid, whether they are intrinsic to the coral, whether they are digestive products, or whether they are due to the presence of symbiotic algae. The other pigments found being probably "lipochromoids" and "melanoids." These latter were first described by the late Professor Krukenberg[1]. The occurrence of the chlorophylloid pigments is of great interest. Prof. Sidney Hickson has expressed the opinion that corals probably contain chlorophyll or an analogous substance[2]. I may refer to the paper of the late Professor Krukenberg again in this connection, "Die Farben der lebenden Korallen des Rothen Meeres," in which he describes a *chlorophylloid* pigment in various *fresh* corals. In stating that this pigment is a "hepatochrome" (or an enterochlorophyll) he is however not correct, as can easily be proved. The greater abundance of helioporin in the surface exposed to sunlight, and its diminution, or even absence, on the lower surface of the corallum, and further its apparent relationship to a chlorophylloid substance, is of great interest.

Doubtless these pigments are of physiological importance to the corals, as Prof. Hickson infers. And the dark pigments referred to above when in solution have the property of arresting the ultra-violet and violet rays of light: in this way they probably act as a screen, protecting the delicate organisms from the irritating effects of the rays of short wave-length.

The pigments, then, of the above corals are either chlorophylloid, or of a closely connected kind of pigment, which latter absorbs the violet end of the spectrum, and seems generally changeable into the next kind, by the agency of heat, etc., namely, into the dark pigment which gives the coral its dark colour in the fresh condition: e.g. brick-red, as in *C. willeyi*, or cloth-black, as in *C. nigrescens*, or velvet-black, as in *Dendrophyllia ramea*. This dark pigment is, as said above, extractable from the decalcified corallum by means of caustic alkali in aqueous solution. I would call attention more especially to the absence of lipochromes, even in the case of the corals possessing a chlorophylloid pigment, and to the presence of the peculiar pigments in some corals, which while being soluble in fat solvents like the lipochromes, yet instead of giving the lipochrome reaction, give a *red* reaction with nitric acid, sulphuric acid and iodine in potassium iodide solution.

6. Integumental Pigment of a Red Asteroid (*Ophidiaster cylindricus*[3]).

The specimens were preserved in pure 70 per cent. spirit and were more or less mottled of a bright red colour. As the spirit was colourless it was evident that the specimens did not owe this colour to a red lipochrome so common among starfishes found in British seas. (MacMunn.)

[1] *Centralbl. f. d. med. Wissenschaften*, 1883, No. 44.

[2] See *A Naturalist in North Celebes*, pp. 149—151.

[3] [I am indebted to Prof. Jeffrey Bell of the British Museum for this identification. Ed.]

On treatment with rectified spirit acidulated with sulphuric acid, only some yellow pigment went into solution; effervescence took place and it was evident that red pigment occurred in combination with lime. It was also evident that no haematoporphyrin was present[1].

On acting on the integument with hydrochloric acid and water a fine red solution was obtained which showed under the microspectroscope a broad band or shading in the green: extending from about λ 566 to λ 495. In deep layers the violet end of the spectrum was strongly obscured. Caustic soda was then added drop by drop until the solution became alkaline, the precipitate—consisting of sodium chloride—was pale pink, and on filtering, the filtrate was almost colourless. Alkalies do not therefore destroy the red colour. This pigment was found to be insoluble in ether and in chloroform.

[1] See the papers by MacMunn in *Journal of Physiology*, vol. VII. No. 3, and vol. VIII. No. 6.

MARINE CRUSTACEANS.

I. ON VARIETIES. II. PORTUNIDAE.

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(With Text-figures 35—38.)

INTRODUCTION.

The collection of Crustaceans from the Island of Minikoi[1] and the Maldive Group has been divided, for purposes of description and comment, into two halves of widely different biological interest. Of these the first, containing the land forms, has been reported upon in Part I. of this publication. The second, containing the marine forms, is too bulky to be described in a single article, and has accordingly been divided into a series of sections which will be dealt with by instalments, of which these pages form the first. Most of the sections will be undertaken by the writer of this introduction, but the collection of prawns of the family Alpheidae is in the hands of Professor Coutière, of Paris.

In reporting on such a collection as this, various questions of a general nature arise, such as that of the crustacean fauna of the several zones of depth, which are best left over for consideration till the whole of the material has been examined. Meanwhile, however, there is one such question which seems to demand attention at an earlier stage. In former papers[2] I have often had occasion to describe and classify groups of individuals to which

[1] By one of the fatalities that wait upon all expeditions, a great part of the Crustaceans from Minikoi were destroyed on the way to England. Fortunately the accident is mitigated by the fact that it is often possible to recognise in the Maldive collection forms seen at Minikoi. It will be necessary to allude to this in the course of the following sections, but the warning must now be given that the absence of mention of Minikoi as a locality for any species is not to be taken to mean that it is not to be found there.

[A large spirit-tank was apparently tapped on the way home and the greater part of the fluid withdrawn. It contained in numbered packages Mr Borradaile's and my collections of Crustacea from Minikoi, which were almost completely rotted. The loss is greatly to be regretted, as the habitat, mode of life, etc., in short the natural history of the specimens in each bag was carefully noted and there is now no means of ascertaining to what species Mr Borradaile's notes apply. Ed.]

[2] "On some Crustaceans from the South Pacific," Pts. i. ii. iv. and v., *P. Z. S.* 1898, pp. 32 and 457; and 1900, pp. 568 and 795; and "On the Stomatopoda and Macrura brought by Dr Willey from the South Seas," Willey's *Zool. Results*, Pt. iv., Cambridge, 1900.

I gave the recognised name of "variety," without attempting to define what that name meant. In many of the sections of this series similar groups of individuals occur, and it seems well to indicate at the outset what value is put upon them, both for the immediate purpose of the better description of the collection in hand, and in the hope of helping other workers in the same field. From these considerations there arise certain others regarding the ultimate nature and fate of varieties, and I shall endeavour to show in what direction my own speculation on this subject has led me. I am well aware that an experience, not of four years, but of forty would barely qualify an investigator to speak with sufficient authority for his words to carry conviction on such intricate and disputed points. But it seems well to indicate in general terms what are the problems involved from the point of view of the systematist.

The first article in the series will therefore be devoted to some remarks on the subject of varieties in the Decapoda. The second and following ones will contain the systematic lists, and the whole will be brought to an end by a discussion of such general questions as may be suggested by the material. Wherever possible the only references will be to Major Alcock's excellent lists of the Indian crabs, which contain full bibliographies and accurate descriptions of the species. These papers appeared in the *Journal of the Royal Asiatic Society of Bengal:* Part 1 (Oxyrhyncha) in Vol. LXIV. ii. p. 157 (1895): Part 2 (Oxystomata) in Vol. LXV. ii. p. 296 (1896): Part 3 (Xanthidae) in Vol. LXVII. ii. p. 67 (1898): Part 4 (Portunidae, etc.) in Vol. LXVIII. ii. p. 1 (1899): Part 5 (Dromiaceae) in Vol. LXVIII. ii. p. 123 (1899): Part 6 (Catometopa) in Vol. LXIX. ii. p. 279 (1900). A reference to this work is to be understood by the mention of Major Alcock's name and the numbers of the part and page of the article referred to. In other cases references will be limited, as far as may be, to indicating a single paper in which a reliable synonymy may be found.

The classification adopted is that of Ortmann in Bronn's "Thierreich," with certain modifications of my own, proposed in a paper in the *Proceedings of the Zoological Society* for 1900 (pp. 568—596).

The several sections will not deal with groups of equal taxonomic value, nor will these necessarily be considered in systematic order. Section II, included in the present instalment, is devoted to the Swimming Crabs (Portunidae).

In conclusion I may be allowed to repeat the acknowledgements I have already made to the Managers of the Balfour Memorial Fund and the Drapers' Company of London for their aid. Nor can I sufficiently express my obligation to Mr Stanley Gardiner for the assistance his great knowledge of tropical marine biology has been to me, confirming, as it has, my own less experienced observations, and for much kind advice on other points.

I. VARIETIES[1] IN THE DECAPOD CRUSTACEANS.

1. *The Nature of Varieties.*

In sorting out a collection of Crabs or Prawns, it is probably the habit of many systematists to separate groups of specimens which seem to belong to single species, and afterwards to examine each of these groups with more care. Now in many cases such a group will prove to be homogeneous, that is, to consist of individuals, differing from one another, it is true, in a greater or less degree, but not separable by their differences into sub-groups. Such a group will be regarded as a *species*. But in other cases careful examination of the specimens will reveal amongst them well-marked differences by which they can be separated into two or more sub-groups. Further, these sub-groups may either be entirely independent of one another, in which case we are dealing with two species confounded at first sorting, or they may be connected by specimens[2] intermediate between them with regard to the features by which they are separated, and not otherwise sharply marked off from them. Such sub-groups are called *varieties*. It must, however, be borne in mind that the intermediate specimens between varieties are much less numerous than those which exhibit the peculiarities of the varieties in a typical development. Otherwise it is only possible to say that the species exhibits considerable range of variation, but that definite varieties are not established. In my own experience, however, wide variability without the formation of definite varieties is rare among Decapods.

The difference, then, between species and varieties as recognised in systematic Carcinology is, or should be, that *species are unconnected by intermediate forms, while varieties are united into species by the existence of specimens intermediate between them in structure.* This is of course a purely empirical distinction, but it has the merit of being easily understood, workable, not likely to be very differently applied by different workers, and, which is decisive, the only one practicable in the present state of our knowledge. With the advantages of empiricism, however, the method of distinction outlined above combines one of its disadvantages, being somewhat too rigid for universal application. It has therefore to be modified in practice by the judgment of the worker in certain cases; that is to say, in those in which the trend of variation in each of two or more groups of individuals makes it probable that a more extensive series of specimens would show complete continuity, though there be, for the time, a gap between them. In such cases it is legitimate to unite the forms in question as varieties of a single species; though at the time of doing this the uncertainty should be distinctly stated. In point of fact surmises of this sort have repeatedly been justified by later knowledge[3].

[1] In this paper the word *variety* is used to denote an assemblage of individuals (as defined below). *A variation* is a peculiarity of a single individual (though it is often repeated in other individuals, in which case the word may be used collectively). *Variation*—without the indefinite article—is the fact of the existence of variations, and *variability* is the name given to the phenomenon of the occurrence of variation in a species or higher group, or between the like parts of an individual. The adjective *varietal* indicates connection with a variety.

[2] Either in the collection or described by former writers on the species.

[3] It is, indeed, a mere commonplace that many so-called species are mere varieties, to which rank some are degraded every year. In the end it will probably be found that every true species has definite habits and habitat, which have brought about its specific distinctness. It is not, of course, on this account any the less important that varieties should be named and registered.

Two or three more characteristics of varieties remain to be alluded to. In the first place it must be noted that varieties, like species, may be sundered by more than one difference, and that these differences, while they are, no doubt, smaller than those between most kindred species, can be easily paralleled by the latter in many cases, both in kind and in magnitude. Again, though the range of variation within a single variety is generally somewhat greater than that found in most homogeneous species, the latter will sometimes almost, if not quite, equal varieties in that respect. The differences between varieties are often less marked in the young than in old specimens, but this is the case with all the peculiar features of individual organisms. Lastly, there is, in many cases, no ascertained connection between varieties and locality, either geographical or bathymetrical, and they are not known to have any peculiar habits.

As an example of a varietal[1] species we may take *Thalamita admeta* (Hbst.), of whose varieties a key is given below in the second section of this report (p. 202). Here there are six varieties, resembling one another closely (that is, having the same range of variation) in most characters, but capable of separation by means of others, such as the depth of the frontal cleft, the fulness and granulation of the hand (propodite of the first leg), the size of the fourth side-tooth of the cephalothoracic shield; and so forth. These characters, be it noticed, are just such as are used in other cases to separate species of swimming crabs. Again, any two of the varieties may differ in one point only, or in more than one; and the varietal differences are less marked in the young than in old specimens.

With the exception of two new varieties, which appear for the first time in the Maldive collection, but will probably be found ere long in some other part of the range of the *T. admeta*, the geographical distribution of these varieties is practically identical. There would be little doubt of finding all of them in a sufficiently large collection from any part of the Indopacific region. Their bathymetrical distribution, on the other hand, would, if we confined ourselves to the data on p. 203, appear to show clear evidence of limitations of range. For the var. *admeta* was only taken by the Expedition as a littoral form, var. *granosimana* and var. *savignyi* at a depth of not less than 20 fathoms. But var. *savignyi* has been constantly taken elsewhere on the shore, and var. *intermedia* extends down to 30 fathoms, and is also taken on the shore[2], while of the varieties *granosimana* and *admeta* we have certainly not sufficient captures to allow of dogmatic statement.

Again, there is no evidence of any difference in either the habits or the habitat of the varieties. In the Island of Minikoi I was able to recognise, besides the type variety of *T. admeta*, another, differing in the slenderness of the chela, which I suspect to have belonged to *savignyi* (or possibly to *intermedia*, see the footnote to p. 191). Between the type and this variety there appeared to be no difference of habit or habitat. Of course, such differences would probably be hard to find, but the negative evidence on this point is supported by the results of dredgings in the Maldives. These dredgings supply data for recognising the connection, if any exist, between three factors of the environment at least and the organisms dredged. The factors are—the nature of the bottom, the presence or absence of weed, and the presence or absence of currents bringing water from without the

[1] By the term "varietal species" I propose to distinguish a species in which definite varieties have been recognised from a "homogeneous species" in which no such varieties have yet been found.

[2] In this paper the word *shore* will be used to denote that part of the littoral belt which lies between tidemarks, including both the reef and the sand-flats of the lagoon.

reef, as indicated by the nearness or remoteness of passages. In four dredgings var. *granosimana* was taken on a bottom of muddy sand, on another with coarse sand and small rubble, on coarse sand with rubble, and on a hard (rocky) bottom. In two of these dredgings weed was present, in two it was not. The number of captures was not enough to make it possible to come to any conclusion as to the effect of the neighbourhood of passages on the distribution of this variety, but in a similar case—that of the varieties of *T. exetastica*—it is quite clear that this factor is without influence. Var. *savignyi* was only taken twice, but *admeta* and *intermedia*, which were found four and six times respectively, showed no greater tendency to restriction to special environments than did *granosimana*.

2. *The Relation between Varieties and Species.*

Among the Decapod Crustaceans, then, species are paralleled by other assemblages of individuals, known as varieties, which differ from them neither in the nature of their characteristic features nor in the magnitude of these, but only in being connected into groups of two or more by the existence of intermediate individuals. It is hardly possible to resist the conclusion that, in many cases at least, species have arisen from such definite varieties as these by the extinction of the intermediate individuals. And it will be interesting to consider of what nature and origin varieties may be, and what processes may turn them into species.

The orthodox explanation of the origin of varieties such as those we are now dealing with would, no doubt, be that they are produced by natural selection of the variations (generally smaller in degree than those which characterise varieties) which are found within the limits of homogeneous species and varieties. Now there can, of course, be no reasonable doubt that natural selection is at work among the Decapoda, and it is probable that in some cases (as, for instance, in that which Professor Weldon has investigated in *Carcinides maenas*) it brings about transformations of species by accumulating small variations. This is especially likely to be taking place where a variety is locally restricted[1]. But in the case of varieties not so restricted, as we are now using the term, it is very difficult to accept the same view, and that for three reasons.

1. *There is no evidence of isolation* such as is presupposed in the evolution of two or more varieties simultaneously from a single species. And it should be observed that this is the problem now before us, not the replacement of an outworn type of the species under stress of uniformly changing environment over its whole range.

Isolation in the organic world may be of four kinds:

i. "Geographical."

ii. "Habitative"—a name which I propose to give to the separation of allied organisms which, living in the same locality, are nevertheless separated by their habits of life—as one prawn will hide among the branches of corals and another in a sponge, one crab burrow just below high-water mark and another just above, and so on. With this kind of isolation

[1] To these cases the name of "subspecies" might well be confined, leaving that of "variety" for non-local forms such as those now under consideration. The ultimate result of such a process is probably to be seen in genera like *Sesarma*, *Potamon*, and perhaps *Pilumnus*, where large numbers of species, differing in small points from one another, are of local distribution.

may be included that brought about by limitation of an organism to certain zones of depth, or bathymetrical isolation.

iii. "Physiological," due to a greater or less degree of infertility accompanying structural differences between allied organisms.

iv. "Sexual," due to a preference by the members of a species or variety for mating with their own kind.

Local variation is, of course, far from unknown in the Decapoda, but of the class of varieties we are now dealing with one of the most marked characteristics is their independence of geographical limitations. In fact it may generally be safely foretold of a Decapod crustacean that, if one variety be taken in a given locality, any others that may be known will probably also be found there, if only the collection be large enough. In the great majority of cases, if not in all[1], the varieties of the Decapoda are not known to affect *special habits or habitats*. Of course it is also true that very little is known about the habits of the group at all; but this does not justify us in assuming that non-local varieties are adapted to special habits. In a few cases of varietal species which I have examined "in the field," I have been unable to find any evidence of such a phenomenon. We have seen that, in the case of *Thalamita admeta*, there is no sign either of varietal habits or of varietal habitats as far as our present knowledge goes. An even better example is *T. exetastica* Alc., whose three varieties have been taken on every kind of bottom and in varying positions with regard to the passages of the reef. To take another instance, from a different group of Decapods, the porcelain crab *Petrolisthes lamarcki* has four varieties which show no divergence either in habits or in habitat. Regarding bathymetrical isolation there is again no evidence of varietal separation. We have seen that the case of *T. admeta* is somewhat doubtful. That of *T. exetastica* is beyond question in this respect, all the varieties having been taken within a few fathoms of one another in the Maldives. Yet *T. exetastica* is a species with a well-marked specific bathymetrical range, the thirteen recorded captures (including that made by the "Investigator") being all below 26 (or possibly below 30) fathoms.

As to *physiological* and *sexual isolation* in the Decapoda there is no evidence.

2. *There is no evidence of adaptation of varieties to special varietal habits or habitats.* This, which is really an entirely different question from that of isolation, resolves itself into a restatement of the evidence just given. For, so long as hardly anything is known of the adaptation of species by their structure to their specific habitats or habits, it is idle to argue that there is no evidence of the utility of varietal characters. But we do know, or at least are beginning to know, that every species has its specific habitat and habits, to which we conclude, from the few cases that we understand, that its specific characters are adapted. It is therefore quite pertinent to argue that, unless varieties can be shown to have definite habitats and habits, their varietal characters cannot be assumed to be adapted to such circumstances. And it is of just this phenomenon—the existence of varietal habitats and habits—that there is at present no evidence.

3. *There is no clear evidence of intermediate stages in the formation of varietal from homogeneous species.* There are plenty of species in which it is impossible to pick out two

[1] Coutière [*Les Alpheidae*, Paris, 1899] seems to have found at Jibuti examples of habitative isolation among one or two Alphëid varieties, but at present there is always a doubt as to the interpretation put on the term variety.

well-characterised non-local varieties, and again there is a certain proportion in which two or more such varieties are seen. But in all these latter, so far as I have met with them, the varieties are sundered by well-marked gaps. That is to say, in sorting fifty specimens of two varieties, there would not, in my experience, be more than two or three whose position would be doubtful. This is, of course, merely negative evidence, but it would not be right to assume that positive evidence in the opposite direction exists till it be forthcoming[1].

In view of the facts just stated, it is, I think, clear that there are considerable difficulties in the way of explaining the origin of varieties in the Decapoda by means of natural selection. Time and research may remove these difficulties, but it is equally likely that they will not. It will be well, therefore, to consider shortly the alternatives. A Lamarckian view of the question, as compared with the Darwinian, is equally difficult to reconcile with the want of any correlation of varietal characters with the environment, which is implied by the absence of geographical and habitative isolation. There is left, if both these fail us, but one alternative possible. Like smaller variations, those which characterise varieties would appear to be produced by intrinsic forces alone, of whose equilibrium they are perhaps the outcome[2]. But questions so momentous are not to be decided by an examination of one group only, nor by any but those who have made variation a study. In their hands may be left the question "*Are varieties the outcome of inward or of outward forces; does the solution of the problem of their origin lie with Physiology or with Natural History?*"

Turning now to an examination of the ways in which varieties might become species, and assuming that natural selection is the transforming agent, we may consider in what manner it would act. There are two conditions under which natural selection can come into play upon a varietal species. Either the environment may alter, or the species may spread into a new area where the environment is different from that under which it has hitherto been living.

[1] Throughout this article statistics have been avoided, as any attempt to draw exact conclusions in a particular case from less than, say, a thousand specimens would be hazardous. But, to take the first example to hand, out of 36 specimens of the type variety of *Thalamita admeta* collected in the Maldives, two only show characters which caused hesitation as to whether they should be placed with the remaining 34 or with examples of var. *savignyi*. These two were of middle size. One small specimen showed some resemblance to var. *edwardsi*, but its position could not be said to be doubtful.

[2] This alternative, if, as seems probable, it coincide with Bateson's theory of Discontinuous Variation, will receive from that fact an advocacy which will make it worth careful consideration. The chief point in which it amplifies Mr Bateson's theory would seem to be that it is now suggested that discontinuous variations may coincide, and so produce entities still more like species than assemblages of individuals separated on one character only, and that there is no evidence of this coincidence being brought about by natural selection, but on the other hand a possibility of its being due to intrinsic causes (correlation). The same cause, for instance, which produces ridges in one part of the body may, under the different conditions of growth prevailing in another region, make tubercles or granulations, and the swelling of a surface may lessen automatically the relative area of granulation or the height of the granules. Of course very many varieties are separated by one character only, or at all events only one such has yet been detected in them. The origin of such a form is a simpler problem than that of one characterised by two or more special features, and is that which has been chiefly discussed above.

No doubt cases exist of discontinuous variations which do not coincide. But in that case one would probably be more conspicuous than the others, and its use for systematic purposes would cause the others to be overlooked. An examination of a key to the varieties of a species will sometimes reveal such characters of secondary prominence by the fact that it is possible to rearrange the key in two or more ways. In these cases it is easy to see that the key by no means necessarily represents genetic affinities, but merely classifies possible combinations of characters. But I am not here concerned to uphold Mr Bateson's theory, and shall enter no farther into a discussion of this point, which concerns variation, not varieties.

(*a*) Let us suppose the environment to alter. Its effect upon a varietal species might take one of several forms: (i) It might affect all varieties equally, either favourably, unfavourably, or not at all. (ii) It might extinguish all but one. In either of these events the species as a whole would change its characters, but there would be no transformation of a group of varieties into a group of species. (iii) In a species with three or more varieties, in which the extreme varieties are connected (structurally, not necessarily genetically) by intermediate varieties, it might extinguish the intermediate variety or varieties, leaving the extreme ones as separate species. (iv) In a species with two or more varieties, it might affect all or some of the varieties favourably in their most marked form and prove prejudicial to the intermediate individuals between the varieties. By this means it might polish the varieties, so to say, into species.

(*b*) Supposing, on the other hand, the species to migrate into a new environment, either geographical or habitative, the possibilities which we have just discussed again present themselves with the addition of a new factor to determine which of them is to come into play. For clearly either one or more than one of the varieties might migrate, and it is probable that the effect of changed conditions on a single variety would be different from that which they would have on a group of varieties. In the one case we should have the new factor of isolation, in the other this would still be wanting.

But here we are brought face to face with a difficulty due to our lack of knowledge of the reproductive physiology of the Decapoda. The above paragraphs dealing with the effect of a changed environment all presuppose that the varieties breed more or less true, that is, that at least the great majority of the offspring of members of one variety belong to that variety. If, on the other hand, any variety give rise plentifully to all, it is clear that the task of natural selection will be much harder, for it will have to reduce this tendency in the surviving varieties as well as to extinguish the unfitted ones. On this point, however, it is useless to say more in the present state of our knowledge.

[*Note. Jan.* 16, 1902. Since the foregoing was written, Mr Bateson's paper on "Heredity, Differentiation, and other Conceptions of Biology" (*Proc. Roy. Soc.* LXII.) has appeared. It seems that I have reached conclusions somewhat similar to those outlined in the later pages of that paper. What I have called "varietal characters" are probably the same as those which are there called "specific variations," while the "normal variations" are with me "variations within a homogeneous species or variety." If Mr Bateson's conceptions, and the terms by which he designates them, be accepted, a very great advance in Systematic Zoology will be possible. But some confusion is likely to result if either of the terms "varietal" and "specific" be applied to phenomena which are at the base of *both* varietal and specific entity. Would not the word "specifactive" meet the case better?]

II. PORTUNIDAE (SWIMMING CRABS).

1. *General.*

The family Portunidae are distinguished from the rest of the round-fronted (cyclometope) crabs by the adaptation of some of their legs for swimming, to which end these limbs are transformed into flattened paddles. The result is often to confer upon the crabs a power of darting at high speed through the water, which would hardly be credited by those who have not watched them. Corresponding to this mobility they have a thin flattened form of body, enabling them to pass sideways through the water, and a lightness gained at the expense of the protective cuticle. These peculiarities give the swimming crabs a strikingly different bodily form from the heavily-built, slow-moving Xanthids, which is moreover accompanied by an equally marked difference of habitat. The Xanthids are usually to be found on the reef or shore exposed to the full force of the breakers. In this position the lightly-built swimming crabs would be dashed to pieces against the rocks. Their proper haunt is a space of quiet waters, such as the lagoon of a coral atoll, and as these places are, in the tropics, generally bottomed with white or greyish coral sand, on which the crabs lie, and in which they often hide their bodies, they frequently mimic it by their pale greyish colour[1], often in a manner as striking as that in which flat-fish resemble the shingly bottom they live on.

At the same time the swimming crabs are by no means entirely confined to a bottom of coral sand even in the tropics. In deep water, where rocks are not associated with danger, they are found on every kind of bottom in about equal numbers, and here, if they hide, it must be under stones. They even occur, though not so very often, on the reef. But the individuals, found in this position, may possibly have strayed from the lagoon with the outgoing tide. Probably, when more is known about the lives of the species, it will be found that certain of them maintain their existence on the reef by sheltering under stones or in blocks of coral, where if anywhere they are always found, and that others—certainly the bulk of individuals—prefer the lagoon. In their habits these crabs are active and intelligent, escaping capture with cleverness. The lagoon forms usually keep close to the sand and do not rise more than a few feet into the water, but others swim as boldly and strongly as fish.

The bodies of most Portunidae are adorned or protected with sharp thorns or teeth, and it is on such characters as the number and size of these and the shape of the lobed front that the species are generally distinguished, though in most cases enough is not known of their habits to make it possible to say whether, and if so how, these be of use to the animals.

The family is highly variable and varietal and is probably undergoing rapid evolution in many directions.

[1] This colouring would also resemble, though not so closely, that of coral blocks or rubble.

2. *Systematic List.*

Subfamily **Carupinae.**

Genus *Lupocyclus* Ad. and Wh., 1848.

1. *Lupocyclus strigosus* Alc. 1900. Alcock, IV. p. 24.

Dredged in Kolumadulu on a bottom of dead and broken shells in 35 fathoms of water. All previous specimens have been dredged in the neighbourhood of India in 15—58 fathoms.

Subfamily **Thalamitinae.**

Genus *Lissocarcinus* Ad. and Wh., 1848.

2. *Lissocarcinus laevis* Miers, 1886. Alcock, IV. p. 21.

Dredged in South Nilandu on a bottom of hard sand in 36 fathoms of water.

3. *Lissocarcinus polybioides* Ad. and Wh., 1848. Alcock, IV. p. 19.

Dredged in Mulaku on a bottom of mud with weed, in 28 fathoms of water.

4. *Lissocarcinus orbicularis* Dana, 1852. Alcock, IV. p. 20.

This crab lives symbiotically[1] with the teat-fish (*Holothuria nigra*). It hides under or among the tentacles, coming out from shelter at times, perhaps to feed, and crawling all over the body of its host on which it crouches if disturbed. Its dark purple colouring with white spots is protective, resembling the sticky black skin of the teat-fish with grains of coral sand adherent. Paler brown forms live on other Holothurians to whose colour their own is adapted. The other two species taken by the Expedition are roughly speaking sand-coloured, and there is no record of their living symbiotically with other organisms. The females of *L. orbicularis* show a very perfect condition of an arrangement found in various other swimming crabs. That is to say, there is a well-developed brood-pouch formed by a deep sternal hollow surrounded with a fringe of hair and floored by the abdomen, whose sides are also edged with hair. One specimen had many fully hatched zoaeas in this pouch, and it would be interesting to know how long these young remain there, and how much of their development is passed there.

The species was taken on the shore and also dredged. It was found in Minikoi, Hulule, Male Atoll, Furnardu velu[2], Miladumadulu, South Nilandu, and Mulaku.

Genus *Charybdis* de Haan, 1835.

5. *Charybdis* (*Gonioneptunus*) *truncata* (Fabr.). Alcock, IV. p. 67.

The size and shape of the teeth on the antero-lateral edge are not constant. This is probably the reason why the descriptions of different writers do not quite agree. Alcock

[1] The words "symbiosis" and "commensalism" appear to be often used as synonymous, but the latter should obviously be restricted to cases where the food of two associated organisms is of the same nature.

[2] [For definition of this term see p. 155. Ed.]

says that the propodite of the last leg has its hinder edge smooth. It is not serrate, but it bears 4 or 5 minute curved spines, indicated in de Haan's figure of the female.

The species was dredged in depths of more than 28 fathoms, on bottoms of sand and mud, in Haddumati, Kolumadulu, and Mulaku.

Genus *Thalamita* Latr., 1829.

6. *Thalamita prymna* (Hbst.), 1803.

Var. *picta* Stimps., 1859. Alcock, IV. p. 79.

Found sheltering in a coral mass on the outer reef at Minikoi.

Var. *danae* Stimps., 1859. Alcock, IV. p. 77.

Taken on the reef at Minikoi.

It would be interesting to know the difference between the habits of this species and those of the equally common and somewhat similarly built, though quite distinct, *T. admeta.* I am under the impression, though the loss of my Minikoi specimens leaves me somewhat in doubt on this point, that *T. prymna* is a reef crab of a darker, more greenish hue than *T. admeta*, generally found in the neighbourhood of living corals, and perhaps of rather more sluggish habits than the latter. *T. admeta* on the other hand, though also found on the reef, is, I fancy, a lagoon crab of a paler colour, sometimes almost white, fond of lying on the sand, and of extremely active habits.

7. *Thalamita sima* H. M. Edw., 1834. Alcock, IV. p. 81.

There is considerable variation in the depth of the frontal cleft of this species, and same also in the granulation of the under side of the hand. A few specimens came near *T. poissoni.* The absence of spines from the hinder edge of the meropodite is, however, always to be relied on as a distinction between the two. The var. *granosimana* of *T. admeta* tends to approach this species, as will be stated later.

Specimens were dredged in Haddumati, Nilandu, Kolumadulu, Suvadiva, Fadifolu, Felidu, and Mahlos on every kind of bottom below 19 fathoms. Elsewhere it appears generally to have been taken as a shore form. Possibly its small size may have caused it to escape collection on the shore in the Maldives. On its absence from Minikoi no stress can be laid, for the reasons stated in a footnote to p. 191. In dredging, the liability of a swimming crab to capture depends, not on its conspicuousness, but on its powers of swimming, which are usually greater in larger crabs. The small average size of dredged specimens of many swimming crabs is probably due to this.

8. *Thalamita poissoni* Aud. and Sav., 1825. Alcock, IV. p. 81.

The hands of the female (and to a less extent the small hand of the male) have well-marked ridges on the outside and are not full but narrow, like those of *T. admeta*, var. *savignyi.* One male specimen from Suvadiva has the spines on the fore edge of the meropodite of the *cheliped* blunt, as they are said to be in *T. chaptali.* The shape of the frontal lobes and of the frontal notch varies considerably, and some specimens can hardly be told from *T. admeta*, var. *savignyi*, when young, or from var. *edwardsi* of the same species when full grown. In other cases there are traces of scaly markings on the under side of the chelipeds which recall *T. admeta*, var. *granosimana* on the one hand, and *T. sima* on the other. From the latter species, however, as well as from *T. chaptali*, *T. poissoni* is sharply distinguished, as yet, by the presence, on the hinder edge of the propodite of the last leg, of several spinules, of which there is no trace in *T. sima* or *T. chaptali*. From *T. admeta* it is sundered by its much smaller size.

At present, therefore, it is necessary to keep separate the four forms of *Thalamita* known as *T. admeta*, *T. sima*, *T. poissoni* and *T. chaptali*; but it is far from impossible that they may eventually prove to be all varieties of one species, perhaps in process of separation as independent species.

Dredged in Suvadiva, South Nilandu, Mulaku, Addu, Haddumati, Miladumadulu, Fadifolu, Kolumadulu, and Minikoi, on all kinds of bottoms, in from 7—43 fathoms. Elsewhere has generally been taken on the shore, but the same remarks apply here as in the case of *T. sima*.

9. *Thalamita admeta* (Hbst.), 1803.

T. admeta and *T. quadrilobata*, Alcock, IV. pp. 82—85.

Among the numerous specimens of this very variable species collected by the Expedition, were examples of two varieties hitherto unrecorded. One of these has characters in common with both *T. quadrilobata* Miers and the type of *T. admeta*, having the front of the latter but resembling the former in all other respects. I propose the name of *intermedia* for this form, and have also taken the step contemplated by Alcock, of including *quadrilobata* with *admeta*. The other variety, which I propose to call *granosimana*, resembles var. *savignyi*, but has the under side of the cheliped granular as in *T. sima*, which it also resembles in a rather less flattened body and more arched front than those of *T. admeta*.

The following key includes all the varieties of this species at present recorded:

I. Crest on the basal joint of the second antenna toothed or granular, not spinose.

1. Space between the two lower ridges of the hand (propodite of cheliped) smooth or only very sparsely granular. Fingers shorter than the palm, dactylopodite hooked. At least the big chela of the male deep and full in shape. Median cleft of the front always deep. Fourth side-tooth of carapace usually quite vestigial.

i. Outer surface of hand more or less granular; ridges strongly developed.

Var. A, *admeta* (Herbst.), 1803.

ii. Outer surface of hand smooth; ridges slight.

Var. B, *edwardsi* Borradaile, 1900.

2. Space between the two lower ridges on the hand strongly granular. Fingers as long as palm, straight. Chelae slender in shape. Median cleft of the front often shallow. Fourth side-tooth of carapace small, but not vestigial.

i. Under side of hands smooth.

Var. C, *savignyi* A. Milne-Edwards, 1861.

ii. Under side of hands granular.

Var. D, *granosimana* n.

II. Crest on basal joint of second antenna with three large spines.

1. Front two-lobed.

Var. E, *intermedia* n.

2. Front four-lobed.

Var. F, *quadrilobata* Miers, 1884.

Admeta was taken on the shore in Minikoi, Goidu, Fadifolu, and S. Mahlos; *intermedia* on the shore in Goidu and Fadifolu, in 5 fathoms at North Male and in 30 fathoms at Haddumati; *granosimana* in 20—43 fathoms on bottoms of varying description in Mahlos, Kolumadulu, South Nilandu and Suvadiva; and *savignyi* in 23—28 fathoms at North Male and Mahlos. The latter variety was probably also seen at Minikoi.

Admeta, savignyi and *intermedia* are, to the best of my knowledge, found both on the reef and in the lagoon[1]. With them go probably *edwardsi* and *quadrilobata*. *Savignyi* and *intermedia* certainly, and probably also the other three, extend from the shore down to 30 or 40 fathoms at least. *Granosimana*, which shows features which tend to ally it with *T. sima*, has, like the latter species, been found only in deep water in the Maldives. If this be a real and not an apparent limitation (see above p. 201), the same cause is probably at work in both cases, and *granosimana* very likely exists elsewhere on the shore with *T. sima* and *T. poissoni*. In that case it is probably an incipient species in a somewhat earlier stage than *T. sima* and *T. poissoni*. On the other hand it may be a genuine local subspecies.

10. *Thalamita exetastica* Alc. 1900. Alcock, IV. p. 86.

The collection contains a number of specimens which are at least closely allied to this species and may all be for the present classed as varieties of it. Some of them approach very closely to Alcock's definition, but there is one point in which all fall somewhat short. This is in the squamiform markings on the chelipeds, which never completely cover the limb but are always replaced to a greater or less extent by more rounded granulations on the upper side, and are often wanting over a part of the lower side.

Three varieties are present:

1. Var. A. Typical, that is, agrees with Alcock's definition in all points (except the granulation of the chelipeds as above).

2. Var. B, *spinifera*. Differs from the type in having a varying number of spines on the hinder edge of the propodite of the last leg. In this point it approaches *T. investigatoris*, Alcock, 1900.

3. Var. C, *macrodonta*. Has no spines on hinder edge of last propodite, but differs from type in that:

(i) The last side-tooth is nearly as large as the third and projects somewhat more than the rest. Fourth tooth rudimentary.

(ii) The median frontal lobes are distinctly narrower than the submedian. About 1 : 2 in the Kolumadulu specimen, and 2 : 3 in the Suvadiva specimen.

In both these respects the variety approaches *T. investigatoris*.

[1] See footnote to p. 191.

Var. A was dredged in 30 and in 37 fathoms in Suvadiva, on a rough stony bottom and on the hard smooth bottom of a passage.

Var. B was dredged in Suvadiva, Kolumadulu, South Nilandu, Haddumati, Mulaku, and Felidu in 30—45 fathoms on every kind of bottom.

Var. C was dredged in Suvadiva and Kolumadulu in 34 and 35 fathoms on bottoms of rubble and broken shells respectively.

It seems not unlikely that the dredgings of the "Investigator" and of Mr Gardiner's Expedition have revealed a new and highly varietal species of *Thalamita* in deep waters near India, of which *T. exetastica*, var. *spinifera*, var. *macrodonta*, *T. investigatoris* and *T. imparimanus* are but varieties. The habitat of this species is probably in moderately deep water only. Allied to it, but separated from it by the form of the chelipeds and their equality in the male, is the species next described of which the only known specimen has been taken on the littoral.

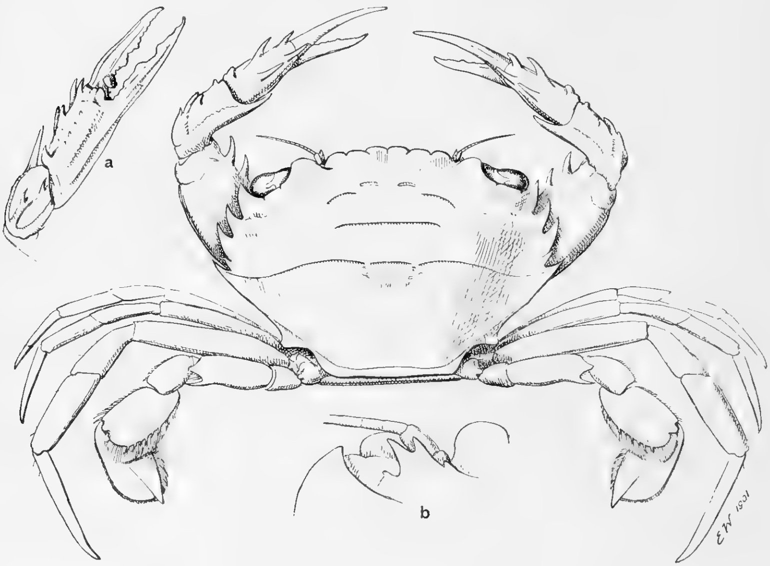


FIG. 35. *Thalamita tenuipes*; *a.* outside of chela, *b.* base of antenna.

11. *Thalamita tenuipes* n. sp.

Closely allied to *T. imparimana* Alc. 1900 (IV. p. 87), but separated from it by the following characters:

(i) Basal joint of antenna has a short crest consisting of two large teeth fused at their bases.

(ii) Chelipeds of male equal, smooth, with a few scattered warts and scanty hairs. Outside the wrist are two ridges, and three spines, at the inner angle one spine. Outside the hand two distinct ridges, with another less distinct above them; on the upper side two pairs of spines. Fingers as long as palm, slender, hooked at tip, grooved within and without.

(iii) Line between 6th and 7th abdominal terga very slightly concave.

(iv) Habitat the shore (?).

Length 10 mm.; breadth 13 mm.

Colour in spirit, ochreous yellow.

One male from Goidu, Goifurfehendu Atoll.

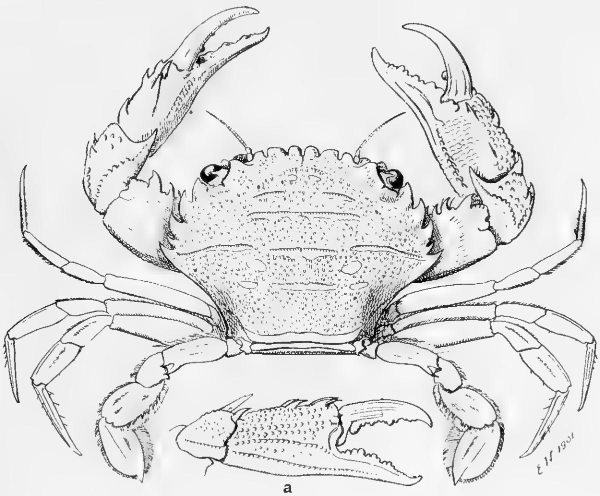


Fig. 36. *Thalamita gardineri*; *a*. outside of chela.

12. *Thalamita gardineri* n. sp.

The *exetastica* group of *Thalamita* approach *Charybdis* in some respects. The present species is allied by its features both to *Charybdis* and to the *exetastica* group. From the latter it is sundered by the following characters:

(i) The transverse ridges of the carapace are disposed as in *T. exetastica* but are rather more prominent than in the type variety.

(ii) The antero-lateral edge slopes outwards, making a greater angle with the middle line of the body than in *T. exetastica*.

(iii) The median frontal lobes are distinctly narrower than the submedian (2 : 3), and on a lower plane than, though not overlapped by, the latter.

(iv) The last side-tooth projects much more than the rest, and is as long as the 2nd or 3rd, though not so broad. The 4th side-tooth is small, but not rudimentary. There is no small tooth at the base of the first side-tooth.

(v) The chelipeds of the adult male are almost absolutely equal. Transverse squamiform markings are almost wanting. The upper side of the hand is covered with rounded granules, but on the inside squamiform markings remain.

(vi) There are about 10 spines on the hinder edge of the last propodite.

Length of longest specimen (♂), 13 mm. Breadth of same specimen, 17 mm.

Colour in spirit, sandy mottled with reddish.

Taken in Minikoi, sheltering under stones on the reef. This species is transitional to *Charybdis* (Goniosoma), but is separated from that genus by having only five side-teeth. The outward trend of the antero-lateral edge is a character which makes its position in the genus *Thalamita* somewhat doubtful.

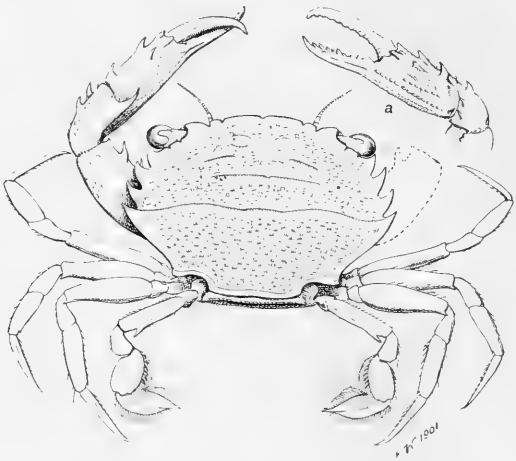


FIG. 37. *Thalamita cooperi*; *a*. outside of chela.

13. *Thalamita cooperi* n. sp.

Closely allied to *T. invicta* Thallw. 1890[1], of which it is possibly only a variety. It differs from Thallwitz' species however in the following points:

(i) The fourth side-tooth is wanting, and not merely vestigial as in *invicta*.

(ii) The outer side of the hand bears the usual five spines, instead of only three.

The front is lobed (excluding the orbital lobes), the middle lobes being the widest and somewhat recalling the frontal lobes of *T. admeta*. There are four side spines including the orbital angle, the fourth of those usually present being lost. The antennal ridge is granular. On the outside of the hand are the usual five spines and three granulated ridges. The fingers are shorter than the hand. The last propodite bears about half-a-dozen spinules.

[1] Thallwitz, *Abh. Zool. Mus. Dresden*, 1890—1891, No. 3, p. 46.

Taken at Goidu, Hulule and Minikoi, on the shore in each case. At the latter island it was sheltering in a coral block on the outer reef.

I have called this species after my friend Mr C. Forster Cooper, who was a member of the Expedition.

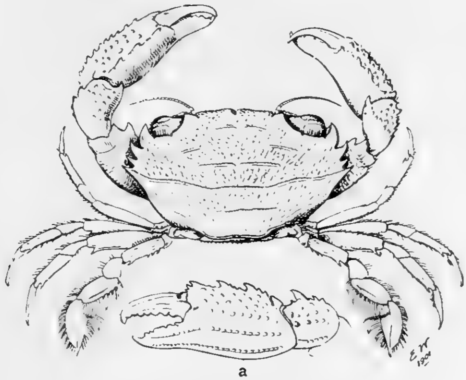


Fig. 38. *Thalamita pilumnoides*; *a*. outside of chela.

14. *Thalamita pilumnoides* n. sp.

Diagnosis: "A *Thalamita* with the body and limbs very hairy; the ridges of the back much as in *T. admeta*; the front bent downwards, slightly arched, and bilobed, the angles of each lobe being slightly produced; the inner supraorbital lobes nearly straight, sloping backwards and inwards, less than half the width of the frontal lobes; side-teeth four in number (including the orbital tooth), the third being the smallest; the hinder edge of the carapace concave, forming a gentle curve with the side edge; the sixth abdominal segment of the male broader than long; the basal joint of the antenna about equal to the orbit in width, its crest with four blunt teeth; the chelipeds stout, unequal (in ♂ at least), with three granular ridges on the outside of the hand, the areas between the ridges smooth, the under side smooth, the upper side covered with sharp tubercles, a row of three teeth along the inner edge of the upper side and one tooth at the articulation with the wrist, the fingers shorter than the palm, the wrist with one spine at the inner angle and three smaller ones on the outside, while the upper side bears some granules as on the hand, the arm with a series of teeth on its fore edge, diminishing from without inwards, and part of the upper surface granular; a spine on the hinder edge of the last meropodite and two or three spinules on the hinder edge of the last propodite."

Length, 4 mm.; breadth, 6·5 mm.

Colour in spirit, pale yellow with minute green spots in places, especially on the front.

One male from a small shoal in the middle of the lagoon at Minikoi.

Subfamily **Portuninae.**

Genus *Neptunus* de Haan, 1833.

15. *Neptunus* (*Achelous*) *granulatus* (H. M. Edw.), 1834. Alcock, IV. p. 45.

Taken in Haddumati, Suvadiva, Felidu, South Nilandu, Male, Kolumadulu, Miladumadulu and Mahlos from 0—43 fathoms on every kind of bottom. Not recorded from a tidal reef.

16. *Neptunus* (*Hellenus*) *longispinosus* (Dana), 1852. Alcock, IV. p. 40.

Taken in Minikoi, Hulule, Mahlos, Male, South Nilandu, Kolumadulu, Haddumati and Miladumadulu in 2—4 fathoms on every kind of bottom. Not recorded from a tidal reef.

17. *Neptunus* (*Hellenus*) *tuberculosus* H. M. Edw. 1861. Alcock, IV. p. 42.

Taken in Haddumati, Kolumadulu, and Felidu in 22—40 fathoms on bottoms of sand with weed or rubble.

18. *Neptunus* (*Hellenus*) *hastatoides* (Fabr.), 1798. Alcock, IV. p. 38.

In all the specimens the middle lobes of the front are distinctly shorter than the others. Taken in South Nilandu and Mulaku in 19—30 fathoms on hard and on muddy bottoms respectively.

19. *Neptunus* (*Hellenus*) *tenuipes* (de Haan), 1835. Alcock, IV. p. 42.

The last side-spine in nearly all the specimens is considerably more than three times the length of any of the others, which is the proportion given by Alcock, but it varies in length a good deal.

Taken in Mulaku, Haddumati, Felidu, South Nilandu, and Suvadiva in 28—40 fathoms on sandy or muddy bottoms.

CHAETOGNATHA,

WITH A NOTE ON THE VARIATION AND DISTRIBUTION OF THE GROUP.

BY LEONARD DONCASTER, B.A., *Scholar of King's College, Cambridge.*

(With Plate XIII, and Text-figures 39 and 40.)

AMONG the pelagic organisms, collected by Mr Stanley Gardiner's Expedition in the Maldive Archipelago in the years 1899 and 1900, were considerable numbers of Chaetognatha. They were fished chiefly at night, in moderate depths, and were preserved directly in 4 per cent. formalin. They are divided into two parts, viz. some were collected between Dec. 10 and Jan. 10, and the rest in April. Those obtained in the winter were much more abundant both in individuals and species, the number of specimens submitted to me being about 900 in the winter months compared with rather over 250 in April.

In classifying the group I have followed Langerhans ("Wurmfauna von Madeira," *Zeitschr. wiss. Zool.* Bd. XXXIV. p. 132, 1880) and Strodtmann ("Systematik der Chaetognathen," *Archiv Naturgeschichte,* Jahrgang 58, Bd. I. p. 333, 1892), and have used the names *Sagitta*, *Spadella* and *Krohnia* in the sense which they have defined, viz.

Sagitta forms with two pairs of lateral fins, and two rows of teeth;

Spadella with one pair of lateral fins on the tail segment only, and two rows of teeth;

Krohnia with one pair of lateral fins extending on the trunk and tail, and one row of teeth.

The Chaetognatha from the Maldives include several species well known from European waters, and others which have been procured only from the American coast or from Japan, but a considerable proportion (6 species out of 15) appear to be undescribed. *Sagitta* is much the most abundant genus, but *Spadella* is represented by one moderately common species, while only two specimens of *Krohnia* were found.

In a Note at the end of the "List of the Species" I have added the description of a new species, found by the late Mr F. P. Bedford at Singapore.

I. LIST OF THE SPECIES.

I. Genus **Sagitta** Slabber.

1. *Sagitta enflata* Grassi.

Strodtmann, *Archiv Naturgeschichte*, Jahrg. 58, Bd. I. p. 348, 1892.

This species is very abundant both in winter and in April, making up perhaps fifty per cent. of each collection. It agrees with Grassi's description in most points; the tail segment is however rather shorter in proportion to the trunk, and the teeth are sometimes more numerous. Exactly the same differences are described by Aida (*Annot. Zool. Jap.* Vol. I. p. 13, 1897) between the *S. enflata* found in Japan and those of European waters.

This species has been hitherto recorded from the Mediterranean, Madeira and Japan.

2. *Sagitta magna* Langerhans.

Strodtmann, *Archiv Naturgeschichte*, Jahrg. 58, Bd. I. p. 343, 1892.

Fairly abundant in the winter, but not found in April. Only a few specimens reached a length of 3 cm. Did not differ in any points from Grassi's and Strodtmann's descriptions.

Recorded hitherto from Madeira and the Mediterranean.

3. *Sagitta tricuspidata* Kent.

Strodtmann, *Archiv Naturgeschichte*, Jahrg. 58, Bd. I. p. 342, 1892.

A rather scarce species in the winter, and not found in April. It is the largest species found, some specimens attaining a length of nearly 4 cm. In shape it is like *S. magna*, but slightly narrower, and while the posterior fins of *magna* are nearly semicircular, those of *tricuspidata* are broader near their posterior ends. The ovaries are long and slender, and may extend to the front end of the anterior fins; the longest observed were 1·5 cm. in length. Hooks 4—8, anterior teeth 3, posterior 1; but in several specimens, making up a large proportion of the whole number, there were 2 anterior and either 2 or 4 posterior teeth. The posterior teeth are attached to a cuticular bar which bears a number of rounded projections. Such projections are commonly found in other Sagittas, corresponding in number and position with the teeth, and are in some cases sharply pointed, and in this species, although the teeth are reduced to very few, the projections remain, but are rounded off. A similar condition exists in *S. magna*. The corona ciliata is short, on the head and neck.

This species has very few distinguishing characters; it is separated from *magna* chiefly by the absence of the very long moveable teeth in the anterior row, and from *hexaptera* by the small number of posterior teeth, but when the latter are as numerous as four, it becomes difficult to separate them with certainty. The teeth seem to have been reduced, and are at present very variable, but the typical number for the species is three anterior and one posterior.

Recorded from the Pacific, the Atlantic, the Mediterranean and the Indian Ocean.

4. *Sagitta serratodentata* Krohn.

Strodtmann, *Archiv Naturgeschichte*, Jahrg. 58, Bd. I. p. 347, 1892.

A moderately common species both in winter and spring. Some specimens had as many as 18—20 posterior teeth and 10 anterior, instead of 12 and 8 respectively as are normal in European waters.

Hitherto recorded from the Mediterranean, the Atlantic, and Japan.

5. *Sagitta hispida* Conant.

F. S. Conant, *Johns Hopkins Univ. Circ.* Vol. XIV. p. 77, 1896, and XV. p. 82, 1896.

This species was rather scarce in the material collected in the winter, but in that obtained in April it was very abundant. It is characterized by the thickness and solidity of the body-wall, the thickened ectoderm behind the head, the intestinal diverticula in the neck, and the great number of tactile prominences. The teeth in the specimens from the Maldives were sometimes more numerous than in Conant's description; Aida mentions the same fact in specimens from Japan. Corona ciliata long and waved; in one specimen I found it divided into two parts, an anterior and a posterior.

Described previously from the Atlantic coast of America, the West Indies, and Japan.

6. *Sagitta regularis* Aida. (Plate XIII, fig. 7.)

T. Aida, *Annot. Zool. Jap.* Vol. I. p. 17, 1897.

Occurred in small numbers in the winter. This species is very small, rarely more than 5 mm. The tail is one-third of the length of the whole. The fins are narrow, semi-elliptical, and have rays extending to the base. The tail fin and the posterior lateral fin both touch the vesiculae seminales, which are small. The ovaries extend to the anterior paired fins. The epidermis is thickened through the whole length of the animal, but very much so behind the head, so that there is no neck. The number of tactile prominences is very large, and they are arranged with great regularity. The intestine has diverticula at its beginning. Hooks 7, anterior teeth about 4, posterior about 6. Corona ciliata rather long, waved, with a constriction in the middle. It is shorter than that of *S. hispida*, and lies entirely on the trunk.

Hitherto recorded only from Japan.

7. *Sagitta flaccida* Conant.

F. S. Conant, *Johns Hopkins Univ. Circ.* Vol. XV. p. 82, 1896.

Only one specimen of this species was found, and it occurred in the collection made in April. The species resembles *S. enflata* very closely, but differs in the form of the teeth. There are seven or eight anterior and 10—12 posterior teeth, and they are longer and more slender than in *enflata*, and the inner ones, especially of the anterior row, are much longer than the outer.

Described only from the Bahamas.

8. *Sagitta robusta* nov. sp. (Plate XIII, figs. 1 *A*, 1 *B*.)

This species is abundant in the material collected in winter, but scarce in that obtained in April. It is characterized by the great thickness of the body-wall, especially of the longitudinal muscles.

The length of mature specimens is 1·6 cm. of which the tail segment makes up one-fourth. The head is broad; the anterior fin is as long as the posterior, but narrower, its front end is opposite the posterior end of the abdominal ganglion. Both posterior lateral fins and tail fin reach the vesiculae seminales. The fin-rays do not extend quite to the base of the fins. The epidermis is thickened behind the head. The corona ciliata is long and narrow, beginning in front of the eyes just behind the brain, and is in shape an elongated ellipse, without the cross-shape found in *S. bipunctata*. There is a pair of diverticula at the beginning of the intestine, like those in *S. minima*. The ovaries are extremely long, and extend in fully mature specimens to the anterior transverse septum, so that the coelom of the trunk becomes almost obliterated. The vesiculae seminales project somewhat. Hooks usually 8, with very small points; anterior teeth 9, posterior 10—14.

I have found this species also among Chaetognatha collected at Singapore.

9. *Sagitta ferox* nov. sp. (Plate XIII, fig. 2.)

A species closely resembling *S. robusta*, but distinguished by several constant differences. It is less abundant than the latter, and did not occur in the April collection.

The body-wall is very thick, with powerful muscles. The tail segment is rather more than one-fourth of the whole length, which is about 1·2 cm. The fins are almost as in *S. robusta*, but the posterior does not quite reach the vesiculae seminales, which project only slightly. The epidermis is slightly thickened behind the head. There are intestinal diverticula as in *S. robusta*, and the ovaries are extremely long, as in the latter, but they do not quite reach the front end of the trunk-cavity. Hooks 5, or sometimes 6, very thick and powerful, with rather blunt points; anterior teeth about 6, posterior 10, with blunt points and rather broad.

As will be seen from the above description, this species differs very slightly from the last, and should possibly be classed with it. In some points, however, there is a constant difference. There are never more than 6 hooks in *S. ferox*, and there are usually only 5, while in *S. robusta* there are 7 or 8, and the hooks of *ferox* are thicker and have larger point-pieces than in the other species. The teeth of *ferox* are also thicker and rather fewer in number. In no specimen was the corona ciliata found complete in *ferox*, but from the traces that remain it seems to resemble that of *robusta*. When preserved in formalin *ferox* always has a faint pink colour, while *robusta* is white or yellow, and is rather less opaque.

10. *Sagitta gardineri* nov. sp. (Plate XIII, figs. 5 *A*, 5 *B*.)

A moderately abundant species in the winter collection.

Length 2·5 cm. Body thick and transparent, resembling that of *S. magna*. Head broad and short. Tail segment one-fifth of length of whole. Fins like those of *S. magna*; the rays do not quite reach the base. Ovaries when mature rather long, extending to the posterior end of the anterior fin; they are thicker and shorter than in *S. magna*, but proportionately longer than in *S. enflata*. Vesiculae seminales spherical, placed at the front end of the tail fin. Corona ciliata entirely on the head; pear-shaped, with the narrow end lying just behind the brain, in front of the eyes. Hooks 8—10; anterior teeth small, about 10; posterior larger, pointed, varying from 12 to 16.

This species is intermediate between *S. hexaptera* and *enflata* in size and in the form of the ovaries, and it differs from both in the larger number of teeth. Although it is closely connected with these two species, yet the differences are so constant that there can be no doubt of its distinctness.

11. *Sagitta pulchra* nov. sp. (Plate XIII, figs. 4 *A*, 4 *B*.)

A moderate number of this species occurred both in the winter and spring collections.

Its length is 2 cm., of which the tail segment makes up one-sixth. The body is slender, with a thin body-wall, so that this species is intermediate between the large, inflated, and the smaller muscular types of *Sagitta*. The head is small, and the epidermis somewhat thickened behind the head. The anterior fin begins at the abdominal ganglion, and is rather long, so as to be separated by a short distance only from the posterior. The front half of the anterior fin is very narrow and has no rays; the posterior part is rather wide. The posterior fin is like the anterior in shape, but the part without rays is shorter and that with rays wider. The rays do not extend quite to the base.

The ovaries are rather long and slender, the vesiculae seminales small. The whole of the tail coelom is filled with developing spermatozoa. The corona ciliata is moderately long; it begins in front of the eyes and rather more than two-thirds of its length is on the trunk; it is narrow and its sides parallel. Hooks 6, rather curved and slender; anterior teeth about 6, posterior about 10.

This species is of interest in combining the characters of two groups of *Sagitta*, viz. the larger species, which have a thin body-wall, short corona and in which only part of the tail coelom is filled with developing sperm; and secondly the smaller species with thick body-wall, long corona and tail full of sperm-morulae.

12. *Sagitta polyodon* nov. sp. (Plate XIII, figs. 3 *A*, 3 *B*.)

Found in fair abundance in both winter and spring.

This species is superficially very like *S. serratodentata*. Its length is about 1·2 cm., the tail one-fourth of the whole. The shape is that of *serratodentata*. The fin-rays spring from the base of the fins. The ovaries are long, extending to the anterior fins. The vesiculae seminales are rather large and projecting. The hooks are 6—7, with no serrations; anterior teeth 9—10, posterior 26; they are slender, truncated at the end, with small processes. The corona ciliata is long and rather wider just behind the neck than elsewhere.

This species is distinguished at once by the great number of its teeth, which are more numerous than in any other known species. It resembles Béraneck's description of *S. bedoti*[1] in many ways, but differs in having a corona, in the length of the ovaries, and the greater number of teeth. Since Béraneck described *S. bedoti* from preserved specimens, in which the corona is often destroyed in one species while well-preserved in

[1] E. Béraneck, "Chétognathes de la baie d'Amboine," *Rev. Zool. Suisse*, Vol. III. p. 147, 1895.

others, it is possible that in this point he was mistaken; but, since the absence of the corona is a definite part of the diagnosis of *S. bedoti*, the present species cannot be identified with it.

13. *Sagitta septata* nov. sp. (Plate XIII, fig. 6.)

Moderately common both in winter and in spring.

It is a small species, generally less than 1 cm. The tail segment is a third of the whole. The fins are narrow, especially the anterior. There is no epidermal thickening behind the head, but the body-wall as a whole is thicker in the posterior part of the trunk than anteriorly. There are intestinal diverticula like those of *S. minima*. The vesiculae seminales are very small. The ovaries are long, extending to the ventral ganglion, and the ova have a very curious appearance in fully adult specimens. They become pressed together so that they are flattened anteriorly and posteriorly, and the flattened faces have the appearance of septa dividing the trunk into a series of compartments on each side.

In no specimen was the corona well preserved, but it could be seen from the fragments remaining that it lies both on the head and on, at least, the beginning of the trunk. Hooks 6—8, anterior teeth 6—8, posterior 13—16, rather narrow and pointed.

The most prominent characteristic of this species is the peculiar structure of the ovaries (Plate XIII, fig. 6 and Text-fig. 39). The eggs appear to have their shells well developed, and the "septa" are due to the shells of two eggs being pressed together. In section it appears that when the eggs assume this condition they are already in the oviduct, which is greatly dilated, for when followed back the cavity containing the eggs is found to open at the usual pore of the oviduct; this view is supported by the fact that the large eggs lie at the outer sides of the ovaries, next to the body-wall, and that no other oviduct is visible, and further that the usual germinal epithelium appears between the large eggs and the alimentary canal. The animals appear to be undergoing histological degeneration, for the alimentary canal has lost its lining cells for the most part, and through the greater part of the body is much reduced in size. A condition comparable with this is frequently found in *S. minima*. A very similar arrangement of the eggs occurs in a fully adult *Krohnia pacifica* in Mr Gardiner's collection, so that it is not quite peculiar to *Sagitta septata*.

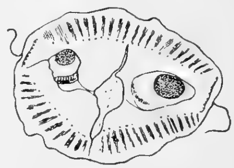


FIG. 39. Transverse section of *Sagitta septata* in the region of the ovaries. The ripe eggs are represented by oval bodies (dotted) lying in spaces which are probably the enlarged oviducts. The germinal epithelium is seen lying at the inner side of each of these spaces, connected with the alimentary canal by a mesentery.

II. Genus **Spadella** Langerhans.

14. *Spadella draco* Krohn.

Strodtmann, *Archiv für Naturgeschichte*, Jahrg. 58, Bd. I. 1892, p. 356.

This species was plentiful in the winter but did not occur in the summer. It agrees in every way with the published descriptions. I found a number of specimens in which the remarkable parenchymatous tissue was entirely absent, and was at first inclined to regard them as a new species, but afterwards found some in which part of the parenchyma remained, showing that it had become detached during preservation or in transit. Some of the best-preserved specimens have a bright yellow colour in formalin, while others are colourless.

This species has been previously recorded from the Mediterranean, both sides of the Atlantic, Java and Japan.

III. Genus **Krohnia** Langerhans.

15. *Krohnia pacifica* Aida.

T. Aida, *Annot. Zool. Jap.* Vol. I. p. 19, 1897.

Only two specimens of this species were obtained; one in the winter and one in the April collection. It is only 7 mm. in length, but the ovaries show it to be mature. In the specimen taken in April the latter had large eggs (text-fig. 40), pressed together as described above in *Sagitta septata*. The tail is a third of the whole length. Both tail-fin and lateral fin meet the vesiculae seminales, which are ovoid. The tactile prominences have very long bristles. Hooks 9, pointed, with very small end-pieces. Teeth 13, very long; the row of one side meets that of the other side. The eyes are very near together.

There can be no doubt that this is the *Krohnia pacifica* described by Aida; the teeth are slightly more numerous, and the green colour which he mentions is not visible in preserved specimens. He describes the mouth as a transverse slit, but this appears to me to be due to a sort of lip overhanging the mouth anteriorly; the true mouth is as usual longitudinal.

Previously described only from Japan.

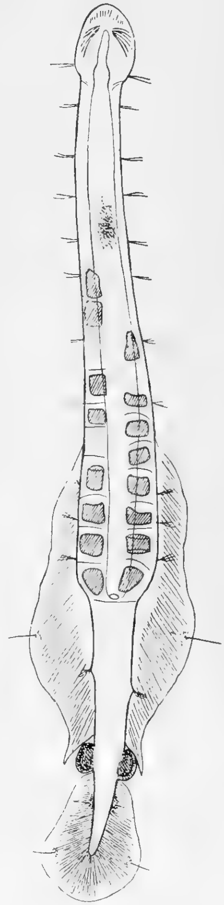


Fig. 40. *Krohnia pacifica.* A specimen taken in April, which has a number of ripe eggs on each side arranged with their shells in contact, giving the appearance of transverse septa. These eggs, as in *Sagitta septata*, are probably in the oviduct.

[Note. On some Chaetognatha from Singapore.

I include here the description of a new species of *Sagitta* obtained by the late F. P. Bedford at Singapore. It was accompanied by a few specimens of *S. enflata* and *S. robusta*. There was only one specimen, which is not fully mature; the condition of the ovaries however shows that it is not very young.

Sagitta bedfordii nov. sp.

Very small; an individual apparently nearing maturity, measures only 3·5 mm. Tail one-third of whole. Fins narrow, with rays springing from the base and placed unusually far apart. Corona ciliata imperfectly preserved, but lying both on head and trunk, and apparently short and pear-shaped. Body-wall thick, with epidermal thickening behind the head. Hooks 10, anterior teeth 2, posterior 2, all, especially the anterior ones, long, narrow and pointed, like those of *S. magna*.

The number and shape of the teeth is sufficient to distinguish this species at once from all the other small species.]

II. VARIATION AND DISTRIBUTION OF THE GROUP.

The examination of the specific characters and the geographical distribution of the Chaetognatha leads to several points of interest. In the first place, it is found that most species are world-wide in their distribution, and are obtained in almost all the warmer seas; only a few species have been observed in very limited areas, and since *Sagitta flaccida* and *S. regularis*, which had hitherto been recorded only from the West Indies and Japan respectively, have now been found also in the Indian Ocean, it seems probable that some, if not all, the remaining local species will be known eventually to have a wider range.

Individuals of the same species have as a rule the same characters in whatever part of the world they occur, but there are a number of exceptions to this rule; for example, the *S. serratodentata* from the Maldive Group had usually a greater number of teeth than those of the Mediterranean, and Aida records the same fact in respect of several species from Japan. But the characters, which are used to distinguish the species of the Chaetognatha, are very variable in themselves, so that examples from the same locality differ considerably from one another, and it is sometimes a matter of difficulty to determine these species with certainty; for example, the individuals described above as *S. tricuspidata*, which have an arrangement of teeth different from that of the type, might be referred to *S. hexaptera*, in which the teeth were fewer than the normal, and so in other cases.

In fact, it almost seems that the species in the Chaetognatha are not very definitely fixed, but graduate into one another to some extent, although they can be separated into several groups, which are very distinct; for example, *Sagitta hexaptera, S. tricuspidata, S. magna* and *S. lyra* form a well-marked group of large species, which can be separated at a glance from the type represented by *S. hispida* and *S. regularis*.

The question of species in the Chaetognatha is an interesting one from the point of view of evolution, for in most seas a great number of individuals of various species are found together but all having, as far as we know, similar habits and living mingled together. Geographical isolation or differences of habitat apparently do not exist, and probably most species breed through the greater part of the year, so that there can be no separation by differences of breeding season.

In many instances two species, living together, are so closely allied that it is very difficult to distinguish them, in which case it seems hardly possible that the separation can have been due to natural selection. Possibly the great variety of Chaetognatha found together, all living under the same conditions and with similar habits, may be best explained by supposing the species to be very ancient, and that the different species have arisen in different parts of the world and have become spread by currents or other means of dispersal, until they are found in all the seas where the temperature is sufficiently high. The characters by which the species are distinguished, such as hooks, teeth, proportions of the body and fins, etc., are very variable within certain limits, as has been shown above. If, then, a part of the ocean became partly or wholly separated from the rest by geological changes, in the course of time this variability would undoubtedly cause the fauna, so cut off, to become different from the remainder, and, when they again became intermingled, they would be classed as different species. The Chaetognatha offer this problem in a peculiarly prominent manner, for there are few other groups of animals of which as many as ten or even more species of one genus are found together in exactly the same environment.

The question of the nature and extent of the variation in each species is also of interest, for there are indications that the characters commonly relied upon as distinctive may sometimes be very untrustworthy. It has been pointed out how in some species local races exist with slightly different characters, as in the case of *Sagitta serratodentata* and *S. hispida*, but some species are markedly variable in the same locality. For example, besides the variation in number of the teeth in *S. tricuspidata* mentioned above, it was found that while the typical number of hooks is 8, one specimen had only 4, another 5, and others 7 on each side.

I observed a more remarkable case of this at Naples, which possibly indicates that the hooks are lost to some extent at maturity. The species in question was *Sagitta lyra*, which Grassi in his monograph (*Fauna et Flora des Golfes von Neapel*; I Chetognati) describes as being very rarely found sexually mature, while immature specimens are comparatively common. At Naples during the early spring of 1901 immature specimens were frequent in the "Auftrieb" from no great depth, and many were of considerable size, *e.g.* as much as 28 mm. with only most minute rudiments of ovaries and testes, and no trace of genital ducts. In April, however, a number of specimens were caught in the neighbourhood of Capri at depths of 400 and 1000 metres, and these were mostly sexually mature. Those from the greater depth were remarkable in that a large proportion had only three hooks on each side instead of seven, although others were nearly or quite mature with the normal seven hooks. These examples had otherwise all the characters of *S. lyra*, except that the head was perhaps shorter and broader than usual.

These facts seem to indicate that either there are two closely allied species or varieties included under the name *S. lyra*, or that when maturity is reached, four out of the seven hooks on each side are, in some cases at least, lost. It also seems to suggest that when mature this species migrates to a much greater depth, for no fully adult specimens were taken at the surface. Grassi did most of his work at Messina, where the currents bring up to the surface animals which normally live in deep water, and this probably accounts for his finding occasional adult specimens.

With regard to variation in different localities, it appears that most of the widely distributed species differ to some extent in widely separated areas, as is mentioned above in respect to the teeth. It is interesting to note that in all cases in the present collection, where the teeth differed in number from those of the European variety, they were more numerous, so that the average number of teeth in specimens from the Indian Ocean is considerably greater than from Europe. Another character which distinguishes the Eastern Sagittas from the European as a whole is the frequency of intestinal diverticula in the neck; these are found only in one European species, but five, or more than one-third of the whole, of those from the Maldives possess them. The same fact has been noticed by Conant with regard to the American Sagittas, a large proportion of which have the diverticula.

The fact that so many species should be common to the Eastern coast of America and to the Indian Ocean, although not found between, is remarkable, but is probably explained by the absence of complete lists from the Southern Atlantic. When the latter area has been more carefully examined, it will probably be seen that this apparent discontinuous distribution is not real. It is rather surprising, however, that a species like *S. hispida*, recorded from the Bahamas and the coast of the United States, and therefore in the path of the Gulf Stream, should not yet have been found in the North-eastern Atlantic.

In conclusion I wish to thank Mr C. Forster Cooper, B.A., for drawing the figures in the accompanying plate.

EXPLANATION OF PLATE XIII.

The corona ciliata has been represented as a dotted line, except in Fig. 7.

Fig. 1 *A*. *Sagitta robusta* nov. sp., outline. 1 *B*. The same, head and neck.

Fig. 2. *Sagitta ferox* nov. sp., head and neck.

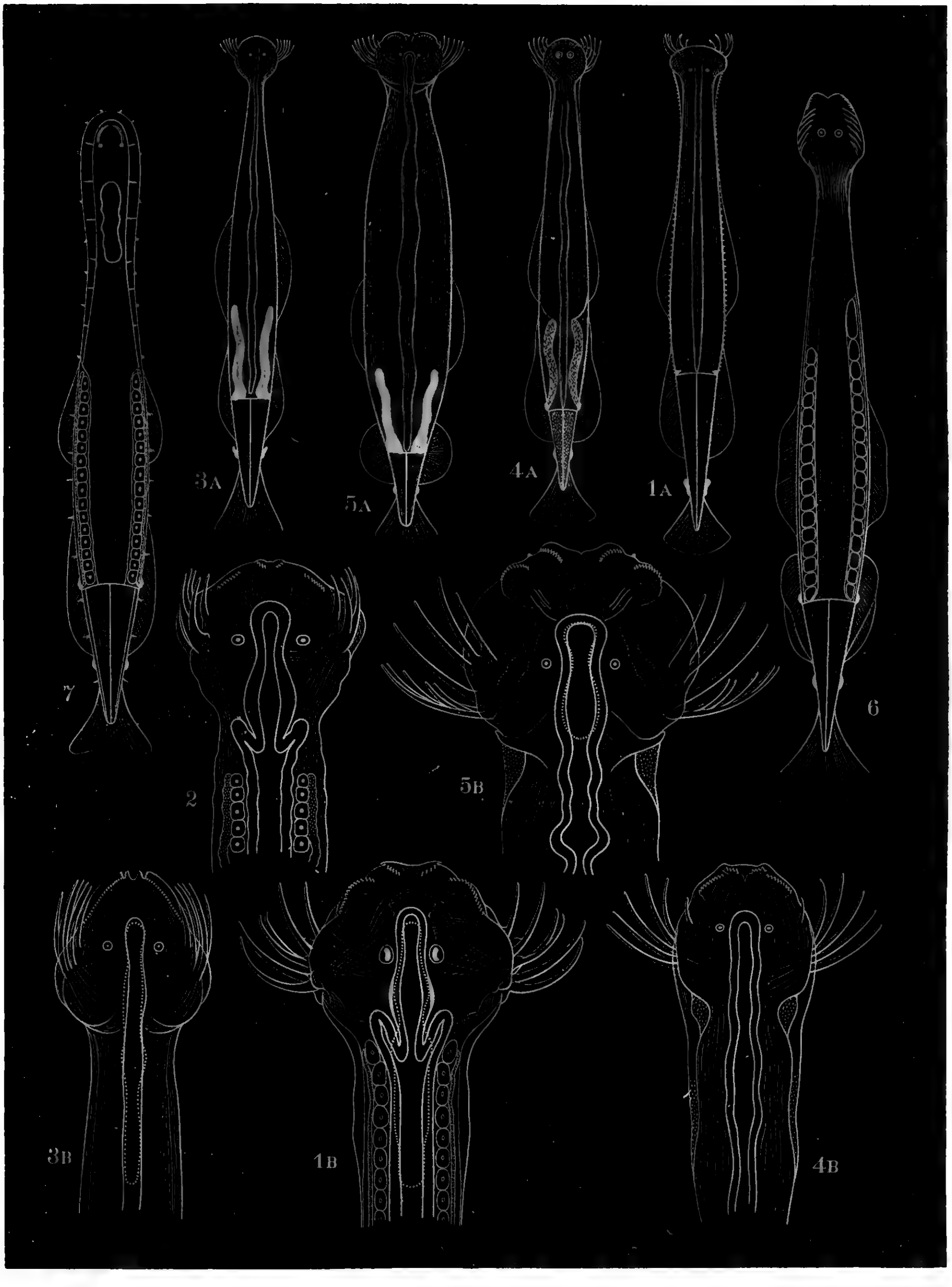
Fig. 3 *A*. *Sagitta polyodon* nov. sp., outline. 3 *B*. The same, head and neck.

Fig. 4 *A*. *Sagitta pulchra* nov. sp., outline. 4 *B*. The same, head and neck.

Fig. 5 *A*. *Sagitta gardineri* nov. sp., outline. 5 *B*. The same, head and neck.

Fig. 6. *Sagitta septata* nov. sp., showing peculiar structure of the ovaries.

Fig. 7. *Sagitta regularis* Aida, showing thickened epidermis, corona, and ovaries.


3A
5A
4A
1A
7
6
2
5B
3B
1B
4B

DRAGON-FLIES.

By F. F. Laidlaw, B.A., *Demonstrator in Zoology of the Owens College, Manchester.*

Only six species are represented in the collection. One of these appears to be new. The rest are all well-known Ceylon and Indian species, or have a still wider distribution.

Sub-Fam. **Libellulinae.**

1. Zyxomma petiolatum Ramb.

Zyxomma petiolatum Kirby, *Cat. Odonata,* p. 35.

This widely distributed Oriental species is represented in the collection by three specimens (2 ♂, 1 ♀) from Hulule.

2. Pantala flavescens (Fabr.).

Pantala flavescens Kirby, *Cat. Odonata,* p. 1.

Two males, one from Hulule, and one from Mahlos. This is the most widely distributed and one of the commonest of existing dragon-flies.

3. Rhyothemis variegata (Joh.).

Rhyothemis variegata Kirby, *Cat. Odonata,* p. 5.

This is a common Ceylon and Indian species, and belongs to a genus whose members frequent especially the neighbourhood of the sea. *R. variegata* is of particular interest on account of the remarkable differences in coloration of the wings of males and females, the pattern being totally different in the two sexes.

Mr Gardiner obtained 4 ♂ and 1 ♀ from Minikoi and a single pair from Hulule. This small series however is of considerable interest, the pair from Hulule differing strikingly from the specimens from Minikoi. These latter agree closely in size and colour with specimens in the British Museum from Ceylon; the pair from Hulule are considerably smaller, and the male in particular shows differences in the wing markings.

The following measurements serve to show the differences in size between specimens from the two localities.

Average	length	of fore-wing of	males	from	Minikoi	38 mm.
„	„	„	male	„	Hulule	34 mm.
„	„	„	female	„	Minikoi	37·5 mm.
„	„	„	„	„	Hulule	30 mm.
„	„	abdomen of	female	from	Minikoi	28 mm.
„	„	„	„	„	Hulule	19 mm.

In the male from Hulule there is a dark spot covering the triangle and supra-triangular space of the fore-wing, in the Minikoi specimens this dark mark is confined to the triangle.

On the hind-wings of the former specimen there is on either side an irregular transverse dark band running from the nodus to the hind margin, in the latter this is represented only by scattered patches of colour.

The yellow on the wing of the female specimen from Minikoi is more intense and extends further than on the wing of that from Hulule.

The neuration of the two forms agrees closely.

4. Trithemis (?) trivialis (Ramb.).

Trithemis trivialis Kirby, *Cat. Odonata*, p. 18.

8 ♂, 7 ♀ labelled Minikoi.
1 ♂, 1 ♀ labelled Maldives.

The length of the fore-wing in the largest male is 28·5 mm., in the smallest 26 mm. The abdomen measures 22 mm. and 19·5 mm. respectively. The average length of the male fore-wing is about 27·5 and of the abdomen about 21 mm. The females vary less in size. In them the average length of the fore-wing is 27 mm. and of the abdomen 21·5 mm., and the range of variation from the average does not exceed a millimetre.

These specimens are considerably larger than specimens in the British Museum from Ceylon, an average male specimen from the latter locality measured about 22 mm. along the fore-wing, whilst a female of the same species from Christmas Island had the fore-wing about 21·5 mm. in length.

In Mr Gardiner's series of this species the average number of costal antenodal nervules is 8, the last not being continuous. In two males and three females there is a supernumerary antenodal on the fore-wing of one side or the other, in most cases interpolated between the 6th and 7th antenodal and not continuous. The largest specimen, a male, has 8 continuous antenodal and a terminal non-continuous antenodal on both fore-wings. The smallest specimen has 8 antenodals in all on both fore-wings. The usual number of postnodals on the fore-wings is 6. In the largest male and in two other large specimens there are 7 on both sides, and in four other cases there are 6 on one side and 7 on the other, the remainder including the smallest specimen have 6 on both sides. Thus the largest specimen has the maximum number of costals on either fore-wing, viz. 16, whilst the smallest specimen, also a male, has the minimum number, 14.

The characters of the triangles, supra- and sub-triangular spaces are constant. The antenodal costals of the hind-wing number 6 6, save in one case, where there are 7 on one side.

All the females have a small area at the base of the hind-wings tinged with bright orange; this mark is almost entirely absent, only a trace of it occurring in the younger specimens. The yellow and black markings on the body become obscured in old males by a dark bluish waxy bloom.

5. ORTHETRUM SABINA (Dru.).

Orthetrum sabina Kirby, *Cat. Odonata,* p. 35.

Five specimens, 4 ♂, 1 ♀ from Minikoi.

These specimens resemble closely examples from Ceylon in the British Museum.

Sub-Fam. **Agrioninae.**

6. ENALLAGMA (?) MALDIVENSIS, sp. n.

Females with a spine at the apex of the eighth abdominal segment on its ventral side. The tenth abdominal segment of the male has no tubercle on its dorsal side.

The lower sector of the triangle of both fore- and hind-wings originates at the level of the basal post-costal cell. The pterostigma is lozenge-shaped, of a dull grey colour, lying over about half a cell; it is slightly smaller in the hind wings than in the front pair.

Lower lip divided for about a fourth part of its length from its apex. Post-ocular markings linear, hinder margin of prothorax not turned up. Abdomen moderately slender, legs small, with 5 spines on the external lateral side of the 3rd pair of tibias.

♂. Coloration for the most part dull bronze-black, variegated as follows:—

Head. Lower lip yellowish-white, labrum dull blue. The first joint of either antennae, and a line connecting them running across the pons, yellowish-white. A pale blue post-ocular line extending right across the occiput.

Prothorax. Anterior margin pale blue, there is also a pale blue spot on either side immediately over the first pair of coxae.

Thorax. Dorsal surface bronze-black with a pale blue humeral stripe on either side. Sides of thorax blue, fading into yellowish-white on the ventral surface. Legs yellowish-white with black spines and a black line running along the posterior surface of each femur.

Abdomen. Segments 1—3 brown-black above, blue at the sides, passing into yellowish-white below. Segments 4—7 similar but the blue on the sides is obscure, these segments being very slender. Segments 8, 9 blue. Segment 8 has a fine mid-dorsal bronze line which widens gradually towards the posterior end of the segment. The posterior half of the upper surface of segment 9 and the whole dorsal surface of 10 bronze. Rest of 10 blue. Appendages black.

Appendages. Upper pair conical, divaricated, larger than the lower pair, each of them with a conical tooth on its ventral surface, directed posteriorly. Lower pair very minute.

♀. Coloration of the head and thorax similar to that of the male, but the blue colour is replaced by a yellowish-brown. The colouring of the first seven segments of the abdomen is as in the male, but the blue at the sides of segments 4—7 is more evident, these segments not being so attenuated as they are in the male. Segments 9 and 10 blue; 9 with a mid-dorsal bronze spot covering its anterior half, 10 with a fine mid-dorsal bronze triangle, having its apex directed posteriorly, which occupies about the first third of the segment. Appendages black.

Length of the fore-wing about 18 mm.

Length of the abdomen ♀ about 22·5 mm.

" " " ♂ " 24 mm.

The first two joints of the antennae are short and stouter than the third, which is however as long as the first two together. The upper side of the quadrilateral of the fore-wing is about one-third as long as the lower side, on the hinder wing it is about two-thirds as long.

Five specimens (2 ♂, 3 ♀) from Mahlos and Hulule. This species differs considerably from the typical species of *Enallagma* in that the lower sector of the triangle rises at the level of the basal post-costal cell, and in the colour pattern of the abdomen. It appears to be an isolated form.