ON A NEW SPECIES OF *GAMMARUS* (*G. TIGRINUS*) FROM DROITWICH DISTRICT

By E. W. Sexton, F.L.S.

With an Appendix by L. H. N. Cooper, D.Sc., F.I.C.

From the Plymouth Laboratory

(Plates IV–VI)

The new species of *Gammarus* here described was first noted in 1931 by Prof. H. Munro Fox, to whom I am indebted for the opportunity of examining it. He found it in abundance in the Droitwich district, living in the brackish waters of the River Salwarpe near the town, in the Canal, and in Wyken Slough near Coventry.

Droitwich is an inland town in Worcestershire, situated on the Salwarpe, a tributary of the River Severn. It is famous for its natural alkaline brine springs, and it is these which make the waters of the district saline.

In August 1938 a quantity of fresh material was collected by Mr G. M. Spooner and Miss M. Mare, who visited several localities in Worcestershire, Warwickshire, and north Gloucestershire. The species was found in numbers at Wyken Slough and at Droitwich (River Salwarpe), and in small numbers in the River Avon at Tewkesbury. The two former localities were already known to Prof. Munro Fox as haunts of *Gammarus tigrinus*. Tewkesbury was visited because of the occurrence of some unknown amphipods in a collection made by Mr G. I. Crawford in 1935. In the light of the fresh material obtained, these specimens are now recognized as the young of *G. tigrinus*. No new localities were discovered. Those visited are listed in the following table, which also gives the occurrence of the only other species of *Gammarus* collected, namely, *G. pulex*.

Locality	*G. tigrinus*	*G. pulex*
River Chelt, Gloucester-Tewkesbury road	o	Abundant
River Avon, Tewkesbury	Sparingly	Scarce
River Arrow, Alcester	o	Scarce
Stratford Canal, north-west of Stratford-on-Avon	o	o
Wyken Slough, north-east of Coventry	Abundant in the lake and connecting streams	o
Oxford Canal, near the above	o	Scarce
River Blythe, Patrick Br.	o	o
Earlswood Reservoir, Canal on north-east side	o	o
Earlswood Reservoir, outflowing stream	o	Numerous
Droitwich, River Salwarpe at exit from town	Abundant	o

(o = species looked for and not found.)

Samples of the water at Wyken Slough, at Droitwich, and at Tewkesbury were taken, and analyses made by Dr L. H. N. Cooper (see Appendix, p. 549). The two former have a high mineral content of peculiar composition, and the latter was found to contain a higher quantity of dissolved matter than is usual in rivers of comparable size.

Mr Spooner supplies the following data on the habitats in which he collected *G. tigrinus*. At Tewkesbury the species was found patchily, at the edge of the river among leaves, roots, and debris around the base of *Glycera aquatica** plants. Here corixids were abundant and *Asellus* common. The few specimens of *Gammarus pulex* obtained were apart from the patches of *G. tigrinus*. Wyken Slough is a shallow lake of about 5 acres extent lying in a hollow on the course of an upper branch of the River Sowe, a tributary of the Avon. It marks a point where Carboniferous, Permian, and Upper Trias strata abut. The bottom consists of black mud, but there is no lack of vegetation round the edges, and the fauna is rich. *G. tigrinus*, *Potamopyrgus jenkinsi*, and a corixid were among the dominant species. The former was sieved in quantity from growths of *Myriophyllum spicatum** and roots of *Oenanthe*: it occurred all round the lake and in both the inflowing and outflowing streams. The River Salwarpe, at the point where the collection was made (on the west side of Droitwich), is a shallow and fairly fast-flowing stream, with a stony bottom deficient in vegetation. The *Gammarus* were collected in numbers from the undersides of stones and bricks lying in the stream. *Potamopyrgus jenkinsi* was present in great abundance—in one place accumulated in such numbers as to form a bottom deposit, in which many *Gammarus tigrinus* were sheltering.

The *Gammarus* collected in the above localities in August were brought back to Plymouth alive and kept under observation in the laboratory. Further consignments of living material were sent by Prof. Munro Fox in November and December 1938.

All the *Gammarus* species which have been studied so far at Plymouth show great adaptability to changes of salinity, provided only that the changes are made very gradually and extended over a considerable period of time. A sudden transference from one medium to the other causes instant death. By working in this way, and with the young rather than with the adult, I have been able to bring, amongst others, the fully marine *G. locusta* to live and breed in fresh water, and, in the reverse direction, *G. pulex* from fresh water to sea water, with no ill effects either during the transition period or afterwards.

The new species has shown an even greater adaptability than the others. Owing to a shortage of the Droitwich water many different mixtures were tried to find the salinity best suited to the animals' needs. This was found to be the "standardized" water used in the *G. chevreuxi* work, namely, one part sea water to four of fresh water from the Plymouth supply, which gives a mixture of about 7‰ salinity. The adults, it is true, died off rather quickly in it, but the young from their matings survived and are still alive and healthy,

* Miss M. Mare det.

some in pure Droitwich river water, some in pure standardized, and others in a mixture of half and half. They are not yet mature (February), but that no doubt is due to winter conditions retarding development.

Gammarus tigrinus n.sp.

Unless otherwise stated, the following description refers to the fully adult male, and the sizes and proportions given apply only to specimens which have attained the maximum growth.

Colour. The specific name, *tigrinus*, refers to the remarkable colour pattern in the living animal, stripes and bars of dark pigment on a light background.

The body colour is a delicate pale green, yellowish green in the male, bluer in the female. The stripes, of deep indigo blue, run transversely across each segment, and extend to halfway down the sides. In addition to the dark stripe or stripes, each segment is banded posteriorly with a clear yellow, so that the effect, seen dorsally, is of alternating bars of pale green, deep blue almost black, and bright gold. From the lateral view the effect is even more striking. Just below where the stripes end, halfway down the sides, two longitudinal bands of colour run along the whole length of the body. The lower one is darkly pigmented and follows the line of the intestine; the upper one is brilliant red. A colour pattern of this type has not been noted, as far as is known, in any other species of *Gammarus*, and would appear to be peculiar to *G. tigrinus*. In some specimens the red shades off on either side, through orange to pale pink, in others it remains as a sharply defined red band. The usual clusters of "oil globules" in the first three pleon segments are also bright red.

The figure of the whole animal (Pl. IV) was taken from a freshly captured specimen, while the colouring was still vivid. In captivity, a steady loss of colour takes place, particularly in the red; after death, and in preservatives, all traces of it vanish.

Size. Compared with others of the genus, *G. tigrinus* is a fairly large species, the males looking larger than they actually are, by reason of the masses of fine hairs on the appendages. The full-grown male averages from 10·5 to 12·5 mm., the female from 8·5 to 10 mm. These measurements are taken, not, as is frequently done, along the dorsal curve, but with the animal straightened out on a micrometer scale, from the tip of the rostrum to the insertion of the telson.

Sex. The difference between the sexes is much more noticeable than is usual in the genus. All the appendages of the male are larger in proportion, the gnathopod hands, for example, being twice the length of those of the female. The male carries masses of the long fine curved sensory hairs peculiar to this species on its second antenna, first, second, fourth and fifth peraeopods, while the female has none of these, and fewer spines and setae than the male. Breeding appears to continue throughout the year.

The gonads and eggs of the female are dark green in colour. The eggs are comparatively large and numerous; the highest number of young, so far, hatched in one brood in laboratory conditions was 50. There are four pairs of incubatory lamellae, or brood-plates, attached to peraeon segments 2–5, of very unusual proportions, two large and two small. The first is the largest and carries the greatest number of fringing hairs, forty-nine in the specimen figured (Pl. V, fig. 11). The second is almost the same size and shape, with 35 hairs; the third is suddenly very small, narrow, strap shaped, with 22 hairs; whilst the fourth, with 14 hairs, is even smaller and narrower. In another younger female examined, the hairs numbered respectively, 31, 26, 13 and 10.

Owing to its curious conformation the pouch looks only about half the ordinary size of the *Gammarus* pouch, and the eggs when deposited appear to lie farther forward under the peraeon than is usual.

The *body* is slender, with the back evenly rounded. The *cuticle* is microscopically spinulose all over (Pl. VI, fig. 27). The spinules are small and not so produced on the anterior part of the body, giving it a surface like a rough file or rasp, but on the pleon, particularly on the dorsal region, they are much longer, very dense and sharp, and look, under a high power, like a thick prickly fur. Scattered over the body and appendages, and inset either singly or in groups, are numerous sensory processes, in little smooth indentations (see figure).

The *gills* are large, oval in shape, and are carried on peraeon segments 2–7. Two are figured (Pl. V, figs. 7, 12).

Side-plates 1–4 are deeper than the corresponding segments, all with an unusually large number of setae inset on the margins, and fine delicate semi-transparent setae on the under surfaces. The fourth side-plate (which is used as a distinguishing specific character) is longer than it is broad, with the posterior expanded portion rounding off into the inferior margin, and inset with five long setae (Pl. V, fig. 13). The sixth and seventh side-plates are both furnished with fine long setae anteriorly, the seventh being noticeable for the number of serrations and setae behind (see Pl. VI, fig. 17).

Pleon segment 1 (Pl. VI, fig. 18) with 12–14 long delicate setae inset in a row around the anterior angle of the epimeron, is deeply notched behind for the insertion of a seta. In pleon segments 2 and 3 (Pl. VI, figs. 19, 22) the epimeral plates are produced acutely backwards, the second with a number of stout spines and setae on the anterior half, and the third with a row of spines and setae on the inferior margin. The *pleopods* (Pl. VI, fig. 18) are long and slender; the rami are subequal and about twice the length of the peduncle, each with a large basal joint, and about 20 small joints furnished with two long plumose setae apiece. The peduncle of pleopod 3 has a large radiating fan of hairs at the anterior distal angle. One of the cleft spines of the basal joint, inner ramus, is figured (Pl. VI, fig. 20). Pl. VI, fig. 21 shows the unusually elaborate form of the coupling spines in this species.

The *head* is about half as long again as peraeon segment 1, measured along the dorsal line. The rostrum is not produced; the lateral lobes are vertically truncate, the upper and lower angles rounded: there is a rather deep sinus below.

The *eyes* are large and reniform; the ommatidia were about 90–100 in number in the specimen examined; the retinal pigment is black, with the "accessory pigment" forming a white reticulation.

Antenna 1 (Pl. V, fig. 1) is much shorter than antenna 2, being only about three-quarters its length. The first joint of the peduncle is large and broad, and almost as long as the second and third taken together. It carries on its upper surface the "sensory groove" (first noted in *Gammarus chevreuxi*, *Journ. Mar. Biol. Assoc.*, vol. XIII, 1924, p. 386), containing, in the full-grown animal, seven very finely plumose sensory hairs, graduated in size, the longest at the distal end of the groove, each mobile in a little socket. The *primary flagellum* appears to be very fragile; in many specimens it was found broken or regenerating, rarely complete. The longest counted, for the male, consisted of 26–27 joints, with an *accessory flagellum* of 6 joints, the terminal joints in both, minute; for a female of 10 mm. length, the primary numbered 26, and the accessory 6, younger females had 16–23 joints in the one, 4–5 in the other. The *flagellum* is almost glabrous, the setae few and short. Each joint, except the formative proximal and the terminal, carries a small stalked calceolus inset on the inner surface (Pl. V, fig. 2).

Antenna 2 of the male (Pl. V, fig. 3), is noteworthy for the length of the fourth and fifth peduncle joints, the latter being the longer. The fourth carries on either side about 9, the fifth about 11 groups of long flexible setae set fanwise on the outer surface; in addition the fourth joint is furnished with several stout spines on its upper surface, 3 on the outside, in the specimen figured, and 1 on the inner side. The *flagellum* has about 14 joints, each with a group of the long setae on the upper and lower margins. The inner surface of the fourth and fifth joints of the peduncle, and 9—10 joints of the flagellum is clothed with masses of the delicate lightly curled hairs peculiar to this species, set in clusters.

In the female (Pl. V, fig. 4) these hairs are entirely lacking. The flagellum in the 10 mm. specimen referred to above numbered 14 joints.

The *gnathopods* show a great disparity in size and armature between the sexes.

Gnathopod 1: in the male (Pl. V, fig. 5) the hand is oblong oval and the palm crenulate, oblique, with a large truncated median spine. At the palmar angle, the long claw shuts down between the "angle-groups" (Pl. V, fig. 6), with one stout and one short curved spine inset together above the tip on each side, and one short curved spine on the upper surface at the tip, with two underneath.

Gnathopod 2: in the male (Pl. V, fig. 7). The hand is broader in proportion to its length than in gnathopod 1; and the palm is sinuous and crenulate, more nearly transverse. It has the truncated median spine on the margin, and, at the palmar angle, a graduated row of three stout spines on the outer side, and two groups of short curved ones underneath (Pl. V, fig. 8).

None of the characteristic sensory curled hairs are developed on the gnathopods.

In the female there is very little difference in the two gnathopod hands (Pl. V, figs. 9, 10). The palm is more oblique in gnathopod 1. They are only half the length of the hands of the male. Gnathopod 2 carries the first and largest of the brood-plates (Pl. V, fig. 11).

The peraeopods. The most noticeable point about the peraeopods, and one which distinguishes this species from the others of the genus, is the sensory armature. Generally speaking, the sensory hairs peculiar to a species which develop in the male at sexual maturity occur only on the first pair of the peraeopods. In *G. tigrinus* the second, fourth, and fifth as well as the first are all furnished with masses of the curled hairs on the under-surface of joints 4–6. The peraeopods carry also dense clusters of strong flexible setae set fanwise on the margins, and groups of various sized sensory spines, including the slender setiform kind developed on these appendages in *Gammarus*. In addition, a new and hitherto undescribed type of spine, is found on the anterior margins of a few of the joints. This is the "stiletto spine" (Pl. VI, fig. 15) shaped like a stiletto, with a strong flat shaft, broad at the base and tapering off to a pointed end.

The fourth is the longest of the peraeopods. The anterior margins of the basal joints of the three hinder peraeopods (Pl. VI, figs. 14, 16, 17) are inset with stout spines; the margin of the posterior expansion in each has a row of setae of varying lengths; the under surfaces in all three carry numbers of the delicate hyaline setae.

In peraeopod 3, the hind-lobe is free; in 4 and 5 the expansion narrows gradually to end in a group of spines and setae at the distal angle.

The peraeopods of the female resemble those of the male, though smaller in all their parts. They have the same groups of long setae and sensory spines, fewer in number, but none of the curled hairs. The stiletto spines are also present, very poorly developed as compared with the male.

The *uropods*. Uropod 1 (Pl. VI, fig. 23) is the longest of the three, a third as long again as the second (Pl. VI, fig. 24). In the third, outer ramus 2-jointed; inner ramus about two-thirds the length of the outer. Both carry spines, clusters of setae, and long plumose setae of two kinds, those bordering the margins being straight with firm shafts. The second kind are few in number, very fine and flexible, curving over at the tips.

The *telson* (Pl. VI, fig. 26) is cleft to the base. There is a lateral group of one spine and setae on each side, and a group of two spines and setae on the apices.

To summarize briefly, the principal distinguishing characters of the new species, *Gammarus tigrinus*, are to be found:

1. *In the antennae*: antenna 1 shorter than antenna 2; accessory flagellum 5–6 jointed; fourth and fifth joints of peduncle of antenna 2 in the male exceptionally

long, the fifth the longer, flagellum about equal in length to these 2 joints together.

2. *In the gnathopods:* the difference in size of the hands between the adult male and female.

3. *In the peraeopods:* the shape of the fourth side-plate (Pl. V, fig. 13).

4. *In the uropods:* the proportions of the rami in the third, the inner ramus two-thirds the length of the outer.

5. *In epidermal structures:* in particular, in the long curled sensory hairs peculiar to the male of this species, and the positions in which they occur.

APPENDIX

By L. H. N. Cooper

Qualitative examination of waters from the Midlands of England, in which Prof. Munro Fox had found the new species, *Gammarus tigrinus*, described above by Mrs Sexton, showed them to be of unusual composition suggesting the need for a quantitative analysis.

Methods of analysis

Standard methods of analysis were used. Sodium was not determined directly but was calculated as the equivalent of alkali required to satisfy the acid radicals not already taken up by calcium and magnesium. Potassium was not present in considerable amount.

The salts composing "total solids" dried at 180° C. should be anhydrous except for magnesium sulphate which is likely to contain one molecule of water of crystallization. This has been computed for Table I. At 180° C. also, bicarbonate must have been converted to carbonate and allowance has been made for this in calculating the composition of total solids.

The positions of the waters sampled in August 1938 have been described by Mrs Sexton. Those from the Droitwich river (River Salwarpe) and from Wyken Slough, which resemble neither diluted sea water nor the hard waters found in limestone districts, must have their origin in the salt springs of the district. The chloride, although not proportionately as high as in sea water, is yet remarkable for an inland stream. Calcium and magnesium are not very much greater than they would be in diluted sea water of the same chlorinity. Bicarbonate and sulphate are high and are present in part as sodium salts, the origin of which is not obvious; unless it be by base exchange between dissolved sodium chloride and limestone rocks. *p*H determined after the samples had stood 18 days was as high as 9·0 in the water from Wyken Slough and 8·8 in that from the Droitwich river. In a sample taken from the Droitwich river on December 8 1938, after a period of heavy rainfall, *p*H had fallen to 7·9 but otherwise the water resembled the August sample somewhat diluted. It is evident that these waters provide an unusual ecological environment and deserve a more systematic investigation than has here been possible. Excess base, *p*H and chloride are expecially worthy of further study.

The water from the Avon at Tewkesbury, in which a few specimens of *G. tigrinus* were found, although essentially a normal hard water contains sufficient sodium chloride to suggest some admixture of saline water of the Droitwich type. Nearly 10 % of the "total solids" remained unaccounted for. Part may be attributed to organic matter in which the water was rich. Since the Avon water was not the main subject of study, the cause of the deficiency was not further sought.

TABLE I.

COMPOSITION IN MILLI-EQUIVALENTS PER LITRE

		Droitwich River		Wyken Slough	River Avon Tewkesbury
	Droitwich Spa*	Aug. 1938	Dec. 1938	Aug. 1938	Aug. 1938
Na^+ (calc.)	5247·4	36·46	—	29·40	2·37
Ca^{++}	68·3	10·22	—	2·22	5·88
Mg^{++}	10·9	6·66	—	3·99	3·92
Total cations	5326·6	53·34	—	35·61	12·17
Cl'	5232·7	41·63	28·89	18·64	2·10
SO_4''	93·5	8·10	—	7·55	4·35
HCO_3'	0·4	3·32	3·02	8·79	5·72
CO_3''	—	0·29	0·00	0·63	0·00
Total anions	5326·6	53·34	—	35·61	12·17
*p*H	—	8·8	7·9	9·0	—

PERCENTAGE COMPOSITION OF TOTAL SOLIDS DRIED AT 180° C.

	Droitwich River		Wyken Slough	River Avon Tewkesbury
	Aug. 1938	Dec. 1938	Aug. 1938	Aug. 1938
Na (calc.)	26·2	—	32·4	7·0
Ca	6·4	—	2·1	15·0
Mg	2·5	—	2·3	6·1
Cl	46·0	47·1	31·0	9·5
SO_4	12·1	—	17·0	26·6
CO_3 (including HCO_3)	3·6	8·46	14·1	21·9
H_2O (in $MgSO_4.H_2O$)	1·9	—	1·7	4·5
	98·7	—	100·6	90·6
Total solids at 180° C. (g./l.)	3·202	2·174	2·135	0·785

* Analysis by H. B. Salt, *The Natural Brine Baths of Droitwich Spa and the Surroundings*. Whately, Droitwich. (No date).

EXPLANATION OF PLATES

Plate IV

Gammarus tigrinus n.sp. × 12. The figure was drawn from a freshly captured male, from Droitwich river, November 1938. It shows the colour pattern in life. The pale green colour of the body is represented here by light grey; the bright yellow bands on the posterior margins of the body-segments by clear spaces; and the deep indigo blue of the stripes, bars and patches by the dark tint. The red is as it appears in the living animal. Most of the sensory hairs on the appendages have been omitted, for the sake of clearness of outline.

Plate V

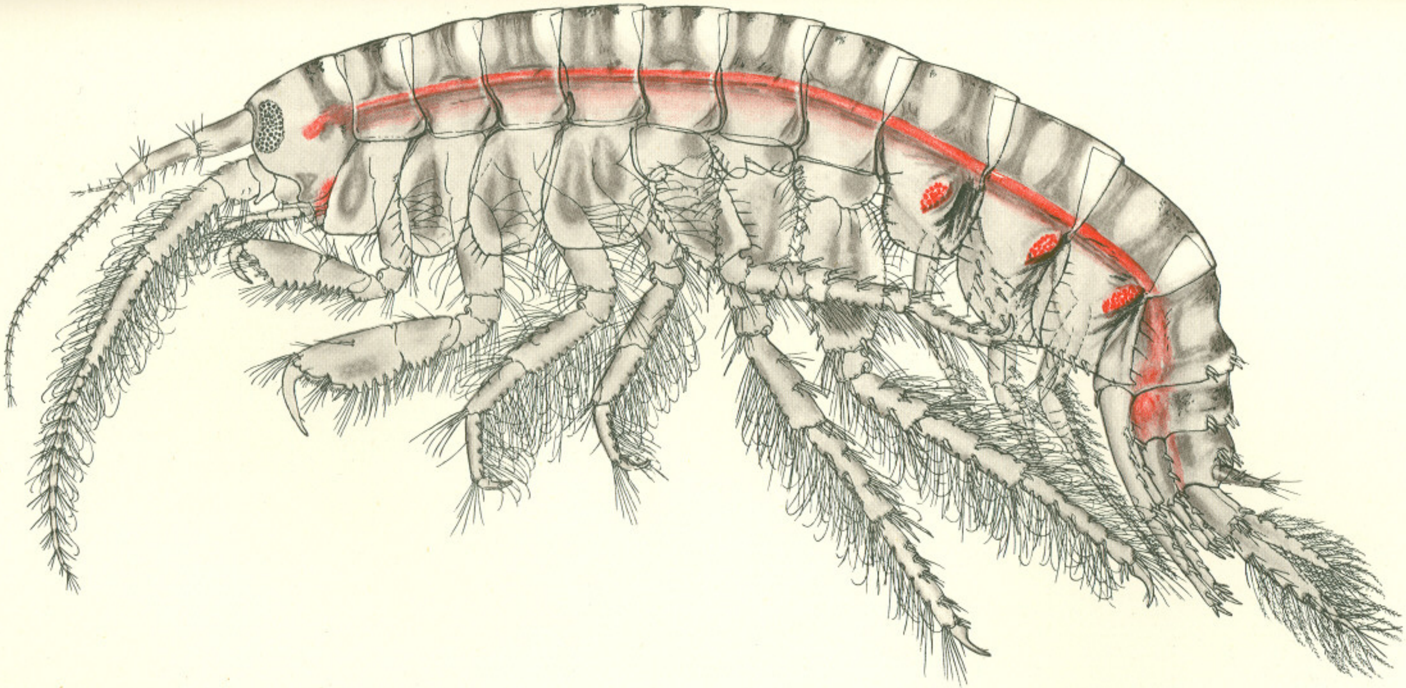
The figures are drawn from one specimen, a male, left side. × 28, unless otherwise stated

Fig. 1. Antenna 1.
Fig. 2. Calceolus from under surface of primary flagellum, antenna 1. × 200.
Fig. 3. Antenna 2.
Fig. 4. Antenna 2, ♀. Left side.
Fig. 5. Gnathopod 1.
Fig. 6. Palmar angle, under-surface, left hand, gnathopod 1, from specimen figured, showing the groups of spines between which the claw closes down. × 57.
Fig. 7. Gnathopod 2, with gill outlined.
Fig. 8. Palmar angle, under surface, left hand, gnathopod 2. × 57.
Fig. 9. Hand of gnathopod 1. ♀.
Fig. 10. Hand of gnathopod 2, ♀, same specimen; gill not shown, brood-plate figured separately.
Fig. 11. Incubatory lamella, or brood-plate from gnathopod 2.
*Fig. 12. Peraeopod 1, with gill attached.
*Fig. 13. Peraeopod 2.

Plate VI

*Fig. 14. Peraeopod 3.
Fig. 15. Stiletto spine from second joint, peraeopod 3. × 200.
*Fig. 16. Peraeopod 4.
*Fig. 17. Peraeopod 5.
Fig. 18. Pleon-segment 1 with pleopod.
Fig. 19. Pleon-segment 2, epimeron.
Fig. 20. Cleft spine, from basal joint of inner ramus, pleopod 3. × 200.
Fig. 21. Coupling-spines from the peduncle of pleopod 3. × 200.
Fig. 22. Pleon segment 3, epimeron.
Fig. 23. First uropod.
Fig. 24. Second uropod.
Fig. 25. Third uropod. (The proportions of the rami are unusual, the inner ramus being shorter than normal, probably regenerating.)
Fig. 26. Telson.
Fig. 27. Cuticle, showing the spinules covering the body, and the inset sensory processes, from the dorsum of pleon segment 4. × 200.

* In these figures it has not been possible to represent the full number of the sensory hairs.



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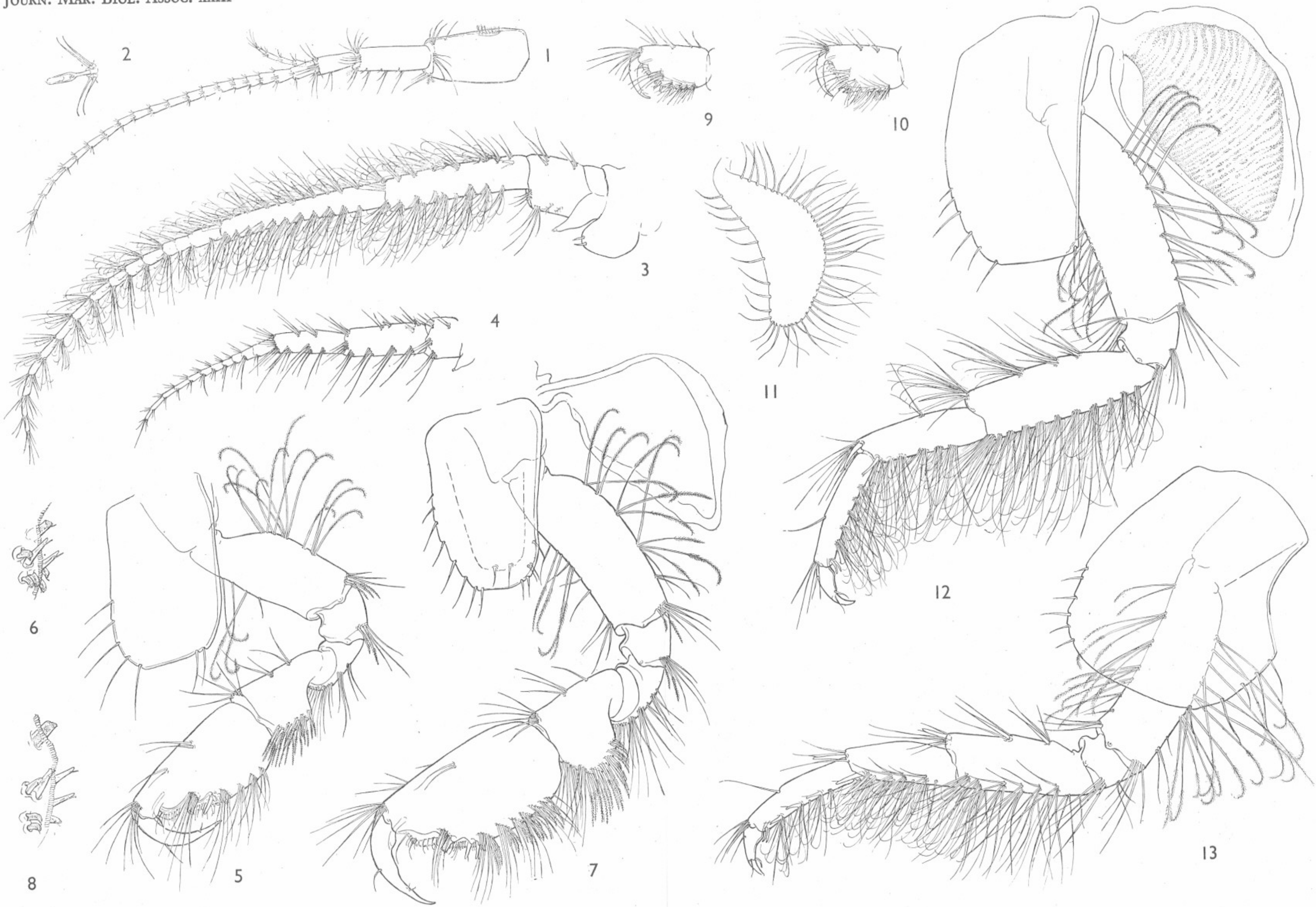
GAMMARUS TIGRINUS n. sp.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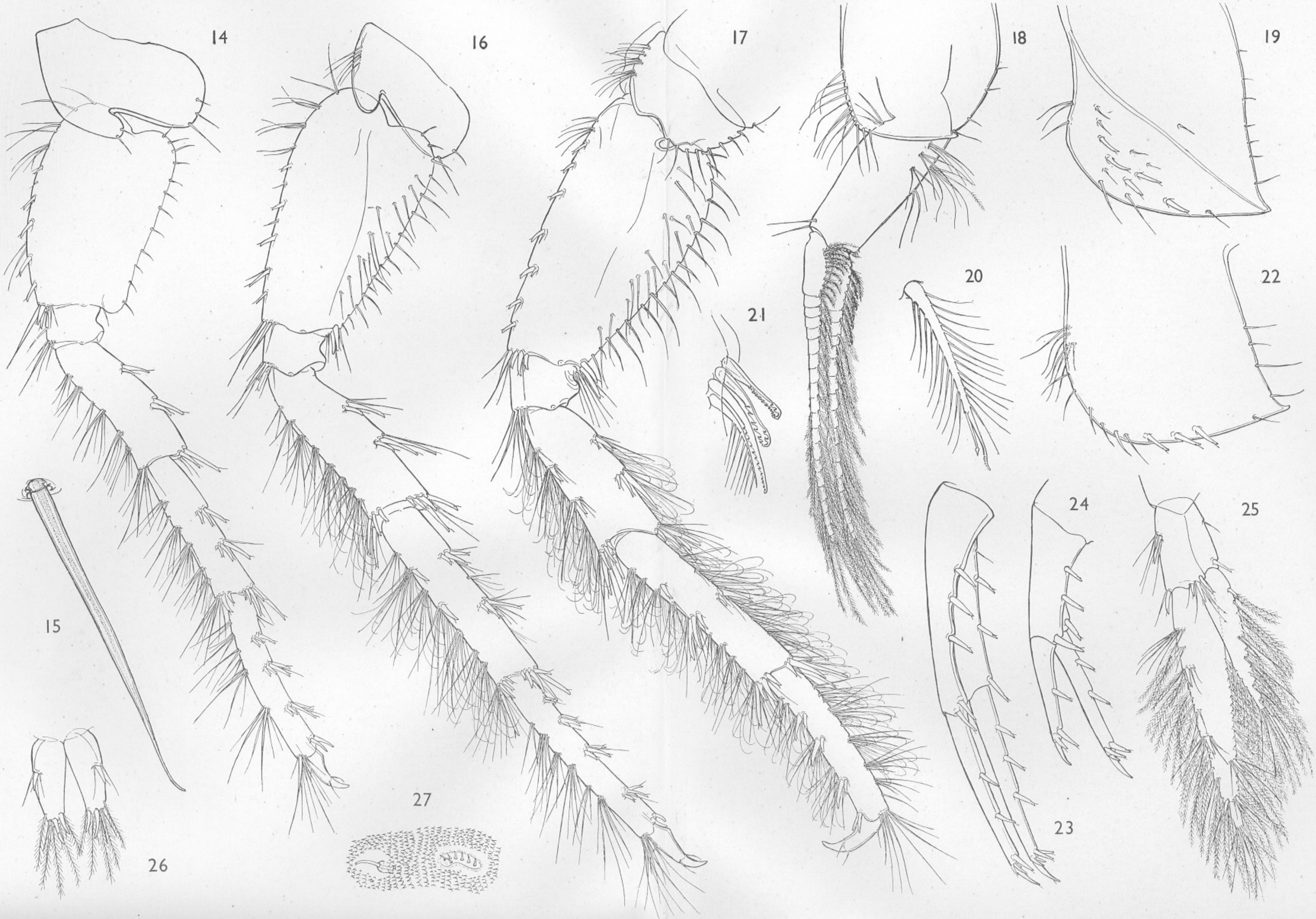
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