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# THE FRESH-WATER EELS OF AUSTRALIA.

## WITH SOME REMARKS ON THE SHORT-FINNED SPECIES OF *Anguilla.*

By

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(Figures 1-14.)

## I. INTRODUCTION.

In the course of my work in describing the fresh-water eels of the genus *Anguilla* throughout the world, I have now come to those of Australia. Prior to this were the descriptions of the eels of Europe, America and Japan (1913, 1915), of the eels in the tropical part of the Southern Pacific (1927) and of the eels of New Zealand.[1, 2, 3, 4] In all of these works I have emphasized the value, or more properly the necessity, of employing numerical characters such as the number of vertebræ and of fin-rays for the classification of the different species of the genus *Anguilla,* which are often very closely related. It is only since the introduction of modern variational-statistic methods that complete certainty has been attained in the classification of the fresh-water eels; and the use of such numerical characters as the number of vertebræ has further rendered it possible to distinguish between the species in their very youngest stages, even when, as tiny, transparent larvæ, they are found floating out in the ocean, far from land.

Most of the more important museums throughout the world have, with the greatest liberality, accorded the Carlsberg Laboratory facilities for investigating their material of the genus *Anguilla,* and taking X-ray photographs of the same. We were thus enabled to include in our investigations all existing types, as well as many other specimens of fresh-water eels mentioned in earlier and recent

[1] Johs. Schmidt.—"First and Second Report on Eel Investigations" (Rapports et Procès-Verbaux du Conseil International pour l'Exploration de la Mer, Vols. XVIII and XXIII, Copenhagen, 1913 and 1915).

[2] *Id.*—"Les Anguilles de Tahiti" (La Nature, Paris, 15 July, 1927, reprint paged 1-8).

[3] *Id.*—"The Fresh-Water Eels of New Zealand" (Transactions of the New Zealand Institute, Wellington, N.Z., Vol. lviii, No. 4 (in the press).

[4] *Id.*—"The Breeding Places of the Eel" (Smithsonian Report for 1924 (1925), p. 279. This includes a survey of the results of my cruises in the Atlantic in order to ascertain the breeding places of the eel and the migrations of the eel-larvæ.

literature, a point which has proved of importance, *inter alia*, for the nomenclature.

Recently (1925) I described the distribution of the eels in the Indo-Pacific region, in a work entitled: "On the Distribution of the Fresh-water Eels (*Anguilla*) throughout the World, II. Indo-Pacific Region."[5] The most important literature on the subject is there noted, and it will here suffice to refer to that work. My task at that time was mainly to describe the distribution of the fresh-water eels in general; the present work, however, is designed to give a closer analytical survey of the *species* and their distribution.

It is my very pleasant duty here to express my appreciation of the readiness with which the fishery authorities of Australia, and the Australian Museum at Sydney, endeavoured to facilitate my task. The last-named institution, for instance, forwarded its entire collection of *Anguilla* to the Carlsberg Laboratory for investigation. The fishery authorities in New South Wales (State Fisheries, Mr. A. W. Wood, Officer-in-Charge), in Victoria (Mr. F. Lewis, Chief Inspector) and in Western Australia (Mr. F. Aldrich, Chief Inspector) have procured for me more or less extensive samples of Australian fresh-water eels, in the forwarding of which valuable assistance was kindly rendered by the Royal Danish Consuls at Sydney (Mr. C. W. Koefoed), Melbourne (Mr. P. Holdensen) and Perth (Mr. P. H. Fraenkel). Collections of fresh-water eels were also made at Lord Howe Island by Mr. R. E. Baxter.

I am indebted to a number of Australian zoologists, who have kindly helped me with information or material, thus to Dr. C. Anderson, the Australian Museum, Sydney, the late Allan R. McCulloch, the Australian Museum, Sydney, Mr. J. A. Kershaw, the National Museum, Melbourne, Mr. Heber A. Longman, Queensland Museum, Brisbane, Mr. T. C. Roughley, the Technological Museum, Sydney, the late Edgar R. Waite, the South Australian Museum, Adelaide, and Mr. Gilbert P. Whitley, the Australian Museum, Sydney.

Finally, I wish to express my hearty thanks to those who have collaborated with me in the work of investigation at the Carlsberg Laboratory, especially Mr. Vilh. Ege, M.Sc., and Miss E. Hansen.

## II. CLASSIFICATION.

Examination of the collections received from Australia, and of the Australian material I have found in the various museums, shows

[5] Schmidt.—Mem. Acad. Roy. Sci. et Lettres de Danemark (8), X, 4, Copenhagen, 1925, pp. 329-382, pls. i-ii and 10 text-figs.

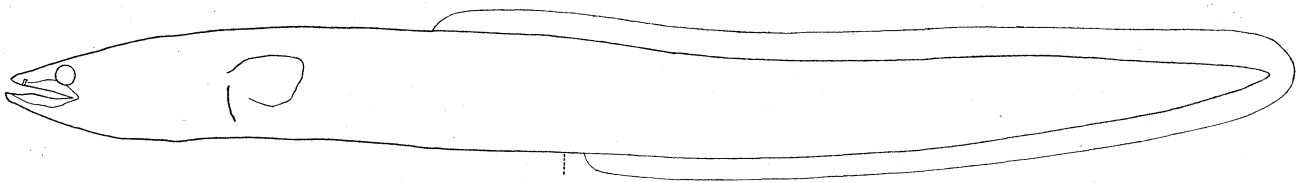

Fig. 1.—*Anguilla reinhardti* Steind., the long-finned or spotted eel. Semi-schematic drawing from a specimen 47 cm. in length, by Mr. Vilh. Ege, M.Sc.

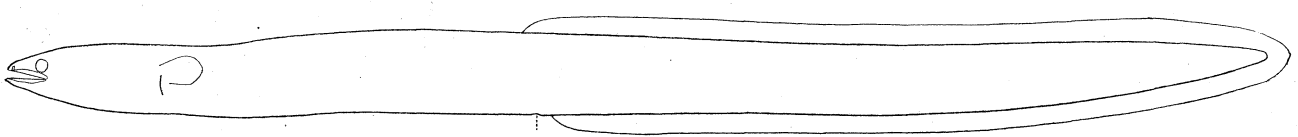

Fig. 2.—*Anguilla australis* Rich. f. *occidentalis* n.f., the short-finned or unspotted eel. Semi-schematic drawing from a specimen 42 cm. in length, by Mr. Vilh. Ege, M.Sc.

that there are *four* species of *Anguilla* to be met with on the continent of Australia, and that they should be named as follows:

*Anguilla australis* Richardson
*Anguilla reinhardti* Steindachner
*Anguilla obscura* Günther
*Anguilla bicolor* McClelland.

The last-named species is an Indian form, occurring in the north-western tropical part of Australia; the other three are all Pacific forms. Of these, *Anguilla obscura* is represented only by a single specimen from the tropical part of Queensland (Burdekin River, north of Bowen); for the rest, its area of distribution comprises the tropical part of the Pacific south of the Equator, where it has been taken as far east as Tahiti.

There remain then, *Anguilla australis* Rich. and *Anguilla reinhardti* Steind. A fresh-water eel caught in any part of Australia south of the tropical belt will in nearly every case be found to belong to one or other of these two species, which are extremely common. Fortunately, there are good distinguishing characters, rendering it a matter of no great difficulty to determine which is which. I suggest that the most conspicuous of these distinguishing characters should be embodied in the English names, so that we have the *long-finned* or *spotted* eel (*Anguilla reinhardti*) and the *short-finned* or *unspotted* eel (*Anguilla australis*). The names long-finned and short-finned have already been employed by other writers.

Generally speaking, the two species are recognizable one from the other at a first glance by their colouring; save in the youngest specimens, *Anguilla reinhardti* is speckled all over with roundish spots, which are *invariably* lacking in *Anguilla australis*. It has been noted, however, that *Anguilla reinhardti*, when approaching maturity, or, to use the term employed in Europe, becoming a "silver eel," and preparing for its migration to the sea, loses its spots more or less completely. This was the case, for instance, with a large sample of eels about a metre long, caught at Prospect Reservoir spillway near Sydney on the 25th June, 1925, and kindly placed at my disposal by the courtesy of the State Fisheries and the Australian Museum at Sydney. This sample consisted almost exclusively of large, "silvery" female specimens of *Anguilla reinhardti*, and the spots had almost entirely disappeared, save for a few cases where some spots remained on the head.

The spotted colouring of *Anguilla reinhardti*, though ordinarily by far the most conspicuous mark of distinction from *Anguilla australis*, which is never spotted, may thus be lacking, firstly in the youngest specimens, and again in the oldest ones. It will therefore be necessary to note the other distinguishing features, or at any rate, the most important ones.

Among these we have first and foremost $(a-d)$, or the distance between the vent and the front of the dorsal fin. The difference between the two species will be at once apparent on comparing Fig. 1 (*Anguilla reinhardti*) and Fig. 2 (*Anguilla australis*). In the former, the dorsal fin extends a long way forward beyond the vent, whereas in *Anguilla australis* the corresponding distance is but short. This character $(a-d)$ is of great value in the classification of the genus *Anguilla*. Our method is to determine it in every single specimen, and express it as a percentage of the total length: $\frac{a-d}{t} \times 100$ or $(a-d)$ percentage.

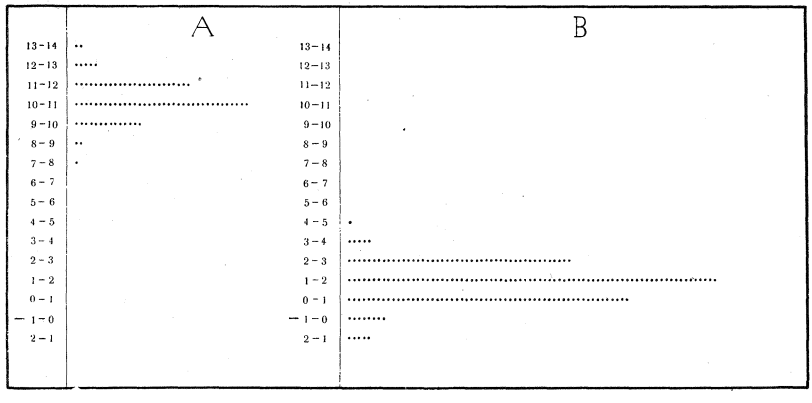


Fig. 3.—$\frac{a-d}{t} \times 100$ in 84 specimens of the long-finned eel (*Anguilla reinhardti* Steind.) from Prospect Reservoir, near Sydney (*A*) and 198 specimens of the short-finned eel (*Anguilla australis* Rich. f. *occidentalis* n.f.) from Victoria (*B*); averages: 10·72% (*Ang. reinhardti*) and 1·27% (*Ang. australis* f. *occidentalis* n.f.).—Each dot denotes a specimen.

Fig. 3 shows, in the form of a graph, $\frac{a-d}{t} \times 100$ for two samples, one of the long-finned eel (*Anguilla reinhardti*) and one of the short-finned eel (*Anguilla australis*), the former from New South Wales (neighbourhood of Sydney), the latter from Victoria. Each dot represents one specimen. In the 84 specimens of *Anguilla reinhardti*, the values varied between 7·8% and 13·2%, with an average of 10·72%; the values for the 198 specimens of *Anguilla australis* range from −1·5% to +4·0%, with an average of 1·27%. The highest value noted for the short-finned eel was thus 4·0%, and the lowest for the long-finned 7·8%.[6]

[6] The value is 0 when the dorsal fin begins immediately above the vent, and negative when the point of commencement lies behind the vent.

Despite the considerable number of specimens, there was no overlapping between the two species, as will at once be evident on glancing at the graph, Fig. 3. The schematic arrangement in Fig. 4 shows the same thing; here, we have the variation of $\frac{a-d}{t} \times 100$ for the two species drawn in one and the same figure.

The examination of these two samples of the two Australian species, together with many others investigated at the Carlsberg Laboratory, shows beyond question that $\frac{a-d}{t} \times 100$ is a good distinguishing character. When carefully measured, it will in practically every case suffice for distinction between the short-finned

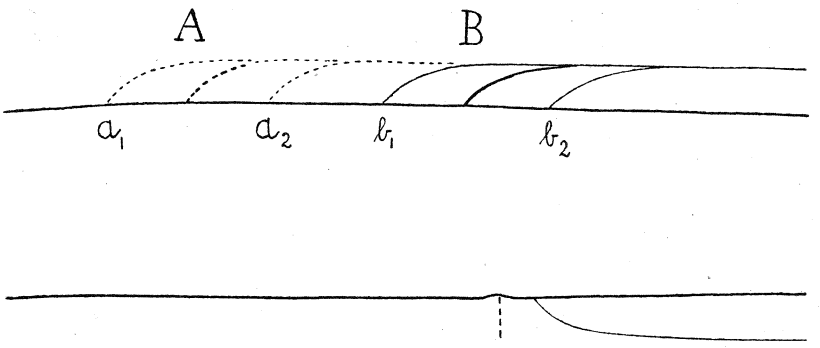


Fig. 4.— $\frac{a-d}{t} \times 100$.—Schematic representation of the variation of this value in the two samples represented graphically in Fig. 3. *A* and *B* = average values; $a_1$ and $b_1$ = highest, $a_2$ and $b_2$ lowest values in long-finned eel (*Anguilla reinhardti*) and short-finned eel (*Anguilla australis* f. *occidentalis* n.f.) respectively.

and the long-finned eel within the States of New South Wales and Victoria. Other useful distinguishing characters are afforded by the number of vertebræ, one in the total number, and another in the number of præhæmal vertebræ.

Fig. 5 shows graphically the total number of vertebræ in a sample of 190 specimens of *Anguilla australis* from New South Wales (near Sydney) and a sample of *Anguilla reinhardti* from the same district. As will be seen, there is but slight overlapping; in *Anguilla australis* the number of vertebræ varied between 109 and 116 with an average of 112·68, in *Anguilla reinhardti* between 104 and 110 with an average of 107·72.

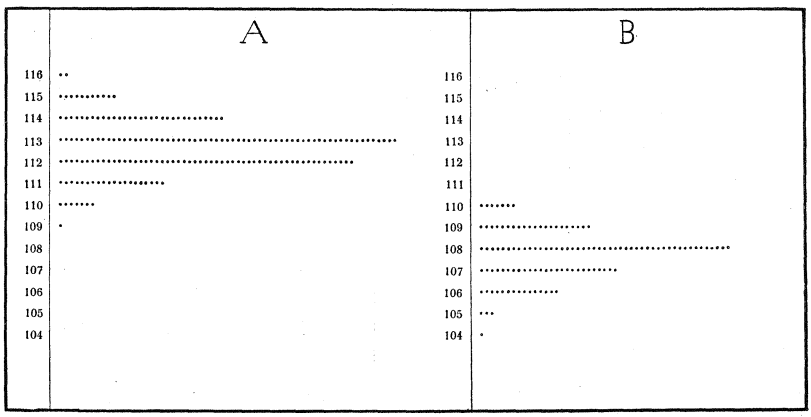


Fig. 5.—Total number of vertebræ in 190 specimens of the short-finned eel (*Anguilla australis* f. *occidentalis* n.f.) from Sydney and Prospect (109) and from Marley Beach, S. of Port Hacking (*A*), and in 120 specimens of the long-finned eel (*Anguilla reinhardti*) from Prospect Reservoir, Sydney (83), and from Marley Beach, S. of Port Hacking (*B*); averages: 112·68 (*Ang. australis* f. *occidentalis* n.f.) and 107·72 (*Ang. reinhardti*).—Each dot denotes a specimen.

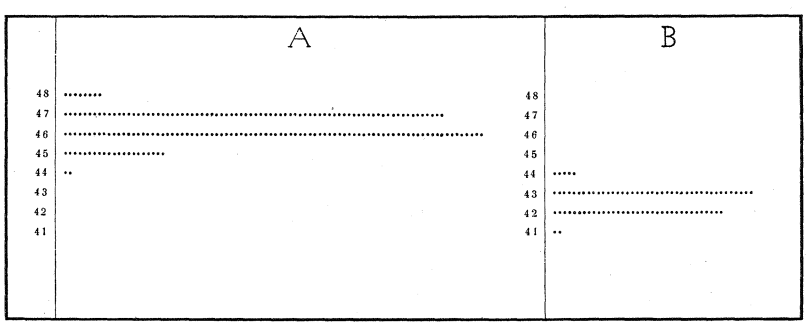


Fig. 6.—Number of præhæmal vertebræ in 195 specimens of the short-finned eel (*Anguilla australis* f. *occidentalis* n.f.) from Victoria (*A*), and in 83 specimens of the long-finned eel (*Anguilla reinhardti*) from Prospect Reservoir, near Sydney (*B*); averages: 46·35 (*Ang. australis* f. *occidentalis* n.f.) and 42·59 (*Ang. reinhardti*).—Each dot denotes a specimen.

The graph in Fig. 6 shows the number of præhæmal vertebræ in a sample of *Anguilla australis* from Victoria and one of *Anguilla reinhardti* from New South Wales. In the former, the number varied between 44 and 48, with an average of 46·35; in the latter, from 41 to 44, with an average of 42·59.

Among other numerical characters I may mention the number of branchiostegal rays and number of pectoral rays.

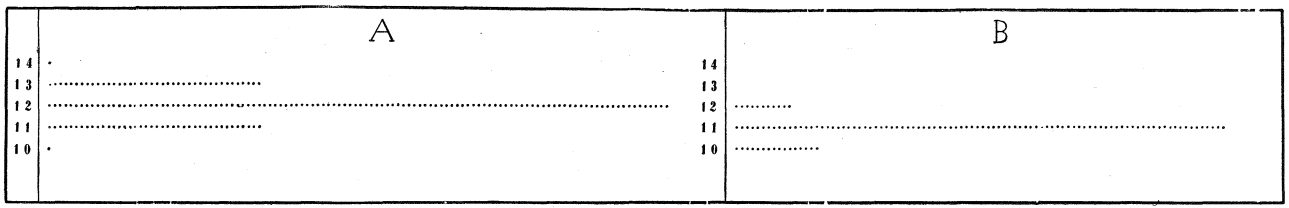


Fig. 7.—Number of branchiostegal rays in 198 specimens of the short-finned eel (*Anguilla australis* f. *occidentalis* n.f.) from Victoria (*A*), and in 119 specimens of the long-finned eel (*Anguilla reinhardti*) from Prospect Reservoir, near Sydney (83), and from Marley Beach, S. of Port Hacking (*B*); averages: 12·00 (*Ang. australis* f. *occidentalis* n.f.) and 10·96 (*Ang. reinhardti*).—Each dot denotes a specimen.

Fig. 7 shows graphically the number of branchiostegal rays in samples of *Anguilla australis* (Victoria) and of *Anguilla reinhardti* (New South Wales). It will be seen that the average number is about 1 higher in *Anguilla australis* than in *Anguilla reinhardti* (12·00 as against 10·96).

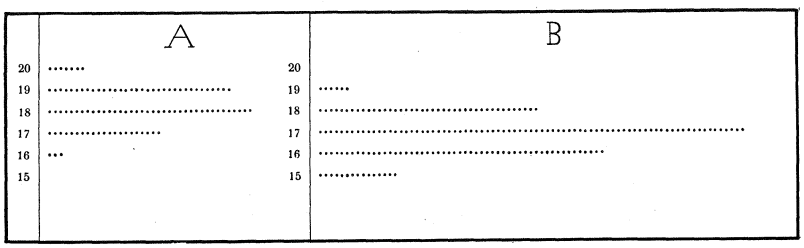


Fig. 8.—Number of pectoral rays in 103 specimens of the long-finned eel (*Anguilla reinhardti*) from Prospect Reservoir, near Sydney (79), and from Marley Beach, S. of Port Hacking (*A*), and in 194 specimens of the short-finned eel (*Anguilla australis* f. *occidentalis* n.f.) from Victoria (*B*); averages: 18·20 (*Ang. reinhardti*) and 16·85 (*Ang. australis* f. *occidentalis* n.f.).—Each dot denotes a specimen.

Fig. 8 represents the number of rays in the right pectoral fin, in the same samples of the two species as those used for Fig. 7. Here, it is *Anguilla reinhardti* which shows the higher average figure, *viz.* 18·20 as against 16·85 for *Anguilla australis*.

Finally, we have the dentition, or form of the teeth-bands, as illustrated in Fig. 9. Like several other spotted species, *Anguilla reinhardti* belongs to a group within the genus *Anguilla* distinguished by having the maxillary and mandibulary teeth-bands longitudinally divided by a groove, the outer strip containing a series of large, the inner a series of minute teeth. This arrangement may be more or less distinct; in *Anguilla reinhardti* it is often less pronounced than in the other species belonging to this group (*Anguilla mauritiana, labiata,* etc.). Figs. 9, *a, b,* and *c* show the dentition of the maxillæ in three specimens of *Anguilla reinhardti,* including the type preserved in the Vienna Museum, described by Steindachner (Fig. 9*a*).

The three figures of the dentition in the upper jaw of *Anguilla australis* (Figs. 9*d, e, f*) show that the maxillary teeth-bands are broader in this species than in *Anguilla reinhardti,* that the toothless groove is lacking, and that the vomerine band is shorter, broader and less pointed. Finally, it may be noted that the greatest breadth of the vomerine band lies as a rule behind the middle, whereas the greatest breadth in *Anguilla reinhardti* (and also in *Anguilla bicolor* and *Anguilla obscura,* see Fig. 10) lies farther forward. The


Fig. 9.—Teeth-bands of the upper jaw in 6 eels, 3 of *Anguilla reinhardti*, the long-finned eel (*a*, *b*, *c*) and 3 of *Anguilla australis* f. *occidentalis* n.f., the short-finned eel (*d*, *e*, *f*).

*a:* *Anguilla reinhardti* Steind., Rockhampton, Queensland, from type in the Natural History Museum of Vienna.

*b:* *Anguilla reinhardti* Steind., Gayndah, Queensland, from specimen in the Zoological Museum of Hamburg.

*c:* *Anguilla marginipinnis* Macleay, Lillesmere Lagoons, Burdekin River, Queensland, from co-type (A 18001) in the Australian Museum, Sydney.

*d:* *Anguilla australis* Rich., Tasmania, from type in the British Museum.

*e:* *Anguilla australis* Rich., Melbourne, from specimen (I 331) in the Australian Museum, Sydney.

*f:* *Anguilla australis* Rich., Delegate, N.S.W., from specimen (I 14637) in the Australian Museum, Sydney.

Drawings by Mr. Vilh. Ege, M.Sc.

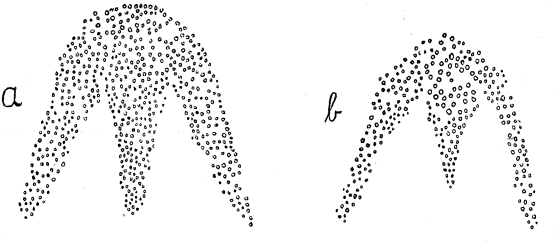


Fig. 10.—Teeth-bands of the upper jaw in *Anguilla bicolor* McClell. (*a*) and *Anguilla obscura* Günther (*b*).

*a:* *Anguilla australis* Rich. (Rendahl, in Meddelelser Zool. Museum, Kristiania, No. 5, 1922), from specimen collected by Dr. Knut Dahl in Roebuck Bay, Western Australia.

*b:* *Anguilla marginipinnis* Macleay, Lillesmere Lagoons, Burdekin River, Queensland, from co-type (A 17998) in the Australian Museum, Sydney.

Drawings by Mr. Vilh. Ege, M.Sc.

vomerine band of *Anguilla australis* is therefore often shaped like the tongue or clapper of a bell (see Figs. 9*d, e, f*).

In the preceding, mention has been made of various characters whereby it is possible with the greatest certainty to distinguish between the two species of fresh-water eels found in the States of Victoria and New South Wales: the long-finned or spotted eel (*Anguilla reinhardti*) and the short-finned or unspotted eel (*Anguilla australis*), which, as a matter of fact, are not very closely related. Even without employing such characters as the number of vertebræ, which call for detailed examination of the specimens, it will as a rule be easy to distinguish between the two species. Given a specimen, or specimens, which it is desired to identify, the following characters should be considered:

1. Whether the body is spotted or not, *Anguilla reinhardti* being typically spotted, *Anguilla australis* never spotted.

2. $\frac{a-d}{t} \times 100$ or the $(a-d)$ percentage, being the distance between front of dorsal fin and vent, expressed in percentage of the total length (see Figures 1-2, 3-4).

3. Shape of the teeth-bands (see Fig. 9).

These three characters will unquestionably always suffice to determine with certainty whether a given specimen belongs to the species *Anguilla reinhardti* or *Anguilla australis.*

Up to the present, we have considered only the two species of *Anguilla* found in the States of New South Wales and Victoria: *viz. Anguilla australis* and *Anguilla reinhardti.* At the beginning of this section it was pointed out that there are two other species found in Australia, *viz. Anguilla bicolor* and *Anguilla obscura,* both short-finned, unspotted species, the former being of Indian, the latter of Pacific origin. Both are easily distinguished from *Anguilla australis,* save when dealing with quite small specimens, by the fact that the angle of the mouth extends back a considerable distance beyond the eye, whereas in *Anguilla australis,* this angle lies approximately below the hind margin of the eye, as shown in Fig. 2. The dentition also is as already noted, a useful character for distinguishing these two species from *Anguilla australis*; this will be seen on comparing Fig. 9 and Fig. 10. This last figure further shows the difference between *Anguilla bicolor* and *Anguilla obscura* in the shape of the teeth-bands, while from Figs. 11 and 12 it will be seen that there is great difference also in regard to the number of vertebræ (averages: 109·37 and 103·90 respectively); the character $\frac{a-d}{t} \times 100$ also shows considerable difference between the two.

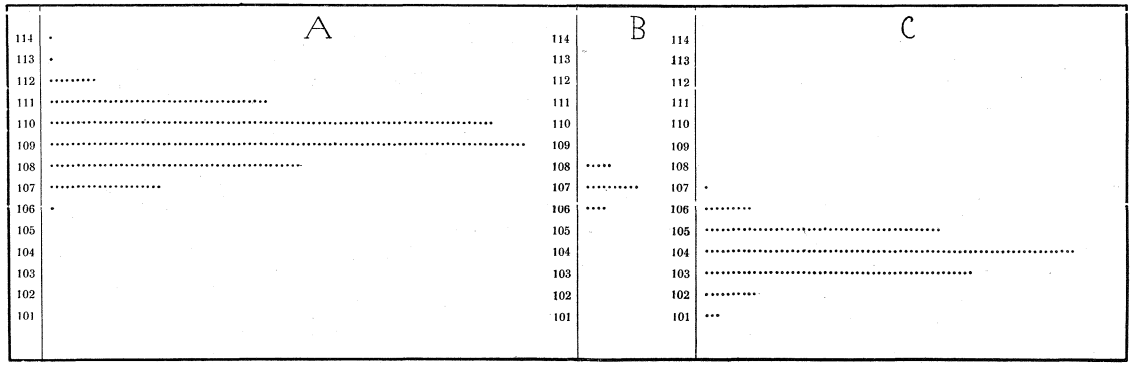


Fig. 11.—Total number of vertebræ in 294 specimens of *Anguilla bicolor* McClell. from Telok Dalem, Nias (*A*), in 19 specimens of *Anguilla pacifica* n.sp. (*B*) and in 188 specimens of *Anguilla obscura* Günther from Tahiti (*C*); averages: 109·37 (*Ang. bicolor*), 107·05 (*Ang. pacifica*) and 103·90 (*Ang. obscura*).—Each dot denotes a specimen.

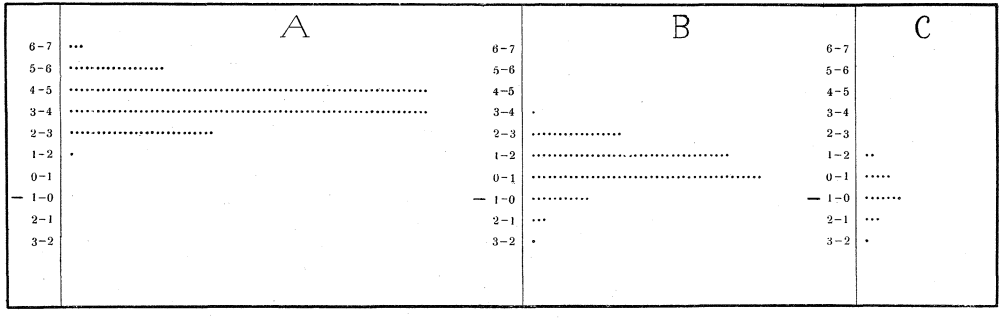


Fig. 12.—$\frac{a \div d}{t} \times 100$ in 183 specimens of *Anguilla obscura* Günther from Tahiti (*A*), in 113 specimens of *Anguilla bicolor* (McClell.) from Tangerang, Java (*B*), and in 19 specimens of *Anguilla pacifica* n.sp. from northern New Guinea, Philippines, *et cetera* (*cf.* Fig. 14) (*C*); averages: 3·91% (*Ang. obscura*), 0·88% (*Ang. bicolor*) and — 0·31% (*Ang. pacifica* n. sp.).—Each dot denotes a specimen.

## III. DISTRIBUTION.

The present work is based on the investigation of 928 specimens of *Anguilla*. Of these, 747 came from the continent of Australia, 51 from Tasmania, including Flinders and Vansittart Islands, 125 from Lord Howe Island and 5 from Norfolk Island. The distribution is as follows:

*Australia*: 547 *Anguilla australis*, 190 *Anguilla reinhardti*, 9 *Anguilla bicolor*, 1 *Anguilla obscura*.

*Tasmania* incl. Flinders and Vansittart Is.: 51 *Anguilla australis*.

*Lord Howe Island*: 85 *Anguilla australis*, 40 *Anguilla reinhardti*.

*Norfolk Island*: 5 *Anguilla australis*.

I will now take the different species separately.

### 1.—ANGUILLA REINHARDTI *Steindachner*.

*The Long-finned or Spotted Eel.*

This species was described in 1867 by Steindachner, from a specimen taken at Rockhampton, Queensland (!). As will be seen from the chart, Fig. 13, it is distributed on the continent of Australia from Cape York (2 samples in the British Museum!) and southward from there along the east coast as far as Port Phillip, Melbourne; I have myself seen a specimen from here, *viz.* the one described by Klunzinger[7] under the name of *Anguilla amboinensis* Peters. Thanks to the courtesy of the Museum at Stuttgart, Germany, where it is preserved, we have been able to examine this specimen. It is a typical *Anguilla reinhardti* with 43 + 66 = 109 vertebræ, and $\frac{a-d}{t} \times 100 = 9{\cdot}2$, values which, as will be seen, are of common occurrence in this species.

Outside the continent of Australia, *Anguilla reinhardti* is found on Lord Howe Island, where it is common; out of 125 specimens of *Anguilla* from here, 40 belonged to this species. It also occurs in New Caledonia; in 1926-27, some hundreds of specimens were sent from there to the Carlsberg Laboratory by Monsieur Jean Risbec, of Noumea. Neither the *Anguilla reinhardti* from Lord Howe Island nor those from New Caledonia are, as far as our investigations go, racially different from those living on the mainland of Australia. As will be seen from Fig. 5, the average number of vertebræ for 120 specimens from Sydney was 107·72, the average for Lord Howe Island (38 specimens) was 107·74 and for Noumea (New Caledonia) 107·82 (62 specimens).

[7] Klunzinger.—Sitzungsber. Akad. Wien, XXX, 1879, p. 419.

*Anguilla reinhardti* is the fresh-water eel *par excellence* of Queensland, all the specimens of eels hitherto known from that State having been found to belong to this species, with but a single exception (a specimen of *Anguilla obscura*). In New South Wales also it is very common, but has here to share the honours with *Anguilla australis,* which, as far south as the neighbourhood of Sydney, seems to be as numerous as *Anguilla reinhardti,* if not more so. Finally, in the State of Victoria, *Anguilla reinhardti* is far less common than *Anguilla australis,* and in Tasmania it has not yet been observed.

It may here be noted that Steindachner's type (Vienna Museum) was found to have 43 + 66 = 109 vertebræ, with an $(a-d)$ percentage of 9·7. It should further be mentioned that a specimen in the British Museum, brought home by H.M.S. "Challenger" from the Mary River, Queensland (Brit. Mus. 79.5.14.430), determined as *Anguilla mauritiana* by Günther,[8] proved to be a typical *Anguilla reinhardti* (vertebræ: 42 + 65 = 107, and $(a-d)$ percentage = 10·5). *Anguilla mauritiana* must therefore be deleted from the fauna of Australia for the time being.

It would be useful in the work of further research if zoologists or other interested parties in Australia would endeavour to ascertain the length and weight attained by *Anguilla reinhardti.* The sample already noted as from Prospect Reservoir, near Sydney (85 specimens) which, thanks to the courtesy of the State Fisheries Department and the Australian Museum, Sydney, we were enabled to investigate at the Carlsberg Laboratory, consisted exclusively of females, about a metre long. The largest measured 128 cm. (weight 4,950 grammes), the smallest 79 cm. (weight 1,275 grammes); the majority were about 1 metre in length, weight about 2,500 grammes.

From the Chief Inspector of Fisheries and Game, Melbourne, I received, through the Danish Consulate in that city, three large eels preserved in formalin, which proved to belong to *Anguilla reinhardti.* They measured 120·5, 123·5 and 135 cm. in length, and weighed 4,760, 6,160 and 4,910 grammes respectively. According to information from the Chief Inspector, in a letter dated Melbourne 11th June, 1925, "these eels were taken in the eastern part of Victoria in brackish water, but are also commonly obtained in the rivers on that State 100 miles from the nearest salt water. They are locally known as Conger eels. The size of these is, I think, somewhat out of the ordinary, and in no other part of this State are eels of this size caught. . . Specimens of these eels have been taken up to as much as 30 lbs. in weight."

During my stay in Australia, in January and February, 1926, I received several letters containing information as to eels in Australia, and was greatly interested in the data supplied. I would here mention a letter from Mr. N. Johnson, dated from Mossiface, East Gippsland, Victoria, 27th January, 1926, who writes: "If you

[8] Günther.—"Challenger" Report, Zoology, i, Shore Fishes, 1880, p. 33.

in Flinders and Vansittart Islands; a sample was kindly sent me by Mr. H. Gottlieb, Lady Barron, Flinders Island. The species will probably also prove to be common on the other islands in Bass Strait.

Unfortunately, I am unable to contribute any information as to the length and weight attained by *Anguilla australis,* as the specimens I have had for investigation were, with a few exceptions, small ones. The largest I have seen came from Prospect Reservoir, and measured 88 cm. in length, weighing 1,225 grammes; it is, however, beyond doubt that the species attains a far more considerable size. A sample of *Anguilla australis* sent me from Christchurch, New Zealand, contained several specimens close on 1 metre long.

I close this discussion with the questions: What length and weight are attained by the Australian short-finned or unspotted eel, *Anguilla australis*? Is it found north of Richmond River, *i.e.* does it penetrate into the State of Queensland? And how far west is it met with on the south coast of Australia?

In the preceding, when dealing with *Anguilla reinhardti,* I mentioned that the populations of this species found outside the continent of Australia do not appear to be racially distinct from those of the mainland. This holds good, as far as our investigations extend, both as regards the populations in New Caledonia and Lord Howe Island, as shown by the average noted on p. 192.

What is now the position of *Anguilla australis* in this respect?

In my work on "The Fresh-water Eels of New Zealand,"[10] I have given a detailed account of our investigations of a great amount of material of *Anguilla australis* from New Zealand. I there refer to Figs. 3 and 6, where the $(a-d)$ percentage and the total number of vertebræ respectively for samples from New Zealand are shown in graphical form. On comparing these characters for the New Zealand samples with the same characters in the samples from Australia (see Figs. 3 and 5 in the present paper), it will be seen that there is a difference which cannot be ignored. The averages for these two characters in the samples from Australia and New Zealand respectively are as follows (figures in parentheses indicate total number of specimens examined):

| | Australia. | New Zealand. |
|---|---|---|
| $\frac{a-d}{t} \times 100$ .. .. .. | 1·27 (198) | 2·41 (93) |
| Vertebræ .. .. .. | 112·68 (190) | 111·64 (165) |

Keeping to the number of vertebræ, which is the more accurately determined of the two characters, we find, then, an average difference of 1 vertebra between Australia (Sydney) and

[10] Schmidt.—Trans. New Zealand Institute, lviii, 4 (in the press).

New Zealand (Waiapu, East Cape). Testing the two values by means of variational statistics, we obtain the following result:[11]

| | Australia. | New Zealand. |
|---|---|---|
| No. .. .. .. .. .. .. | 190 | 165 |
| Average .. .. .. .. .. | 112·679 | 111·642 |
| $\sigma$ (standard deviation) .. | ± 1·230 | ± 1·049 |
| P.E.A. (probable error of average) .. .. .. .. | ± 0·0602 | ± 0·055 |
| P.F.A. (probable fluctuation of average) .. .. .. | 112·378-112·980 | 111·367-111·917 |

Those who are familiar with investigations based on variational statistics will see from the preceding that there is a real difference in the number of vertebræ between the *Anguilla australis* of the continent of Australia and those of New Zealand.

The table below shows the average number of vertebræ for all the 29 samples of *Anguilla australis* which we have investigated, both from New Zealand and from the continent of Australia *et cetera*. It will be observed that there is a decided difference, apparent in all samples; the averages for Australian samples are invariably over, those for the New Zealand samples invariably under 112. Zoologists not conversant with the methods of variational statistics will perhaps find this simple arrangement of the averages more convincing proof that there exists, as above mentioned, a real difference in the number of vertebræ between the *Anguilla australis* of Australia and those of New Zealand.

*Anguilla australis* Rich., average number of vertebræ in 29 samples:[12]

*Australia and Lord Howe Island.*

| | | | |
|---|---|---|---|
| Prospect Fish Hatchery, N.S.W.—13.v.1905 .. .. .. | a | (25) | = 112·52 |
| Prospect Reservoir, near Sydney.—Sept., 1914 .. .. .. | a | (19) | = 112·37 |
| Prospect Trout Ponds.—12.viii.1925 .. .. .. .. .. | a | (45) | = 112·93 |
| Sydney Water Supply Reserve.—Feb.-Aug., 1924 .. .. | a | (20) | = 113·00 |
| Maroubra, near Sydney (Mus. Sydney, I A 2642).—27.ix and 18.x.1925 .. .. .. .. .. .. .. .. .. .. | a | (12) | = 112·75 |
| Marley Beach, S. of Port Hacking (Mus. Sydney, I A 2972).—6.xi.1926 .. .. .. .. .. .. .. .. .. .. | a | (81) | = 112·58 |
| Long Bay Beach, N.S.W. (Mus. Sydney, I A 2959).—29.ix.1926 .. .. .. .. .. .. .. .. .. .. | a | (19) | = 112·79 |
| Hopkins River, Warrnambool, Victoria.—Dec., 1909 .. .. | a | (35) | = 112·51 |
| Melbourne, 1st sample.—1925 .. .. .. .. .. .. .. | a | (109) | = 112·51 |
| Melbourne, 2nd sample.—1925 .. .. .. .. .. .. .. | a | (50) | = 112·72 |
| Flinders Isl. and Vansittart Isl., Bass Strait .. .. .. | a | (22) | = 112·95 |
| River Tamar, Tasmania .. .. .. .. .. .. .. .. | a | (17) | = 112·65 |
| Lord Howe Isl., 1st sample.—Oct., 1924 .. .. .. .. .. | a | (20) | = 112·75 |
| Lord Howe Isl., 2nd sample .. .. .. .. .. .. .. | a | (27) | = 112·30 |
| Lord Howe Isl., 3rd sample (Mus. Sydney, I A 3251).—late 1926 .. .. .. .. .. .. .. .. .. .. .. .. | a | (34) | = 112·65 |

[11] *Cf.* Johs. Schmidt.—"First and Second Report on Eel Investigations," Vol. XVIII and Vol. XXIII des Rapports et Procès-Verbaux du Conseil International pour l'Exploration de la Mer, Copenhagen, 1913 and 1915.

[12] Figures in brackets indicate number of specimens examined.

*New Zealand.*

| | | | |
|---|---|---|---|
| Pipiriki, Wanganui River.—18-26.ii.1926 | a | (41) | = 111·78 |
| Thames and Kaipara Harbour Streams, N. Auckland.—Jan., April, 1925 | a | (98) | = 111·89 |
| Wairua R., a branch of the N. Wairoa R., Whangarei, N. Auckland.—12.ii.1927 | a | (94) | = 111·51 |
| Hawkes Bay, near Napier.—Oct., 1926 | a | (36) | = 111·47 |
| Poropora Stream, Waiapu, East Cape District.—21.xi.1926 | a | (165) | = 111·64 |
| Christchurch.—1912 | a | (110) | = 111·55 |
| Waimakiriri River.—5 and 14.x.1925 | a | (95) | = 111·92 |
| Waimakiriri, 1st sample.—End of Oct., 1926 | a | (89) | = 111·52 |
| Waimakiriri, 2nd sample.—End of Oct., 1926 | a | (40) | = 111·35 |

*New Caledonia.*

| | | | |
|---|---|---|---|
| Caniveaux de Nouméa.—26.v.-19.vii.1926 | a | (159) | = 111·57 |
| Marais de Magenta.—Sept., 1926 | a | (50) | = 111·84 |
| Magenta and Dumbéa.—26.ix.-23.x.1926 | a | (13) | = 111·69 |
| Plum.—24.ii.1927 | a | (28) | = 111·71 |
| Caniveaux de Nouméa.—11.iii.1927 | a | (11) | = 111·45 |

On the basis of the preceding, I propose that this difference—which appears not only in the total number of vertebræ but also in the number of præhæmal and caudal vertebræ and in the $(a-d)$ percentage—as between the populations of *Anguilla australis* in Australia and those in New Zealand should be emphasized by naming the former:

ANGUILLA AUSTRALIS *forma* OCCIDENTALIS *n.f.*, and the latter ANGUILLA AUSTRALIS *forma* ORIENTALIS *n.f.*

And now, what is the position as regards *Anguilla australis* on Lord Howe Island and Norfolk Island? Do they belong to f. *occidentalis* or to f. *orientalis*?

In the 83 specimens from Lord Howe Island which we have examined, the average number of vertebræ was 112·59, and there can thus be no doubt but that these belong to f. *occidentalis*.

In the case of Norfolk Island, we have only been able to examine 5 specimens, which is not a sufficient number to permit of any definite decision. The figures for these 5 were 113, 113, 112, 111 and 111 vertebræ respectively (average 112·0), and the $(a-d)$ percentages 2·1, 4·5, 2·6, 3·0 and 2·1 (average 2·86). The probability here is rather in favour of f. *orientalis*, the high $(a-d)$ percentage especially pointing in this direction.

In my own oft-quoted work "On the Distribution of the Fresh-water Eels (*Anguilla*) throughout the World,"[13] I stated that *Anguilla australis* "must probably be subdivided." I had not then seen sufficient material, and was obliged to leave the question open. There will no doubt be a number of zoologists, not

[13] Schmidt.—Mem. Acad. Roy. Sci. et Lettres de Danemark (8), x, 4, 1925, p. 366.

accustomed to base their classification on so delicate an analysis as that of variational statistics, who will consider an average difference of one vertebra as too slight a foundation for the establishment of two new forms. I must here point out, however, that the difference between the European and the East-Asiatic eel (*Anguilla vulgaris* Turton and *Anguilla japonica* Schlegel) is only very little more, *viz.* about 1·1 between the average numbers of vertebræ.[14]

I was particularly interested in demonstrating this slight average difference between the two forms *occidentalis* and *orientalis*, as I have no doubt but that it indicates a difference in their life-history and in their breeding-places. On comparing a depth chart with a chart showing the occurrence of the two forms, one can hardly doubt but that it is the New Caledonian submarine ridge, running north-west and north from western New Zealand, which separates the two forms, f. *occidentalis* breeding in the deep basin west of the ridge, and f. *orientalis* on the east of this barrier. A fact which also points in this direction is that we have succeeded in showing, firstly that *Anguilla australis*, hitherto known only from temperate regions, is met with *en masse* in the tropical island of New Caledonia, and further, that it is f. *orientalis*, i.e. the New Zealand form, which occurs there (see Table p. 198, and later Section v with Fig. 14). Investigations in the waters concerned, similar to those which I carried out in the Atlantic in 1920-1922, would be required to locate more precisely the actual breeding places of the two forms.

Up to the present, the ascent of enormous hosts of young transparent *elvers* (eel young) from the sea, to fresh waters inland, as witnessed in Europe, America, and Japan during the spring, has never been recorded in Australia. Our Australian colleagues have, however, taken up the matter for investigation, and I have before me a small collection of young *Anguilla australis* taken on the 29th September, 1926, in a creek crossing the beach at Long Bay, near Sydney, by Dr. C. Anderson and Mr. Gilbert P. Whitley (Australian Museum, Reg. No. I.A.2959). None of these is a quite young transparent elver; there are, however, some fairly young stages (stage vi A ii according to the terminology introduced by A. Strubberg[15]); the lengths of these varied from 47 to 57 mm. We have also examined a few specimens of *Anguilla reinhardti, e.g.* a small sample of 4 (Australian Museum I.A.708) taken on the 12th March, 1922, in a rock-pool at Coogee, near Sydney, by Messrs. F. A. McNeill and A. A. Livingstone. The length of these varied from 45·5 to 48 mm. but the stage was indeterminable, as the pigment had disappeared.

[14] Schmidt.—First Report on Eel Investigations, Rapports et Procès-Verbaux du Conseil International pour l'Exploration de la Mer, Vol. XVIII, p. 16, Copenhagen, 1913, where it is noted that *Anguilla vulgaris* has 114.728 and *Anguilla japonica* 115.876 vertebræ, average figures.

[15] Strubberg.—The metamorphosis of Elvers as influenced by outward conditions (Meddelelser fra Kommissionen for Havundersogelser, Ser. Fiskeri, Bind IV, No. 3, Copenhagen, 1913).

It is highly desirable that endeavours should be made to demonstrate the occurrence in Australia of transparent elvers in large numbers, in order to ascertain at what places and seasons this stage of development is to be met with, both as regards *Anguilla australis* and *Anguilla reinhardti*. I would here point out that elvers should *not* be preserved in alcohol, which is a bad preservative as far as they are concerned, but in a weak solution of formol (2-4%). For the rest, I would refer to the article by H. K. Anderson and G. P. Whitley.[16]

### 3.—Anguilla bicolor *McClelland.*

*The Short-finned Eel of the Indian Ocean.*

The chart, Fig. 13, shows that we have only found this species in the tropical part of Western Australia. For the rest, it occurs along the shores of the Indian Ocean, both in East Africa with Madagascar *et cetera,* and in British India and the Dutch Indies.

The first find of this species in Australia was made by a Norwegian explorer, Dr. Knut Dahl, who gives an interesting description of how the specimens lived buried deep down in the mud in a salt marsh, so that one had to dig them out with spades. The locality was Broome, about 20 miles north of Roebuck Bay (about 18° S. lat.). We have examined the 7 specimens brought home by Dr. Dahl, which are preserved in the Museum at Christiania; they were referred by Rendahl[17] to *Anguilla australis* Rich. The teeth-bands in the upper jaw of one of these specimens is shown in Fig. 10*a* in the present paper. I have further seen two female specimens of this species sent me through the Royal Danish Consulate at Perth, from the Chief Inspector of Fisheries, Mr. F. Aldrich, W. Australia. The two specimens referred to were secured at a waterhole inland from Beagle Bay, about 65 miles north of Broome. The lengths were 64 and 61 cm.; number of vertebræ 43 + 65 = 108 and 43 + 47 = 110, the $(a-d)$ percentage $-0{\cdot}5$ and $-1{\cdot}0$ respectively.

*Anguilla bicolor* is thus known up to the present only from a restricted area in north-western Australia. It would be most interesting to ascertain how far south this tropical species extends, and also its northern limit of distribution.

### 4.—Anguilla obscura *Günther.*

*The Short-finned Eel of the Tropical Part of the South Pacific.*

In a paper by W. Macleay, "Notes on a collection of fishes from the Burdekin and Mary Rivers, Queensland,"[18] there is a

[16] Anderson and Whitley.—The Australian Museum Magazine, II, 8, pp. 266-270, 1925.
[17] Rendahl.—Meddelelser fra det zoologiske Museum, Kristiania, No. 5, 1922.
[18] Macleay.—Proc. Linn. Soc. N. S. Wales, VIII, p. 210, 1884.

description of a new species, *Anguilla marginipinnis* Macleay, from the Lillesmere Lagoon, Burdekin River. In my work "On the Distribution of the Fresh-water Eels (*Anguilla*) throughout the World,"[19] I stated, after noting *Anguilla australis* and *reinhardti*: "From the tropical part of the east coast (Burdekin, Queensland) Macleay (1884, p. 210) has described a long-finned, uniformly coloured species, *Anguilla marginipinnis*. There are thus at any rate three *Anguilla* species in eastern Australia, but I cannot say what *A. marginipinnis* may be without having seen a specimen."

By the courtesy of the Australian Museum at Sydney, we have been enabled to examine here at the Carlsberg Laboratory the 6 co-types of *Anguilla marginipinnis* preserved in that Museum, which are labelled "A.17994, A.17995, A.17997, A.17998, A.17999, A.18001, Lillesmere Lagoons, Burdekin River, Queensland, coll. A. Morton, 1883." The specimens were in poor condition, but careful investigation and close examination of X-ray photographs of them showed that 5 of the specimens belonged to *Anguilla reinhardti*, and the sixth to *Anguilla obscura* Günther. The name *Anguilla marginipinnis* must therefore disappear.[20]

The specimen of *Anguilla obscura* (A.17998) was about 67 cm. long, with 42 + 64 = 106 vertebræ and an $(a-d)$ percentage of 4·2; the teeth-bands of the upper jaw are shown in Fig. 10*b*.

With the disappearance of *Anguilla marginipinnis* then, we have at the same time to note *Anguilla obscura* as a further species of *Anguilla* living in Australia; it is also distributed throughout the tropical parts of the Pacific south of the Equator, from southern New Guinea to Tahiti. A further description of the species, with illustrations, is given in my paper "Les Anguilles de Tahiti,"[21] to which reference may be made. The species was originally established by Günther in 1872,[22] who described it more fully subsequently[23] (1910). Fortunately his type still exists (in the British Museum) and it was from examination of this, and from X-ray photographs of it, that we were able to demonstrate that *Anguilla obscura* is actually an extremely well established species, differing considerably from the other short-finned species of *Anguilla*; it has also been found to have a very characteristic area of distribution in the tropical waters of the Pacific south of the Equator (see Section v, and Fig. 14).

[19] Schmidt.—Mem. Acad. Roy. Sci. et Lettres de Danemark (8), x, 4, 1925, p. 345.

[20] I give here the number of vertebræ and $(a-d)$ percentages for these 5 specimens of *Anguilla reinhardti*:

*Vertebræ*: 42 + 66 = 108, 42 + 66 = 108, 43 + 62 = 105, 44 + 65 = 109, 43 + 65 = 108.

$\frac{a-d}{t} \times 100$ : 11·4, 11·6, 10·9, 7·6, 10·2.

The dentition shown in Fig. 9*c* is from one of these specimens.

[21] Schmidt.—La Nature, Paris, 15th July, 1927.

[22] Günther.—Proc. Zool. Soc., 1871 (1872), p. 673.

[23] Günther.—Journal des Museum Godeffroy, VI, 17 (Garrett's Fische der Südsee, IX), 1910, p. 392.

Finally, it will be interesting to compare our material according to States. We find the following distribution:

Queensland: 35 *Anguilla reinhardti* + 1 *Anguilla obscura.*
New South Wales: 305 *Anguilla australis* + 155 *Anguilla reinhardti.*
Victoria: 242 *Anguilla australis* + 4 *Anguilla reinhardti.*
Western Australia: 9 *Anguilla bicolor.*

It would be unreasonable to suppose that this small amount of casually collected material should be regarded as representative. Nevertheless I do not doubt but that it does give, to some extent, an idea of the actual conditions. Taking, for instance, the percentage of *Anguilla reinhardti* and *Anguilla australis* in the different States from north to south, we find the following:

| | *Anguilla reinhardti.* | *Anguilla australis.* |
|---|---|---|
| Queensland .. .. .. | 100% | 0% |
| New South Wales .. .. | 33% | 67% |
| Victoria .. .. .. .. | 2% | 98% |

Even though these figures may not be representative, there can hardly be any doubt as to the correctness of the order of precedence.

We know, then, four species of *Anguilla* from Australia. There would, presumably, be nothing to prevent two others from finding their way to the tropical part of Queensland, *viz. Anguilla megastoma* Kaup and *Anguilla mauritiana* Bennett. Both these species occur, for instance, in New Caledonia. Both are figured and mentioned in my work on "Les Anguilles de Tahiti."[24] In the tropical part of Western Australia one might perhaps expect to find, in addition to *Anguilla bicolor,* also the Indian form of *Anguilla mauritiana,* possibly also *Anguilla celebesensis* Kaup.

It is a remarkable fact that the common New Zealand eel, *Anguilla aucklandi* Rich., has not been met with either in Australia or on Lord Howe Island.

## IV. SUMMARY.

I shall in the following pages, for the sake of convenience, give a brief summary of the essential facts.

1. ANGUILLA REINHARDTI *Steind.,* the *long-finned* or *spotted* eel.

*Chief characteristics*: Spotted; long-finned (Fig. 4); comparatively small mouth (cleft of mouth extending to hind margin of eye or a little farther, Fig. 1); maxillary and mandibulary teeth-bands divided longitudinally by toothless groove (Figs. 9*a, b, c*). Pacific, tropical and temperate (Fig. 13).

[24] Schmidt.—La Nature, Paris, 15th July, 1927.

*Numerical characters*: Total number of vertebræ: 104-110, average: 107·72 (Fig. 5 B); præhæmal vertebræ: 41-44, average: 42·59 (Fig. 6 B); branchiostegal rays: 10-12, average: 10·06 (Fig. 7 B); rays in right pectoral fin: 16-20, average: 18·20 (Fig. 8 A); $(a-d)$ percentage: 7·8 to 13·2, average: 10·72 (Fig. 3 A).

*Distribution*: Pacific, from Cape York to Melbourne on the Australian continent; also known from Lord Howe Island and New Caledonia.

2. ANGUILLA AUSTRALIS *Rich.* f. OCCIDENTALIS n.f., the *short-finned* or *unspotted* eel.

*Chief characteristics*: Unspotted; short-finned (Fig. 4); small mouth (cleft of mouth extending about to hind margin of eye, Fig. 1); no toothless groove, vomerine band most often distinctly shorter than maxillary bands, often shaped like the clapper or tongue of a bell, its greatest breadth at or rather behind the middle (Figs. 9*d, e, f*). Pacific, temperate (Figs. 13 and 14).

*Numerical characters*: Total number of vertebræ: 109-116, average: 112·68 (Fig. 5 A); præhæmal vertebræ: 44-48, average: 46·35 (Fig. 6 A); branchiostegal rays: 10-14, average: 12·00 (Fig. 7 A); rays in right pectoral fin: 15-19, average: 16·85 (Fig. 8 B); $(a-d)$ percentage: – 1·5 to + 4·0, average: 1·27 (Fig. 3 B).

*Distribution*: Pacific, from Richmond River in New South Wales to 140° E. Long. on the south coast of Australia, Tasmania, Flinders Island, Vansittart Island; also Lord Howe Island (not New Zealand, which has *Anguilla australis* Rich. f. *orientalis* n.f.).

3. ANGUILLA BICOLOR *McClelland,* the *short-finned* eel of the *Indian Ocean.*

*Chief characteristics*: Unspotted, short-finned; large mouth (cleft of mouth extending beyond eye); no toothless groove, vomerine band not much shorter than maxillary bands, its greatest breadth most often in front of the middle (Fig. 10*a*). Indian Ocean, tropical (Figs. 13 and 14).

*Numerical characters*: Total number of vertebræ: 106-114; average: 109·34 (Fig. 11 A); $(a-d)$ percentage: – 2·4 to + 3·1, average: 0·88 (Fig. 12 B).

*Distribution*: Roebuck Bay and Beagle Bay, tropical part of Western Australia, also found on the other tropical shores of the Indian Ocean.

4. ANGUILLA OBSCURA *Günther,* the *short-finned* eel of the *tropical* part of the *South Pacific.*

*Chief characteristics*: Unspotted, short-finned; large mouth (cleft of mouth extending beyond eye); no toothless groove, vomerine band often considerably shorter than maxillary bands, its greatest breadth in front of the middle (Fig. 10*b*). Pacific, tropical (Figs. 13 and 14).

*Numerical characters*: Total number of vertebræ: 101-107, average: 103·90 (Fig. 11 C); (*a* – *d*) percentage: 1·8-6·5, average: 3·91 (Fig. 12 B).

*Distribution*: Burdekin (Queensland), also met with from southern New Guinea to Tahiti.

## V. SOME REMARKS ON THE SHORT-FINNED SPECIES OF ANGUILLA.

The short-finned species of eels, three of which were mentioned in the preceding, inhabit the Indo-Pacific region from the east coast of Africa to Tahiti reckoning from west to east, and from the Philippines to New Zealand reckoning north to south. In earlier times especially, a great number of species was established among the short-finned eels, but in most cases they were not well founded, so that neither later writers nor the authors concerned have been able to recognize them. Consequently, the classification was in a chaotic state, and it is not surprising that Weber[25] and later Boulenger,[26] as also Weber and Beaufort[27] abandoned all distinction of species among the short-finned eels, combining them all under the name of *Anguilla australis* Richardson, established in 1841[28] on the basis of specimens from the temperate Pacific Region.[29]

This then was the position when I entered upon the study of the short-finned eels, and endeavoured to introduce the statistical method, working with some hundreds of specimens. It was soon found that *"Anguilla australis"* was not one species but a number of species, each with its own characteristic features and distribution; and there is no reason to doubt that, given a sufficient number of specimens from the whole of the Indo-Pacific region, the entire problem could be thoroughly solved by the aid of the statistical method.

This was the practical side of the matter. There remains the formal aspect, *i.e.* the question as to denomination of the species based on and separated by characters with which the earlier writers, who established and named species of short-finned eels had never

[25] Weber.—"Versuch einer Revision der Indo-pacifischen Anguillidæ," Zool. Jahrbücher, Supplement XV, 1 Band, 1912.

[26] Boulenger.—Cat. Fresh-water Fishes of Africa, in the British Museum, III, 1915, p. 9.

[27] Weber and Beaufort.—Fishes of the Indo-Australian Archipelago, III, 1916, p. 249.

[28] Richardson.—Proc. Zool. Soc. London, p. 22, 1841.

[29] Weber, however, *l.c.* 1912, established the short-finned species *Anguilla spengeli*, based on the very large eyes. I have seen such large-eyed specimens among *Anguilla bicolor*, *obscura* and others, and do not consider the character of specific value any more than the large-eyed silvery stages of our European eels. Large eyes in *Anguilla* are a sign of approaching sexual maturity.

concerned themselves at all. In this respect, my view is that the decisive point in pleading for or against the retention of old names of species inadequately described from insufficient characters should be *whether authentic type specimens are preserved* or not. Only where the types exist is there any real possibility of ascertaining the valid characters and thus determining whether the name shall be retained.

As an example, I may mention *Anguilla obscura* Günther. This was described by Günther in 1872,[30] from a specimen from the Fiji Islands, but it has not been found again, or accepted by later writers; while Günther himself in his later work[31] still noted only the type of *Anguilla obscura* from Fiji, though a large number of other short-finned eels from the tropical part of the South Pacific are given under the names of *Anguilla virescens* Peters and *Anguilla sidat* Bleeker.

Jordan and Seale, in their "Fishes of Samoa,"[32] enumerating the *Anguilla* species of Oceania, note among short-finned species, besides the type of *Anguilla obscura* from Fiji, which they had not seen, *Anguilla sidat* Bleeker (Samoa, New Zealand) and *Anguilla australis* Richardson (Samoa, New Zealand, East Indies).

Jordan and Seale, as also Günther, were, as we now can see, faced with an impossible task in attempting to separate the short-finned species of Oceania without having recourse to numerical characters. Erroneous results were also naturally arrived at, as for instance the identification of the temperate *Anguilla australis* Rich. with forms from the tropical Pacific and the East Indies. The application of numerical characters to extensive material has obviated the difficulties here. As regards Günther's *Anguilla obscura,* it has further been found that it is really a very characteristic species, albeit not in respect of the characters noted by Günther. With regard to these, I may refer to the previous sections, and to Figs. 10 and 9 *d, e, f* as also Figs. 11, 12 and 5 A and 3 B; and I may add that the number of præhæmal vertebræ is characteristic in *Anguilla obscura* (in a sample from Tahiti, the average for 158 specimens was 41·28 as against 46·35 in *Anguilla australis*, see Fig. 6 A; and the numbers varied from 40 to 43). The type of *Anguilla obscura* preserved in the British Museum was examined by Mr. Vilh. Ege, M.Sc. and found to have 42 + 63 = 105 vertebræ, with an $(a - d)$ percentage of 5·4; these values correspond nicely to those given in the graphs Figs. 11 and 12.

The examination of Günther's specimens of *Anguilla virescens* and *Anguilla sidat* (Günther, *l.c.* p. 392, 1910) in the British

[30] Günther.—Proc. Zool. Soc. of London, 1871 (1872), p. 673.

[31] Günther.—Journal des Museum Godeffroy, VI, 17 (Garrett's Fische der Südsee, IX), 1910, p. 392.

[32] Jordan and Seale.—Bull. U.S. Bureau of Fisheries, XXV, 1906, p. 192.

Museum showed that the specimens from Oceania did not belong to these species, which were described from the Indian Ocean, but to Günther's own *Anguilla obscura*; as a matter of fact this is also the case with a specimen from Vavao, Tonga, which Günther (*l.c.* p. 391, 1910) refers to *Anguilla aneitensis* Günther: it had 41 + 64 = 105 vertebræ and an $(a - d)$ percentage of 5·3, values not found in *Anguilla aneitensis,* or, as it should be called, *Anguilla megastoma* Kaup, as to which see my account in "Les Anguilles de Tahiti."[33]

We have also been able to examine some of Jordan and Seale's specimens, preserved in the United States National Museum, as for instance that of *"Anguilla sidat"* noted on p. 392, *l.c.* as from Samoa, and one of the *"Anguilla australis"* from Apia, Samoa, mentioned on the same page. The former (U.S.N.M. 52489), which was 885 mm. long, had 41 + 63 = 104 vertebræ, and an $(a - d)$ percentage of 2·8; the latter (U.S.N.M. 52533), 159 mm. long, had 43 + 60 = 103 vertebræ and an $(a - d)$ percentage of 3·1. These values absolutely exclude all possibilities of the specimens being either the East Indian *Anguilla sidat* (the large specimen first noted) or the temperate *Anguilla australis* Rich. (the smaller one) and show that both specimens belong to *Anguilla obscura* Günther.

It would take too long to catalogue in detail all the specimens from various Museums in different parts of the world which were preserved under other names, but on investigation of numerical characters proved to belong to *Anguilla obscura*; I will merely note two specimens from Tahiti, determined by Kendall and Goldsbrough[34] as *Anguilla otaheitensis*, but which proved to be typical *Anguilla obscura* (U.S.N.M. 65731 and 65733, with vertebræ 42 + 63 = 105 and 42 + 62 = 104 respectively). I would also refer to my previously quoted work "On the Distribution of the Fresh-water Eels (*Anguilla*) throughout the World," II, 1925,[35] where several other instances are mentioned.

The chart Fig. 14 shows, by means of different signs, the occurrence of those species of short-finned eels which we have been able to distinguish by means of numerical characters. We find here that *Anguilla obscura,* which proved so admirable a subject for characterization by the statistical method, also exhibits a characteristic and natural range of distribution, throughout a zone lying between that of the temperate *Anguilla australis* forms in the south and that of *Anguilla pacifica* n. sp. which occurs north of the Equator, in the north. Altogether, the distribution of the forms into which I have, by these statistical investigations, divided the collective species *"Anguilla australis"* seems to argue strongly in favour of the delicate analysis which this method involved; the

[33] Schmidt.—La Nature, Paris, 15th July, 1927.

[34] Kendall and Goldsborough.—Mem. Mus. Comp. Zool., Harvard, XXVI, 7, 1911, p. 244.

[35] Schmidt.—Mem. Acad. Roy. Sci. et Lettres de Danemark (8), x, 4, 1925.

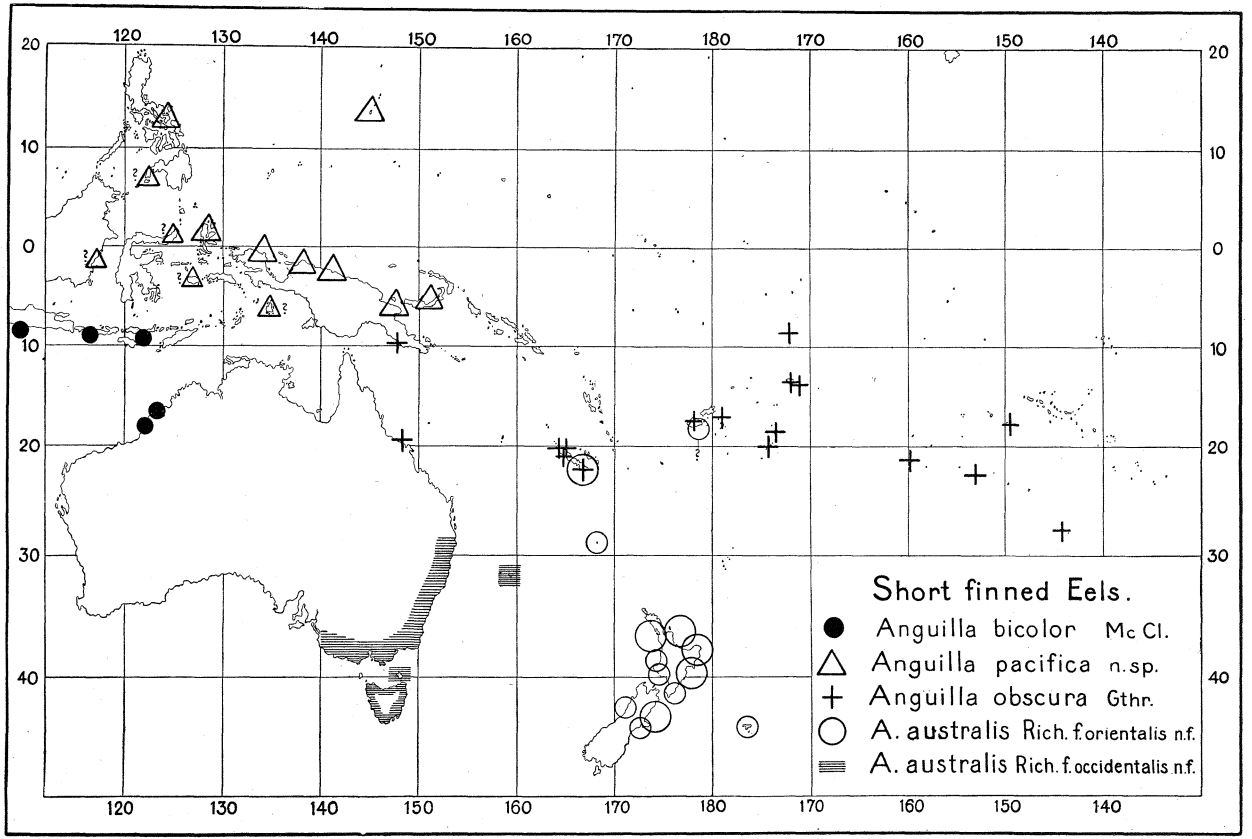


Fig. 14.—Distribution of the short-finned eels.

areas of distribution so found appear in every case natural and well founded.

In the Pacific, the species are distributed according to latitude as follows: North of, and close to, the Equator, a tropical species (*Anguilla pacifica* n. sp.), south of the Equator another tropical species (*Anguilla obscura* Günther) and south of this again the temperate *Anguilla australis* Rich., which is divided into two forms: a western, f. *occidentalis* n.f. belonging to Australia, and an eastern, f. *orientalis* in New Zealand and New Caledonia.

On the shores of the Indian Ocean, short-finned eels occur both in East Africa with Madagascar and other islands, in British India and from the northern extremity of Sumatra to north-western Australia. I have in this present work named them *Anguilla bicolor* McClelland. Up to now, I have not been able to demonstrate the existence of differences great enough to warrant division into species or forms between the populations in the western and eastern parts of the Indian Ocean; it should here be noted, however, that the material from the western part is still insufficient, and that I do not wish to take any final decision as to the nomenclature before enough material has been procured to permit of a thorough comparison of the populations of short-finned eels from the western and eastern parts of the Indian Ocean.

The short-finned eel living in the tropical part of the Pacific north of and close to the Equator I have named *Anguilla pacifica n. sp.* It is most nearly related to *Anguilla bicolor* from the Indian Ocean, but differs in having a smaller number of vertebræ, between 2 and 3 on an average, and a shorter $(a-d)$ than *Anguilla bicolor,* as will be seen from Figs. 11 and 12. The chart Fig. 14 shows where *Anguilla pacifica* has hitherto been found, *viz.* on the shores of that portion of the Pacific which is bounded by the Philippines on the west and New Guinea on the south. Owing to insufficiency of material, we cannot say how far the species extends towards the east; the most easterly finds up to now are from the island of Guam in the Marianne group and New Ireland (Neu Pommern).

In the easternmost part of the Dutch East Indies (shores of the Sea of Celebes, Banda Sea *et cetera*), also, short-finned eels are found, and I have seen a small number of specimens from these localities. They are not identical with *Anguilla bicolor* from the Indian Ocean, but seem rather more nearly related to *Anguilla pacifica*; no final decision, however, can be arrived at from the material at present available. We cannot yet say whether they breed in this Archipelago, where there are, of course, great depths, or whether the populations living there consist of individuals immigrated as larvæ from the Pacific Ocean.

Finally, we come to the short-finned eels of the temperate zone: *Anguilla australis* Rich. with its two forms *occidentalis* and

*orientalis,* the former from the Australian continent, Tasmania and Lord Howe Island, the latter from New Zealand (see Fig. 14). I have long fancied that the eels of the temperate regions (New Zealand and Australia) must have their breeding places in the neighbourhood of the tropics, as with the eels of Europe and North America, migrating northward from New Zealand and the south-east coast of Australia in order to breed. It is only since we succeeded in ascertaining the relation between the temperate *Anguilla australis* and the tropical short-finned eels like *Anguilla obscura,* that the way was open for further exploration of the life-history of *Anguilla australis.* On going through the material of short-finned eels from Oceania preserved in the museums, we found numbers of specimens which, from the very small number of vertebræ, as a rule 103, 104 or 105, were at once recognizable as *Anguilla obscura.* Among all these numerous specimens of *Anguilla obscura* from the whole long range between New Guinea and Tahiti there was one which attracted special attention. It was preserved in a collection kindly placed at our disposal for examination by the Hamburg Museum, marked No. 2415, Godeffroy, 1877, Viti Levu, Fiji. We had already seen several typical specimens of *Anguilla obscura* from Fiji with 103-106 vertebræ; this specimen, however, when photographed by the X-rays, was found to have 46 + 67 = 113 vertebræ, with an $(a - d)$ percentage of 2·1; in other words, we had here a specimen of the true temperate *Anguilla australis* Rich. taken in the tropical zone. This discovery could not but confirm my idea that the breeding places of *Anguilla australis* lay far to the north, near the tropics. On the other hand, we had only the evidence of a single museum specimen, and that an old one, while previous painful experience in several cases had taught us that museums in earlier times were not so particular about the precise locality of their finds. My endeavours were therefore directed towards the procuring of further and extensive material of short-finned eels from Fiji; up to the present, however, without result. Naturally, I also tried to obtain material from the other groups of islands which might be considered in this connection, especially New Caledonia and the New Hebrides. From the latter group I have no result as yet. Otherwise, however, as regards New Caledonia, I have in the first place seen the collection procured by F. Sarasin and J. Roux, examined by Weber and Beaufort.[36] The short-finned eels in this connection were referred by Weber and Beaufort to their collective species *Anguilla australis,* which as we have seen from our investigations, is not the same as *Anguilla australis* Rich. X-ray photographs showed that the specimens belonged to *Anguilla obscura*[37] with one exception, this being rather an intermediate form between *Anguilla bicolor* and *obscura.* None of them was *Anguilla australis* Rich. The extant collections from New Caledonia thus afforded

[36] Weber and Beaufort.—Les Poissons d'eau douce de la Nouvelle Calédonie" *in* Sarasin and Roux: Nova Caledonia, Zoologie, ii, i, 2, Wiesbaden, 1915, p. 20.

[37] The nos. of vertebræ were as follows: 104, 105, 103, 105, 105, 105, 105.

no support for the theory as to occurrence of the temperate *Anguilla australis* Rich. in the tropics. In the course of the last two years, however, some large collections of fresh-water eels from the southern part of New Caledonia, have come into my possession. These collections, for which I have to thank the keen French zoologist, M. Jean Risbec, of Noumea, proved of great importance, containing several hundred specimens of short-finned eels. The examination of these was a great surprise. We had expected to find mainly the ordinary tropical species *Anguilla obscura.* This was present, it is true; but by far the greater number belonged to the temperate form *Anguilla australis,* with the large number of vertebræ. A survey of these samples is in the accompanying table, where the average number of vertebræ is noted.

*Anguilla australis* Rich. f. *orientalis* n.f., New Caledonia, 1926-27.

| Locality. | Date. | Number of Specimens. | Average Number of Vertebræ. |
|---|---|---|---|
| Noumea .. .. .. | 26/5-19/7, 1926 | 159 | 111·57 |
| Magenta .. .. .. | Sept., 1926. | 50 | 111·84 |
| Magenta and Dumbéa | Sept., Oct., 1926. | 13 | 111·69 |
| Plum .. .. .. .. | 24/2, 1927. | 28 | 111·71 |
| Noumea .. .. .. | 11/3, 1927. | 11 | 111·45 |

The specimens from Noumea were taken in gutters, and the majority of them were transparent elvers, some of them indeed very young, from Stage V A upwards.

On considering the average number of vertebræ in our samples of *Anguilla australis* from New Caledonia, also noted in the table on pages 197-198 for the Australian and New Zealand samples, we find that they belong to the New Zealand form, which was given the name of *Anguilla australis* Rich. f. *orientalis* n.f.

Altogether, the examination of the collections from New Caledonia must be said to have largely confirmed the supposition that the temperate *Anguilla australis* Rich. has its breeding places in the neighbourhood of the tropics. Taking all the available data regarding distribution of this species (see table on p. 197 and chart, Fig. 14), it is natural to suppose that the western form (f. *occidentalis*), which inhabits the continent of Australia *et cetera,* must have its breeding place in the basin on the west of the New Caledonian submarine ridge, the eastern form (f. *orientalis*), which lives in New Zealand *et cetera,* having its breeding grounds east of the barrier in question.

Carlsberg Laboratory, Copenhagen,
November 6, 1927.