THE OPHIODERMATIDAE

(OPHIUROIDEA)

By F. JENSENIUS MADSEN
Zoological Museum, University of Copenhagen

The ophiuroids of the family Ophiodermatidae Ljungman, 1867, are distinguished by laterally inserted, tapering, rather stout arms, a continuous series of closely set oral papillae, a single series of teeth and a disk profusely covered with granules in the adult stage. The about 20 recognized genera are mainly sublittoral. Only *Bathypectinura* occurs primarily in bathyal and upper abyssal depths.

Bathypectinura H. L. Clark, 1909

The genus *Bathypectinura* was erected by H. L. CLARK (1909 : 128) for seven species formerly referred to *Pectinura* (*heros* Lyman, 1879; *tessellata* Lyman, 1883; *lacertosa* Lyman, 1883, which was selected as the type species; *conspicua* Koehler, 1897; *modesta* Koehler, 1904; and *elata* Koehler, 1906). In his new genus H. L. CLARK also tentatively included *Ophiopeza reducta* Koehler, 1907, which, however, as noted by MATSUMOTO (1915:89) is an *Ophioplax*. A single additional species, *B. gotoi,* was described by MATSUMOTO (1915).

Bathypectinura belongs with its few (3-5) rather short and adpressed arm spines to the subfamily Ophiodermatinae Matsumoto, 1915 (p. 83). It is principally distinguished by having single tentacle scales and by having the oral shields and part of the radial shields devoid of granules also when fully grown.

KOEHLER (1922 : 345), after he had examined 24 specimens of *Bathypectinura* from the Philippine region, became in doubt about the validity of most of the species. He concluded that his own *modesta* (East Indies, 330 m) and *elata* (near Canary Is., E. Atlantic, ca. 2500 m) were both the same as his *conspicua* (Sea of Bengal, 750 m). He further presumed that this species should prove identical with LYMAN's *heros* (East Indies, 1500 m), and that also LYMAN's *tessellata* (West Indies, ca. 850 m) and MATSUMOTO's *gotoi* (Japan, ca. 300 m) were synonyms thereof. Only LYMAN's *lacertosa* (West Indies, ca. 300 m) was by KOEHLER assumed specifically distinct. However, HERTZ (1927:116), when recording *Bathypectinura* specimens from the East Atlantic and Indian Ocean, simply listed all hitherto described species as synonyms of *heros*. SCHOENER (1967:75), when recording a couple of specimens from off the North East Coast of New Zealand, similarly considered *Bathypectinura* monotypic.

H. L. CLARK (1939 : 96) identified a material of *Bathypectinura* from the Indian Ocean with *conspicua* without taking any definite view on its possible synonymy with *heros*. He noted, however, that he was inclined to consider *gotoi* a distinct species, and later (1941 : 90) he recorded a West Indian material as *B. lacertosa*.

The present study of more than seventy specimens of *Bathypectinura* from twelve localities distributed from the West Indies to Japan, the whole known area of distribution, confirms HERTZ' suggestion that the species of *Bathypectinura* hitherto described have mainly been based on different age stages of one and the same species, and that although large specimens may differ slightly in the appearance of the ventral arm plates in various populations only one species, *B. heros,* can be recognized. It has further been found that also the genus *Ophiocrates,* with three nominal species, as well as one nominal species of *Ophiozonella* in reality have merely been based on different juvenile stages of this species.

Bathypectinura heros (Lyman)

Pectinura heros Lyman, 1879: 48, pl. 14, 389-391; 1882: 16, pl. 23, 7-9.
P. tessellata Lyman, 1883: 230, pl. 3, 1-3.
P. lacertosa Lyman, 1883: 231, pl. 3, 4-6.
P. conspicua Koehler, 1897: 322, pl. 7, 36-37; 1899: 37, pl. 2, 14-15.
P. heros, KOEHLER 1897: 325; 1899: 38.
P. modesta Koehler, 1904: 7, pl. 2, 4-6.

P. conspicua, KOEHLER 1904: 9, pl. 1, 1.
P. heros, KOEHLER 1904: 9.
Ophiocrates lenta Koehler, 1904: 19, pl. 4, 7-8.
Pectinura elata Koehler, 1906: 7, pl. 1, 1-3; 1907: 249, pl. 18, 1-3.
Ophiocrates secunda Koehler, 1906. pl. 1, 13-14; 1907: 253, pl. 18, 13-14.
Bathypectinura lacertosa, elata, heros, modesta, conspicua, tessellata, H. L. CLARK 1909: 129-130; 1915: 306.
B. gotoi Matsumoto, 1915: 87; 1917: 320, fig. 89.
P. elata, GRIEG 1921: 32.
B. conspicua, KOEHLER 1922: 342, pl. 77, 1-15.
B. heros, HERTZ 1927: 116.
B. conspicua, H. L. CLARK 1939: 96.
Ophiozonella brachyactis H. L. Clark, 1939: 129, figs. 61-62.
Ophiocrates secunda, H. L. CLARK 1939: 132.
Bathypectinura lacertosa, H. L. CLARK 1941: 90.
Ophiocrates intervallus Madsen, 1947: 9, fig. 3.
Bathypectinura heros, SCHOENER 1967: 77, fig. A-C.
B. heros, ROWE & MENZIES 1969: 533.

Materials (d.d. = disk diameter)

West Atlantic

North of Oriente Province, Cuba. 2350 m. ("Atlantis" Exp., 1938). – 2 specimens, d.d. 25-28 mm.

Off North Carolina, 32°50′N, 76°08′W. 2050-1920 m, mud. ("Eastward" St. 20093, 1972). – 21 specimens, d.d. 23-42 mm.

East Atlantic

"Galathea" St. 52. Bay of Guinea, 1°42′N, 7°51′E. 2550 m, muddy clay. – 14 specimens, d.d. 12-45 mm.

"Galathea" St. 65. Bay of Guinea, 2°17′S, 8°10′E. 2770 m, bluish clay. – 2 specimens, d.d. 41-42 mm.

"Galathea" St. 99. Off Angola, 8°40′S, 11°10′E. 2690 m, yellowish clay. – 29 specimens, d.d. 7.5-44 mm.

Near Cape Verdes. 2580 m. ("Valdivia" St. 32, 1898). – 1 specimen, d.d. 14 mm.

Off Morocco. 2055 m. ("Michael Sars" St. 25, 1910). – 1 specimen, d.d. 23 mm.

Indian Ocean

Gulf of Aden. 1295 m. ("John Murray" Exp., St. 33, 1933). – 1 specimen, d.d. 20 mm.

Maldive area. 494 m. ("John Murray" Exp., St. 145, 1934). – 1 specimen, d.d. 43 mm.

West Pacific

"Galathea" St. 443. Mindanao Sea, 8°48′N, 124°09′E. 1500 m, mud. – 3 specimens, d.d. 10-33 mm.

Bali Sea, East Indies, 8°30′S, 114°38′E. 450 m, mud. (Th. Mortensen's Java – S. Africa Exp., St. 11, 1929). – 1 specimen, d.d. 24 mm.

Sagami Sea, Japan. (Seitaro Goto coll., ca. 1900). – 1 specimen, d.d. 42 mm.

The 77 specimens of *Bathypectinura* at hand range in disk diameter from about 7 to 45 mm and include specimens agreeing closely with any previously figured ones. The largest size recorded in the literature is 53 mm and the smallest 9 m in d.d. Smaller specimens (d.d. 5-13 mm) have been recorded as species of *Ophiocrates* and *Ophiozonella.*

The disk in the preserved specimens is rather flat, usually pentagonal and somewhat incurved interradially, but circular in those few which have the stomach filled with organic detritus.

KOEHLER (1922: 350) considered Lyman's *lacertosa* distinct from *conspicua* (= *heros*) on account of the "very short arms" which also LYMAN, 1883: 231, had regarded a specific characteristic, and he further wondered why MATSUMOTO compared *gotoi* only with this short armed *lacertosa* and not with the other species with elongated arms like itself. It is a mistake, however, that *lacertosa* is especially short armed. Its arms were by LYMAN recorded as $3\frac{1}{2}$-4 × d.d., e.g., 135 mm for a specimen with a d.d. of 35 mm, and MATSUMOTO (1915: 87) recorded in *gotoi* an arm length of 195 mm for a d.d. of 50 mm, likewise about 4 × d.d. However, in both cases the length stated have probably referred to arms with the distal part lost. The specimen at hand from the Sagami Sea, d.d. 42 mm, corresponds to those described by MATSUMOTO and has arms which have been more than 230 mm long when intact, thus at least $5\frac{1}{2}$ × d.d. Moreover, H. L. CLARK (1941: 90) recorded the arm length in some West Indian specimens identified as *lacertosa* as 3-7 times a d.d. of 9-35 mm.

A relative arm length (measured from the center of disk), increasing from 3 × d.d. in the small specimens less than 10 mm in d.d. to 7 × d.d. in some of the large ones, is also found in the present material. The arms generally appear to be about 5 × d.d. in medium-sized specimens (d.d. about 25 mm) and $5\frac{1}{2}$-6 × d.d. in large specimens (d.d. 40-45 mm). The distal fine part of the arms is always lost and the figures are therefore only

approximate and may be too small. The fairly intact arms in two rather small specimens from Galathea St. 443, d.d. 10 and 15 mm, thus must have been respectively 5 and 7 × d.d. in life.

The width of the arms at base changes with age from about half the disk radius in specimens with a d.d. about 10 mm, to about a third (to a fourth) the disk radius in the large ones. The arms are roundish in cross section in specimens up to about 10 mm in d.d. but with growth become highly arched in their proximal part (rounded equi-triangular in cross section). The flatter arm mentioned by LYMAN (1883: 231) as one of the characters distinguishing his *tessellata* (d.d. 17.5 mm) from his *heros* (d.d. 22 mm) and *lacertosa* (d.d. 35 mm) is explained by the different sizes.

The granulation. The disk is covered with thin, overlapping, small scales which with age become completely hidden by a uniform, close granulation, and the extent to which this granulation is developed is another feature which has been supposed to distinguish different species. The type specimen of *heros,* d.d. 22 mm, had the disk evenly covered with granules except on the oral shields, adoral plates, radial shields, the interradial marginal scales dorsally and a few other scattered disk scales. The slightly smaller type specimen of *tessellata,* d.d. 17.5 mm, had also numerous more or less naked disk scales ventrally, while the larger type of *lacertosa,* d.d. 35 mm, was completely covered with granules except on the oral shields and parts of the radial shields and the adoral plates. Finally, in the large type specimen of *gotoi,* d.d. 50 mm, the radial shields too were almost completely covered with granules and only the oral shields and part of the adoral plates left exposed.

The smallest specimens examined, d.d. 6.5-7.5 mm, have the granules developed in single series at the borders of the disk scales, which gives the disk a nicely reticulated appearance (Fig. 1 a), and specimens up to about 10 mm in d.d. may be similarly granulated. With growth, first more and more of the dorsal disk scales and slightly later also more and more of the ventral ones become wholly covered with granules (1 d-e). Specimens about 15 mm in d.d. have the majority of the dorsal disk scales completely granule covered while the majority of the ventral scales are still mostly naked. Dorsally the larger interradial marginal scale is the last to be completely covered with granules, usually being still exposed in specimens 25-30 mm in d.d. and sometimes even in specimens 40 mm in d.d. Ventrally the scales adjoining the oral shield are the last to be granule covered, and a few of them may remain more or less naked in the largest specimens examined. A single larger naked scale (a supplementary oral shield) may be found in one or more of the interradii. After the specimens have reached a size of about 10 mm in d.d., granules appear gradually on the distal interradial part of the adoral plates, the proximal exposed part of the oral ossicles and eventually also on the proximal lateral arm plates.

The oral shields always remain devoid of granules except for some scattered marginal ones. Also a distal but with age continually diminished area on the radial shields and the adradial part of the adoral plates remains naked even in the largest specimens examined.

The granule covered marginal part of the scales and plates is markedly thinner than the exposed naked part.

MATSUMOTO (1915: 87) noted as one of the characters supposed to distinguish his *gotoi* from *lacertosa* that its granulation was coarser, the granules numbering 4-5 instead of 6-8 per mm. The number of granules per mm depends, however, primarily on which area of the disk the count is made. Further, the granules become slightly larger with age. The large specimens from "Galathea" Sts. 52 and 99, d.d. 40-45 mm, have near the dorsal disk margin where the granulation is the coarsest about 5 granules per mm while there are 9 centrally on the disk. Ventrally the granulation is on the whole sparser than dorsally, and the granules are of about the same size as the more central dorsal ones. A smaller specimen from "Galathea" St. 99, d.d. 18 mm, has about 7 granules per mm near the dorsal margin and about 8 centrally. The specimen from the Bali Sea, d.d. 24 mm, has about 8 granules near the dorsal margin, and 9-10 centrally and ventrally. Ten granules per mm is the highest number counted on any of the examined specimens, including the smallest ones at hand.

The arm plates. The proximal lateral arm plates become with growth almost restricted to the ventral side, simultaneously with the increasing size of the dorsal arm plates. The arm spines are borne on a ridge which runs somewhat inside the thin distal edge and becomes very pronounced in some old specimens (Fig. 1 n and p).

The proximal dorsal arm plates cover almost the whole dorsal side when they are fully developed,

as in specimens about 20 mm in d.d. or larger. Their proximal and distal margins are nearly straight, with the distal one slightly wider and just overlapping the succeeding. The proximal dorsal arm plates are in medium-sized specimens about twice as wide as long (Fig. 1 f) and with age gradually become relatively wider so that in the largest specimens they are about 4 times as wide as long (1 q). Their shape in cross section change at the same time from half circular to an inverted V-shape (1 s). Some of the proximal arm plates in the larger specimens, d.d. 30 mm or more, are often found broken into two halves and in the case of senescent specimens may be fragmented into several irregular pieces (2 h).

The still not fully developed proximal dorsal arm plates found in specimens less than about 15 mm in d.d. are fan-shaped like the distal ones in the arms of larger specimens, and in the smallest specimen described, d.d. 6.5 mm, they are still all separated by the lateral ones (1 a).

The proximal ventral arm plates are when still abortive rather pentagonal in shape and in specimens up to about 7 mm in d.d. separated by the lateral arm plates (1 b) but become contiguous in the specimens about 10 mm in d.d. (1 c). The appearance of the first ventral arm plate changes gradually from subpentagonal in the small specimens to broadly hexagonal, up to four times as broad as long, in the larger ones, the plate becoming with growth more and more vertically orientated and its proximal part within the mouth angle relatively diminished. The following ventral arm plates are in the medium-sized specimens rather more subhexagonal or suboctagonal (1 d) than subpentagonal in shape and about half as wide as the arm. The distal margin is regularly curved outwards, the lateral sides are deeply incurved for the tentacle pores, and the proximal margin in contact with the preceding plate is more or less incurved to either side by the lateral arm plates.

With growth the first pair of arm tentacle pores increases relatively much in size and the whole lateral side of the second ventral arm plate then becomes incurved by the pore. This is to a lesser extent also the case with the third ventral arm plate and possibly to a certain extent with the fourth too (Fig. 1 n). The following ventral arm plates within the disk area and in the proximal part of the free arm usually become rather broadly octagonal in shape, and in specimens of about 40 mm in d.d. almost twice as wide as long. In the larger specimens the successive ventral arm plates are usually in fairly broad contact with each other, and in some large ones the distal margin may be slightly incurved in the arm midline.

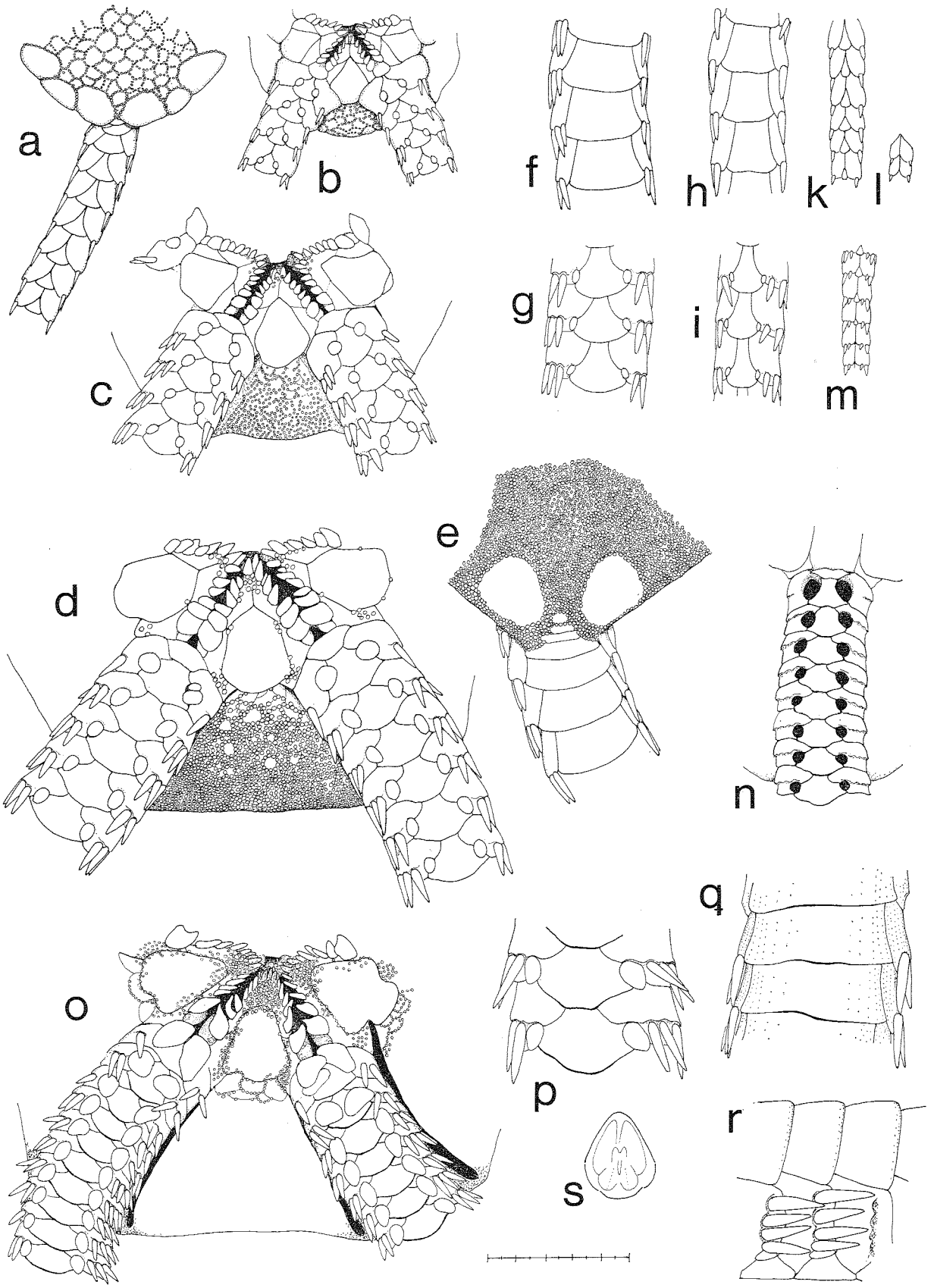
However, in some other large specimens the proximal ventral arm plates may retain a rather juvenile appearance, being almost as long as wide, with a distinctly curved distal margin and often with the proximal part incurved by the lateral arm plates to such a degree that it appears like a handle on the other part of the plate (2 f).

In some specimens, particularly those from the Indian Ocean, the proximal part of the ventral arm plate is thickened in the midline (this part taking the appearance of a keel), while the side parts are very thin, and like depressed when seen in oral view (2 l).

The number of arm joints included in the disk, which incorrectly has been used as a specific character, is as follows: d.d. about 10 mm: 2; d.d. about 15 mm: 3; d.d. about 20 mm: 4; d.d. 25-30 mm: 5; d.d. more than 40 mm: 6-7. The large specimens also have a few abortive dorsal arm plates within the disk margin.

The arm spines. The number of arm spines in medium-sized specimens is usually 3, falling to 2 distally in the arms, and specimens less than 10 mm in d.d. still have only 2 arm spines on most joints. Large specimens may bear 4 spines on a varying number of the proximal arm joints (e.g., the first 20-22 joints in a specimen d.d. 30 mm), and a few specimens may bear 5 spines on one or more joints. Independent of the size of the specimens the first arm joint within the disk area may bear 1, 2, or 3 spines. Five arm spines is also the largest number recorded in *Bathypectinura* by other

Fig. 1. *Bathypectinura heros* (Lyman). The gradual changes in appearance with growth. a-b, a very young specimen, d.d. 7.5 mm, from the East Atlantic, "Galathea" St. 99; c, a young specimen, d.d. 12 mm, from the East Atlantic, "Galathea" St. 52; d-m, a medium-sized specimen, d.d. 17 mm, from "Galathea" St. 99; f-g, arm joints nos 13-15, and h-i, nos 33-35, from the dorsal and the ventral side; k-l, dorsal side and m, ventral side of distal part of arm; n, arm joints within the disk area with arm spines and tentacle scales removed of a specimen, d.d. 44 mm, from "Galathea" St. 99; o-s, a large and presumably old specimen, d.d. 42 mm, from "Galathea" St. 99; o, ventral side but the granules covering the interradial area not drawn; p-r, arm joints nos 18-19; s, cross-section at joint no. 20.
Scale: Figs. a-m and p-r: 5 mm; Figs. n-o and s: 10 mm.


a
b
c
d
e
f
g
h
i
k
l
m
n
o
p
q
r
s

authors, except H. L. CLARK (1909: 129) who gave the number as up to 6. However, when the arm is examined from the side the tentacle scale may easily inadvertently be included in a counting of the arm spines.

HERTZ (1929: 116) thought that there was a reduction in the number of arm spines simultaneously with the relative reduction with age in the size of the lateral arm plates. This, however, must be a misinterpretation of the small and somewhat varying number of arm spines in even the largest specimens.

The proximal arm spines are in most of the larger specimens up to about as long as the joint, subcylindrical, almost straight and usually with a sharpened point (Fig. 1 d), but they may also as in the specimen from Sagami Sea and some of those from off North Carolina be only slightly more than half as long and are then often blunt (2 k). The short arm spines in a somewhat aberrant, perhaps senescent specimen, d.d. 41 mm, appear abraded (2 g). The arm spines are in most specimens rather subequal in length, the ventral one usually being slightly longer and stouter while the median one is slightly smaller.

In the small specimens the arm spines are generally relatively shorter, about half as long as the joint. The "longer and differently placed arm spines" mentioned by LYMAN (1883: 232) as a character distinguishing *lacertosa* from *heros,* and the greater length of the arm spines noted by KOEHLER (1906: 8) as one of the characters distinguishing *elata* from *heros* thus are in both cases accounted for by the larger size of the described specimens.

The tentacle scale. The conspicuous single tentacle scale is flat and roundish or more or less elongate oval (egg-shaped) in outline. Scattered ones in a few specimens are abnormal in being shaped like the arm spines. The scales are hinged on the lateral arm plates at the abradial side of the pores of the first arm joint and on the adoral side of the following pores. Some large specimens may at the first pair of arm pores have an additional, opposite and very low scale on the ventral arm plates. The first pair of tentacle scales increases in size with age so that eventually in most large specimens the scales touch each other in the arm midline besides reaching somewhat over the mouth slit. At the same time they become rather irregular in outline, and they may be doubled at one or more of the pores (1 o). Also the second and possibly third and fourth pair of arm tentacle scales may become somewhat enlarged with age. In some large specimens the following proximal tentacle scales become almost as long as the joints (or about the length of the arm spines) but usually, and at least in all the younger specimens, they are much smaller.

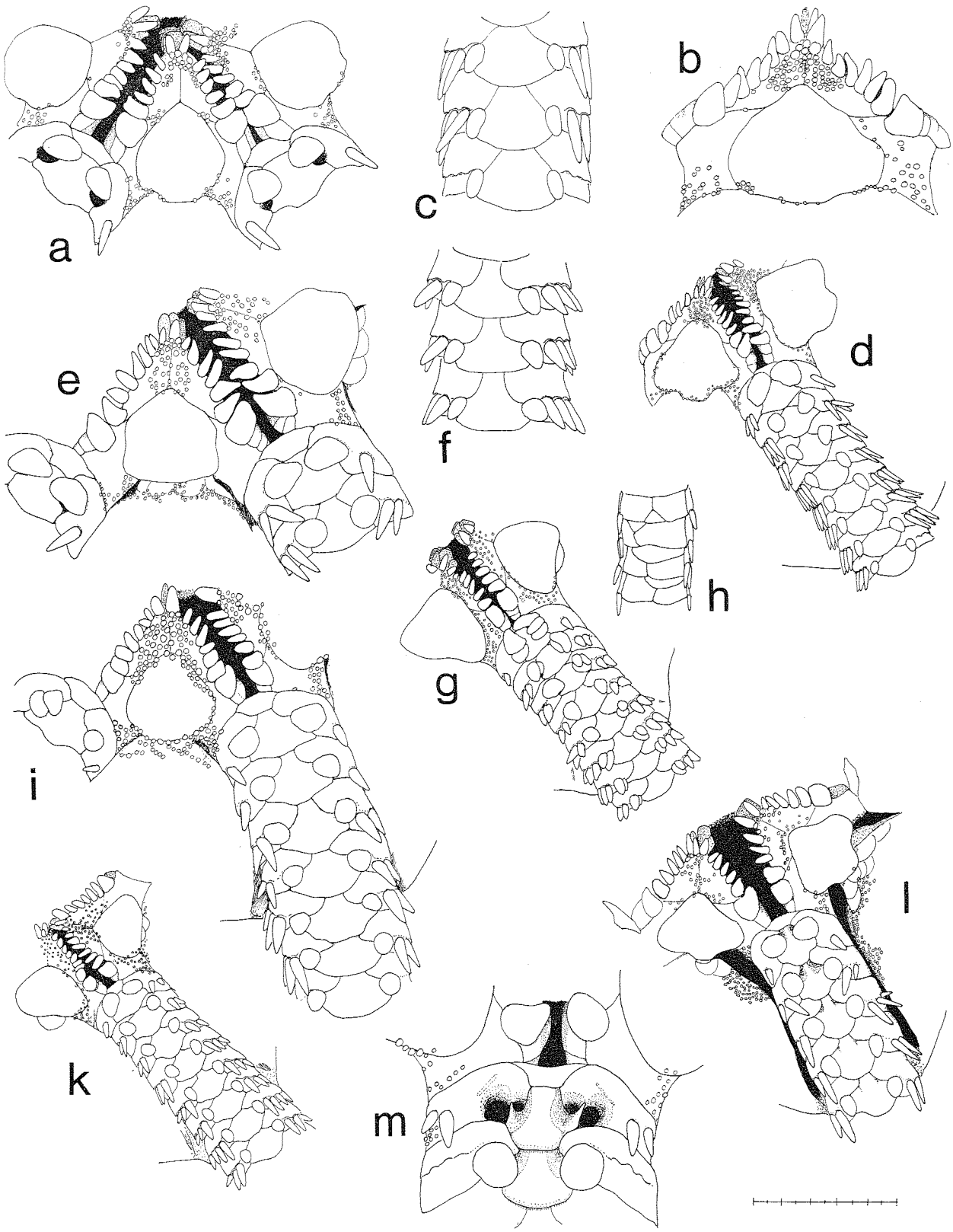
One large (possibly senescent) specimen, d.d. 42 mm, from the otherwise normal material from North Carolina is aberrant in having the tentacle scales doubled and sometimes even trebled at many of the arm pores also far out on the arms (2 g).

Extra "pores". Extra pairs of smaller pores between the first 4-6 succeeding arm plates were noted by KOEHLER (1897: 324) as found in his *conspicua* from the Bay of Bengal and (1922: 346), although less developed, in part of his Philippine specimens, independent of whether large or only medium-sized. LYMAN (1883: 231) had mentioned "Indentions, but no pores, between the first four or five lower arm-plates" in his *lacertosa* from the West Indies.

KOEHLER's figures (1896: pl. 7, 37 and 1899: pl. 2, 15) show these "pores" as openings between successive ventral arm plates and the adjoining lateral one. Various other ophiodermatids possess similar extra pore pairs proximally in the arms, bordering the lateral arm plates as shown in *Bathypectinura* by KOEHLER or formed by a pair of invaginations in the proximal border of the ventral arm plate. The presence or absence of such extra pores may be a constant specific character

Fig. 2. *Bathypectinura heros* (Lyman). Examples of the variation in appearance. a, a medium-sized specimen, d.d. 23 mm, from the East Atlantic, "Galathea" St. 99; b, a full-grown specimen, d.d. 42 mm, from the East Atlantic, "Galathea" St. 52; c-d, a full-grown specimen in which the ventral arm plates are only slightly incurved by the lateral ones, d.d. 45 mm, "Galathea" St. 52; c, arm joints nos 19-21; e, a West Atlantic specimen, d.d. 25 mm, from off Cuba; f, the ventral arm plates nos 13-15 of a West Atlantic specimen, d.d. 39 mm, from off North Carolina; g-h, a large and aberrant, probably senescent specimen, d.d. 42 mm, from the West Atlantic off North Carolina; h, arm joints nos 16-19; i, a West Pacific specimen from the Bali Sea, d.d. 25 mm; k, a West Pacific specimen from Sagami Sea, Japan, d.d. 42 mm; l, a medium-sized specimen, d.d. 20 mm, from the Indian Ocean, Gulf of Aden, showing keeled proximal ventral arm plates; m, the extra pores developed between the ventral arm plate and the lateral plates of the first arm joint in a large specimen, d.d. 43 mm, from the Indian Ocean near the Maldives.

Scale: Figs. a-c, e-f, i and l-m: 5 mm; Figs. d, g-h, and k: 10 mm.


a
c
b
e
f
d
h
g
i
k
m
l

in the ophiodermatids, but may also (H. L. CLARK 1909: 114) be just as inconstant as the presence or absence of a supplementary oral shield.

In the present material a tendency to such extra "pores" is seen only in the two specimens from the Indian Ocean, on the 2-4 proximal-most joints in the smaller specimen (d.d. 20 mm) and on the 2 proximal-most joints in the larger one (d.d. 43 mm). In the smaller specimen there are no real pores, but the proximal part of the ventral arm plates in question is markedly pressed in to either side of the prominent keel-like median part and here very or even extremely thin (2 l). In the larger specimen, however, there are actually gaps in the ventral arm plates in these places in some joints (2 m). In the present material the "extra pores" are found not between successive ventral arm plates as indicated by KOEHLER's drawings from 1896 and 1899 and confirmed by a photograph (1922, pl. 77, 1), but between the proximal part of the ventral arm plate and the adjoining lateral one, in which place the "extra pores" also appear developed in the Philippine specimen shown by KOEHLER in another photograph (1922, pl. 77, 2). The place for the possible "extra pores" thus appear less fixed in the present species than in some other ophiodermatids.

The radial shields, which are just separated by a wedge of scales, are in the smallest specimens transversely oval or rounded triangular (1 a). They become with growth gradually more elongated radially and in the largest specimens rather irregularly battleaxe-shaped, with a narrow proximal part and a widened distal part along the disk margin. Their size varies from half to a third the disk radius. When denuded the radial shields rather resemble elm seeds, the thin marginal part which has been granule covered appearing like the wings of the seed (the thicker part without granules).

The oral shields are usually rounded triangular, varying from $^2/_3$ as wide as long (this mainly in the smaller specimens) to $1^1/_3$ as wide as long, but may also show considerable diversity even in the different radii in the same specimen, sometimes being slightly incurved laterally and sometimes having a broad outwards curved peak distally. In the smallest specimens where the oral shields are still in contact with the lateral arm plates their shape is rather pentagonal. Regardless of the size of the specimens the oral shields are about as long as two arm joints.

In several specimens the oral shield in one or more interradii is adjoined by a large naked scale (2 k) which may appear exactly like the supplementary oral shield found regularly in some other ophiodermatids, but most frequently the oral shields are adjoined by a number of scales only slightly larger on average than the other disk scales.

The adoral plates appear in the juvenile specimens (d.d. less than 10 mm) as a narrow plate which proximally reaches almost to the tip of the oral shield and distally to its lateral corner (1 b). With growth the adoral plates also become exposed between the oral shields and the first lateral arm plates, and the proximal visible part becomes somewhat displaced in distal direction so that in the largest specimens it usually appears about a third to half way from the tip of the oral shield (2 d). When the oral shield is exceptionally broad it may cover the adoral plate to such an extent that only a narrow strip is visible proximal to the lateral arm plate.

The exposed part of the oral plates is in the juvenile specimens triangular and about half as long as the oral shields, and in the largest specimens relatively slightly smaller and often more rectangular than triangular.

The peristomial plates are small and single as, e.g., in *Ophiarachna incrassata.*

The oral papillae number from 5 on each side of the jaw in the small specimens (1 b) to about 10 in the large ones (1 o and 2 d). In the juvenile specimens the distal oral papilla which adjoins the adoral plate and protects the second mouth tentacle is flat and rounded and about the size of the first arm tentacle scale, while the other four oral papillae, borne on the exposed part of the oral plates, are conical and pointed.

The originally single oral papilla at the adoral plate increases in size with growth so that it almost keeps up with the first arm tentacle scales and often like these becomes rather irregular in shape. Distal to this papilla a second smaller one is added in the medium-sized specimens, and, finally, in the large specimens a somewhat irregular and possibly granulate arrangement of papillae develops within the preoral cavity around the mouth tentacle pore and is partly visible in oral view.

The oral papillae on the oral plate increase to 7(8) in number in the large specimens. With age the distal one (or more) usually become rather flat and rounded, somewhat like the papilla at the adoral plate, but may also remain conical and

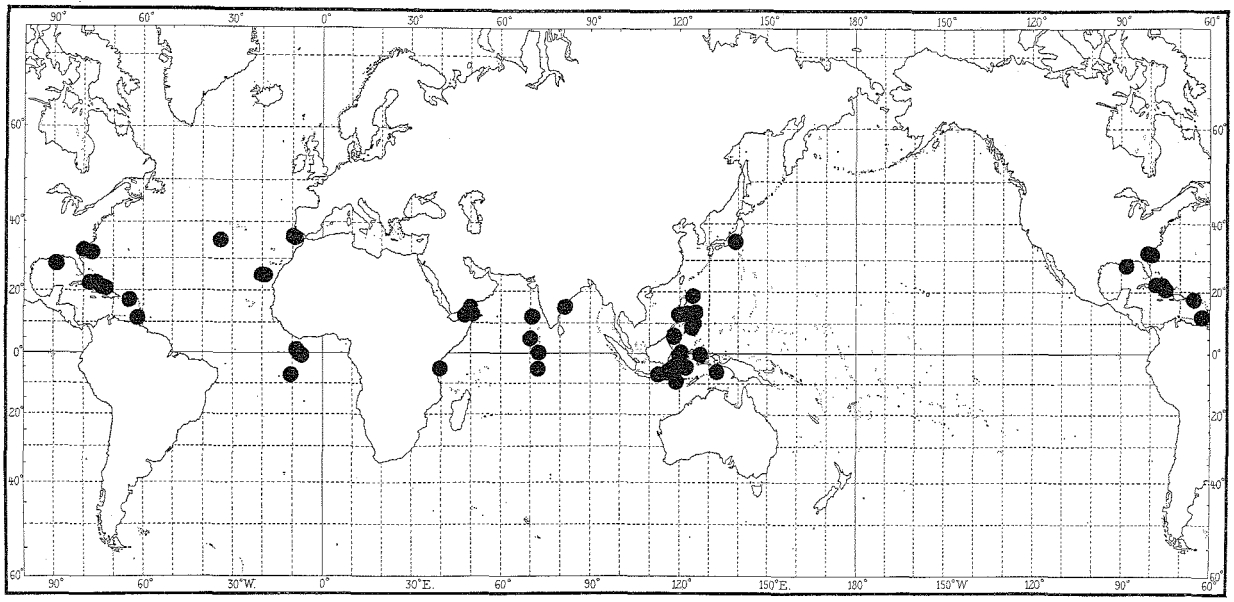


Fig. 3. The known distribution of *Bathypectinura heros* (Lyman).

pointed or possibly become rather hook-shaped (1 o).

Apically the jaws in the juvenile specimens bear a single conical papilla slightly larger than the proximal oral papillae or a pair of smaller ones (1 b). The jaw tips, which in the younger specimens are level with the oral disk, become with growth displaced somewhat within the oral cavity and at the same time the number of apical papillae increases, up to about 10 in the largest specimens (1 o).

The teeth, which are borne on a single, entire maxillar plate, number up to 7 in the largest specimens and vary in shape from rounded quadrangular to irregularly conical. The ventral tooth in medium-sized specimens and most of the teeth in very large specimens are often cleft.

A reconsideration of other deep-sea ophiuroids with single tentacle scales has revealed that all three nominal species of the genus *Ophiocrates* and one nominal species of *Ophiozonella* have merely been based on juvenile *Bathypectinura* specimens. *Ophiocrates* was hitherto referred to the Ophiolepididae or the Ophioleucidae, and *Ophiozonella* otherwise belongs to the Ophiolepididae.

The type species of *Ophiocrates, O. lenta* (KOEHLER 1904: 19), was based on an East Indian specimen, d. d. 8 mm, taken at a "Siboga" station together with larger ophiurans which were recorded as *Pectinura conspicua* and *P. heros*. It is only distinguished from these in its juvenile condition: the arm plates not yet fully developed, the dorsal ones all rather narrow and fan-shaped and the ventral ones triangular, only 2 arm spines and only scattered granules marginally on the disk scales.

Ophiocrates secunda was described by KOEHLER (1906: 14) on three specimens (d. d. 13 mm, 10 mm, and one smaller) from two dredgings near the Canary Islands, one of which also yielded several larger specimens of *Pectinura elata*. It represents that growth stage of *B. heros* in which the dorsal side of the disk has become profusely granulated while the ventral scales still bear only marginal granules, and in which the proximal dorsal arm plates are still rather fan-shaped.

Ophiocrates intervallus was erected by myself (MADSEN 1947: 9) on a single specimen (d. d. 6.5 mm) from off Morocco. It represents a very young stage of *B. heros*, the dorsal and ventral arm plates still all being rather triangular and separated by the lateral arm plates, granules developed only marginally on the disk scales and only the first arm joint fully within the disk area.

Ophiozonella brachyactis was described by H. L. CLARK (1939: 129) on 4 specimens, d. d. 7-10 mm, from two dredgings in the area of the Arabian Sea. CLARK further (1939: 132) identified 3 other specimens, d. d. 5-8 mm, with *Ophiocrates secunda* and noted the "extraordinary resemblance" between the two species, adding: "It is hard to believe they belong in different families".

The figures of *Ophiozonella brachyactis* show a juvenile *B. heros* at that stage in which the dorsal arm plates are still fan-shaped, the granulation

still very limited, and the adoral shields still about as long as the oral shield. The adoral shields, however, are fully separated by the oral shields, and this rules out the reference of the species to *Ophiozonella* where the adoral shields are joined proximally. Actually CLARK's figures of *brachyactis* agree closely with those KOEHLER had given of the type species of *Ophiocrates, O. lenta.*

Part of CLARK's material of both *Ophiocrates secunda* and *Ophiozonella brachyactis* were taken together with larger ophiurans which he recorded as *Bathypectinura conspicua* and this supports the conviction that they are merely juveniles of that species (= *B. heros*).

Bathypectinura conspicua (= *heros*) was by KOEHLER (1922: 348) considered a rather polymorphic species which assumption, however, may have mainly been due to its somewhat changing appearance with growth. When equal-sized smaller specimens are compared the variation in the external characters appears insignificant throughout the wide range of the species, while when large specimens are considered some slight diversities, especially in the shape of the proximal ventral arm plates, are found both in specimens from the same population and in specimens from different regions; particularly some populations from the northern Indian Ocean and Philippine region appear distinguishable in this respect.

The colour of *Bathypectinura heros* when alive is the pale red or yellowish common to most deep-sea ophiuroids. The alcohol preserved specimens are of the usual greyish white appearance.

A few stomach contents were examined and found to be made up of a mainly undefinable organic detritus, in one stomach with numerous yellowish cells, in others including a few foraminiferans (globigerinas and minute sand-incrusted forms), some chitinous remains which look like hydroid stolons, traces of crustaceans?, a spine of a minute echinoid, and in one stomach two cone-shaped, 0.7 mm large, gelatinous planktonic larvae.

The geographical distribution of *B. heros* (Fig. 3) is the one common to many mud-dwelling bathyal-upper abyssal species, viz. the main Atlantic, Indian Ocean and Western Pacific within 40°N and 40°S. The known range of depth is 240 to 2960 m.

SUMMARY

Bathypectinura, the only known deep-sea genus of the ophiuroid family Ophiodermatidae, has been studied on the basis of a material from all three oceans. Only a single species, *B. heros* (Lyman), with an Atlantic-West Pacific, bathyal-upper abyssal distribution is recognized. The gradual change in the external appearance with growth is described and it is shown that all three nominal species of Koehler's *Ophiocrates* and one nominal species of *Ophiozonella, O. brachyactis* H. L. Clark, merely represent different juvenile stages.

LITERATURE

CLARK, H. L., 1909: Notes on some Australian and Indo-Pacific echinoderms. – Bull. Mus. comp. Zool. Harv. **52**, 7: 109-135.

– 1915: Catalogue of Recent Ophiurans. – Mem. Mus. Comp. Zool. Harv. **25**, 4: 1-376.

– 1939: Ophiuroidea. – Scient. Rep. John Murray Exped. **6**, 2: 29-136.

– 1941: The echinoderms (other than holothurians). Rep. Atlantis Exped. to the West Indies. – Mem. Soc. Cubana Hist. Nat. **15**, 1: 1-54.

GRIEG, J., 1921: Echinodermata. – Rep. scient. Results Michael Sars N. Atlant. Deep-Sea Exped. **3**: 1-44.

HERTZ, M., 1927: Die Ophiuroiden der deutschen Tiefsee-Expedition, 1. – Wiss. Ergebn. dt. Tiefsee-Exped. "Valdivia" **22**, 3: 57-122.

KOEHLER, R., 1897: Echinodermes recueillis par l'"Investigator" dans l'Océan Indien. – Annls Sci. nat., Zool. (8), **4**: 277-372.

– 1899: An account of the deep-sea Ophiuroidea collected by the Royal Indian Marine Survey Ship "Investigator". – Echinoderma of the Indian Museum. Pp. 1-76.

– 1904: Ophiures de mer profonde. – Siboga Exped. **14a**: 1-176.

– 1906: Description des ophiures nouvelles recueillies par le Travailleur et le Talisman. – Mem. Soc. Zool. France **19**: 5-34.

– 1907: Ophiures. – Expéd. scient. Travailleur Talisman **8** (1906): 245-311.

– 1922: Ophiurans of the Philippine Seas. – Bull. U. S. natn. Mus. **100**: I-X, 1-486.

LYMAN, TH., 1879: Ophiuridæ and Astrophytidæ of the "Challenger" Exped. II. – Bull. Mus. comp. Zool. Harv. **6**, 2: 17-83.

– 1882: Report on the Ophiuroidea. – Rep. Scient. Results Voyage Challenger (Zool. 5) **14**: 1-386.

– 1883: Report on the Ophiuroidea (of the "Blake"). – Bull. Mus. comp. Zool. Harv. **10**, 6: 227-287.

MADSEN, F. JENSENIUS, 1947: The echinoderms collected by the "Skagerak" Expedition in the Eastern Atlantic. – Göteborgs K. Vetensk. o. VitterhSamh. Handl. (6)B, **5**, 7: 1-16.

MATSUMOTO, H., 1915: A new classification of the Ophiuroidea, with descriptions of new genera and species. – Proc. Acad. nat. Sci. Philad. **47**: 43-92.

– 1917: A monograph of Japanese Ophiuroidea, arranged according to a new classification. – J. Coll. Sci. imp. Univ. Tokyo **38**, 2: 1-104.

ROWE, G.T. & R.J. MENZIES, 1969: Zonation of large benthic invertebrates in the deep-sea off the Carolinas. – Deep-Sea Res. **16**: 531-537.

SCHOENER, A., 1967: Occurrence of *Bathypectinura* (Ophiuroidea) in New Zealand waters. – Trans. R. Soc. N. Z., Zool. **10**, 9: 77-80.

Issued 15. Dec. 1973. (600. 210)