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THE THALASSINID BURROWING SHRIMP, *CALLIANASSA* (*CALLICHIRUS*) *MAXIMA* M. EDWARDS, 1870 (CRUSTACEA : DECAPODA : CALLIANASSIDAE) AS A PEST IN THE SALT FACTORIES IN VOYALUR IN CHINGLEPUT DISTRICT OF TAMIL NADU AND IN MANGINAPUDI IN KRISHNA DISTRICT OF ANDHRA PRADESH

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ABSTRACT

The occurrence of the thalassinid shrimp, *Callianassa* (*challichirus*) *maxima* Milne-Edwards, 1870, as a prolific burrower in the salt pans at Voyalur in Tamil Nadu and at Manginapudi in Andhra Pradesh, is reported in this paper. Due to the heavy infestation of this shrimp along with *Uca annulipes* and *Marphysa gravelyi*, the salt pans are made porous rendering the impoundment of brine difficult. Details of its taxonomy, morphology and ecology of the adult and its larval stages are included in the paper. Suggestions for the effective control of this shrimp in the salt pan beds are also provided in the paper.

INTRODUCTION

The Deputy Salt Commissioner of the Government of India Salt Department, Madras, Shri D. V. Kirtikar, discussed with the author in October 1977, about the salt pans at Voyalur in Chingleput District of Tamil Nadu and in the Manginapudi Salt Factory in Krishna Distrtct of Andhra Pradesh being infested with burrowers, making the land porous and impoundment of brine in the pan area difficult, since the brine seeped through these holes to the lower layers of the earth thus rendering salt manufacturing operations impossible. He requested that investigations should be conducted on the marine burrowers hindering salt manufacture and to recommend remedial measures for eradicating the burrowers. Accordingly, on-the-spot detailed investigations on the burrowers infesting the salt pans, their horizontal and vertical areas of operation were conducted from November, 1977 onwards. The sampling of the sites at the heavily infested areas at both these salt factories revealed that two species of crustaceans and one species of polychaete were burrowing in the salt pans and had made tunnels ranging from 0.5 mm to 55.0 mm in diameter from the surface to the subsoil brine level, which at both the areas was at a depth of 300 mm during high tide and about 700 mm at low tide. In highly infested saltpan areas, these burrows extended

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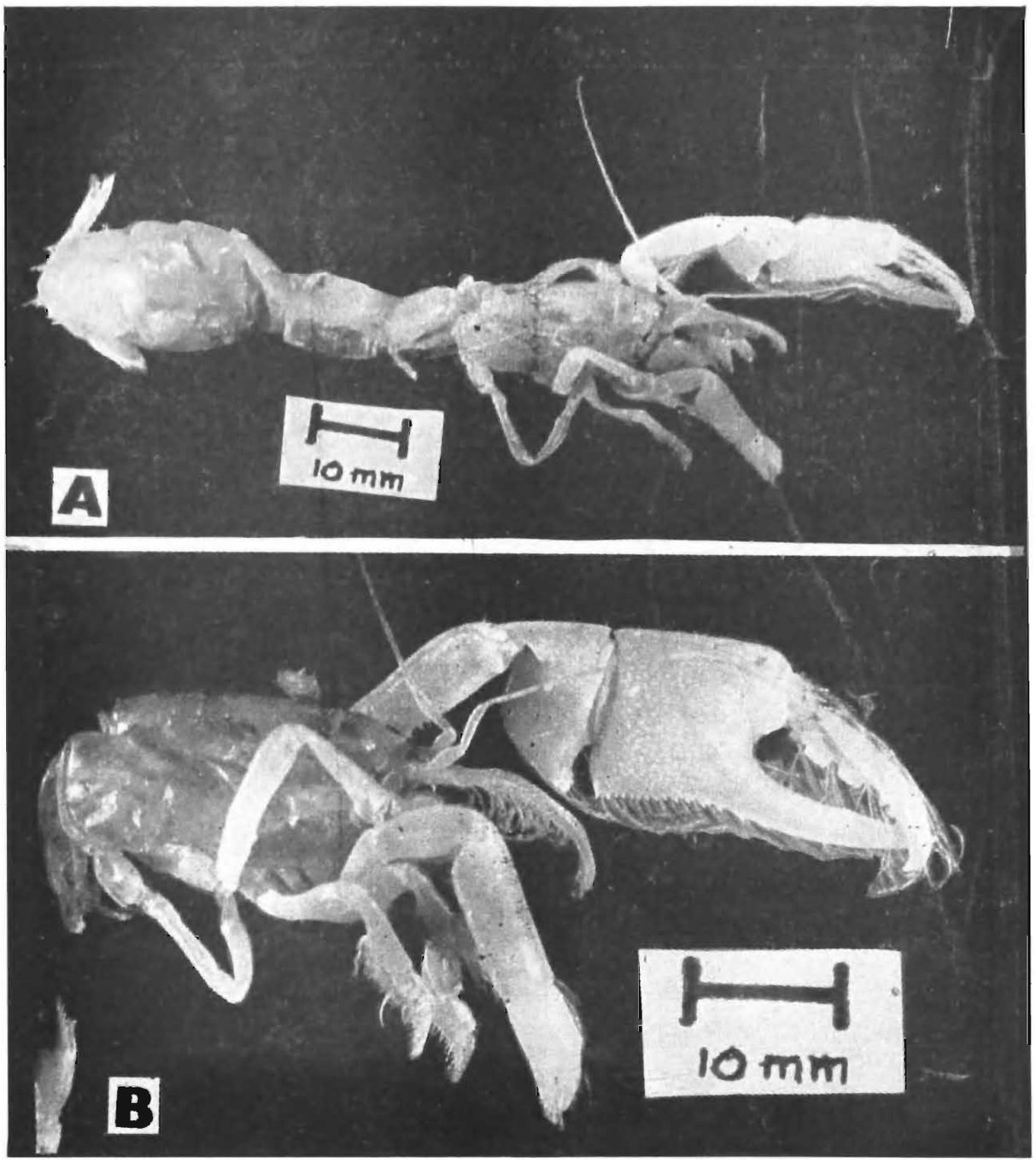
PLATE V

Showing highly infested salt pan area.



(A & B) *Callianassa* (*Callichirus*) *maxima*—M. Edwards, 1870 ; A—Entire adult animal ; B—Enlarged anterior area of same specimen

down to a depth of at least 1500 mm where at the surface an average of 400 holes (each hole ranging from 0.5 mm to 5.0 mm) per square metre were counted (Pl. V). These three burrowing organisms were identified as (i) *Callianassa* (*Callichirus*) *maxima* M. Edwards, 1870, (ii) *Uca annulipes* (H. Milne Edwards, 1852) = syn = *Gelasimus annulipes*, and (iii) *Marphysa gravelyi* Southern 1921.

Of these three burrowers, the most prolific and thus the most important in these two areas under investigation, is the decapod Thalassinid mud shrimp, *Callianassa* (*Callichirus*) *maxima*, which was responsible for the larger sized holes ranging from 3.0 mm to even 55.0 mm in diameter (Pls. V & VI).

Specifically, this paper reports (i) the occurrence of *Callianassa* (*Callichirus*) *maxima* as a prolific burrower in saltpans in Tamil Nadu and Andhra Pradesh, and the occurrence and collection of berried females during October and November, (ii) the details of its taxonomy, descriptions and figures of this species which had so far been described only from single adult specimens or from single chela or from young specimens, (iii) correlation during the adult stage with its true fossorial habitat in the salt pans, near the sea or estuarine muddy areas developed for salt manufacture and (iv) details of some of the planktonic larval stages, the first stage of larvae *i.e.*, zoea with all three pairs of maxillipeds, biramous and functional from low salinity brine pools in the saltpans and also from plankton collections in the coastal inshore seas off Madras from the "R. V. Chota Investigator" collections during December and January. The investigations conducted on the crab, *Uca annulipes* and the polychaete *Marphysa gravelyi* Southern 1921 is being published separately as collaboration papers.

Taxonomy

Order DECAPODA

Sub-order *REPTANTIA*

Section Macrura

Tribe Thalassinidea

Compressed carapace. First pair of legs in form of Chelipeds but unsymmetrical; third pair not Chelate-Marine, burrowing shrimps.

Family Callianassidae

This family consists of two subfamilies, namely, Callianassinae and Upogebinae the larvae of the former being hatched out as a zoea with all three pairs of maxillipeds, biramous and functional, a character in which they differ not only from the other subfamily but also from the remaining tribes of Anomura (In Axiidae also there are 3 maxillipeds).

Genus **Callianassa** (Leach) Borradaile, 1903

Callianassa Borradaile, 1903, p. 544.

The genus *Callianassa* enjoys a world wide distribution, but many of the species are imperfectly known as the fossorial mode of life makes their capture difficult. It includes three subgenera *Calliactites*, *Cheramus*, and *Callichirus* (*vide* Edmondson, 1944). According to the generic scheme of de Saint Laurent, 1973, the subgenus *Callichirus* along with the other two subgenera have been elevated as distinct genera (*vide* Felder, 1979).

In the Indian Seas, so far, only two species of the genus *Callianassa* have been reported. They are (i) *Callianassa* (*Callichirus*) *maxima* Milne Edwards (Ratton, 1882, Revised publication, 1921, identified as burrowing prawn): Kemp, 1915; Pillai, N. K., 1954) on the adults, and Menon, M. K. 1933 and 1940 on the larval forms of the same species from the

Madras plankton ; and (ii) *Callianassa* (*Callichirus*) *audax* De Man, 1911 (Vedavysa Rao & Raschandra Kartha 1966). However, none of the two species of this genus *Callianassa* recorded from India have been noted to cause extensive infestation of salt pans, burrowing tunnels, thus causing the brine to seep out from the pans during low tide and gushing up of the subsoil and sea water during high tide.

Callianassa (Callichirus) maxima A. Milne Edwards, 1870

(Pl. VI & Figs. 1A-I)

Callianassa maxima, 1870. A. Milne Edwards, VI, p. 97.

Callianassa maxima, 1915. Kemp. S. p. 252, pl. XIII. figs. 1—5.

Callianassa maxima. 1954. Pillai, N. K. **3** (1) C : 23—26.

The shrimp *Callianassa* (*Callichirus*) *maxima* was first named by M. Edwards (1870) from a single chela obtained in a sub-fossil condition from Siam. Ratton, in his book entitled "A Hand-book of common Salt", originally published in 1882, and revised, enlarged and reprinted in 1921, mentioned the occurrence of a "Prawn as a salt-pan pest in India, which usually drilled burrows from the shelving bank of the estuary into the condensor and thus let out the brine. This burrower was also considered by him as difficult to dislodge." There is no evidence in literature of this salt-pan burrowing prawn of India, having ever been identified and given its rightful place in crustacean taxonomy, although, Kemp (1915) described in detail this species from a single complete specimen obtained from "some part of Madras", the exact locality being unknown. Kemp's collections included a large chela and two young specimens collected from the Chilka Lake. No mention was however made by him on these specimens being pests of salt-pans. Much later, in 1954 Krishna Pillai obtained a single specimen of this species from the Kayamkulam Lake from Central Travancore ; and although assigning this specimen to this species pointed out nine differences from the descriptions given by Kemp in 1915. All the specimens obtained from these two salt pan areas, *viz.*, the Voyalur Salt Factory and the Manginapudi Salt Factory, resemble in minute detail the characters given in detail by Kemp (1915). Thus, hitherto, this burrowing shrimp *Callianassa maxima* which had been described from single specimens or from single chela, was not correlated with its true habitat in the salt pans, although it was apparently well known among Zoologists that the species of the genus *Callianassa* were fossorial in habit. Berried females were obtained during October and November, in both the salt pan areas.

Description of the adult : The rostrum is sharply pointed, without lateral teeth, and is short, reaching barely to one-third the length of the eyes (Fig. 1A). There is no tooth on the frontal margin of the carapace between the eyes and the antennal peduncles.

The eyes are subquadrilateral in dorsal view with their inner distal angles produced to a bluntly pointed process and their anterior margins oblique and concave. The inner margins are almost contiguous ; they are straight and parallel with the outer margins. In the middle of the distal half there is a small round patch of black retinal pigment. The apices of the eyes reach a little beyond the articulation between the first and second antennular segments. The latter segment is stout, scarcely twice as long as broad. The third segment is more slender, but compared with some other species of the genus, is comparatively short, less than one and half times

the length of the second. The distal extremity of the third segment reaches about to the middle of the terminal segment of the antennal peduncle. The antennal flagellum is considerably longer than the subequal flagella of the antennules and is fully one and a half times the length of its peduncle (Pl. VI A & B).

The form of the outer maxillipede is shown in Pl. VI and Fig. 1 H. The ischium, merus and propodus are extremely broad and on the inner face of the first of these segments is a longitudinal row of small granules commencing close to the articulation with the basis.

The first legs are very unequal (Pl. VI A & Fig. 1B). In the larger, the ischium is slender, but considerably expanded towards its distal end. The inferior edge is finely but irregularly tuberculate, the tubercles sometimes taking the form of small spinules on the outer surface in the proximal two-thirds there is a sharply defined crenulate carina. Between this carina and the lower margin, the surface is covered with close-set granules that extend nearly to the ischio-meral joint. The merus is a trifle longer than the ischium and is rather more than two and a third times as long as broad. In form, it is trigonal, the outer surface being traversed longitudinally by a conspicuous ridge, smooth distally, but crenulate at its proximal end. The upper border is finely crenulate in its basal half; otherwise the surface above the median ridge is quite smooth. Below it, the surface is covered with tubercles, which are larger towards the proximal end, and near the inferior margin there is an oblique granular crest. The inferior margin is granular and setose and near the ischial articulation is produced to a large acute tooth. On its inner face the merus bears two conspicuous grooves that run close to and parallel with, the upper and lower borders; the surface is granular at the proximal end, otherwise quite smooth.

The carpus of the same limb is one-third broader than long; its length is about two-thirds that of the merus. The outer surface is smooth and evenly convex. The posterior margin below the merocarpal joint is setose and a little uneven and the infero-distal angle bears a few spinules at its apex. On the inner surface the upper limit of the excavation into which the merus fits is defined by a strongly granular ridge and there are also scattered tubercles near the sharp crest that forms the upper margin and near the inferior angle. The distal margin, next the propodus, is finely crenulate internally; externally it is smooth.

The palm of the chela, (Pl. VI A & Fig. 1B) measured along its upper margin, is one quarter longer than the carpus and is equal in breadth with that segment; it is rather more than two-thirds the length of the dactylus. The upper margin of the palm, in its basal two-thirds only, bears a sharp ridge that is obscurely notched. The outer surface of the palm is evenly convex and the whole of its middle part is covered with granules which increase in size distally. Close to the gape of the fingers there is a cluster of large spinules and at the proximal end of a smooth blunt ridge that extends the entire length of the fixed finger, there is a short row of rounded tubercles. On the inferior edge of the palm there is a series of close-set spinules. The inner face of the palm is covered with granules larger than those on the external surface and there are a few tubercles near the gape of the fingers. The inner edge of the fixed finger is without teeth and is feebly crenulate at the

proximal end. In the gape at the base of the dactylar articulation is a blunt lobe serrated at the distal end. When the claw is closed the fingers meet only at the tip. The dactylus edge there is a large bluntly trilobed tooth at the proximal end, a single large blunt tooth in the middle of the margin and a series of seven smaller teeth, also blunt, behind the

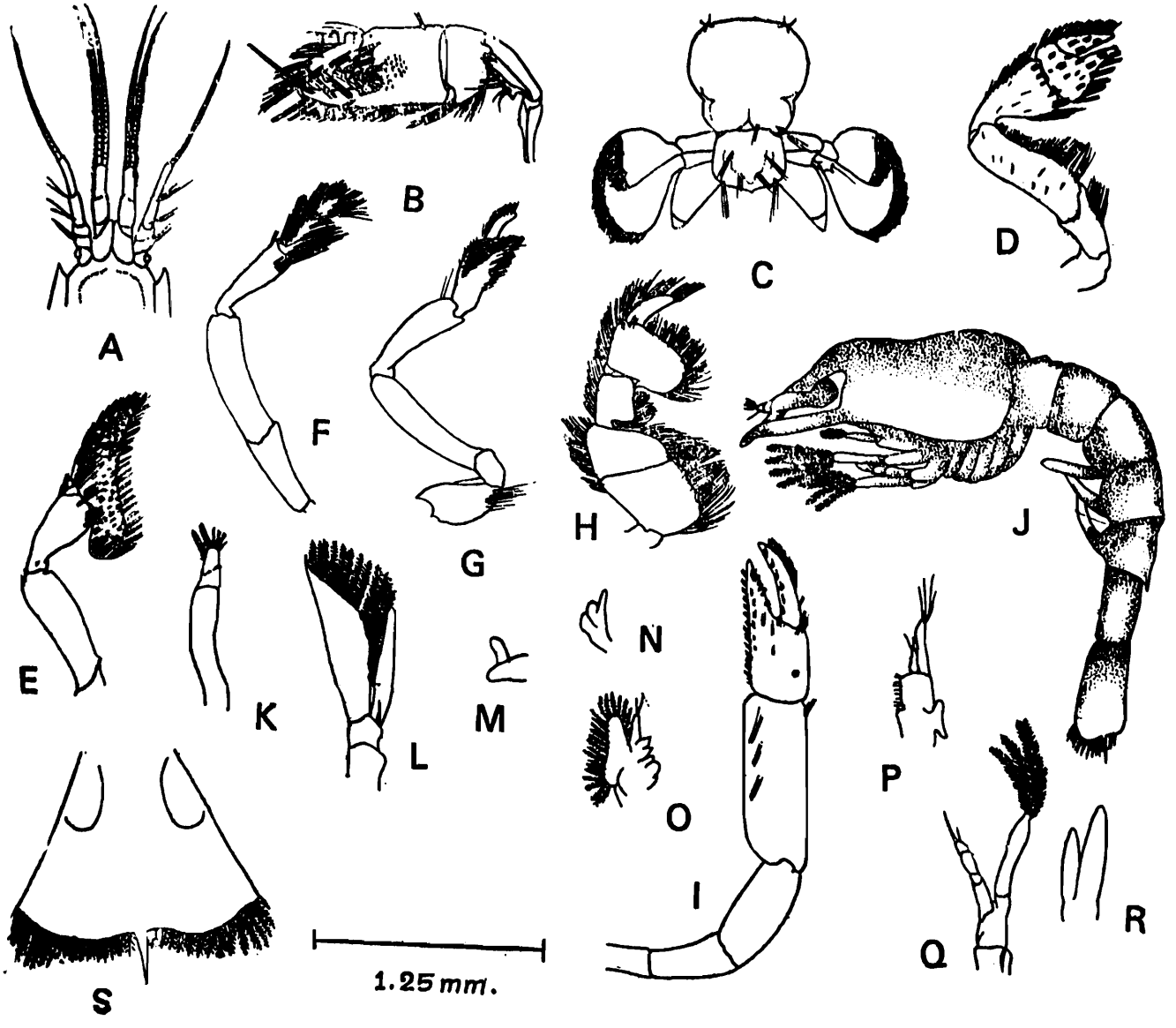


Fig. 1. *Callianassa* (*challichirus*) *maxima* : (A-I) Adult : A—Anterior part of Carapace, rostrum, eyes of adult ; B—Large Chelipede of adult ; C—Last abdominal somite, telson and uropods of adult ; D—Second peraeopod of adult ; E—Third peraeopod of adult ; F—Fourth peraeopod of adult ; G—Fifth peraeopod of adult ; H—Third maxillipede of adult ; I—Smaller peraeopod of first pair of adult.

(J-S) Larvae : J—First stage entire animal ; K—Antennule of first stage ; L—Antenna of first stage ; M—Mandible of first stage ; N—First maxilla of first stage ; O—Second maxilla of first stage ; P—First maxillipede ; Q—Second maxillipede ; R—Pleopod of first stage ; S—Telson of first stage.

is curved and pointed at the apex and bears a few coarse and rather obscure tubercles on its upper margin near the base. On the inner tip. On both upper and lower margins of the palm and on the fingers are numerous tufts of coarse yellowish setae.

The smaller left leg of the first pair (Fig. 1, I) is totally different in form and bears no spinules or tubercles (Pl. VI A). The merus is about as long as broad and is longer than the ischium ; the outer surface shows traces of ridge. The carpus is about two and a half times as long as wide; the upper and lower margins are sharply crested and, throughout the greater part of their length, are strictly parallel.

The chela is a little shorter than the carpus and about one and a half times the length of the merus. The fingers are about as long as the palm ; they are obscurely serrate internally and bear tufts of coarse setae.

The form of the remaining pairs of legs is illustrated (Figs. 1 D, E, F & G). The propodus in the third pair (Fig. 1F) bears a conspicuous lobe on its inferior margin ; the fifth pair is perfectly chelate (Fig. 1G).

The second abdominal segment is the longest, equal to the fourth and fifth combined and a little longer than the sixth (Pl. VI). There is a patch of soft hairs on the postero-lateral angles of the third and fourth and a similar patch in the middle of the fifth. The sixth somite is subcircular, narrower than the fifth ; it is excavated on either side in the posterior third and in the middle of distal margin there is a short longitudinal furrow. The first two abdominal appendages are slender ; the remaining three are broadly foliaceous.

The telson is subquadrilateral little more than half the width of the somite and one quarter broader than long. The lateral margins are gently rounded and the posterior margin slightly convex with a tuft of long setae on either side. In the middle of the upper surface there is a smooth hemispherical swelling, bearing tufts of setae, and behind this swelling are three conspicuous dimples, the middle one larger than the two lateral (Fig. 1C).

The uropods are much longer than the telson. The inner is triangular in shape, the outer ovoid, with a small bilobed tubercle against which the endopod is folded when the tail-fan is closed. (Fig. 1C).

The lower border of the large leg of the merus is armed with large irregular spinules (the proximal one of the series taking the form of a bilobed tubercle) ; the tubercles on the upper edge of the dactylus, near the base, are more prominent and the surface granulation is in most places more scanty.

Larval Stages

First stage larva. (Fig. 1J).

(Fig. 1J-Q)

The rostrum is as long as the antennules, broad and dorsoventrally flattened. At the anterior end it narrows considerably and ends in a point. A few minute teeth are present on the edges at the anterior end. The antero-lateral edge of the carapace is serrated there being about 10 small teeth, and there is a distinct sub-orbital spine at the anterior end. The posterior end of the carapace is deeply concave and is rounded at the corners. Unlike the larvae of other species of *Callianassa* there is no large dorsal spine on the second abdominal segment. The third fourth and fifth have small dorsal spines at their posterior ends of which the last is larger than the others and is curved down.

The eyes are carried on short thick peduncles and are pigmented.

Antennule : (Fig. 1K) There is a peduncle and two short flagella. The former does not

show segmentation and has neither spines nor setae. The internal flagellum is half as long as the external and carries one long stout plumose seta terminally. The outer shows three faintly marked joints, the first two of which have each two large aesthetes. The third has three which are narrower than those of the lower segment and also three ordinary setae.

Antenna : (Fig. 1 L) The peduncle is two-jointed. Basipodite is produced into a short spine above the base of the flagellum. The latter is about three-fourths as the scale and does not show clear indications of segmentation. Terminally it is armed with two plumose setae. The scale ends distally in a short stout spine and is fringed along the inner edge and tip with seven plumose setae.

Mandible : (Fig. 1 M) Has a well developed unjointed palp. The cutting edge is smooth except for the presence of a minute tooth.

First Maxilla : (Fig. 1 N) The proximal endite is armed with five teeth, one of which is very small. The distal endite has one very small tooth as its lower end and two or three minute tubercles above. There is well developed unjointed palp.

Second Maxilla : (Fig. 1 O) There are four endites, the two middle ones of which are smaller than the others. The basal and the next are unarmed ; the other two are armed each with a small seta. The endopodite is unjointed and tipped with two setae. The scale has a fringe of 24 plumose setae.

First Maxillipede : (Fig. 1 P) The coxopodite bears only one seta on its inner margin. The liasipodite has eight which are, however, shorter than that of the former. The endopodite has three terminal setae of which one is rudimentary. The exopodite is twice as long as the endopodite unjointed and is tipped with four plumose setae. There is a flat epipodite.

Second Maxillipede. (Fig. 1Q) The endopodite is four-jointed. A slight constriction towards the base of the proximal joint may indicate that it is formed by the fusion of the first two joints. Exopodite has four terminal plumose setae.

Third Maxillipede : (Fig. 1 J) Similar to second. The exopodite has five plumose setae.

Behind the third maxillipede there is no free appendage in the thorax though the full number of appendages appear as prominent swellings beneath the cuticle of the ventral side.

Abdomen : (Fig. 1 J) Consists of six segments besides the telson. The first segment is the shortest, being only half is long as the second and the sixth is the longest. The first two segments are without appendages. The three following ones possess well-developed biramous pleopods (Fig. 1 R) which are not clothed with setae. There are no uropods.

The telson (Fig. 1 R) is a broadly triangular structure with a slight notch in the middle of its posterior edge, where there is a large median spine. This does not show any articulation with the telson, but seems to be a continuation of the edge. On either side of this there are 17-19 spines of which the second from the side is reduced and hair-like. The spines gradually increase in size from the centre to the sides. All spines except the median and the two outermost ones are serrated.

The body is perfectly transparent except for a short streak of pink colour along the lateral margin of the carapace and a patch of similar pigment on the ventral side just behind the mouth (Fig. 10).

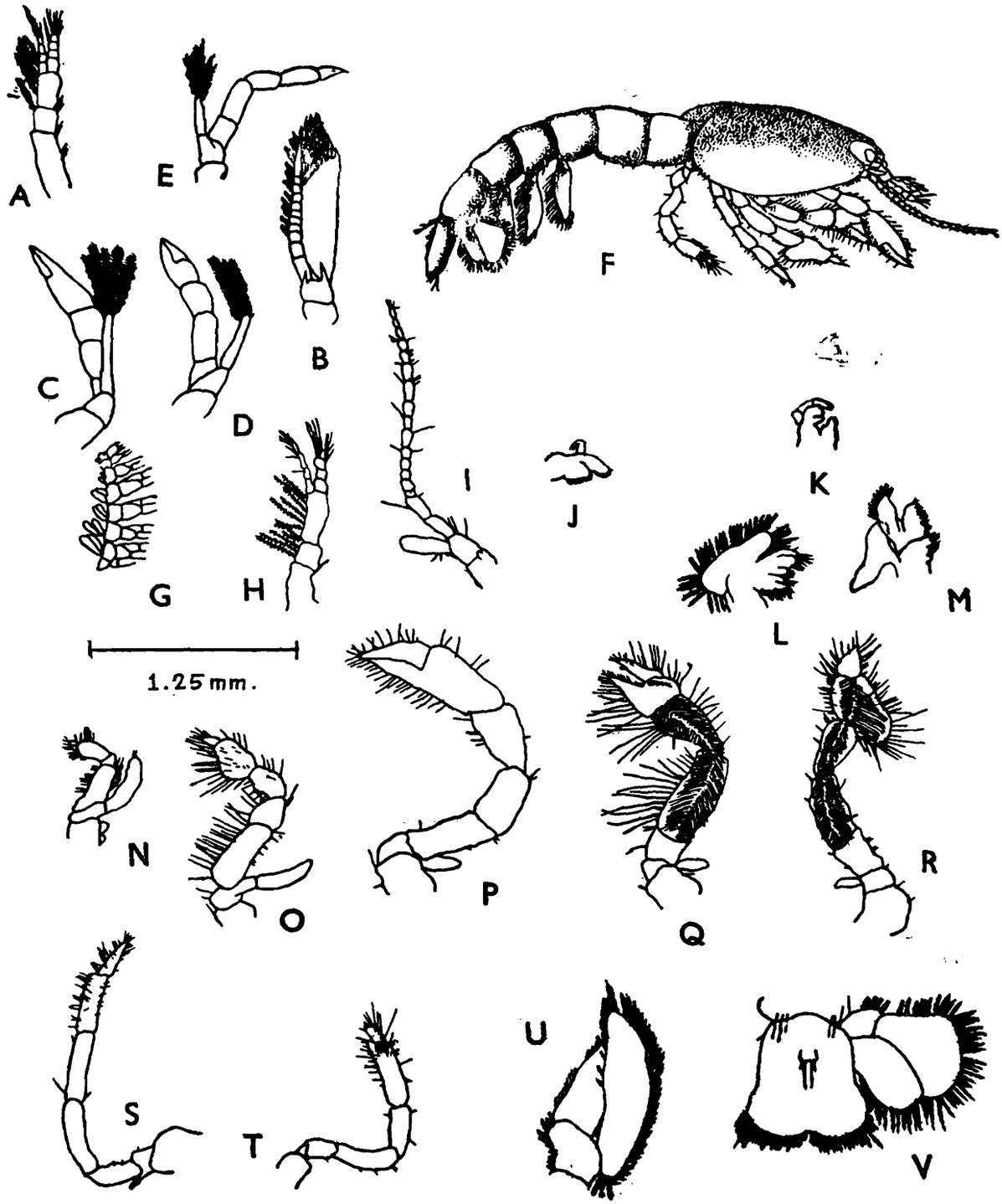


Fig. 2. Larvae : A—Antennule of second stage ; B—Antenna of second stage ; C—First thoracic leg of second stage ; D—Second thoracic leg of second stage ; E—Fourth thoracic leg of second stage ; F—First part larval stage ; G—Arrangement of gills of second stage larva ; H—Antennule of first post larval stage ; I—Antenna of first post larval stage ; J—Mandible of first post larval stage ; K—First maxilla of first post larval stage ; L—Second maxilla of first post larval stage ; M—First maxillipede of first post larval stage ; N—Second maxillipede of first post larval stage ; O—Third maxillipede of first post larval stage ; P—First thoracic leg of first post larval stage ; Q—Second thoracic leg of first post larval stage ; R—Third thoracic leg of first post larval stage ; S—Fourth thoracic leg of first post larval stage ; T—Fifth thoracic leg of first post larval stage ; U—Pleopod of first post larval stage ; V—Uropod and telson of first post larval stage.

Second stage larvae—Total length 7.5 mm. (Figs. 2A—E & G)

In shape and general appearance the larva has undergone no modification. The most important difference between this and the previous stage is the presence of the full number of free thoracic appendages in this. The lateral margins of the rostrum are toothed along their whole length. The carapace remains as it was in the previous stage ; in the abdomen the spine on the third somite is better developed in addition to those already existing ; a small dorsal spine and a much larger ventral one are present at the posterior end of the sixth somite. An extremely small lateral spine may also be present in the same somite.

Antennule : (Fig. 2A) The peduncle is now clearly three-jointed, the basal joint being the longest. The first and second joints carry four and five short plumose setae respectively, on their outer margin. On the inner margin of the second joint there is one long plumose seta and five similar ones are present on the third. The inner flagellum has elongated and equals the outer in length which is as long as the distal joint of the peduncle. The external flagellum has got the same number of aesthetes as in the last stage and the internal is tipped with two unequal setae, the larger of which is plumose.

Antenna : (Fig. 2B) The basipodite now carries two spines, one above the base of the flagellum and the other above that of the scale. The scale is bordered on the inside and tip with 18—20 plumose setae. The flagellum is as long as the sclae and is tipped with two short setae. Faint indications of segmentations are seen beneath its cuticle.

Mandible : The cutting edge shows two well-defined round smooth lobes, but is devoid of teeth.

First Maxilla : The palp has a small terminal seta. The armature of the endites shows no difference from that of the previous stage except the addition of a tooth on the distal endite.

Second Maxilla : Has not altered appreciably. The fringe of plumose setae on the scale has increased in number to about thirty.

First Maxillipede : The endopodite and exopodite are armed terminally with four and five setae respectively. The other parts remain unchanged.

Second Maxillipede : A small epipodial rudiment has appeared on the coxopodite.

Third Maxillipede : Remains unaltered. Behind the maxillipedes all the other thoracic appendages are now free and functional.

The legs, (Figs. 2C, D & E) except the last, have well-developed exopodites with five terminal plumose setae. The last does not show any trace of an expodite. The endopodites are all five jointed. The first and second terminate in well-developed chelae, the others in long, pointed, claw-like processes of the dactylopodites. The propodite of the third is expanded and has more or less acquired the characteristic shape it has in the adult. The same segment in the last leg sends a short process from its tip below the base of the dactylopodite so that the tip of this leg already shows its subchelate nature.

Gills : (Fig. 2G) Rudiments of the full number of the adult are present. The maxillipede and the following four legs have each two gill-rudiments. The last leg has none and the single rudiment of the second maxillipede is hardly perceptible.

Abdomen : Shows a slight elongation. The first and second somites are still without appendages. The uropods are not yet fully developed, but appear in the form of thickenings along the sides of the anterior part of the telson.

Telson : So far as shape is concerned there is absolutely no change. Only sixteen spines are now present on either side of the large median spine. In most of the interior spaces between the spines the edge of the telson bears two or three small setiform teeth.

There is no change in colouration.

First Postlarval Stage : (Figs. 2F, H-V)

Total length of the animal is 6 mm. Like the previous stages this is also perfectly transparent and colourless except for the ventral side near the mouth where there is a patch of red colour. There is a short broad rostrum with blunt tip which is bent down between the eyes. The hind end of the carapace is deeply concave and the postero-lateral portions are rounded. The lateral and posterior margins bear a few short setae. The eyes are short and thick and the cornea is well pigmented. The proximal portions of the stalks are flattened on the inside and are closely pressed together (Fig. 2F).

Antennule : (Fig. 2 H) The peduncle is three-jointed and bear about eleven setae on the two distal segments. The flagella are now distinctly segmented, both having five segments. The inner is slightly longer than the outer which is as long as the third joint of the peduncle. Both are armed with setae and the outer has four aesthetes in addition.

Antenna : (Fig. 2, I) The two spine-like processes of the basipodite have now disappeared. The scale persists in the form of a club-shaped structure as long as the peduncle and armed with two or three setae. The flagellum has increased greatly in length and has got 15-17 joints, most of the joints being armed with short setae.

Mandible : (Fig. 2 J) The masticatory portion is deeply divided into two lobes, both of which carry long, narrow, pointed teeth. The palp is unjointed and bears terminally a rudimentary seta.

First Maxilla : (Fig. 2 K) The palp is three-jointed and is armed with six very short setae at the distal end. The proximal endite is very small and devoid of setae. The distal one is broad and has four small blunt prominences.

Second Maxilla : (Fig. 2 L) All the endites are armed with numerous setae. The scaphognathite is bordered with 37 plumose setae. The endopodite carries five setae of which three are terminal.

First Maxillipede : (Fig. 2 M) Both the coxo and basi-podites have well-developed masticatory lobes armed with several setae, a few of which, springing from the middle of the proximal lobe, are plumose. The extreme basal part of the proximal lobe is bare. The endopodite is small, being not even half as long as the expodite and is unarmed. The inner is broad and unjointed and carries ten plumose setae which are distributed on the tip and the distal half of the outer margin. Besides these a rudimentary one is present on the inner margin close to the tip. The epipodite has increased considerably in size.

Second Maxillipede : (Fig. 2 N) The endopodite is rather broad, curved inwards and four-jointed. The basal joint is the largest and as in the previous stages shows a slight constriction near the base thus indicating that it is formed by the fusion of two joints. There is a rudimentary epipodite in

the form of a round protuberance. The exopodite is a vestige about as long as the first two segments of the endopodite and tipped with two short setae. All joints of the endopodite except the second bear setae.

Third Maxillipede : (Fig. 2, O) Is rather broad due to the flattening of the first four joints, among which the propodus is a little broadar than the others. The dactylus as in the preceding limb is very small. All joints are armed with setae, those along the inner margin being larger and more closely arranged. The exopodite is similar to that of the second maxillipede.

Pereiopods : The first and second are chelate.

The chelae are equal. In the first, the ischiopodite is rather slender The carpus and propodus, especially the latter, are large and massive. The fingers are almost equal in size and about 2/3 as long as the rest of the propodus. The distal portion of the inner margin of the carpus and the entire inner margin of the propodus as well as the outer borders of the fingers are armed with long setae. The cutting edge of the fixed finger shows three small triangular cusps while that of the other is smooth (Fig. 2 P).

In the second leg all the segments are rather stout. The fingers are equal in size. The inner edge of the fixed fiinger bears three prominent teeth rudiments, while the dactylus has a smooth cutting edge. The inner margin of the merus and both margins of the carpus and propodus are armed with setae, those on the inner being longer and stouter. The fingers are also provided with setae along the outer edge and a few are present on the inner edge also (Fig. 2 Q).

Third leg : (Fig. 2R) The ischium, merus and carpus are rather slender, but the propodus is greatly expanded at the base so as to form a triangular lobe. The dactylus is small and triangular. Both the propodus and dactylus are thickly set with setae, those along the hinder edge of the propodus being much larger than the others.

The fourth and fifth legs are very slender when compared with the preceding. The last two joints of both are provided with close set setae. (Fig. 2S & T).

The fifth leg is distinctly subchelate and its propodite is armed with a cluster of setae arising just behind its distal end.

Each of the first four pereiopods carries a small spineless process on the outer of the basipodite which is the vestige of the exopodite (Fig. 2F).

Abdomen : The sixth segment is longer than those in front. The pleural margin of the first five somites have a few hairs but those of the sixth segment have fringed stout plumose setae through-out their length all of which are curved backwards. The two somites are still devoid of appendages, the succeeding four segments having pleopods.

Pleopods : Each pleopod has a short thick peduncle and two flattened lobes, the inner of which is shorter than the outer. Both the lobes are borne with long plumose setae except on the proximal half of the inner margin of the outer. The inner margin of the endopodite has a small appendix interna carrying five keels (Fig. 2U).

Uropods : (Fig. 2V) These are large. The outer lobes are much broader than inner, their outer margins being almost twice as broad as those of the inner interior, outer and distal halves of the posterior margins are set with plumose setae of which are considerably shorter than the others. The inner lobe is shorter than outer and bears setae only on

its posterior border. A few plumose setae are present in the peduncle.

Telson : (Fig. 2V) Shows variations in length in different specimens. It may be as long as or slightly longer or shorter than the inner lobe of the uropods. It is not rectangular as in other species of *Callianassa*, the posterior end being about a third as broad again as the anterior end. The posterior edge has still got a shallow central notch in which a vestige of the median spine persists. On either side of this there are short, plumose setae and a few smooth, slender setae arising in front of the edge. On the dorsal side arising from a prominence there are four or two of which are shorter than the other two.

Experimental Observations

Experimental investigations on the tolerance of the burrowing shrimp to increase in salinity (density) was conducted by introducing the animals at 10°Be at normal temperature, 28°C. This experiment was repeated thrice in the field, and revealed that at 20° Be the shrimps survived for 8—10 minutes after which period they became moribund and died. In the 10°Be brine water, the shrimps survived for 120 minutes although the beating of the appendages became erratic after 30 minutes. In another series of experiments, in which the experimental shrimps were subjected to alternate submersion in 10°Be brine water for 30 minutes and exposure to atmospheric air for 20 minutes (with wet gills) these animals survived for 4—5 hours.

In a third series of experiments, these burrowing shrimps were introduced into plastic containers which had been half filled with loose clayey mud along with brine water of 5°Be which were collected from the salt-pan area. The shrimps burrowed into this loosely laid layer. At this stage sandy clay was set compactly above the layer to a height of 40 cm. above which salt mixed with sandy clay in the proportion of 1 : 10 was set for 2 cm. Brine water of 5°Be was poured once in every three hours. Under these conditions the experimental shrimps died within 12 hours.

Recommendations

The following recommendations are therefore given for killing the prime burrower *Callianassa maxima* inhabiting the upper six feet (180) cm vertical zone and driving the hardier adults deeper below the six feet depth so that the salt water and subsequently the brine can be retained in the pans without seepage during low tide and diluted with lower saline water during the subsequent high tide.

1. Ploughing of the infested area should be done and the ploughed land has to be left undisturbed for two days during the hot season, preferably April-May. At this stage, by the use of a suitable heavy roller or by the age-old method of using a plank weighted down by 8-10 persons and pulled over the fields by mechanical or manual means which would make the upper surface region compact, these alternate ploughing and ramming operations should be carried out, eight to ten times. At this stage after blocking the burrows and by letting condensed brines at 8°Be flow into infested places, this shrimp pest can be vanquished slowly, so that in the third month of salt manufacture the "Shrimp past" disappears. By such a method, the burrowers upto a depth of one foot will be killed or driven below 1 foot depth and the tunnels fortified with the shells would crumble and cave in resulting in the vertical zone of one

foot from the surface becoming compact, non-porous without any tunnels, so that the burrowers are not able to set up a current facilitating feeding and respiratory activities, due to lack of plankton, detritus and lack of oxygen. Now, salt should be sprayed on the infested beds and the roller applied again so that the salt is driven into the top most layers of the surface and any surviving burrowers would be killed on contact. Later the pans should be prepared for the introduction of high density brine, so that any accidental percolation of the brine into the lower layers would not allow the animals to rehabilitate themselves in the one foot vertical zone.

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