Redescription of Lamproglena Clariae Fryer, 1956 (Copepoda, Lernaeidae), With Notes On Its Occurrence and Distribution

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REDESCRIPTION OF *LAMPROGLENA CLARIAE* FRYER, 1956 (COPEPODA, LERNAEIDAE), WITH NOTES ON ITS OCCURRENCE AND DISTRIBUTION

BY

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ABSTRACT

The morphology of the gill parasite *Lamproglena clariae* Fryer, 1956, from the Olifants River, Kruger National Park, South Africa, was studied with the aid of light and scanning electron microscopy. Ultrastructural details of all appendages are given as well as a table and map with information on the occurrence and distribution of *L. clariae* in Africa. Important morphological findings include: the observation of only one claw on the maxilla; first time findings and descriptions of the nuchal organ, upper and lower lips, the fifth pair of legs and circular openings on all appendages.

RÉSUMÉ

La morphologie du parasite branchial *Lamproglena clariae* Fryer, 1956, de la rivière Olifants, Parc National Kruger, Afrique du Sud, a été étudiée en microscopie optique et électronique à balayage. Les détails ultrastructuraux de tous les appendices sont donnés, de même qu'une carte et un tableau présentant les informations sur la présence et la distribution de *L. clariae* en Afrique. Les constatations morphologiques importantes concernent: l'observation d'une seule griffe sur la maxille, les premières découvertes et descriptions de l'organe nucal, des lévres supérieure et inférieure, les pattes de la cinquième paire biramées, et des orifices circulaires sur tous les appendices.

INTRODUCTION

Lamproglena Von Nordmann, 1832, is a cosmopolitan parasitic genus, comprising 28 species. Thirteen of these species occur in Africa, 14 in Asia, and one in Europe (Kumarie et al., 1989). The African ectoparasitic copepod *Lam-*

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proglena clariae Fryer, 1956, attaches to the gill filaments of freshwater fish of the family Clariidae.

Lamproglena clariae was first described by Fryer (1956) from material collected from Lake Malawi. This description, although adequate at the time, lacks detail of a number of morphological features. With the discovery of specimens of *L. clariae* from Lake Victoria and the White Nile (Fryer, 1961, 1964) additional morphological detail was added, for example the number of setae forming the armature of the legs and the furcal rami. Specimens of *L. clariae* from *Clarias gariepinus* (Burchell, 1822) in the Olifants River, Kruger National Park, South Africa and the Cuando River in the Caprivi strip are redescribed here with the aid of light and scanning electron microscopy.

MATERIALS AND METHODS

Females of *L. clariae*, were collected from the gills of *C. gariepinus*, in the Olifants River in the Kruger National Park, South Africa and in the Cuando River in the Caprivi Strip, Namibia. Specimens were fixed in 70% AFA (Alcohol-formaldehyde-acetic acid) and 70% ethanol. Ethanol fixed specimens were cleared in 90% lactic acid, mounted and drawn with the aid of a drawing tube attachment. The syntypes (1957.9.6.8.) of *L. clariae* from the Lake Malawi collection (Fryer, 1956), were obtained from The Natural History Museum, London, for comparison. Specimens for scanning electron microscopy, were rehydrated, brushed in water and freeze dried for a minimum of 12 hours at $-60°C$. Specimens were sputter coated with gold and examined at 10 kV.

AFA fixed specimens for histological study were dehydrated and embedded in Transmit (LM) resin (Spurr, 1969), sectioned at 5 μm and stained with azan (Humason, 1979).

RESULTS

Lamproglena clariae Fryer, 1956 (figs. 1-7)

Description of the adult female. — Body elongated (fig. 1a), 5.39 mm (4.62-7.35 mm; $n = 12$), widest at the centre, tapering slightly anteriorly and posteriorly. Head as wide as the middle body region. Slightly transparent yellow body, digestive tract distinct, containing red blood cells. Cephalothorax, thorax and abdomen more distinctly demarcated from each other than the segmentation within these regions.

A disc-shaped nuchal organ is present dorsally, sunken centrally on the cephalothorax, the surface is papillated and periphery raised from body surface

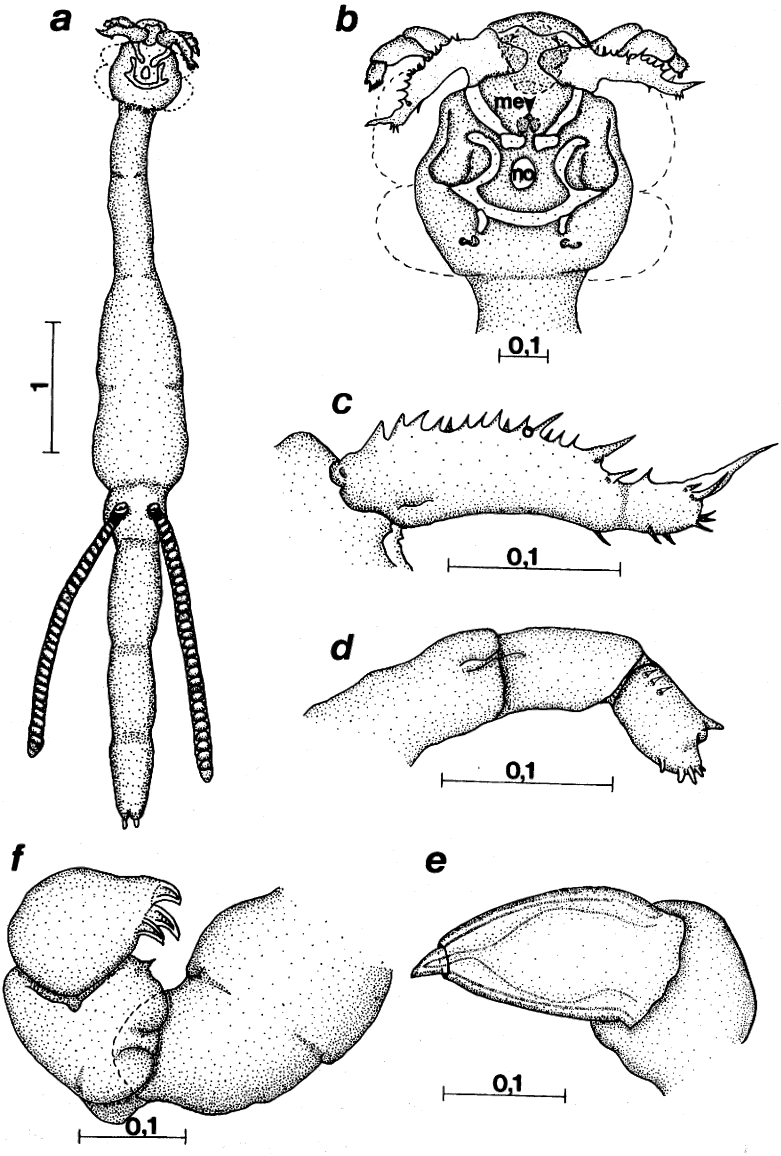

Fig. 1. *Lamproglena clariae* Fryer, 1956. a, female, dorsal view; b, head, dorsal view showing nuchal organ (no) and median eye (me); c, antennula; d, antenna; e, maxilla; f, maxilliped with accessory seta. (Scale bar in mm.)

(figs. 1a, b, 3a). Degeneration of this organ was found on older mature females. The median eye consists of three red ocelli and occurs mid-dorsally, anteriorly from the nuchal organ (fig. 1b).

Paired sensory antennulae are elongated and made up of one podomere with a slight constriction, about three quarters down its length (fig. 3b, c). Eighteen to nineteen setae line the preaxial margin. One large seta (47.1 μm) and five to six small setae (12.9 μm) are situated terminally. On the inferior margin up to three setae were observed (fig. 1c). The surface of the antennulae appears to have a mildly studded texture and a number of circular pores were observed on the surface of the antennulae (fig. 3c).

Antennae (fig. 1d) occur posterior to the antennulae and consist of three distinct podomeres, the basal slightly longer than the other two podomeres. Distal podomere terminates in two papillae, i.e., inferior and superior papillae bearing five and one blunt setae, respectively. Situated posteriorly from these papillae is a group of three spines (figs. 1d, 3d).

The mouth and buccal cavity (fig. 3e) are situated on the ventral side of the cephalothorax, anterior to the maxillae. The buccal cavity is surrounded by a sclerotized framework, with a raised upper lip covering the mouth (figs. 2b, 3f) and lower lip (fig. 4a). Both the upper and lower lips are triangular in shape and have circular pores on both lateral sides. No mandibles and maxillulae or associated musculature were observed in light microscopy, scanning electron microscopy or transverse serial sections.

Posterior to the buccal opening three papillated, finger-like cuticulated processes originate from the ventral surface of the head (fig. 3f). No musculature was observed associated with these papillae in transverse serial sections. The maxillae (figs. 1e, 3f) are short and strong, consisting of two podomeres. Preceding the swollen basal, is the terminal podomere which narrows and terminates in a sclerotized claw. The base of the claw is covered with a chitinous sheath. Maxillipeds comprise three podomeres (fig. 1f) each. The stout, basal podomere is twice as large as the other two, the terminal podomere bears three claws, two of equal size and one slightly larger. The second podomere is furnished with a small accessory seta on its anterior margin (fig. 1f).

Thorax elongated, five-segmented. The first two form the neck region. Segmentation of the first four segments is inconspicuous except for the genital segment which is distinctly demarcated from the thorax and abdomen (fig. 1a). Segments one to four bear one pair of biramous legs, which decrease in size and simplify in form, from the first to the fourth thoracic segment, with the endo- and exopodite of each pair made up of two podomeres each. The proto-, exo-, and endopodites of all legs have varying numbers of circular pores on their surfaces (fig. 4c, d).

On the first pair of legs, the protopodite bears one seta at the base in conjunction with a lateral opening. A semi-circular structure carrying a series of

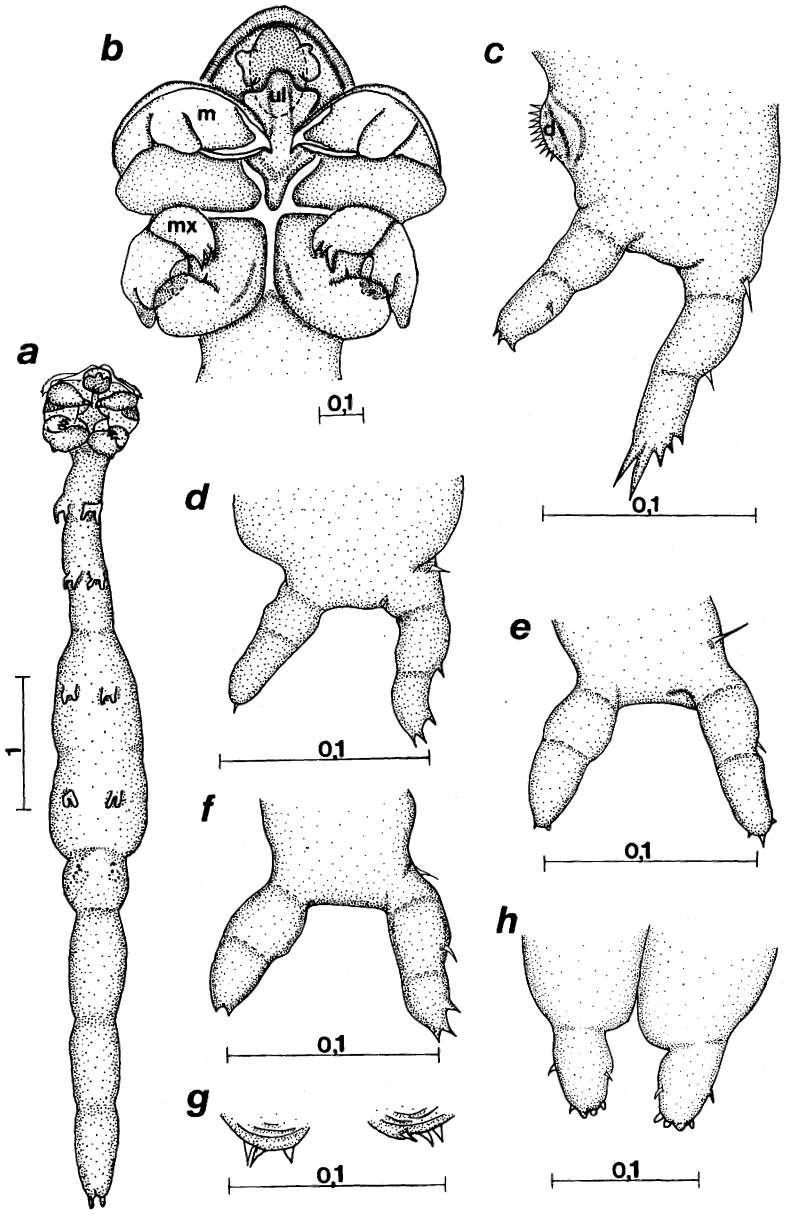

Fig. 2. *Lamproglena clariae* Fryer, 1956. a, female, ventral view; b, head, ventral view with maxillae (m), maxillipedes (mx) and upper lip (ul); c, first leg with denticle (d); d, second leg; e, third leg; f, fourth leg; g, fifth legs; h, furcal rami. (Scale bar in mm.)

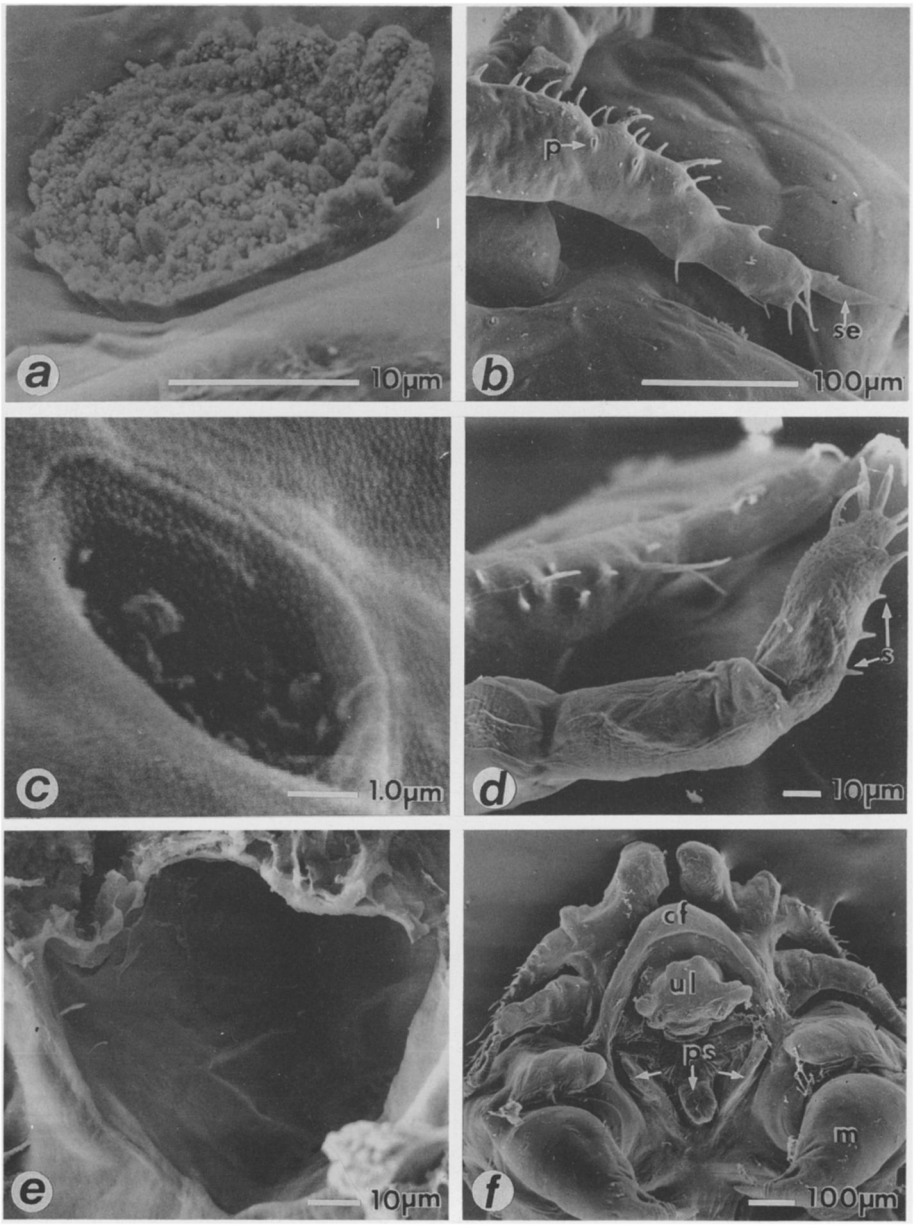

Fig. 3. Scanning electron micrographs of *Lamproglena clariae* Fryer, 1956. a, nuchal organ; b, antennula with large seta (se) and circular pores (p); c, pore on antennula showing surrounding studded texture; d, antenna with three triangular spines (s); e, buccal cavity after microdissection; f, head with chitinized framework (cf), upper lip (ul), three papillated structures (ps) and maxilla (m).

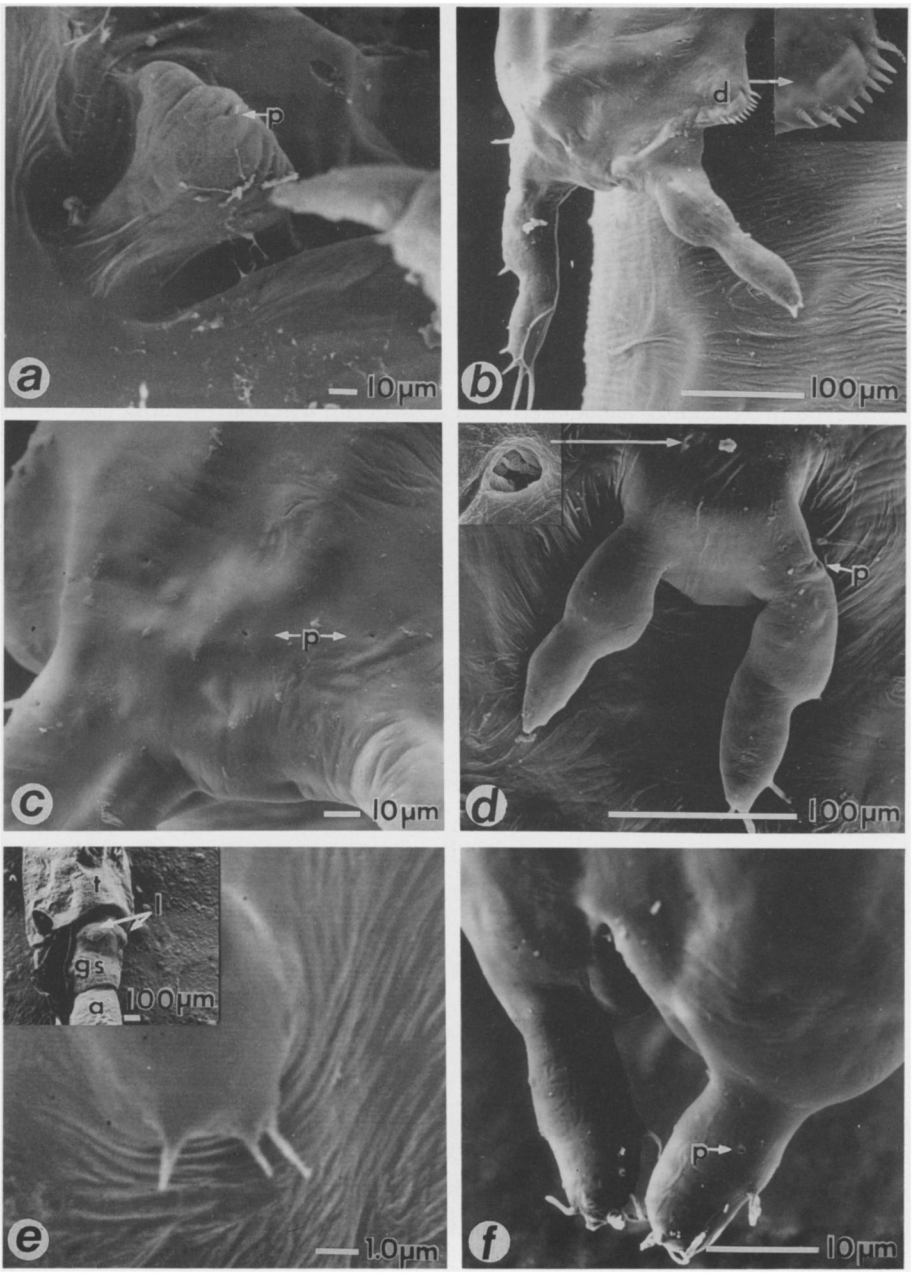

Fig. 4. Scanning electron micrographs of *Lamproglena clariae* Fryer, 1956. a, lower lip showing circular pores (p); b, first thoracic leg with denticled protrusion (d); c, protopodite showing circular pores; d, third leg with setation and circular pores (p); e, (small) overview of genital segment (gs) between thorax (t) and abdomen (a) showing the fifth pair of legs (l) and (large) a detail of a fifth leg; f, furcal rami with setation and pores.

8-12 minute denticles, protrudes from the margin of the protopodite above the endopodite (figs. 2c, 4b). A second lateral seta is present on the first podomere and two long and three short setae are present on the exopodite's terminal podomere. The endopodite has one lateral seta on the terminal podomere, and terminates in three inconspicuous setae (fig. 2c).

A lateral seta as well as a posterior circular opening occur on the protopodite of the second pair of legs. It furthermore bears a plain, semi-circular protrusion (fig. 2d). One lateral seta present on the exopodite of the first podomere, terminal podomere bearing three setae terminally. Endopodite bears one inconspicuous terminal seta (fig. 2d).

On the third and fourth pairs of legs, the exopodites bear two lateral setae, one on the protopodite, associated with a posterior circular opening (fig. 4d) and the other on the first podomere. The terminal podomere bears three reduced setae, one of which extends slightly lateral. Endopodites have two reduced setae terminally (fig. 2e, f). Fifth pair of legs present on the fifth (genital) segment (fig. 4e) significantly reduced, consisting of a minute papillar swelling surmounted by three setae (figs. 2g, 4e).

The genital segment furthermore bears two dorsal genital openings from where two uniseriated egg sacs extend, carrying between 18 and 40 ($n = 11$) eggs each (fig. 1a). In the third and fourth thoracic segments eggs are visible in the oviduct and ovarium.

Abdomen made up of three distinct segments, only the terminal segment bears any structures, i.e., the furcal rami (figs. 1a, 2a, 2h, 4f). These structures are short and blunt, with two setae extending laterally and four to five blunt setae extending terminally (fig. 2h). Circular openings present at all setal bases.

Occurrence and distribution. — *Lamproglena clariae* is endemic to Africa. Although not regarded as pan-African by Fryer (1968), it was subsequently found in East, West, Southern and Central Africa (Shötter, 1977; Euler & Avenant-Oldewage, 1992). The occurrence and distribution of this parasite is summarised in table I, and illustrated in fig. 5. *L. clariae* were generally found on either extremity of the gills (fig. 6a) and attached midway along the gill filaments (fig. 6b) and on the apex. Lesions, caused by the parasite, were haemorrhaged and hyperplasia was frequently observed around the site of attachment.

Prevalence and intensity of *L. clariae* on *C. gariepinus* from two locations at the study site were recorded during 1990-1994. Two locations were sampled, i.e., Mamba Weir, in the vicinity of asbestos and copper mines and therefore affected by its effluent (Van Vuren et al., unpublished) and Balule, $\pm$ 80 km into the Kruger National Park, preceded by a reed bed and therefore less affected by

TABLE I

Occurrence and distribution of *Lamproglena clariae* Fryer, 1956

Numbering on map	Reference	Location	Host species
1	Fryer, 1956	Lake Malawi,	Clariid species
2		Banga River tributary of Luweya	*Clarias mossambicus* Peters, 1852
3	Fryer, 1961	Lake Victoria,	*Clarias mossambicus*
4		Iragalla, Malagarasi Swamps	*Heterobronchus longifilis* Valenciennes, 1840
5	Fryer, 1964	White Nile near Khartoum	*Clarias lazera* Cuvier & Valenciennes, 1840
1	Fryer, 1968	Lake Malawi,	Clariid species
3		Lake Victoria/ Albert, Lower Nile	
6	Thurston, 1970	Edward-George Lake System, Kazinga Channel, Uganda	*Clarias lazera*
7	Shötter, 1977	Galma River, lakes around Zaria in Nigeria	*Clarias anguillaris* Linnaeus, 1758
8	O.U.R.	Cuando River Namibia	*Clarias gariepinus* (Burchell, 1822)
9	Euler & Avenant-Oldewage, 1992	Olifants River South Africa	*Clarias gariepinus*

O.U.R. = Own Unpublished Records.

pollution (Van Vuren et al., unpublished). This section of the Olifants River is characterized by small and shallow pools. The occurrence and distribution of the parasite in the above-mentioned sites and in the Cuando River is summarized in fig. 7 and table II.

The general trend appears to be that the less polluted site, Balule, has the highest prevalence, intensity and relative parasite density, for example as regards the relative parasite densities of *L. clariae* in October 1990, Balule has a value of 1.00 compared to a value of 0.20 found at Mamba (table II). With regard to seasonal variability, more host species were infested in both localities; in August 1991, 42.9% of fish were infested and in July 1994, 52.5% were infested. Intensity of infestation was highest in winter (July and August), with a decrease in autumn through summer. The highest number of parasites on a single host (17) was recorded at Balule in May 1994 (late autumn) at which time the second highest prevalence was also recorded, i.e., 50%.

Fig. 5. Map of Africa showing the distribution of *Lamproglena clariae* Fryer, 1956.

DISCUSSION

With the restriction of *L. clariae* to the Clariidae, its geographical distribution is surprisingly wide (Fryer, 1968), with Shötter (1977) even regarding it as pan-African. This phenomenon occurs as a result of their host being able to lock their pectoral fins allowing them to crawl across watersheds and even land to new water sources (Skelton, 1993). Adaptation and survival of these parasites in air during crossings and to new water conditions is highly probable as permanent attachment to its host allows for a continuous supply of food and a decrease in the desiccation rate seems likely.

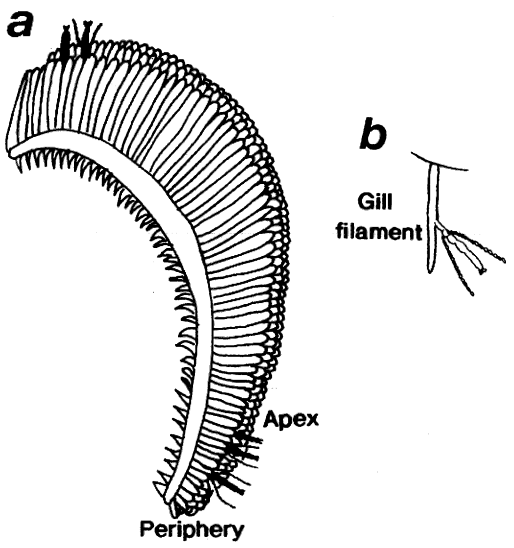

Fig. 6. a, gill arch of *Clarias gariepinus* (Burchell, 1822) to show the position of *Lamproglena clariae* Fryer, 1956; b, position of attachment of *Lamproglena clariae* on a single gill filament.

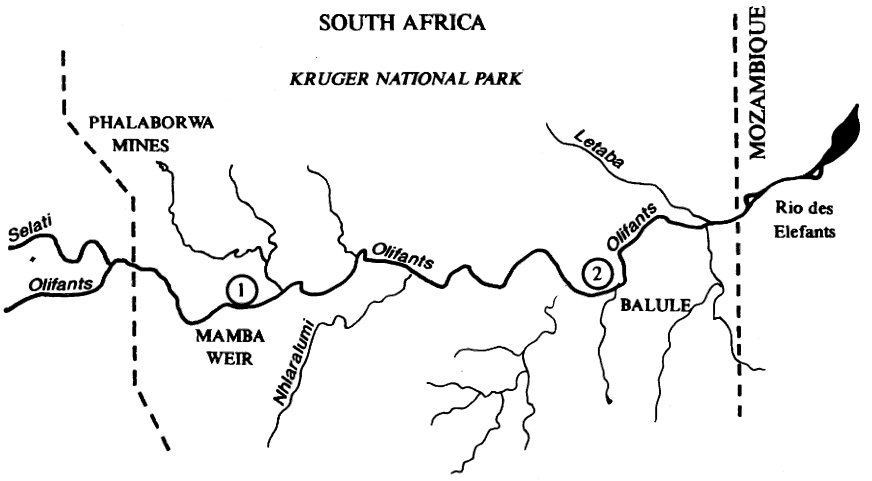

Fig. 7. Map showing sampling locations of *Lamproglena clariae* Fryer, 1956, in the Olifants River, Kruger National Park, South Africa.

The effect of the host on the parasite can be a result of structural (Sproston et al., 1950) adaptations and as in most parasite-host relationships, immunological responses (Schmidt & Roberts, 1989). The structure of the gill-chamber and consequently the respiratory current through it, as well as parasite competi-

tion are micro-habitat factors determining parasite distribution therein. Sproston et al. (1950) state that *Lamproglena* prefers the apex of the gill filaments, however contradictory to the statement regarding the genus *Lamproglena*, *L. clariae* attaches midway along the gill filament. *Lamproglena* is also commonly found concentrated at the ends of the gill arch (Sproston et al., 1950), which appears to be the case in *L. clariae*. The latter position allows for reduced velocity of the water current, making attachment to the gill filament far easier and less hazardous as parasites trying to attach to the center may be washed away with the current.

TABLE II

Infestation statistics of *Lamproglena clariae* Fryer, 1956, on *Clarias gariepinus* (Burchell, 1822) in the period 1990-1994

Location	Date	*Prevalence (%)	*Intensity 0	Lowest # of parasites per infested host	Highest # of parasites per infested host	Relative parasite density	# of host fish in sample
Cuando River	Sep. 91	3	1.00	1	1	0.03	32
Olifants River							
Mamba	Oct. 90	20	1.00	1	1	0.20	5
Balule		50	2.00	2	2	1.00	4
Mamba	Aug. 91	43	2.00	1	3	0.86	7
Balule		13.3	3.50	3	4	0.47	15
Mamba	Oct. 91	0	–	–	–	0	0
Balule		0	–	–	–	0	0
Mamba	Jan. 92	0	–	–	–	0	0
Balule		6	1.00	1	1	0.06	33
Mamba	Apr. 92	0	–	–	–	0	10
Balule		30	2.33	1	4	0.70	10
Mamba	Oct. 92	7	1.00	1	1	0.07	14
Balule		0	–	–	–	0	13
Mamba	Jan. 94	15	1.33	1	2	0.20	20
Balule		25	1.20	1	2	0.30	20
Mamba	May 94	0	0	–	–	0	18
Balule		50	5.00	1	17	2.50	20
Mamba	Jul. 94	50	1.40	1	4	0.70	20
Balule		55	2.70	1	12	1.50	20

*Infestation statistics as defined by Margolis et al. (1982):
Prevalence = number of infested individuals of a host species divided by number of hosts examined.
Intensity = total number of a particular parasite species divided by number of infested hosts.
Relative density (Abundance) = total number of a particular parasite species divided by total number of hosts in a sample.

As previously stated by Sproston et al. (1950) and agreed with in the present study the elongated form of the parasite is a direct parasitic adaptation to its micro-habitat. The longer the gill filaments are, increasing with host size, the longer the parasite grows. With extension of the abdomen into the open gill cavity, respiratory swinging movements and aeration of the two egg sacs in particular are allowed, as well as aiding in the distribution of the eggs.

With regard to the effect of the parasite on the host, the adult female grips the gill filament with the strong maxillae using the maxillipeds as attachment and feeding appendages, penetrates the gill tissue with these appendages and consumes blood. This induces hypertrophy of the connective tissue, with degeneration of the blood capillaries in the filaments (Sproston et al., 1950). The head then becomes embedded, possibly as a result of stimulation of tissue growth around it.

In the event of many *L. clariae* attaching to gill filaments, respiratory problems could arise, denying the host of oxygen, ultimately leading to anaemia; as could be seen in a few specimens with high parasite loads, gills and pseudobranchs appeared to be extremely pale and unhealthy. As noted by Paperna (1980) extreme infestations of ergasilids, a copepod parasitic on the gills of *Clarias lazera*, occurs without death of the host thereby substantiating the fact that accessory pseudobranchs in Clariid fish could counteract these types and *Lamproglena* type infestations, allowing host and parasite longer life-spans.

The prevalence and intensity of *Lamproglena clariae* differ significantly between the two locations sampled in this study, the reasons could be twofold (table II). Firstly the higher metal pollution level in the water at Mamba could have an effect on the survival of *L. clariae*, as its life-cycle and health could be negatively influenced. Secondly the less polluted water at Balule can allow for parasite proliferation and with water concentrated in smaller pools the chance of finding a host is far higher.

The fact that parasite prevalence, intensity and relative parasite density increased during winter may imply that fluctuating water levels concentrate parasites and hence the probability of infestation increases. Another contributory factor could be decreased immunity of the fish in winter due to temperature stressors and hence a decrease in food consumption allowing greater infestation of immunosuppressed fish as was shown by Esch et al. (1975) and Singhal et al. (1986) in the silver carp and carp infested with *Trichodina* (Protozoa) and *Posthodiplastomum* (Trematoda) respectively; and in the catfish infested with *Myxobolus* (Protozoa).

L. clariae can be regarded as a good example of an apomorphous parasite species, which shows secondary reductions in the loss of segmentation, develop-

ment of a neck and reduction of the swimming appendages, antennulae, antennae and furcal rami. Comparison with type specimens showed differences to the descriptions given by Fryer (1956) in proportion, number of podomeres, armature of appendages and never before mentioned structures. For example, the maxillae Fryer (1956) describes bear two short chitinized teeth distally, whereas the sketches and the findings in this paper show only one. Secondly the genital somite is allocated to the abdomen, where in fact it is part of the thorax. The number of podomeres in all appendages differs from that described by Fryer (1956), especially the legs where Fryer noted none at all. The latter author also makes no mention of the upper and lower lips, seen here for the first time, which could perhaps be of taxonomical importance.

With no mandibles or maxillulae present, the three papillated structures posterior to the buccal cavity could well represent archiac remnants of these appendages. However, with no musculature found associated with any of the papillated structures, they should rather be considered only as sclerotized elements of cuticle until further evidence becomes available.

The rounded nuchal organ has never before been described on *L. clariae*. Piasecki (1993) mentions the nuchal organ on *L. pulchella* Von Nordmann, 1832, *L. hemprichii* Von Nordmann, 1832, and *L. lichiae* Von Nordmann, 1832. This organ looks similar to caligid larval attachment discs which degenerate in mature adult females (Kabata, 1979). As the nuchal organ degenerates in *L. clariae* it may imply that it is also used for larval attachment.

Fryer (1956) does not mention the number of setae on the pairs of biramous legs, however, he has a single illustration of the second leg in which the number of setae corresponds to that in the present study. The illustrations of the first four pairs of legs from his 1964 paper are vague and Fryer (1964) states that they vary from his original description. No note was made by Fryer of the fifth pair of legs which is described here for the first time. The fifth pair of legs is situated on the genital segment. This contradicts the finding of Huys & Boxshall (1991) in *Lamproglena monodi* Capart, 1944, who show the fifth pair of legs situated on the posterior region of the fourth thoracic segment. Comparing the setation of the first, third and fourth pairs of legs with those in Fryer (1964) there is an obvious difference in setation between his results and ours, with more setae noted in the Olifants River specimens. Discrepancies between Fryer's (1956, 1961) articles and the findings in this paper also occur in the structure of furcal rami. Fryer (1964) suggests that this variability of vestigial structures should not be regarded as significant or taxonomically viable. Perhaps these differences, which occur in all *L. clariae* described from different regions, could be due to geographical variation.

REFERENCES

ESCH, G. W., J. WHITEFIELD GIBBONS & J. E. BOURQUE, 1975. An analysis of the relationship between stress and parasitism. American Midl. Natural., **93** (2): 339-335.

EULER, C. & A. AVENANT-OLDEWAGE, 1992. Die biologie van verteenwoordiges van die genus *Lamproglena*. Suid Afrikaanse Tydskr. Natuurwetenskap en Tegnologie, **11** (2): 72-73.

FRYER, G., 1956. A report on the parasitic Copepoda and Branchiura of the fishes of Lake Nyasa. Proc. zool. Soc. London, **127**: 305-309.

— —, 1961. The parasitic Copepoda and Branchiura of the fishes of Lake Victoria and the Victoria Nile. Proc. zool. Soc. London, **137** (1): 41-60.

— —, 1965. Parasitic Crustaceans of African freshwater fishes from the Nile and Niger Systems. Proc. zool. Soc. London, **145**: 285-303.

— —, 1968. The parasitic Crustacea of African freshwater fishes; their biology and distribution. Journ. Zool., London, **156**: 45-95.

HUMASON, G. L., 1979. Animal tissue techniques: 1-139. (4th ed., W. H. Freeman and Cy, San Francisco).

HUYS, R. & G. A. BOXSHALL, 1991. Copepod evolution. Ray Society, London, **159**: 1-468.

KABATA, Z., 1979. Parasitic Copepoda of British fishes. Ray Society, London, **152**: 1-468, figs. 1-2031.

KUMARIE, P., S. KHERA & N. K. GUPTA, 1989. On six species of the genus *Lamproglena* Nordmann (Copepoda: Eudactylinidae), ectoparasitic on fishes of India. Res. Bull. (Sci.) Punjab Univ., **40** (1-2): 9-23.

MARGOLIS, L., G. W. ESCH, J. C. HOLMES, A. M. KURIS & G. A. SCHAD, 1982. The use of ecological terms in parasitology (Report of an ad hoc committee of the American Society of Parasitologists). Journ. Parasitol., **68**: 131-133.

PAPERNA, I., 1980. Infections and diseases in fish in Africa. CIFA Techn. Pap., **7**: 216pp.

PIASECKI, W., 1993. Comparative morphology of three species of *Lamproglena* (Copepoda, Cyclopodia, Lernaeidae) described by Von Nordmann, based on re-examination of the types. Mitt. zool. Mus. Berlin, **69** (2): 307-315.

SCHMIDT, G. D. & L. S. ROBERTS, 1989. Foundations of parasitology: 1-750. (4th ed., Times Mirror/Mosby College Publishing, Missouri).

SHÖTTER, R. A., 1977. Copepod parasites of fishes from northern Nigeria. Bull. I.F.A.N., **39** (3): 583-600.

SINGHAL, R. N., S. JEET & R. W. DAVIES, 1986. The relationships between changes in selected physico-chemical properties of water and the occurrence of fish parasites in Haryana, India. Trop. Ecol., **27**: 1-9.

SKELTON, P., 1993. A complete guide to the freshwater fishes of Southern Africa: 1-388. (Southern Book Publishers, Halfway House, South Africa).

SPROSTON, G. N., W. Y. YIN & Y. T. HU, 1950. The genus *Lamproglena* (Copepoda Parasitica): The discovery of the life-histories and males of two Chinese species from food fishes, revealing their relationship with *Lernaea* and of both the Cyclopoidea. Sinensia, (n. ser.) **1** (1-4): 51-84.

SPURR, A. J., 1969. A low viscosity embedding medium for electron microscopy. Ultrastructural Res., **26**: 31-43.

THURSTON, P., 1970. The incidence of Monogenea and parasitic Crustacea on the gills of fish in Uganda. Rev. Zool. Bot. Africaine, **82**: 1-2.

VUREN, J. H. J. VAN, H. H. DU PREEZ & A. R. DEACON, unpubl. Effect of pollutants on the physiology of fish in the Olifants River (Eastern Transvaal): 1-124. (Unpublished report, Research Unit for Aquatic and Terrestrial Ecosystems, Department of Zoology, Rand Afrikaans University, South Africa, 1994).

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