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Lernaeid Copepod Parasitic on the Freshwater Fishes of Godavari River, Rajahmundry, Andhra Pradesh, India with Description of a New Species, *Lernaea notopteri* n.sp. from *Notopterus notopterus*

Anu Prasanna Vankara[1*], Mani Gudivada[2] and Vijayalakshmi Chikkam[3]

[1]Department of Zoology, Yogi Vemana University, Kadapa, 516 003, India.
[2]Department of Zoology, Maharajah College, Vizianagaram-535 002, India.
[3]Department of Zoology, Andhra University, Visakhapatnam, 530 003, India.

Authors' contributions

This work was carried out in collaboration between all authors. Author APV designed the study, collected the host samples from sampling sites, carried out dissections, collected the parasites and managed the literature searches. Authors MG and VC helped in processing the parasites and preparing the first and final draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Lernaeid copepods are one of the most detrimental and ubiquitous ectoparasites of cultured and wild variety freshwater fishes. River Godavari offers a dynamic habitat to a wide variety of fishes which are in turn infected by endo and ectoparasites. In a copepod parasitic survey on various species of freshwater fishes of River Godavari, Rajahmundry from 2007-2009, a total of 5 freshwater fishes were parasitized by copepods of the genus *Lernaea*. Four different adult species of *Lernaea* were found clinging to the skin of *Channa punctatus*, *Catla catla*, *Barbus sp.*, *Macrognathus aculeatus* and *Notopterus notopterus* i.e., *Lernaea bengalensis* Gnanamuthu, [17],

**Corresponding author: E-mail: dr.anu@yogivemanauniversity.ac.in, annuprasanna@gmail.com;*

Lernaea cyprinacea Linnaeus, 1758, *Lernaea cyprinacea mastacembeli* Hu, [13] and a new species, *Lernaea notopteri* n.sp. The new lerneaid copepod, *Lernaea notopteri* was reported from *Notopterus notopterus* showed variations in cephalic arms, antenna, maxillipede and Leg-V from the other closely related species and hence was designated as new species.

Keywords: Crustacea; lernaeidae; India; River Godavari; fresh water fish; descriptions; n. sp (new species).

1. INTRODUCTION

Ectoparasites in particular, lernaeids are deemed to be one of the most harmful and prevalent ectoparasites of cultured fishes [1]. Lernaeids commonly known as 'anchor worms' are the crustacean copepod parasites infecting a wide variety of wild caught and pond-raised freshwater fishes. Approximately, 110 lernaeid species have been reported under the genus [2]. Damage caused by Lerneids is very severe and can result in "Lernaeosis" outbreak infecting major parts of the body such as skin, eyes, gills, fins, mouth and tissues of infected fishes and results in the mortality of the young fishes [3-6]. Female lernaeids are known to be more parasitic in nature as they attack body surface of fish and penetrates deep into the tissues after eating fish scales forming a deep wounds which in turn invite secondary microbial infections [7-12]. Many scientists all over world focused on the severity, pathogenicity and diversity of lernaeid parasites infesting various freshwater fishes [2,3,13-32]. Also, few scientists added a note on the life-history of lernaeid parasites [15,33-35]. River Godavari is known for its dynamic environment, enriched by the nutrients proved to be a highly productive and prospective field to accomplish fishery research. Godavari River inhabits a diversified array of teleostean fauna which in turn offer a diversified range of habitat to the metazoan parasitic fauna. This study aims to analyse the lernaeid copepods keeping the severity of the infection in view caused by these parasites on the freshwater fishes of River Godavari, Rajahmundry.

2. MATERIALS AND METHODS

Fish were collected from fishery locations and local markets near River Godavari, Rajahmundry, Andhra Pradesh during 2007-2009 and were brought to the laboratory for thorough examination of skin and gills. The skin and gill filaments were carefully washed and teased, and the contents were observed under a stereo microscope (LM-52-3621 Elegant). Standard protocols were followed to preserve and identify the parasites [36,37]. Copepod parasites were collected and fixed in 10% formalin. The parasites were identified by keeping them in cavity blocks with a few drops of lactic acid for 12-24 hrs for clearing. Parasites were observed, identified and captured in photographs under Lynx trinocular microscope (N-800M). For detailed study, one parasite from each group was dissected; mouthparts and appendages were separated to draw line diagrams with the aid of attached drawing tube in the microscope. Measurements are given in millimetres (mm) with ocular micrometer unless otherwise stated.

3. RESULTS

In the present survey, only 5 freshwater fish were infected with the copepods of the genus *Lernaea*. Out of four adult species of *Lernaea*, i.e *Lernaea bengalensis* Gnanamuthu, [17] from *Channa punctatus*, *Lernaea cyprinacea* Linnaeus, 1758 from *Catla catla* and *Barbus sp.*, *Lernaea cyprinacea mastacembeli* Hu, [13] from *Macrognathus aculeatus* are redescriptions while *Lernaea notopteri* n. sp. found adhered to the skin of *Notopterus notopterus* is reported as new species and is described in detail. The diversity parameters of each lernaeid species is detailed in Table 5.

Family	*:* Lernaeidae Cobbold, 1879
Genus	: *Lernaea* Linnaeus, [38]

***Lernaea bengalensis* Gnanamuthu, [17]**
(Plate-1: Figs. 1-10; Tables 1 and 5)

Host: *Channa punctatus* Bloch

Site of infection: skin of the fish near dorsal, anal and pectoral fins

Locality: Godavari River, Rajahmundry, Andhra Pradesh

Description (based on 38 specimens):

Body (4.52-5.11) elongate, cylindrical, straight. Body well-marked into head, neck, trunk and abdomen. Head (0.21-0.28) covered by sub-

elliptical lobe, fused all around. Mouth parts covered by lobe. First thoracic segment fused with the head and is the broadest part of the body, extends laterally into four unbranched, simple cephalic arms which appear as 'X' when viewed from the front. Anterior arms shorter than posterior. Cephalic arms 1.18-2.01. Posterior region of first segment with first pair of legs curved towards each other. Neck uniformly slender, cylindrical and bears second and third pair of legs. Trunk (3.42-3.56) is the longest part of the body, broadens posteriorly and bulges to form genital region and bears fourth and fifth legs. Two large round swellings pressed together form 'heel' known as pregenital prominces lodge the egg sacs. Abdomen (0.85-0.98) cylindrical, squarish or slightly round bears two anal laminae. Lamina (0.21-0.25) two segmented, basal, naked; distal with three short spines and a long seta. *First antenna*: 5-segmented; basal short with one seta on the outer distal corner, second segment with a long seta and few short setae on the outer margin; third segment naked; fourth with a long, blunt seta on the distal margin and distal with three setae on the inner margin and few setae apically. *Second antenna*: 3-segmented, basal short and naked; middle longer than basal and naked and distal curved to a blunt terminal claw and with setae apically. *Maxillule*: First maxilla not clearly visible. Maxilla: 2-segmented, basal broad and short; distal curved to a blunt claw. *Maxilliped*: Two-segmented, basal short, naked and distal long, with five terminal claws, a blunt process and a conical process with short setae on the inner medial margin. Legs I to IV biramous; with three-segmented exopod and endopod. Of the four pairs of thoracic legs, the first pair occurs on the first thoracic segment fused with head, while the remaining four are spaced on the neck and trunk. Coxapod with seta on either side. Leg-V: Rudimentary.

Table 1. Armature of legs (Roman numerals indicate spines and Arabic numerals indicate setae)

Legs	Exopod	Endopod
Leg-I	I-1; I-1; II-5	0-1; 0-1; II-4
Leg-II	I-1; I-1;II-6	0-1; 0-2, II-3
Leg-III	I-1, I-1; II-6	0-1; 0-1; II-3
Leg-IV	I-1; I-1; II-5	0-1; 0-1; I-4

***Lernaea cyprinacea* Linnaeus, 1758 (Plate-2: Figs. 1-11; Tables 2 and 5)**

Host: *Catla catla*., *Barbus* sp.

Site of infection: Skin

Locality: Godavari River, Rajahmundry, Andhra Pradesh

Description (based on 12 specimens):

Total body 4.58-4.78. Head circular, projects out from the body in the form of a protruberance. Head (0.17-0.18 x 0.15-0.16) fused all around. First thoracic segment fused with cephalon and is the broadest part of the body, extending laterally into four bifid cephalic arms. Cephalic arms in the form of 'X' when viewed from the front. Anterior arms (0.30-0.45 x 0.20) shorter than posterior arms (0.50 x 0.20). Posterior region of the first segment bears first pair of legs which curve towards each other between the two ventro-lateral arms. Neck or free thorax slender, cylindrical bearing second and third pairs of legs. Behind the third pair starts the trunk, to form genital region and bears fourth and fifth pair of legs. Abdomen (0.52-0.55 x 0.34-0.36) cylindrical. Posterior tip of abdomen bears to elongated, small, conical anal laminae. Each lamina (0.20-0.22) with a long seta and two short spine like setae. *First antenna*: 4-segmented, basal naked, second segment large and broad with numerous setae scattered on the outer margin; third segment with one seta on the inner distal margin; distal with one seta on the outer margin, three setae on the inner margin and a tuft of setae apically. *Second antenna*: Three-segmented; basal and second segment naked, distal long and slender terminally curved to a blunt spine with three setae on the inner margin and few setae apically. *Maxillule*: First maxilla not clearly visible. *Maxilla*: 2-segmented; basal stout and broader with a blunt conical process on the inner medial margin; distal narrow, short and curved to two stout claws. *Maxilliped*: Maxillipeds directed forwards close to other mouth appendages. It is short, with five terminal claws on the distal segment. Basal broad with a blunt conical process on the inner distal margin and a conical process with a spine on the inner proximal region. Legs I to IV biramous; with three-segmented exopod and endopod. Of the five pairs of thoracic legs, the first pair occurs on the first thoracic segment fused with head, while the remaining four are spaced on the neck and trunk. Coxapod with setae on either side. Leg-V: Uniramous, with one long and three short setae apically.

Table 2. Armature of legs (Roman numerals indicate spines and Arabic numerals indicate setae)

Legs	Exopod	Endopod
Leg-I	I-1; I-1; II-5	0-1; 0-1; II-4
Leg-II	I-1; I-1; II-6	0-1; 0-2, II-4
Leg-III	I-1, I-1; II-6	0-1; 0-2; II-4
Leg-IV	I-1; I-1; III-5	0-1; 0-2; I-4

***Lernaea cyprinacea mastacembeli* Hu, [13] (Plate- 3: Figs. 1-12; Tables 3 and 5)**

Host: *Macrognathus aculeatus*.

Site of infection: Skin

Locality: Godavari River, Rajahmundry, Andhra Pradesh

Description (based on 33 specimens):

Body (5.43-5.65) elongate, cylindrical, slightly S-shaped. Body divisible into head, trunk and abdomen. Head (0.22-0.26 x 0.19-0.21) covered by sub- elliptical lobe and is free anteriorly. Mouth parts not covered by lobe, located posterior to the lobe (Cephalon). First thoracic segment, broader part of the body, fused with head and extends into four cephalic arms. Cephalic arms (0.65-0.70 x 0.17-0.19) simple, unbranched, anterior arms shorter than the posterior and length of the arms slightly variable. Distal end of the anterior arms meet below the head. It also bears first pair of thoracic segment which is curved towards each other. Neck slender, bearing second and third pair of legs with a node-like swelling or constricts at their origin. Behind third pair starts the trunk, the longest part of the body, slender as neck anteriorly but widens gradually to form genital region and bears fourth and fifth legs. Abdomen (0.50-0.58 x 0.34-0.39) cylindrical, blunt-ended. Between the abdomen and posterior end of the trunk occurs a deep notch which lodges the two large cylindrical egg sacs but in the collected specimens the egg sacs are detached. Posterior tip of abdomen squarish, bears two elongated and small conical anal laminae. Each lamina (0.190) bears a long slender seta and four short setae and lamina. *First antenna*: 4-segmented, basal with a spine like seta, second segment with 7 short setae and a long seta, third segment with three long setae on the inner margin and distal with 8 setae. *Second antennna*: 3-segmented, shorter and attached close to the first antenna. Basal and middle segments naked and distal longer with terminal hook like spine and 7 setae apically. First maxilla has a narrow hook like blade, second maxilla has double blades. Maxilliped long, 3 segmented, basal broad and naked, middle with a pointed spine, conical process on the inner proximal margin and a knob with a spine medio-dorsally and distal with 4 long spines and 2 short stout spines apically. Leg 1 to 4 biramous, with 3-segmented exopod and endopod. Of the five pairs of thoracic legs, the first occurs in the cephalic region, while the remaining four are spaced on the neck and trunk. Fifth pair of legs clearly visible. First pair of legs are arched and kept at right angles to the body. Coxopod with a seta on either side. Leg-V: Uniramous, basipod with a spine on the inner margin and distal segment with 4 setae apically.

Table 3. Armature of legs (Roman numerals indicate spines and Arabic numerals indicate setae)

Legs	Exopod	Endopod
Leg-I	I-1; I-1; II-5	0-1; 0-2; II-4
Leg-II	I-1; I-1; II-6	0-1; 0-2, II-4
Leg-III	I-1, I-1; II-6	0-1; 0-2; II-4
Leg-IV	I-1; I-1; II-4	0-1; 0-2; II-4

***Lernaea notopteri* n. sp. (Plate- 4: Figs. 1-10, Plate-5; Tables 4 and 5)**

Family	*:* Lernaeidae Cobbold, 1879
Genus	: *Lernaea* Linnaeus, 1746
	: *Lernaea notopteri* n. sp.

Host: *Notopterus notopterus*

Site of infection: Skin

Locality: Godavari River, Rajahmundry, Andhra Pradesh

Description (based on 4 specimens):

Body (4.00-4.5) elongate, thin and slender, creamy white in colour. Head covered by a sub-elliptical lobe and free anteriorly. Head (0.15-0.18) fused with first thoracic segment, broader and bears four short, stout cephalic arms. Arms almost equal in length 0.30-0.32. Distal end of anterior arms meet below the head. First thoracic segment bears first pair of legs curved towards each other. Neck slender, thin and bears second and third pair of legs. Trunk broadens posteroirly to form genital region and bears fourth and fifth pair of legs. Abdomen slender, short, bluntly round and bears anal laminae. Anal lamina two-

segmented, basal naked and distal with three short spines and a long seta apically. *First antenna*: Four- segmented, basal short and naked; second with a tuft of setae on the outer margin, longer than other segments, third with 4 setae on outer margin and distal with 4 setae on inner margin and 5 setae apically. *Second antenna*: 3- segmented, basal and middle segments naked and distal longer than other two, curved to a claw, with a few setae apically. *Maxilla*: 2-segmented, basal broad and naked and distal curved into bifid claws. *Maxilliped*: 3-segmented, basal broad, middle long, with a small conical process and setae on its inner proximal corner and distal curved into 5 terminal claws. Legs I to IV biramous, with segmented exopod and endopod. Of the five pairs of thoracic legs, the first occurs in the cephalic region, while the remaining four are spaced on the neck and trunk. Exopod with a seta on either side. Leg-V: Uniramous, 2-segmented. Basal with one seta on outer distal margin and distal segment with one long seta and 3 short setae apically.

Table 4. Armature of legs (Roman numerals indicate spines and Arabic numerals indicate setae)

Legs	Exopod	Endopod
Leg-I	I-1; I-1; II-5	0-1; 0-2; II-4
Leg-II	I-1; I-1; II-6	0-1; 0-2, II-4
Leg-III	I-1, I-1; III-5	0-1; 0-2; II-4
Leg-IV	I-1; I-1; III-5	0-1; 0-2; II-3

4. DISCUSSION

Lernaea is the widely distributed parasitic genus of the freshwater fishes. The genus *Lernaea* was first erected with *L. cyprinacea* Linnaeus, 1758 the type-species [38]. Later, the first Asiatic species *L. elegans* was reported from *Anguilla Anguilla* [39]. But this species was later considered as junior synonym of *L. cyprinacea* [40]. Ho (1998) documented the cladistics of Lernaeidae and classified it into two sub-families Lernaeinae and Lamprogleinae consisting of seven genera in each sub-family. *Lernaea* is the most widely distributed genus with 3 valid species reported from Channidae family. Gnanamuthu [17] reported *L. bengalensis* from *Channa punctatus* from India. In the present study, the first lernaeid copepod was collected from the same host which resembles *L. bengalensis* in almost all characters, hence they are considered as *L. bengalensis*.

The second lernaeid copepod, *L. cyprinacea* is a widely distributed parasite of freshwater fishes in various parts of the world [21,41]. This species was later described as *L. elegans* by Leigh-sharpe [39] which was considered as junior synonym of *L. cyprinacea* by Harding [40]. *L. cyprinacea* is not a host-specific and has a wide host range [10,18,21,42-51]. According to Kabata [21], this species has been recorded from over 100 fish species from 25 families and 10 orders. Nagasawa et al. [51] recorded this species from 34 species and sub-species of fishes from 17 families and 10 orders and 2 amphibians of 2 families and 2 orders. In the present survey, these parasites were collected from *Catla catla* and *Barbus sp*. and hence were considered as *L. cyprinacea*.

The third lernaeid copepod identified in *Macrognathus aculeatus* was *L. cyprinacea mastacembeli* which was first proposed by Hu [13] from the gills of *Mastacembelus aculeatus*. It was considered as valid sub-species of *L. cyprinacea* [52]. In the present study, a large number of copepodid stages-I and IV of this species were obtained from *Mastacembelus armatus* and only single adult species was obtained from *Macrognathus aculeatus* and hence they were redescribed as *L. cyprinacea mastacembeli* Hu, [13].

In this study, the fourth species described was reported for the first time from the fish *Notopterus notopterus*. *L.cruciata* was described from *Notopterus kapirat* from River Godavari, Nanded but it differs from the present material in shape of cephalic arms [53]. This species was compared with the known four valid Indian reports of the genus, *L. chackoensis* Gnanamuthu, [14,15], *L. bengalensis* Gnanamuthu, [17], *L. hersaragattensis* Srinivasachar and Sundarabai, [23] and *L.osphronemi* Thomas and Hameed, [24] which shows few resemblances and differences with these parasites. Ho [2] gave a detailed cladistic analysis on *Lernaea*idae from 8 families of the total 13 families of fish hosts examined. However, he didn't encounter any speices of *Lernaea* from notopterid fish. The present material resembles *L. bengalensis* in the leg armature, body size and shape but differ in the cephalic arms, presence of unisegmented fifth leg and first antenna. Cephalic arms are short, equal and simple in present parasites while they are unequal, long and unlobed in *L. bengalensis*. Leg-V is unisegmented with three short setae and a long seta terminally while it is vestigial in *L. bengalensis*. First antenna of our specimens is provided by 24 spine like setae while setation is reduced in *L.*

bengalensis. These parasites resemble *L. chackoensis* in leg armature but differ on the branching of cephalic arms, setation on first antenna, number of claws on maxilliped and fifth leg. Fifth leg is vestigial in *L. chackoensis* while it is unisegmented with 3 short setae and a long seta terminally in the present parasites. Maxilliped possesses 7 terminal claws in *L. chackoensis* while they are 5 in the present parasites. Present specimens resemble *L. hersaragattensis* in the setation on first antenna and leg armature but differ in their body shape,

PLATE-1

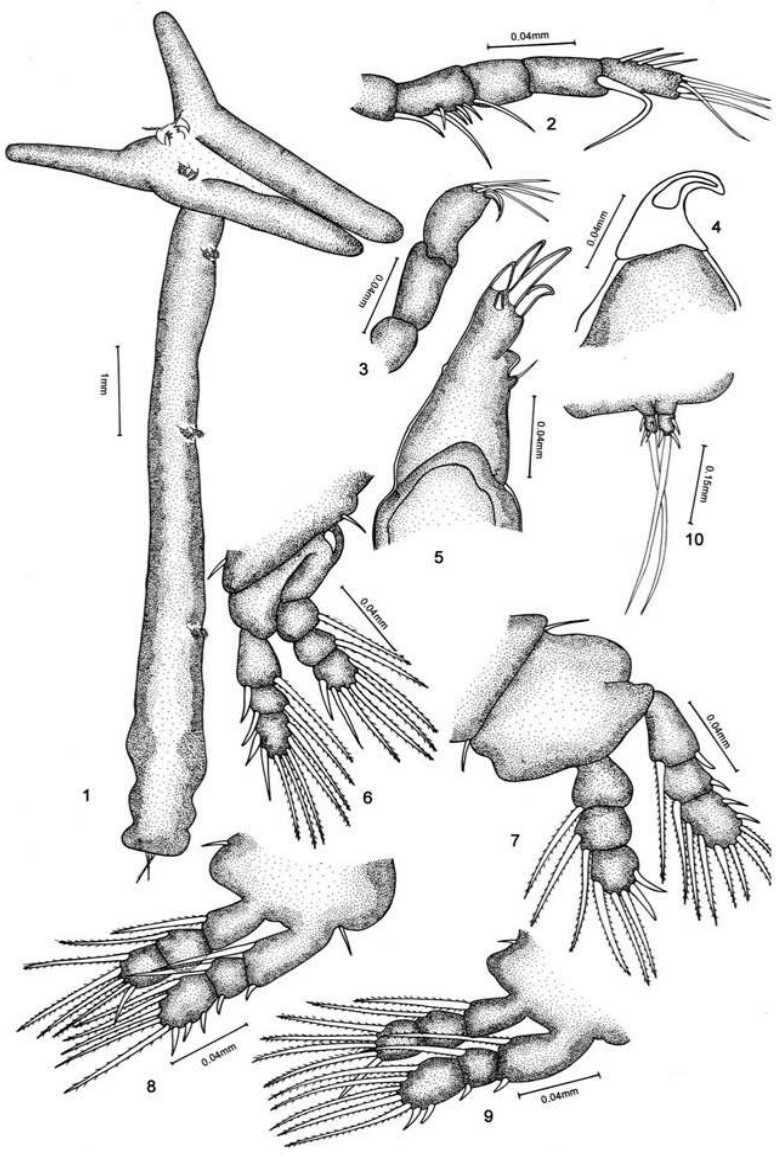

Plate-1. *Lernaea bengalensis* Gnanamuthu, [17]

1: Adult female-ventral view
2. Antennule
3: Antenna
4: Maxilla
5: Maxillipede
6: Leg-I
7: Leg-II
8: Leg-III
9: Leg-IV
10: Caudal rami

PLATE-2

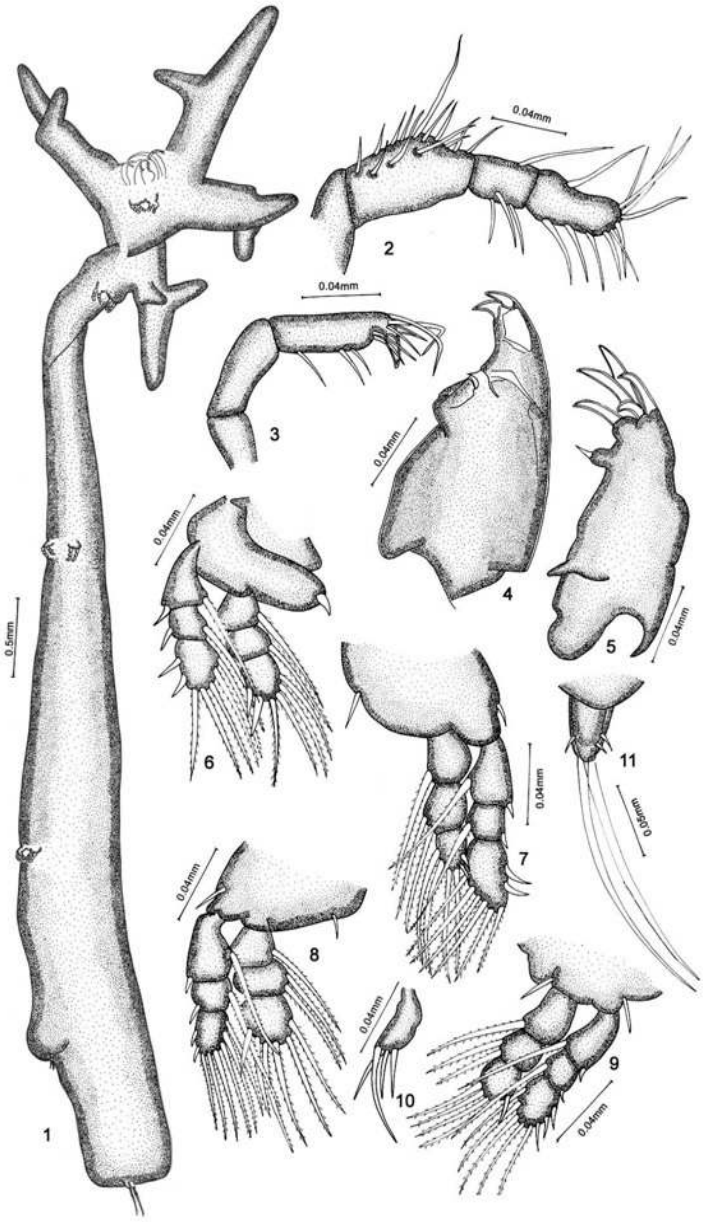

Plate-2. *Lernaea cyprinacea* Linnaeus, 1758

1: Adult female-ventral view	**5: Maxillipede**	**9: Leg-IV**
2. Antennule	**6: Leg-I**	**10: Leg-V**
3: Antenna	**7: Leg-II**	**11: Caudal rami**
4: Maxilla	**8: Leg-III**	

size, possessing simple cephalic arms and host. Maxilliped possesses 4 terminal claws in *L. hersaragattensis* while they are 5 in the present parasites. The present specimens resemble *L. osphronemi* in possessing a small cephalic arms, but differs in having 4-segmented first antenna, maxilliped with 5 terminal claws and absence of sixth leg as single setae. Present parasites

characteristically differ from all these parasites in the shape of body, cephalic arms, first antenna and number of terminal claws in maxillipeds. A table comparing these parasites with related species is given in Table 6. In view of the above differentiating characters and the occurrence of the parasites in *Notopterus notopterus*, it is justified to erect it to the status of a new species and is named as *Lernaea notopteri* taking the name of the host into consideration.

PLATE-3

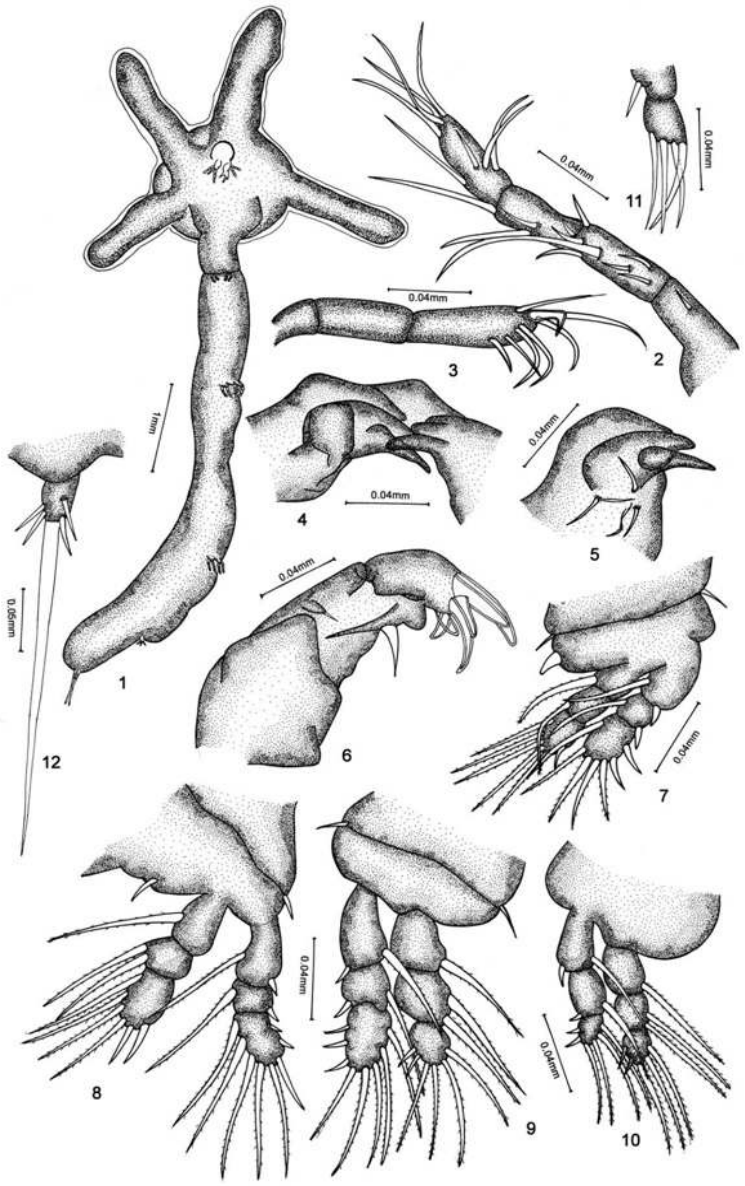

Plate-3. *Lernaea cyprinacea mastacembeli* Hu, [13]

1: Adult female-ventral view
2. Antennule
3: Antenna
4: Maxillules
5: Maxilla
6: Maxillipede
7: Leg-I
8: Leg-II
9: Leg-III
10: Leg-IV
11: Leg-V
12: Caudal rami

PLATE-4

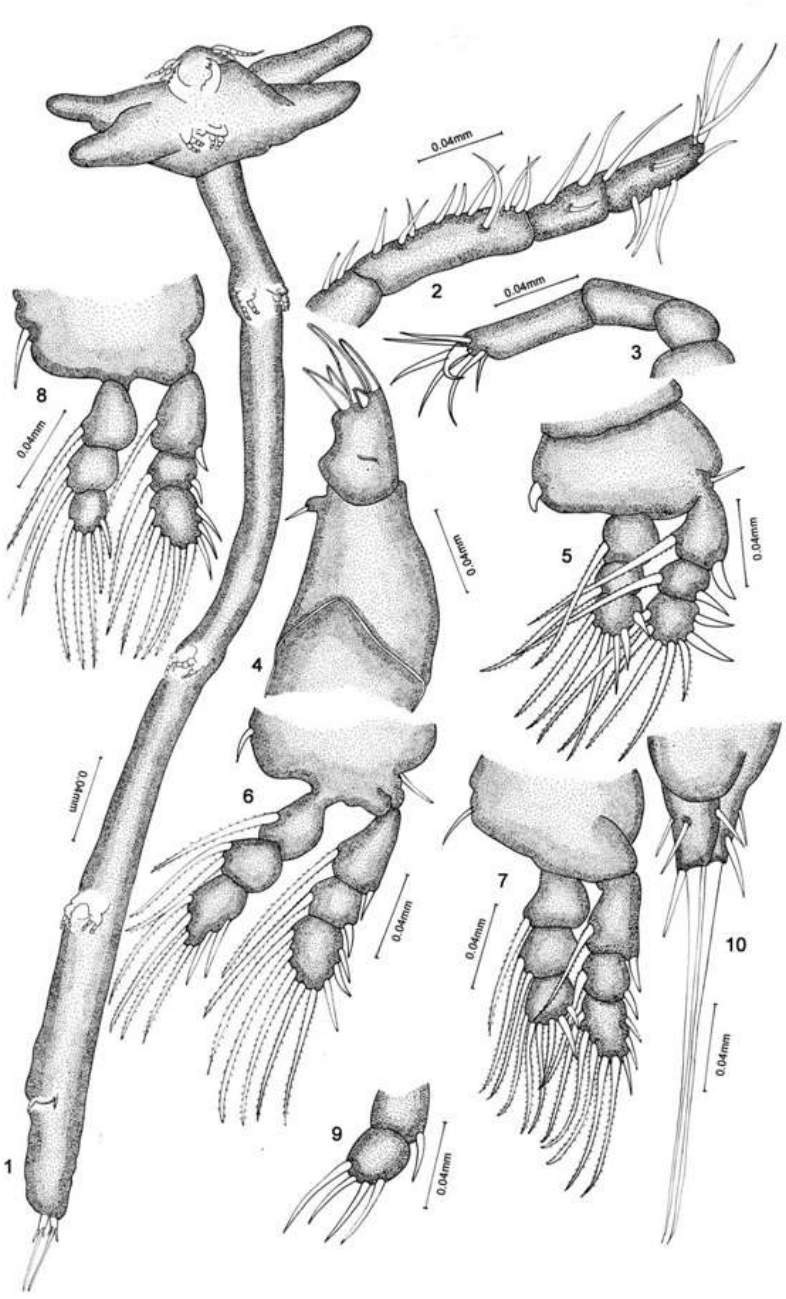

Plate-4. *Lernaea notopteri* n.sp.

1: Adult female-ventral view
2. Antennule
3: Antenna
4: Maxillipede
5: Leg-I
6: Leg-II
7: Leg-III
8: Leg-IV
9: Leg-V
10: Caudal rami

Table 5. Diversity parameters of lernaeids in different freshwater fishes of Godavari river

Name of the parasite	Name of the fish	No. of examined fish (a)	No. of infected fish (b)	No. of parasites Collected (c)	Prevalence % b/a*100	Mean intensity c/b	Mean abundance c/a
L. bengalensis Gnanamuthu, [14,15]	*C. punctatus* (Bloch)	252	25	38	9.92	1.52	0.15
L. cyprinacea	*Barbus* sp.	85	5	9	5.88	1.8	0.11
Linnaeus, 1758	*C. catla* (Hamilton)	198	43	3	21.72	0.07	0.015
L. cyprinacea mastacembeli Hu, [13]	*M. aculeatus* (Bloch)	561	25	33	4.46	1.32	0.06
L. notopteri n. sp.	*N. notopterus* (Pallas)	58	2	4	3.45	2	0.07

Table 6. Comparison of the *Lernaea notopteri* n.sp. with closely related species of the genus

Features	***Lernaea chackoensis*** **Gnanamuthu, [14,15]**	***L. bengalensis*** **Gnanamuthu, [17]**	***L. hesaragattensis*** **Srinivaschar & Sundarabai, [23]**	***L.osphronemi*** **Thomas and Hameed, [24]**	**Present species**
Host	*Catla catla*	*Channa punctatus*	*Lebistes reticulatus*	*Osphronemus goramy*	*Notopterus notopterus*
Body	Elongate, cylindrical straight body	Elongate, cylindrical, straight body	Elongate, cylindrical	Elonagate, Subcylindrical	Very long, thin and cylindrical
Cephalic arms	4, completely branched and asymmetrical arms; X-shaped	4, Simple, unlobed arms, anterior short and posterior long, X-shaped	4, highly branched and asymmetrical arms, anterior short, posterior long, X-shaped	4, Ventral arms slightly longer than dorsal arms	4, simple, equal and unlobed
First Antenna	4 segmented with 26 spine like setae	5-segmented, setation reduced (15)	4-segmented, with 24 spine like setae	Uniramous, 3-segmented with 24 spine like setae	4-segemtned with 24 spine like setae
Maxilliped	Terminal claws are seven	Terminal claws-five	Terminal claws- four	2-segmented, terminal claws-four	Terminal claws- five
Leg-V	Vestigeal, uniramous	Vestigeal	Vestigeal, uniramous	Unisegmented with 4 small setae of unequal length; sixth leg present as single seta.	Unisegmented, with three short setae and a long seta

PLATE-5

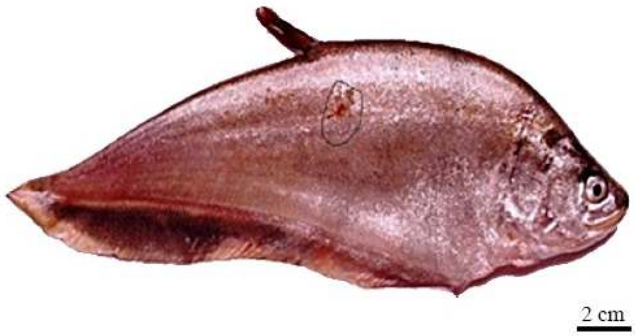

Plate 5. Infection of *Lernaea notopteri* n.sp. on the skin of *N. notopterus*

5. CONCLUSION

The present copepod parasitic survey on the various species of freshwater fishes of River Godavari, Rajahmundry showed a total of 4 adult species of *Lernaea* found adhered to the skin of *Channa punctatus*, *Catla catla*, *Barbus* sp., *Macrognathus aculeatus* and *Notopterus notopterus*. The new lerneaid copepod, *Lernaea notopteri* was reported from *N.notopterus* which showed variations in the body, antennules, maxillipeds, cephalic arms and leg-V when compared with closely related species. This type of study will benefit future generations to conduct molecular systematics studies of the different lernaeid copepods.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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