ECTOPARASITES OF FISHES FROM SOETDORING NATURE RESERVE

By

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Chapter 1

Introduction

Fish have been of importance to man since the dawn of our ancestors. Man has been utilising fish from the rivers of southern Africa for as long as they have been present in the area. According to Skelton (1993) remains of fish are frequently found at archaeological sites associated with the dwellings of the Khoi and San peoples. Traditional fisheries have, however, only survived in areas where sufficient fish communities were available, such as in the tropics. Subsistence and commercial fisheries do still exist, for example the "kapenta" sardine fisheries of Lake Kariba (Skelton 1993). Some of the many threats to freshwater fishes, are introduced fishes and their parasites, as well as the activities of man, which also indirectly threaten fish populations, by creating environments in which parasites may thrive and adversely affect host fishes. These threats also apply to fish populations from aquaculture activities, which have become a rapidly growing sector of agriculture (Skelton 1993).

Fish parasitological research in Africa resulted in a steady flow of papers, but dried up during the political instability during the post-colonial era. Presently a number of parasitologists are still active in Africa, although the numbers are much reduced.

Parasitological research in southern Africa has received much attention under the guidance of Prof. Jo van As at RAU since 1980 and at the University of the Free State since 1988. Research surveys conducted by the University of the Free State's Aquatic Parasitology Research Group includes various freshwater fish research projects (e.g. Basson & Van As 1987, Basson & Van As 1989, Van As & Van As 1993, Van As & van As 1999) and marine projects at the de Hoop Nature Reserve (Loubser 1994, Van As & Basson 1996, Smit & Davis 1999).

The present study was initiated on request of the Department of Environmental affairs and Tourism of the Free State, who were interested in the fish parasites of the Modder River System. The main objective of the study was to determine infection patterns of parasites of the fishes from the Soetdoring Nature Reserve. This would include determining whether any introduced parasites are prevalent on the fishes and to investigate the various host-parasite associations. Initially the project was intended to be a comprehensive study on the endo-and ectoparasites associated with the various fish hosts. It was soon realised that such a study would be to broad for a Masters study, especially due to the extent of the systematics and identification of endoparasitic helminths.

Up until this point in time, research projects of this study group, as well as the research groups of other South African institutions have focused on a specific group of parasites associated with fish hosts. Even in the whole of Africa most of the research was focused either on a specific host, or on a specific group of parasites. Very little research work on a spectrum of parasites or fish hosts of a specific river system has been done in Africa. Such works include: Paperna (1964a), Khalil (1968), Paperna (1968), Paperna & Thurston (1968a), Lombaard (1968), Thurston (1970), Khalil (1971), Paperna & Lahav (1971), Van As & Basson (1988), Douëllou (1992) and Hecht & Endemann (1998).

Although some unpublished data of freshwater parasites of the Free State exists, research is limited to that of Barkhuizen (1991), who researched the life strategies and occurrence of the cestode *Bothriocephalus acheilognathi* Yamaguti, 1934 in the Free State and the work of King & Van As 1996, King & Van As 1997a, King & Van As 1997b and King & Van As 2001 on trematodes associated with snail hosts in the Free State. Other research on freshwater systems conducted by the University of the Free State includes that of Seaman, Roos & Watson (2001a, b), who researched the ecological state of the Modder River. This dissertation would then be the first of its kind to study the whole spectrum of fish ectoparasites present in a reservoir.

This study provides a unique opportunity to study the fish populations as well as the parasites of the upper Modder River, as the study area is situated at the Soetdoring Nature Reserve. It will also be the first project to provide information on a spectrum of fish parasites that occur in the Modder River. During the first survey, the water level of the Krugersdrift Dam was estimated at only 23%. This made the collection of fish an easy task. In the months to follow, the Free State had exceptionally high rainfall, which continued for the remainder of the study period. This high rainfall had an adverse effect on the project, as the collection of fish was no longer simple, and the numbers of fish collected dropped significantly.

The layout of this dissertation is as follows: The materials and methods used during field and laboratory work is described in Chapter 2 as well a section providing information on the study area. The fish species that occur in the Orange River system are discussed in Chapter 3, followed by a discussion of the ciliophoran parasites in Chapter 4. The monogeneans and parasitic crustaceans are discussed in Chapter 5 and Chapter 6 respectively. Results of the statistical analysis of data are presented in Chapter 7 and the general discussion in Chapter 8. Chapter 9 contains the literature references, which is followed by the Abstract and Acknowledgements. A copy of the permit for collection of fish at the Soetdoring Nature Reserve is included in Appendix A.

Chapter 2

Materials and Methods

Study Area

The Modder River is one of the smaller rivers in South Africa. It forms part of one of the most prominent river systems of southern Africa, the Orange-Vaal River System. The main constituents of this system, the Orange- and Vaal Rivers, have their origins in the Drakensberg in the eastern part of the country. These two rivers flow in a western direction and the Vaal River joins the Orange River east of Douglas, a small town in the Northern Cape Province. From here the Orange River flows all the way to the West Coast, where it has its mouth near Alexander Bay. Smaller rivers that form part of the system include the Vet-, Riet-, and Caledon Rivers.

The Modder River has its origins in the hills of southeastern Free State, from where it flows in a northwestern direction and then turns west (Anon 1966) (Figure 2.1). Its origins are in the Moist Cool Highveld Grassland, which changes as it flows to the west into Dry Sandy Highveld Grassland, Eastern Mixed Nama-Karoo and then Kimberley Thorn Veld. The Modder River joins the Riet River, which then flows on to join the Vaal River west of Douglas. The largest part of the catchment area of the Modder River is situated in the south central Free State Province and a smaller part in the Northern Cape Province (Seaman, Roos & Watson 2001a). This catchment comprises an area of about 17 360 km^2 (Midgley, Pitman & Middleton 1994). According to Grobbelaar (1992) the Modder River has a mean annual runoff of 184 x 10^6 m^3.

In the Free State, the Modder River is an important water source, as it supplies water to Bloemfontein and some of the surrounding areas. Since 1896, several dams and weirs have been built in the Modder River, either to provide water to Bloemfontein and surrounding towns (Botshabelo and Thaba Nchu), or for irrigation purposes. The Sannaspos Weir was built in 1896 to provide Bloemfontein with water, which was supplemented in 1904 with the

Mazelspoort Weir and in 1913 with Mockes Dam. Rustfontein Dam was completed in 1955, which currently supplies Thaba Nchu and Botshabelo with water.

The Modder River flows through the Soetdoring Nature Reserve and into the Krugersdrift Dam, which forms part of the nature reserve (Figure 2.2, Figure 2.4A). Krugersdrift Dam was built in 1970 and provides irrigation water for farmers along the lower reaches of the river.

According to Seaman *et al.* (2001a), most of the Modder River catchment consists mainly of rocks of the Karoo Sequence, which are interspersed with dolerite dykes in places. The origin of the Modder River is in Adelaide formation and as it flows northwest through Ecca formation and Kalahari Sands where it joins the Riet River. At this confluence, Dwyka tillite as well as interbedded sedimentary and volcanic material are also found.

Soetdoring Nature Reserve

The Soetdoring Nature Reserve is situated 45km north west of Bloemfontein on the Modder River (Figure 2.2). It was established on 28 July 1978 and comprises 7500ha, of which approximately 2000ha encloses the Krugersdrift Dam.

The rainfall season is mainly between January and March and the average annual rainfall is 560mm. During the period of the study, however, the rainfall was substantially higher, causing the water levels of the Krugersdrift Dam to rise considerably (Figure 2.3).

Main vegetation types of the reserve include False Upper Karoo and Dry *Cymbopogon* – *Themeda* Veld. Four types of vegetation can be recognised; grassveld, which is dominated by *Themeda triandra* and karroid veld, in which *Felicia muricata* is dominant. In the riparian bush *Acacia karroo* is dominant, and koppie scrub is dominated by *Olea africana*.

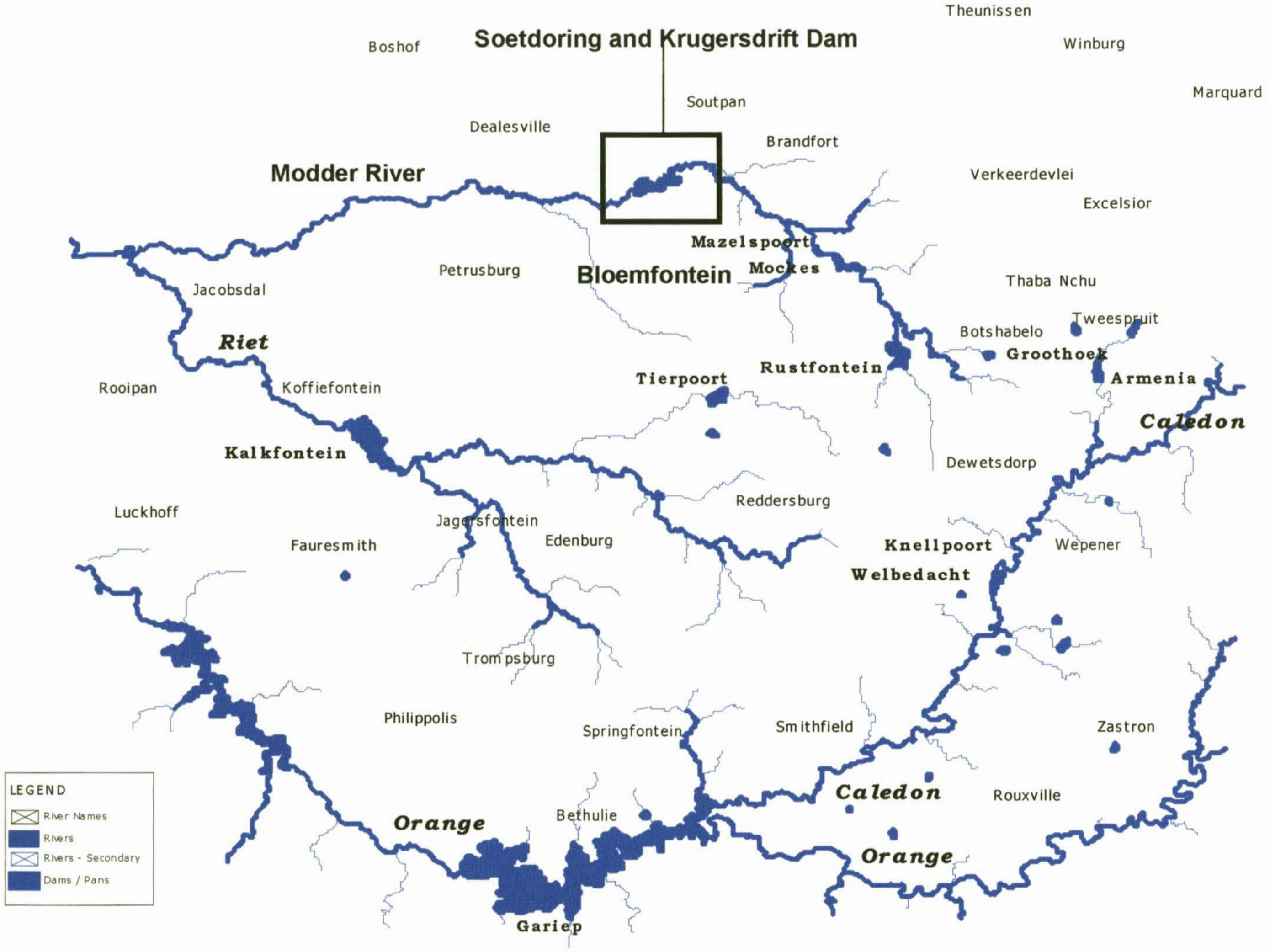


Figure 2.1. Map of the rivers of the Free State to indicate the position of the Modder River, Soetdoring Nature Reserve and Krugersdrift Dam (adapted from Seaman *et al.* 2001a).

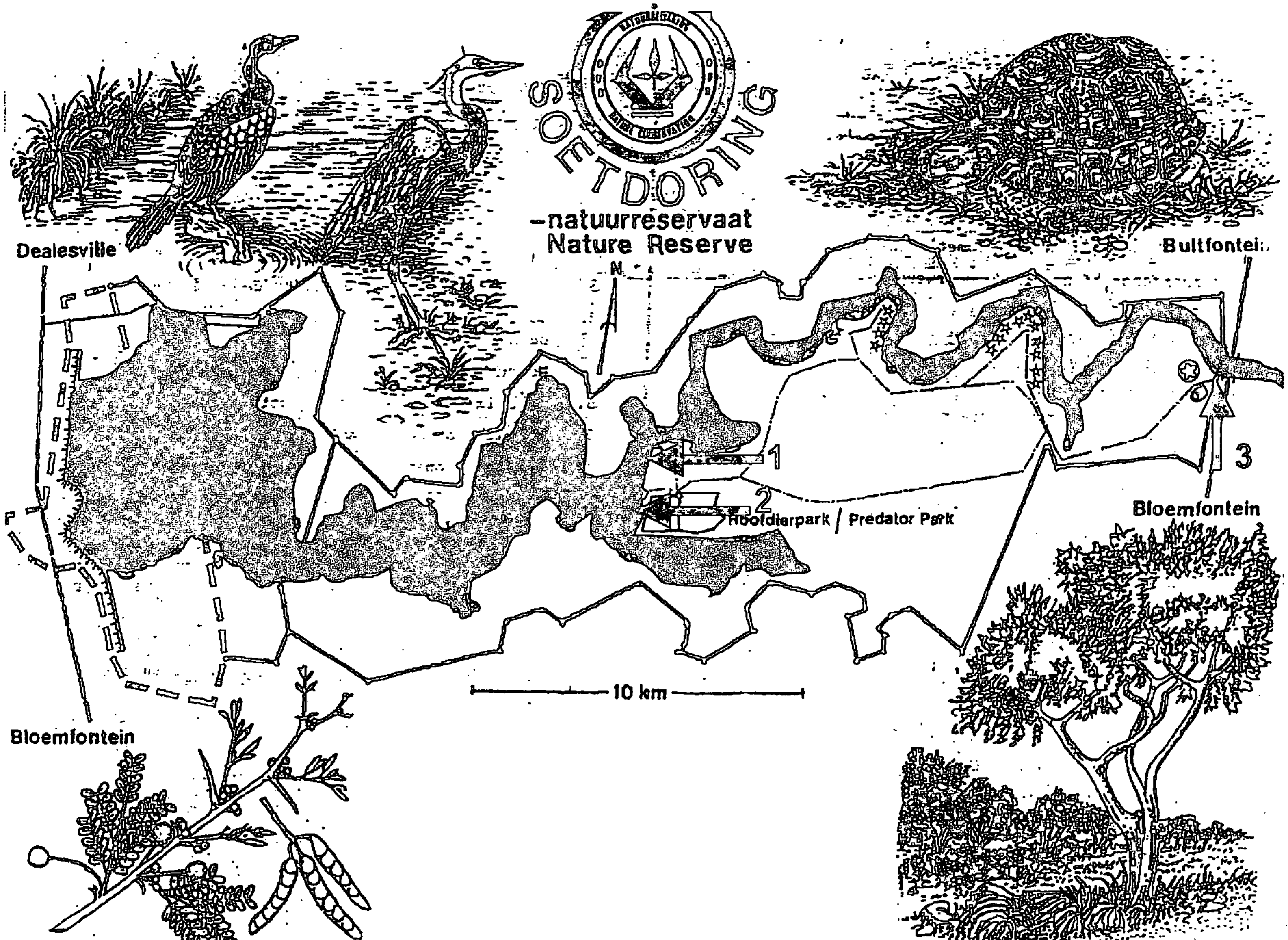


Figure 2.2. Map of the Krugersdrift Dam at the Soetdoring Nature Reserve showing sampling localities. (adapted from tourist information map). **1 & 2**-sampling localities that are permanently dammed, **3**-riverine sampling locality.

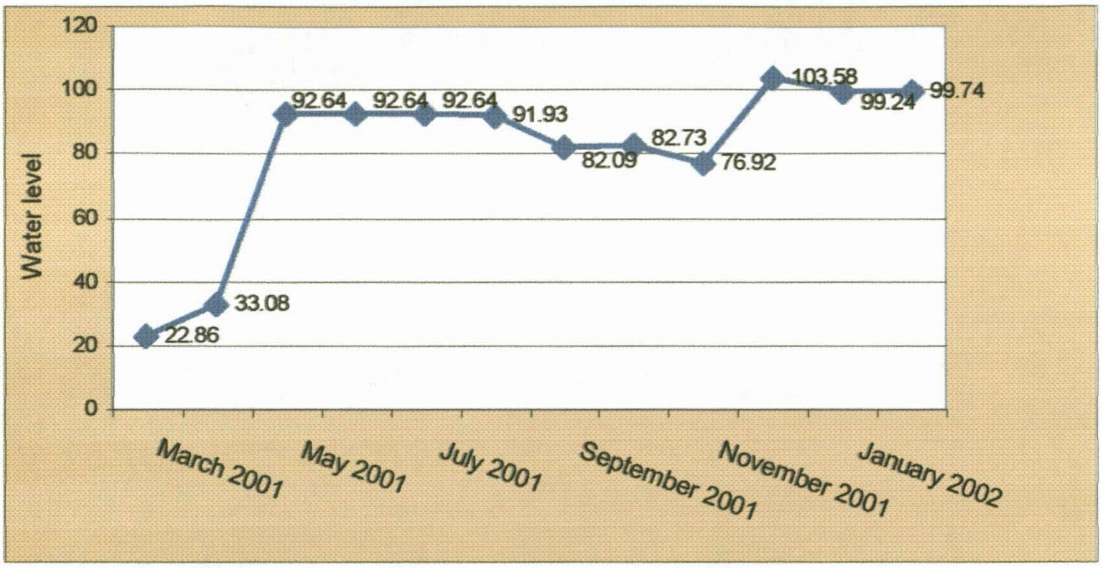


Figure 2.3. Line graph illustrating the water level of the Krugersdrift Dam during the study period

A variety of mammals are found on the reserve, including a predator park, which is home to a few lions. Some of the dominant mammals that roam the reserve include black wildebeest, eland, blesbok, red hartebeest, springbok, Burchull's zebra and gemsbok. A number of ostrich as well as white rhino also occur on the reserve. The bush amongst the riverbanks gives sanctuary to kudu, waterbuck, common reedbuck and impala.

Several facilities of the Soetdoring Nature Reserve are accessible to tourists, including a Train Camp, which offers overnight accommodation. Various picnic spots and barbecue facilities are also available. Recreational activities at the reserve include game viewing, bird watching and a two-day canoe route. Angling is a popular attraction at the Krugersdrift dam, as well as windsurfing, camping and canoeing.

Fieldwork

All the fieldwork for this research project was conducted at the Soetdoring Nature Reserve. Collections took place at three different localities (Figure 2.2, Figure 2.4D-F). During March 2001, an initial weeklong fieldtrip was conducted at the reserve to aid as a pilot study. A fully equipped field laboratory was set up during this week in the vicinity of the Train Camp (Figure 2.4B, C). Subsequent fieldwork consisted of day trips to the reserve on a monthly basis. Two of the collection sites (including the site at the Train Camp) fell within the reserve itself, including the Krugersdrift Dam (Figure 2.2, Figure 2.4D, E). The other site was situated on the Modder River before it flows into the dam (Figure 2.2, Figure 2.4E).

Sample localities in and around the Krugersdrift Dam were characterised by slow flowing water, surrounded with grassy banks and *Acacia* trees. The riverine locality had similar characteristics to the localities situated in the dam. The riverine locality, however, had a rocky substrate. During the first survey in March 2001, the water level of the dam was very low and the dam was estimated to be only 23% full. The implication of the low water level was that the riverine locality consisted of only rocky pools. In the following months, after high rainfall to the region, this locality was transformed into fast flowing rapids.

Collection of fish

The methods for collecting fish consisted of cast nets as well as gill nets. Gill nets consisted of a graded series of lengths, each 10 m long and each of a different mesh size. The minimum mesh size was 40 mm and the maximum 140 mm (40 mm, 70 mm, 90 mm, 100 mm, 110 mm, 120 mm & 140 mm). These nets were set early in the morning and lifted throughout the day to prevent fish mortalities. Nets were removed again in the late afternoon. An electro-fishing apparatus was also used, but with less success.

Examination of hosts

After collection, fishes were taken to a field laboratory during the first survey where they were examined. During the succeeding field trips, fish were kept alive in temporary holding tanks and transported to the laboratory in Bloemfontein for examination. Fishes were anaesthetised and examined mainly for ectoparasites but some endoparasites were also collected.

Figure 2.4. Various localities at the Soetdoring Nature Reserve. **A** – Modder River at Soetdoring Nature Reserve, **B**, **C** – field laboratory in vicinity of the Train Camp, **D** – locality 1 at Krugersdrift Dam, **E** – locality 2 at Krugersdrift Dam, **F** – locality 3 at Modder River before flowing into Krugersdrift Dam.

The method for studying the different types of ectoparasites are unique, thus each method will be described separately.

Ciliophorans

Smears of gills as well as skin were made of each fish. After collection, wet smears were examined using a Zeiss Axiophot compound microscope. Smears were allowed to dry for later processing or were fixed in Bouins' fixative for further staining techniques.

- **Light microscopy preparation**

In preparation for compound microscopy sessiline ciliophorans were stained with Harris' Hematoxylin according to Wellborn (1967) to study the shape and size of the macronucleus. Smears containing mobiline ciliophorans were impregnated with silver nitrate in order to study the adhesive disc as described by Basson, Van As & Paperna (1983).

- **Morphological measurements**

Measurements obtained from sessiline ciliophorans included length and width of the body and the shape and size of the micronucleus and macronucleus. Measurements of mobiline ciliophorans were made according to the method of Van As & Basson (1989), in addition to the system proposed by Lom (1958). Eleven measurements were obtained from the silver impregnated structures (Figure 2.5), i.e. body diameter, diameter of adhesive disc, width of border membrane, diameter of denticle ring, number of denticles, number of radial pins per denticle, length of denticle, length of ray, width of central part and length of blade. Measurements are presented in the following way: minimum and maximum, followed in parentheses by the arithmic mean and standard deviation (only in $n>9$) and number of specimens measured. In the case of denticle number, and radial pins, the mode was used as suggested by Van As & Basson (1989).

Monogeneans

After gills were examined for monogeneans, infested gill arches were placed in a 1: 4 000 formalin solution for about half an hour. When possible, live specimens were first removed from the gills, before being placed in the formalin solution. This solution is insufficient to fix the monogeneans, but will kill them in a relatively short time. Host tissue was fixed in a 10% neutral buffered formalin solution with monogeneans still attached. This method of killing and fixing ensures that very few monogeneans contract on contact with the formalin.

- **Light microscopy preparation**

In preparation for compound microscopy, individual specimens were removed from the gill tissue and mounted in a glycerine ammonium picrate solution similar to that used by Malmberg (1957), to study the opisthaptoral structures. Diplozoid specimens were stained using Mayer's paracarmine and mounted in Eukitt.

- **Morphological measurements**

Measurements of the sclerotised parts of specimens from the genus *Dactylogyrus* Diesing, 1850 were done according to the method of N'Douba, Pariselle and Euzet (1997) (Figure 2.6A-K). Six basic measurements, i.e. total length, base width, inner root, outer root, shaft and the tip were obtained from the anchors. The dorsal and ventral bars were measured in terms of the total length and width. The marginal hooklets were numbered according to the system proposed by Malmberg (1990) and only the total length was measured. The total length of the cirrus as well as the accessory piece were measured and not only the length of the axis.

Sclerotised structures of specimens from the genus *Dogielius* Bychowsky, 1936 were measured according to Guegan, Lambert & Euzet (1988) (Figure 2.6L-S). Three basic measurements, i.e. total length, shaft + outer root, and the tip were obtained from the anchors. Two basic measurements were obtained from the transverse bar, i.e. total length and width. The marginal hooklets were numbered according to the system proposed by Malmberg (1990). The total length of the cirrus as well as the accessory piece were measured and not only the length of the axis.

Measurements of the sclerotised parts of all specimens from the genus *Quadriacanthus* Paperna, 1961, were measured according to the method of N'Douba, Lambert and Euzet (1999) (Figure 2.7A-M). Three basic measurements were obtained from the anchors, i.e. total length, base width and the tip length. Both the dorsal and ventral anchors possessed an accessory sclerite, which was measured in length and width, respectively. The half-length of the dorsal bar was measured as well as the centrum height and the median process length. Half of the ventral bar was measured and the width was measured at its widest point. The marginal hooklets were numbered according to the system proposed by Malmberg (1990) and only the total length was measured. The total length of the cirrus as well as the accessory piece were measured and not only the length of their axis.

Specimens of the genus *Paradiplozoon* Achmerow, 1974 were measured in a similar fashion to that proposed by Thomas (1957) and Fischthal & Kuntz (1963). Two basic measurements, i.e. length and width were obtained from the opisthaptoral clamps (Figure 2.7N-P). In addition to these measurements, the length of the spur on the dorsal sclerite was also measured. Two measurements were obtained from the prohaptoral region, namely diameter of the oral suckers and the length of the pharynx. Measurements obtained from the reproductive organs included length and width of the intra-uterine eggs, ovary and testis.

Measurements of the monogeneans are presented in the following manner: mean and standard deviation followed in parentheses by the minimum and maximum values.

Crustaceans

After examination of the skin and gills, branchiurans were removed with the aid of a scalpel and brush. Specimens were placed in a petri dish on a slide with a drop of water. A cover slip was placed on the specimen and slight pressure applied, while 70% ethanol was dripped in between the slide and cover slip. This ensures that the organism is in a flattened position. Thereafter the specimen was transferred to 70% ethanol. Copepods were removed from the gills with two fine brushes and fixed in 70% ethanol.

- **Light microscopy preparation**

The method proposed by Benz & Otting (1996) was used for the study of branchiurans with the aid of light microscopy. Copepods were studied in a similar fashion.

- **Scanning electron microscopy (SEM) preparation**

Specimens used for SEM studies were cleaned with two fine brushes to remove mucus and debris, dehydrated in graded ethanol concentrations, critical point dried, gold coated using an Emscope SC500 sputter coater and viewed with a Jeol Winsem JSM 6400 SEM at 10 kV.

- **Morphological measurements**

Measurements of the branchiurans were made according to standard methods. Seven basic morphological measurements were obtained from the specimens, i.e. total length of the body, width of the body, carapace length, length of carapace sinus, abdominal length, abdominal width and length of abdominal sinus (Figure 2.8).

Imaging

Digital images of the respective structures and parasites were taken using a Zeiss Axiophot compound microscope and a Nikon Coolpix 990 digital camera. These images were analysed and respective measurements made using the Scion Image software package. Unless otherwise indicated, all measurements are in micrometers.

Type and reference material

All type and reference material is in the collection of the Aquatic Parasitology Research Group, Department of Zoology and Entomology, University of the Free State.

Data analysis

Raw data was analysed to determine parasite prevalence of the fish populations. Prevalence of parasites is presented as the percentage of hosts infested with ectoparasites. The mean intensity was calculated as mean number of parasites per infested host and abundance as the mean number of parasites for all hosts collected (infested and uninfested).

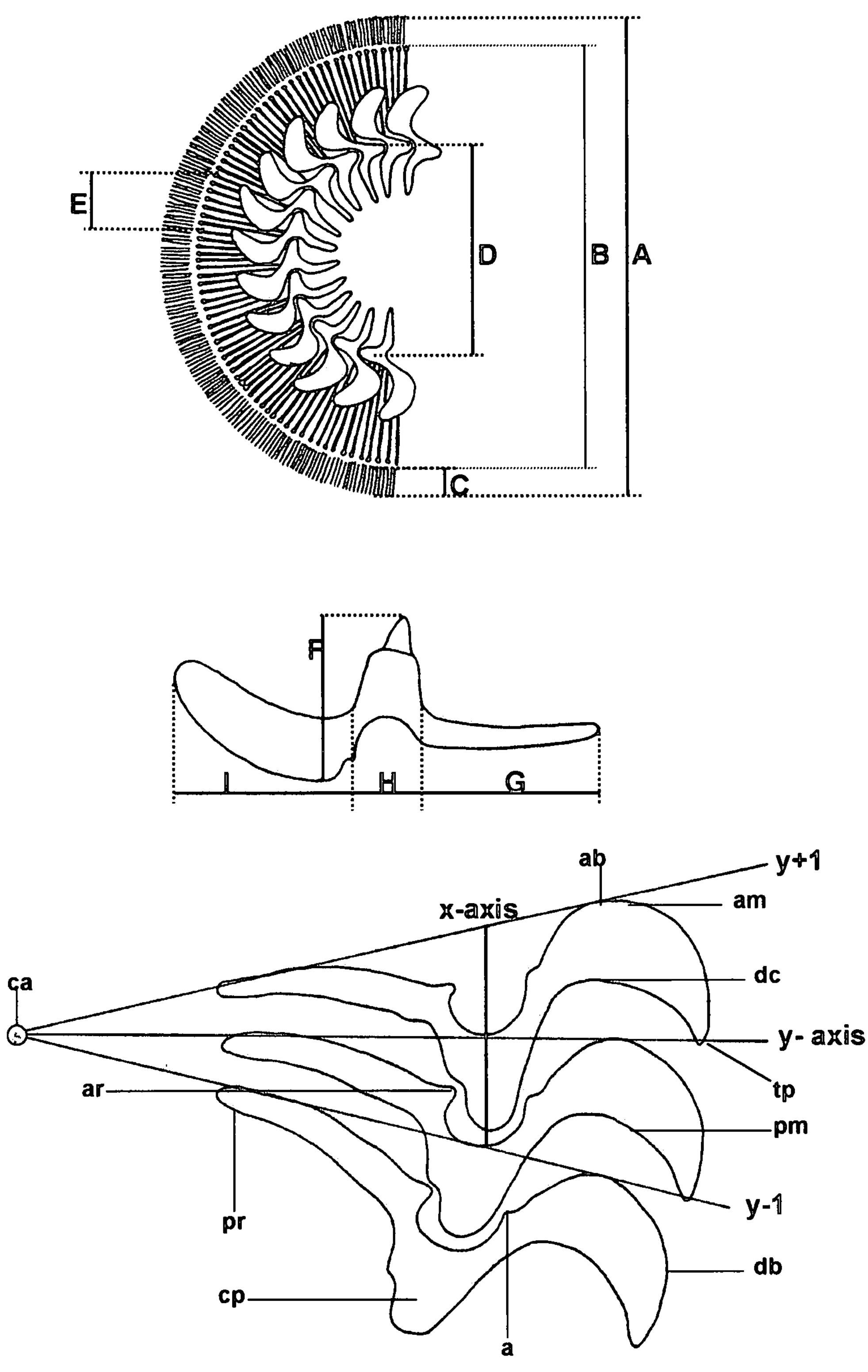


Figure 2.5. Illustrations of the measurements made from the silver impregnated structures of mobiline ciliophorans. **A** – body diameter, **B** – adhesive disc diameter, **C** – border membrane width, **D** – denticle ring diameter, **E** – number of radial pins per denticle, **F** – denticle length, **G** – ray length, **H** – central part width, **I** – blade length. **a**-apophysis of blade, **ab**-apex of blade, **am**-anterior margin of blade, **ar**-apophysis of ray, **ca**-centre of adhesive disc, **cp**-central part, **db**-distal surface of blade, **dc**-deepest point of curve, **pm**-posterior margin of blade, **pr**-point of ray, **tp**-tangent point

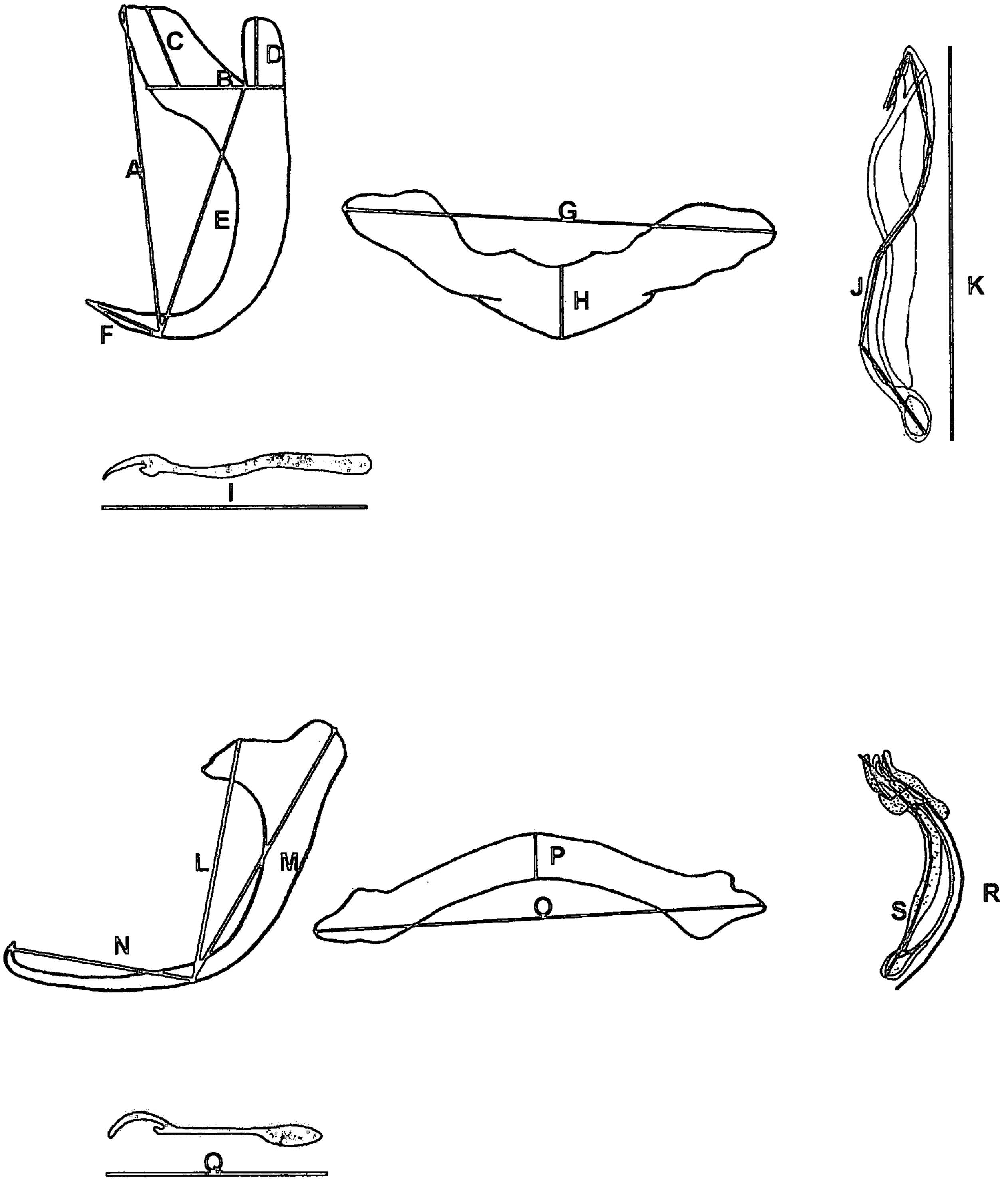


Figure 2.6. Illustrations of the measurements of sclerotised structures of *Dactylogyrus* Diesing, 1850 and *Dogielius* Bychowsky, 1937. **A-K** – *Dactylogyrus*. **A** – total length of anchor, **B** – base width, **C** – inner root, **D** – outer root, **E** – shaft, **F** – tip, **G** – dorsal bar length, **H** – dorsal bar width, **I** – marginal hooklet length, **J** – length of cirrus, **K** – length of accessory piece. **L-S** – *Dogielius*. **L** – total length of anchor, **M** – shaft+outer root, - **N** – tip, **O** – length of dorsal bar, **P** – width of dorsal bar, **Q** – marginal hooklet length, **R** – length of cirrus, **S** – length of accessory piece.

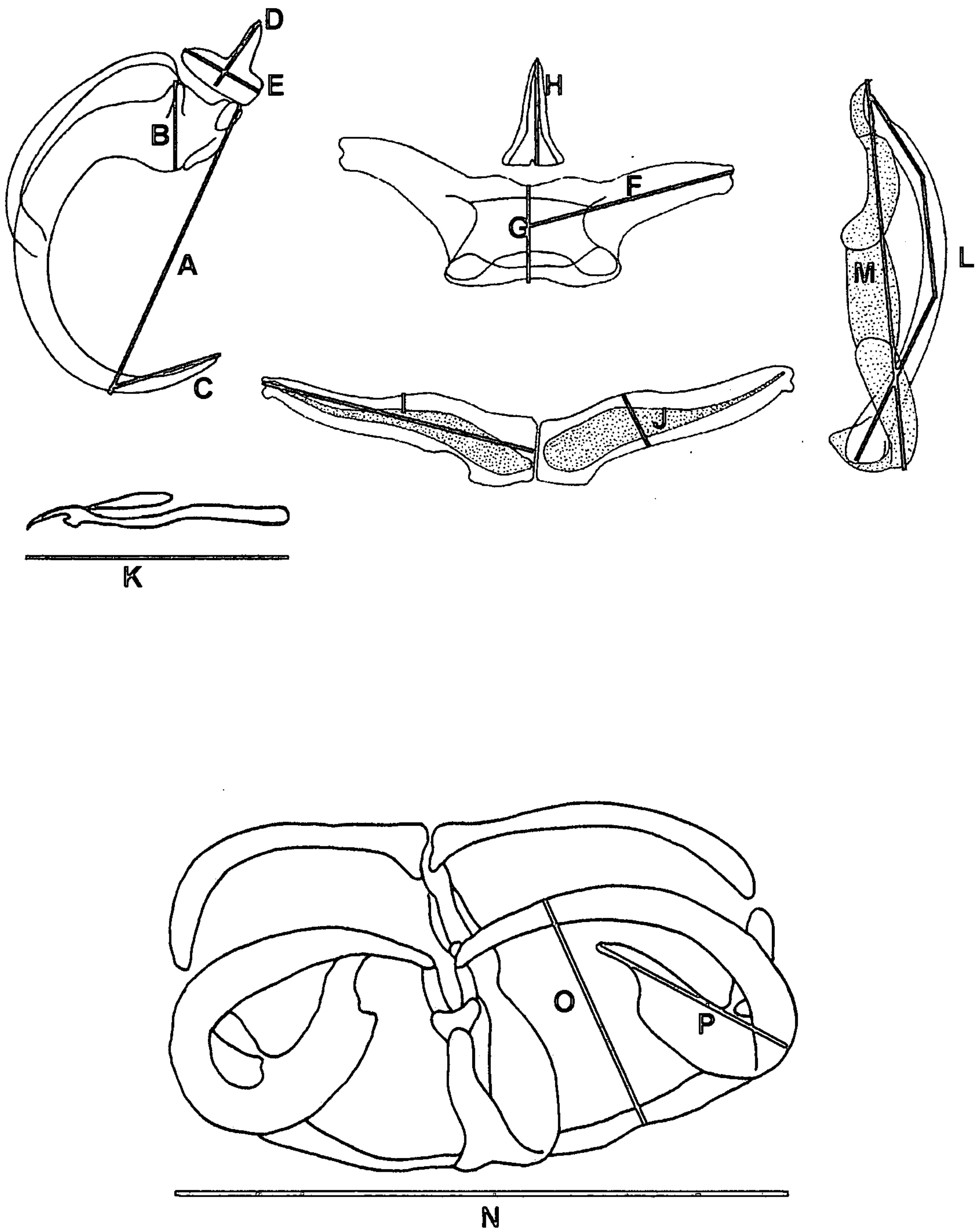


Figure 2.7. Illustrations of the measurements of the sclerotised structures of *Quadriacanthus* Paperna, 1961 and *Paradiplozoon* Achmerov, 1974. **A-N** – *Quadriacanthus*. **A** – total length of anchor, **B** – base width, **C** – tip, **D** – length of accessory sclerite, **E** – width of accessory sclerite, **F** – half length of dorsal bar, **G** – width of dorsal bar, **H** – length of median process, **I** – half length of ventral bar, **J** – width of ventral bar, **K** – marginal hooklet length, **L** – length of cirrus, **M** – length of accessory piece. **N-P** – *Paradiplozoon*. **N** – length of clamp, **O** – width of clamp, **P** – length of spur.

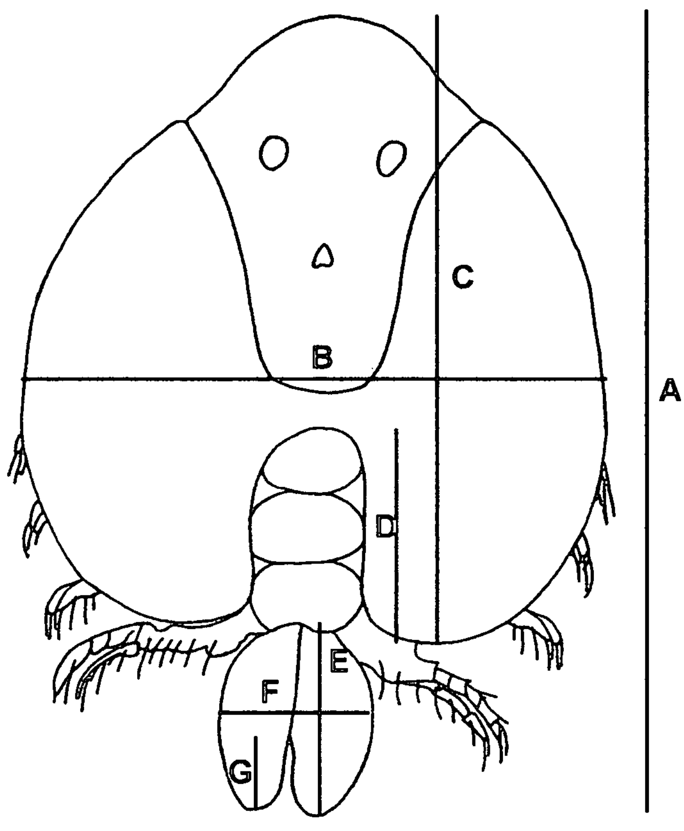
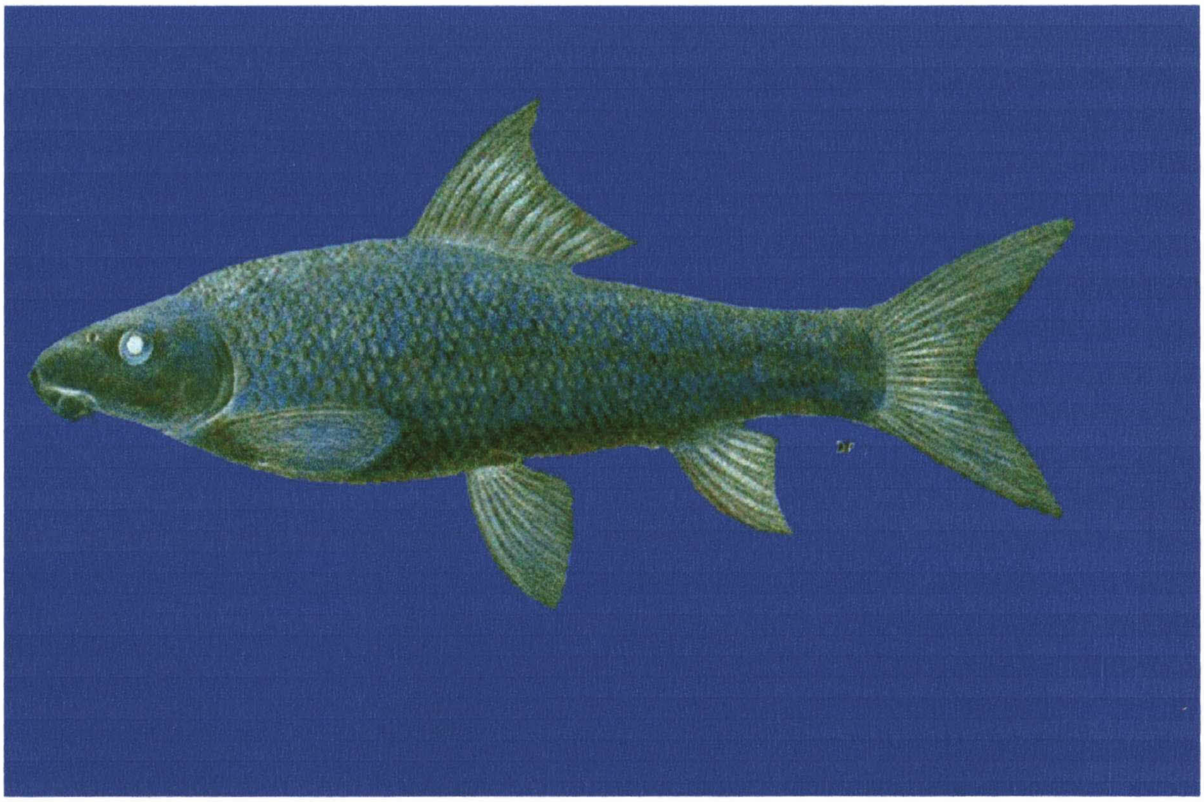


Figure 2.8. Illustration of morphological measurements of *Argulus* Thiele, 1900. **A** – total body length, **B** – width of body, **C** – carapace length, **D** – length of carapace sinus, **E** – length of abdomen, **F** – width of abdomen, **G** – length of abdominal sinus.



Chapter 3

Fishes of southern Africa

Southern Africa covers 16% of the continent, the fish fauna, however, contribute less than 10% of the total African fish fauna. For example, in the Congo River System, there are more than 700 species. The African Rift lakes each have a large species composition, ranging from more than 300 to over 800 species. Thus, compared to the rest of Africa, southern Africa's fish fauna is relatively poor. The following account of the fish fauna of southern Africa is, except where other authors are given, taken from Skelton (2001).

In southern Africa, 60% of the fish are primary freshwater fishes, meaning that approximately 160 fish species occur in inland water, and have little or no tolerance to salt water. The secondary freshwater fish species consists of 56 species. These occur mainly in freshwater systems, but may be tolerant of salt water. The majority of the fishes are Afrotropical, which have affinities with taxa in Northern Africa (Skelton 2000).

Distribution of fish fauna

According to Gabie (1965), there are several anomalies showed by the distribution of fishes in southern Africa. It was believed that Central Africa is the source of origin for most of the southern freshwater species and it has been suggested that Africa was covered by large areas of internal drainage, which could have offered a link between river systems (Gabie 1965). These interconnected river basins, together with evolutionary as well as ecological events in the history of the earth, might explain the distribution of fish in southern Africa. According to Skelton (2000), the earlier model that the present day fauna has arisen through a series of invasions from the tropics is rejected, and a new model, which proposes two overlapping, but distinct faunas that have largely evolved *in situ*, is suggested.

The fish fauna of southern Africa can be grouped into a tropical Zambezian fauna and a temperate fauna, with the latter then being further divided into a Cape group and the Karoo group. The Zambezian fauna is not only the largest, but it also includes some very diverse families. The temperate fauna is relatively small and comprises about 36 species, but is completely endemic. Most of the temperate species are cyprinids, although there are some interesting austroglanidids and anabantids. On the other hand, the Cape fauna is relatively poor, with only 15 species, which are restricted to the Cape Fold Mountains, the Amatolas, and the Drakensberg. The Karoo fauna is centered on the Orange River basin, and this includes the yellowfishes, labeos, barbs, and the southern rock catfishes.

Proceeding from north to south, the numbers as well as diversity of fishes in southern African rivers decreases (Figure 3.1), and according to Gabie (1965) endemic tropical fish are few south of the Zambezi. For example, the Zambezi River System fauna consists of 134 primary and secondary freshwater fish species. Moving south, the Limpopo has only 50, the Phongolo 40, the Tugela 12, the Cunene 66, the Orange 16, the Olifants 10, and the Berg four (Figure 3.1). Of the 22 families that comprise these species, the Cyprinidae and the Cichlidae dominate the fauna. The alien fish fauna of southern Africa consists of 24 species, which is approximately 9% of the total fish fauna (Skelton 2001).

Endemic fish of southern Africa comprises 61% of the total primary and secondary freshwater species. A unique composition of fish species is found in the different river systems, and each system has its own endemic fish fauna. Eight species are endemic to the Clanwilliam-Olifants River System, six species are endemic to the Orange River System, whilst two species are endemic to the Limpopo River System, and the Zambezi River System has 23 endemic species.

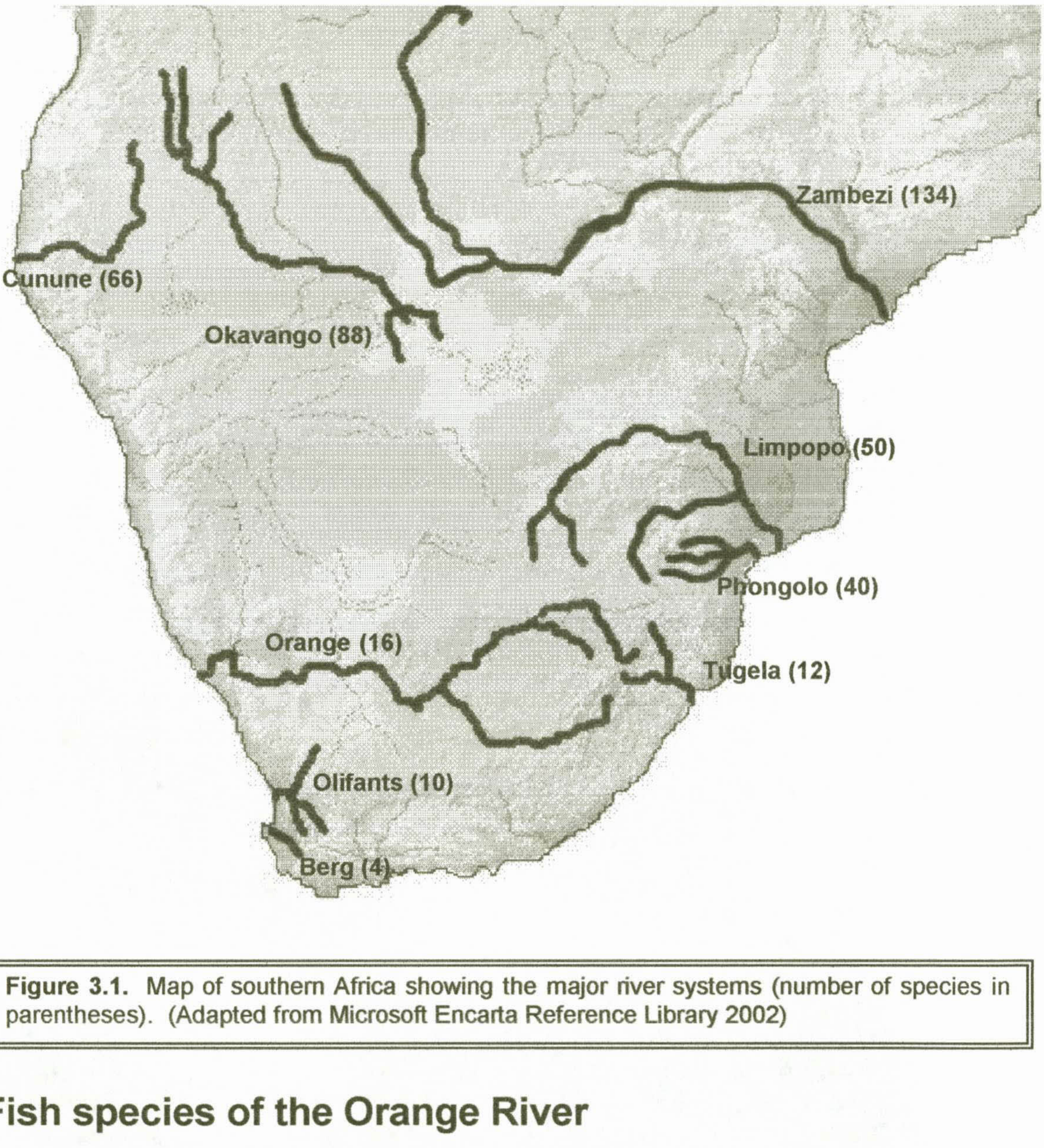


Figure 3.1. Map of southern Africa showing the major river systems (number of species in parentheses). (Adapted from Microsoft Encarta Reference Library 2002)

Fish species of the Orange River

The Free State fauna consists of fishes from the Cyprinidae, Cichlidae, Austroglanididae and Clariidae. Cyprinids, austroglanidids and clariids are all primary freshwater species, being unable to survive in saltwater (Jubb & Farquharson 1965). The cichlids, however, have representatives that are tolerant of salt water (Gabie 1965).

Jubb and Farquharson (1965) state that there are only 14 indigenous species in the Orange River, but according to Skelton (2001) there are 16 indigenous fish species. Six of the species are endemic to the Orange River, or endemic to a river or group of rivers within the Orange River drainage basin (Jubb 1964). The distribution of fish in the Orange River is not homogenous. Jubb (1972) mentions that in the part of the drainage system that flows into the Gariep Dam, only seven indigenous species are found.

Cyprinidae

The cyprinids are an extremely large family of primary freshwater fishes. They are distributed worldwide, with about 275 genera and more than 1600 species. At least 24 of the genera and 475 of the species occur in Africa. Cyprinids are highly variable regarding their biology as well as anatomy. They lack teeth on the jaws, as well as a true stomach, but have strong pharyngeal bones in the throat, and an extended and convoluted gut. Most of the cyprinids are adapted for living in fast flowing water, which means that most of them are strong swimmers.

Yellowfishes

Until recently all the yellowfishes belonged to the genus *Barbus* Cuvier & Cloquet, 1916. For ichthyologists, this genus has long been a taxonomic problem (Myers 1960). Taxonomists have recognized that the African species are polyphyletic, and distinct at generic level from the European *Barbus barbus* Linnaeus, 1758, which is the type species of the genus. According to Skelton (2002), the yellowfishes have been moved to the genus *Labeobarbus* Rüppell, 1836 because of the genetic differences with other *Barbus* species. The yellowfishes have a hexaploid karyotipe, while the European species are tetraploid (Skelton 2002).

Yellowfishes are large barbine cyprinids, which can live for many years and are characteristic to many African rivers and lakes, and according to Jubb (1964) there are two species in the Orange River drainage basin, namely *Labeobarbus aneus* (Burchell, 1822), and *L. kimberleyensis* (Gilchrist & Thompson, 1913).

Within populations there can be a wide variation in the anatomical features of these fish. Three forms are recognized based on the mouth and lips, which are especially variable: the normal U-shaped mouth with normal lips; straight-edged mouth with horny lower lips; and fleshy lips. The development of the lips is determined by the feeding habits and can change from normal to thick depending on the food resources. Each variation of mouth and lips appear to be an adaptation for feeding from different substrates.

Species: ***Labeobarbus kimberleyensis*** (Gilchrist & Thomson, 1913) (Figure 3.1A)

Common name: Largemouth yellowfish

This is the largest scale bearing fish in southern Africa, and can reach weights of up to 22kg. They are absent from the southern tributaries in the Cape and higher reaches of Lesotho and prefer the larger tributaries and dams. According to Jubb (1964), the largemouth yellowfish is endemic to the Orange River drainage basin. This fish is primarily a predator that prefers flowing water, but they also survive well in dams. The young initially feed on insects, but become piscivorous above 300mm. Breeding occurs in mid to late summer, in flowing water over gravel beds. After two to three days the eggs hatch, and feeding begins three to four days later. The males mature only after six years and the females after eight. Because of its large size and piscivorous feeding habits, this species will regularly take live bait and a variety of lures. This makes the largemouth yellowfish a very popular angling species. Jubb (1972) noted that the largemouth yellowfish used to be common in the Caledon River below 1500m. This species is now becoming scarce and are being artificially cultured to restock their numbers (Skelton 2001).

Species: ***Labeobarbus aneus*** (Burchell, 1822) (Figure 3.1B)

Common name: Smallmouth yellowfish

This is a smaller species than *L. kimberleyensis* attaining weights of 7kg. Smallmouth yellowfish occur naturally in the Orange River drainage system and this species is also endemic to the Orange River drainage basin (Jubb 1964), but it has been translocated to larger Cape coastal rivers. According to Jubb (1972), this species is more widely distributed in the system than the largemouth yellowfish. These fish migrate upstream to spawn on gravel beds in spring to midsummer after the first substantial rain of the season. Eggs hatch after 3-8 days and feeding begins after another 4-6 days. The large fish are omnivorous, and feed on available food, which includes benthic invertebrates, plants, algae and detritus. Smallmouth yellowfish is also an important angling species.

Labeos or Mudfishes

The genus *Labeo* Cuvier, 1817 comprises at least 80 species in Africa. The labeos are specialised feeders and have well adapted mouthparts. Labeos also have well adapted intestines, which is long and coiling, because of their feeding habits. They often occur in flowing water, and most of them are strong swimmers. Labeos migrate upstream to breed, and some have been observed to cross exposed surfaces.

Species: *Labeo umbratus* (Smith, 1841) (Figure 3.1C)

Common name: Moggel

This species has commercial as well as subsistence uses and occurs in the Orange-Vaal system, as well as several other systems of the south and southeast Cape regions. The moggel is endemic to the region (Jubb 1964), but has also been translocated to several systems in the eastern Cape as well as Gauteng. They prefer standing and slow flowing water where they feed on soft sediments and detritus. *Labeo umbratus* (Smith, 1841) has an extremely long and coiling intestine (Jubb 1972). They are also capable of surviving conditions in dwindling pools of mud. These fish can breed prolifically, and produce a high number of offspring. The moggel is likely to constitute a large proportion of the fish population in dams where it occurs (Jubb 1972). Flooded grassy riverbanks are preferred spawning sites, and after the summer rains, breeding adults migrate upstream to these sites. Eggs hatch after only 40 hours, and the growth rate is rapid.

Species: *Labeo capensis* (Smith, 1841) (Figure 3.1D)

Common name: Orange River mudfish

The mudfish is used in physiological as well as ecological research, and also has potential commercial value. This species prefers running water and occurs in the Orange-Vaal system, and according to Jubb & Farquharson (1965) it is endemic to the system. The mudfish is also a detritus feeder (Jubb 1972). Spawning migrations to shallow rocky rapids take place from November to January. The growth rate of the mudfish is also fairly rapid.

Barbs or Minnows

The minnows have a tetraploid number of chromosomes, unlike the yellowfishes, which are hexaploid. Minnows occur in shoals, and are well camouflaged, but often have distinct markings. They form an important food for larger fish, and are also used for live bait, and as fodder for bass and trout. Breeding takes place in a variety of ways, and males usually develop bright colours.

Species: *Barbus anoplus* Weber, 1897 (Figure 3.1E)

Common name: Chubbyhead barb

Chubbyhead barbs are widely distributed through the whole system (Jubb 1972), but are absent from the lower Orange. This species is used as forage fish, is omnivorous, feeding on zooplankton and a variety of phytoplankton. The chubbyhead barb prefers habitats with vegetation that can provide shelter. Females lay adhesive eggs amongst the vegetation during summer after rain. Larvae hatch after three days and three or four days later begin to feed and swim.

Species: *Barbus pallidus* Smith, 1841

Common Name: Goldie barb

The goldie barbs distribution is divided between the coastal streams of eastern Cape and tributaries of the Vaal. This species form pairs when breeding in the summer and eggs are laid in the marginal vegetation of rocky clear water streams.

Species: *Barbus trimaculatus* Peters, 1952

Common name: Threespot barb

The threespot barb is part of a group of barbs known as the spinefin barbs. Spinefin barbs differ from the other barbs in that their primary dorsal fin ray is spinous and not serrated. Threespot barb is a hardy species with a very wide distribution, and prefers vegetated waters. After rain the breeding adults occur in shoals that migrate upstream to spawn.

Species: *Barbus paludinosus* Peters, 1852 (Figure 3.1F)

Common name: Straightfin barb

The straightfin barb is placed in the sawfin barb group, which have a bony, serrated primary dorsal fin ray. This group includes a third of the *Barbus* species in southern Africa. The distribution is wide, occurring from the Orange to tributaries of the Congo. These fish prefer larger rivers and slow flowing streams and occurs in vegetated, marginal waters. They feed on a wide variety of small animals as well as algae, diatoms and detritus. Spawning takes place during summer, and females can lie up to 2500 eggs. The straightfin barb is prayed upon by a variety of larger fish, as well as man, as it forms an important component of the "matemba" fishery of Malawi.

Species: *Barbus hospes* Barnard, 1938

Common name: Namaqua barb

This species occurs only below the Augrabies Falls in the Orange River, and also belongs to the sawfin barb group. According to Jubb (1964) the Namaqua barb is endemic to the Orange River. They occur in the open water and feeds on zooplankton. The conservation status of *B. hospes* Barnard, 1938 is now classified as near threatened, but has benefited from the regulated water flow below the hydroelectric dams.

Barilins and Neobolins

These are related groups of large mouth predatory species. The anal fin of these fishes is longer based than that of the other African cyprinids. The larger barilins occur in the tropics of Africa and Asia, with the neobolins being smaller and entirely African.

Species: *Mesobola brevianalis* (Boulenger, 1908)

Common name: River sardine

These small, sardine-like fishes occur in the Orange River, but only below the Augrabies Falls. This species was formerly placed in the genus *Engraulicypris* Gunther, 1893, but was later placed in the genus *Mesobola* Howes, 1984. It also occurs in the Cunene, the Okavango, and the upper Zambezi as well as on the east coast. The river sardine occurs in well-aerated water of flowing rivers where they shoal together and feed on zooplankton. Breeding takes place during early summer.

Austroglanididae

These small catfishes are endemic to southern Africa, and one of their characteristics is the placement of barbels on the lower jaw. The austroglanidids resembles fish from the Bagridae and until recently the three known species were placed in the genus *Gephyroglanis* Boulenger, 1899 (Jubb 1964, Jubb 1972, Jubb & Farquharson 1965 and Gabie 1965), within the Bagridae. However, the African rock catfishes are now classified within the genus *Austroglanis* Skelton, Risch & De Vos, 1984.

Species: ***Austroglanis sclateri*** (Boulenger, 1901) (Figure 3.2A)

Common name: Rock catfish

This small silurid occurs in the major tributaries and mainstream of the Orange-Vaal system. According to Jubb (1972), this species frequents rocky areas, and it prefers the rapids of these rocky habitats. Rock catfish feed on small invertebrates, with the larger specimens also feeding on small fish. Unfortunately, no information is available on the breeding habits of *A. sclateri* (Boulenger, 1901). All three species of the genus *Austroglanis* are listed in the Red Data Book. This species is threatened mainly due to changes to their habitat, including building of weirs and dams, and other human activities.

Clariidae

Clariids are well known for their ability to breathe air, which is attributed to the multi-branched accessory branchial air-breathing organ (Jubb & Farquharson 1965), and are also able to withstand desiccation. Most clariid species are relatively small, although some species like the vundu and the sharptooth catfish can attain very large sizes, up to 59kg.

Species: ***Clarias gariepinus*** (Burchell, 1822) (Figure 3.2B)

Common name: Sharptooth catfish

In Africa, the genus *Clarias* Scopoli, 1777 comprises eight species, with the sharptooth catfish being the most widespread, occurring almost throughout the whole continent. This is also a very large species, found in almost any habitat, but prefer slow flowing rivers, dams and lakes, and can dig burrows when faced with diminishing water. These fish have also been observed crossing patches of land. The sharptooth catfish feeds on any organic matter, and scavenges for any available food. It is also an important source of food for many predators, and is also a source of food for man. This species is capable of feeding in packs, where they herd together small fish. Breeding takes place in summer and eggs are laid on vegetation in shallow grassy verges of rivers and dams. Eggs hatch after 25-40 hours and the free swimming larvae feed within two to three days.

Most individuals take two years to mature and are capable of living up to eight years or more. This is a very dominant species where they occur and translocation may threaten indigenous species. *Clarias lazera* Valenciennes, 1840, *C. mossambicus* Peters, 1852 and *C. gariepinus* (Burchell, 1822) were once treated as separate species, but they have all been synonymised with *C. gariepinus* (Skelton 2001). Therefore, in the following sections, only reference to *Clarias gariepinus* will be made.

Cichlidae

Representatives of the Cichlidae have a worldwide distribution, occuring in Africa, parts of south America, and parts of Asia. According to Gabie (1965), some of the members of the Cichlidae are tolerant of salt water. Cichlids are important as food, and are also used in scientific studies. They are characterised by scales on the head and the body, the pelvic fins are in the thoracic position, the lateral line is divided, and a single nostril is found on each side of the snout. In many cases pairs are formed during breeding, and usually the adults guard the eggs and the young. Nests are also often built. In many species the eggs are incubated in the mouth of one of the parents, usually the female. Two main lineages exist within the southern African area. One line is those who are sedimentary and plant feeders, the tilapiines, and are characterised by a dark eye-spot on the base of the dorsal fin when they are young, called the "tilapia-spot". The other line is the haplochromines, which tend to be predators. Adult haplochromines usually have clear spots or ocelli on the anal fin, often referred to as "egg-spots". The function of these spots is to assist in the fertilisation of the eggs. This is the largest African family with eight genera and 41 species reported in southern Africa.

River Breams

This group consists of seven different genera. They are, however, not necessarily closely related. Most of these species are small, or moderate in size. Only one genus from this group, namely *Hemichromis* Peters 1858, is not a mouthbrooder. The males are usually brightly coloured during the breeding season and most have egg-spots.

Species: *Pseudocrenilabrus philander* (Weber, 1897) (Figure 3.1C)
Common name: Southern mouthbrooder
This species was formerly placed in the genus *Hemihaplochromis* Wickler, 1963, but was later placed in the genus *Pseudocrenilabrus* Fowler, 1934. Southern mouthbrooders are distributed from the Orange River and southern Natal northwards to the southern Zaire tributaries and Lake Malawi. These fish occur in a variety of habitats and prefer vegetated zones, where they feed on small arthropods as well as small fish. The males establish a territory, and build a simple nest during the breeding season, which is from spring to summer. The males defend their territory and also attract sexually mature females. The female collects the eggs in the nest and then retreats to a quiet area where the eggs, larvae and juveniles are brooded. This species is used as an aquarium species and also in behavioural and evolutionary research. Threats to the southern mouthbrooder include introduced species, habitat change and pollution.

Tilapiines
This is a major branch of the African cichlids. Most of the species have a vegetarian diet, with small teeth, fine pharyngeal teeth, and extended intestines. Some of the genera are substrate brooders, while others are mouthbrooders. These fishes are of importance to man as food, and some are popular angling species.

Species: *Tilapia sparrmanii* Smith, 1840 (Figure 3.2D)
Common name: Banded tilapia
The genus *Tilapia* Smith, 1840 includes all the species that are substrate brooders, and adults retain the "tilapia spot". Banded tilapia are tolerant of a wide range of habitats, and Jubb (1972) states that it is tolerant of cold water, but prefers temperatures above 15°C. Skelton (2001) notes that this species is more

restricted by warmer than colder waters. It has a wide distribution, and has also been translocated to the Cape. The banded tilapia is also an omnivore, feeding on a wide range of available foods, even small fish. According to Jubb (1972), the banded tilapia forms breeding pairs and both parents guard the nest. This species is a common component of subsistence fishing and is an occasional angling species.

Introduced fishes of the Orange River

At least 22 species of fish have been introduced to southern Africa (Skelton 2001). According to Bruton & Van As (1986), the first fishes were introduced into southern Africa over 260 years ago. Reasons for introducing the fish range from sport fishing, aquaculture, which includes food for introduced fishes, the stocking of man-made dams and biological control. The most important impact of the introduced fishes is the introduction of their parasites, which threaten natural communities (Bruton & Van As 1986). Another impact is the predation of introduced fish on the indigenous species. Alien fish species can also affect the water quality, for example the carp that disturbs the bottom sediments during feeding and increases turbidity (Bruton 1985; Schrader 1985). Another threat is the hybridization with invasive fish (Bruton & Van As 1986), which could produce viable offspring. In the Orange River there are seven introduced fish species, which will be discussed below.

Cyprinidae

Species: ***Cyprinus carpio*** Linnaeus, 1758 (Figure 3.2E)

Common name: Carp

The carp was introduced into South Africa in the 1700s and several importations are reported in the 1800s, while the Aischgrund strain was imported in 1955. Introduced carp is now widespread throughout southern Africa, but are absent from mountain areas and restricted to the warmer tropical areas. Carp has invaded more catchments areas than any other species and its range has recently been extended into the Phongolo and upper Mkuze systems (De Moor &

Bruton 1996). The natural distribution includes Central Asia to the Black Sea and the Danube in Europe, but carp is now widespread throughout the world. Being an omnivorous species, carp feed by grubbing in sediments. Breeding takes place in spring and summer, and they lay sticky eggs amongst the vegetation. It is reported that large females can lie up to a million eggs. Carp is considered as a valued angling and aquaculture species, although it is considered as a pest by conservation authorities.

Poeciliidae

Species: *Gambusia affinis* (Baird & Girard, 1853) (Figure 3.2F)

Common name: Mosquitofish

These fish are unique in that fertilisation is internal and they bear live young. The anal fin of the male is modified to form an intromittent organ. Naturally occurring in Central and South America, mosquitofish was introduced in 1936 by aquarists, and scattered populations now occur throughout southern Africa. Mosquitofish was bred and distributed by Cape Inland Fisheries as a mosquito control agent, but has proven to be an aggressive invader species capable of restricting other fish populations. Mosquitofish are tolerant of a wide range of water temperatures, as well as salinities ranging from fresh to higher than seawater.

Salmonidae

Species: *Salmo trutta* Linnaeus, 1752

Common name: Brown trout

Brown trout occurs naturally in Europe and North East Africa, but have been introduced to streams of the South West Cape, Southern Cape, Eastern Cape, the Drakensberg and Lesotho. These fish prefer mountain or upland streams with well-oxygenated water, where it feeds on aquatic and terrestrial insects, crabs, frogs and small fish. Breeding takes place in autumn or early winter when males migrate to suitable gravel beds and establish territories. The female excavates a nest by rapidly beating her body and tail. Eggs usually hatch after about three weeks and small trout gradually move downstream and begin feeding.

Species: ***Oncorhynchus mykiss*** (Walbaum, 1792)

Common name: Rainbow trout

This species occur naturally in rivers of the Pacific Coast of North America from northern Mexico to Alaska. Rainbow trout was introduced to dams and mountain streams of southwestern, southern, eastern, northeastern Cape, Kwazulu – Natal, eastern Gauteng, Swaziland and eastern Zimbabwe. Rainbow trout occurs in clear well-aerated waters, feeding on a wide range of food sources such as small invertebrates, crabs, frogs and even small fish. According to Jubb (1972) in areas where the rainbow trout and the smallmouth yellowfish ranges overlap, the number of small yellowfishes are becoming scarce due to the predation of the trout on young immature yellowfish. Breeding takes place in winter when breeding fish move to gravel beds where females dig a nest in which spawning takes place. Eggs hatch after four to seven weeks and the larvae are free swimming within a week.

Centrarchidae

Species: ***Lepomis macrochirus*** Rafinesque, 1819

Common name: Bluegill Sunfish

The natural distribution of the bluegill sunfish is eastern and central North America. They are found in Cape coastal drainages, the middle reaches of rivers in Kwazulu – Natal, southeastern and eastern Gauteng and northeastern Free State. It was introduced into Lesotho as forage fish for the largemouth bass (Jubb 1972). This species prefers well-vegetated water in rivers and dams. They prey on invertebrates and small fish. Bluegill sunfish are considered a pest, as they tend to overpopulate water and feed on the indigenous fish species.

Species: ***Micropterus salmoides*** (Lacepède, 1802)

Common name: Largemouth Bass

Largemouth bass occur naturally in central and eastern North America from the Gulf of Mexico to southern Canada. It was introduced to the Cape in 1928 and a subspecies known as Florida Bass (*M. s. floridianus*) was introduced to Kwazulu – Natal in 1980. It occurs throughout Cape coastal drainages, Kwazulu – Natal and Gauteng, although Jubb (1972) stated that there was no evidence that bass have escaped and become established in any of the rivers. Largemouth bass are also found in Malawi, Namibia and Zimbabwe. These fish prefer standing or slow-flowing waters with submerged and floating vegetation. This is a primarily piscivorous species, but will also feed on frogs, snakes and small mammals. Males construct a nest and guard it, as well as the newly hatched larvae. Largemouth bass is a very popular freshwater gamefish species.

Species: ***Micropterus dolomieu*** (Lacepède, 1802)

Common name: Smallmouth bass

According to Jubb (1972), the smallmouth bass was introduced into some dams in Lesotho in 1937 to enhance the river fishing below the Trout zone. It now also occurs in some rivers in southwest and eastern Cape, Kwazulu – Natal and Gauteng and is found in the Caledon and Orange Rivers. Normally smallmouth bass occur in flowing water and prefers rocky substrates. Males also construct a nest and guard the eggs and larvae. The young fish feed on insects and small fish, whilst the adults are mainly piscivorous, feeding on crabs occasionally. This species is very successful in southwest Cape, and for this reason bass is no longer stocked or produced by nature conservation authorities.

The fish species of the Modder River

In Table 3.1 a list of fishes that occur in the Modder River, a tributary of the Orange River, is compiled. The species in bold print indicate those that were collected during the study period.

Table 3.1. Twelve fish species that have been recorded from the Modder River (Seaman, Roos & Watson 2001a)

	Species
Cyprinidae	***Labeobarbus kimberleyensis*** (Gilchrist & Thompson, 1913)
	Labeobarbus aneus (Burchell, 1822)
	Labeo umbratus (Smith, 1841)
	Labeo capensis (Smith, 1841)
	Barbus anoplus Weber, 1897
	Barbus paludinosus Peters, 1852
Austroglanididae	*Austroglanis sclateri* (Boulenger, 1801)
Clariidae	***Clarias gariepinus*** (Burchell, 1822)
Cichlidae	***Pseudocrenilabrus philander*** (Weber, 1897)
	Tilapia sparrmanii Smith, 1840
Introduced species	***Cyprinus carpio*** Linnaeus, 1758
	Gambusia affinis (Baird & Girard, 1853)

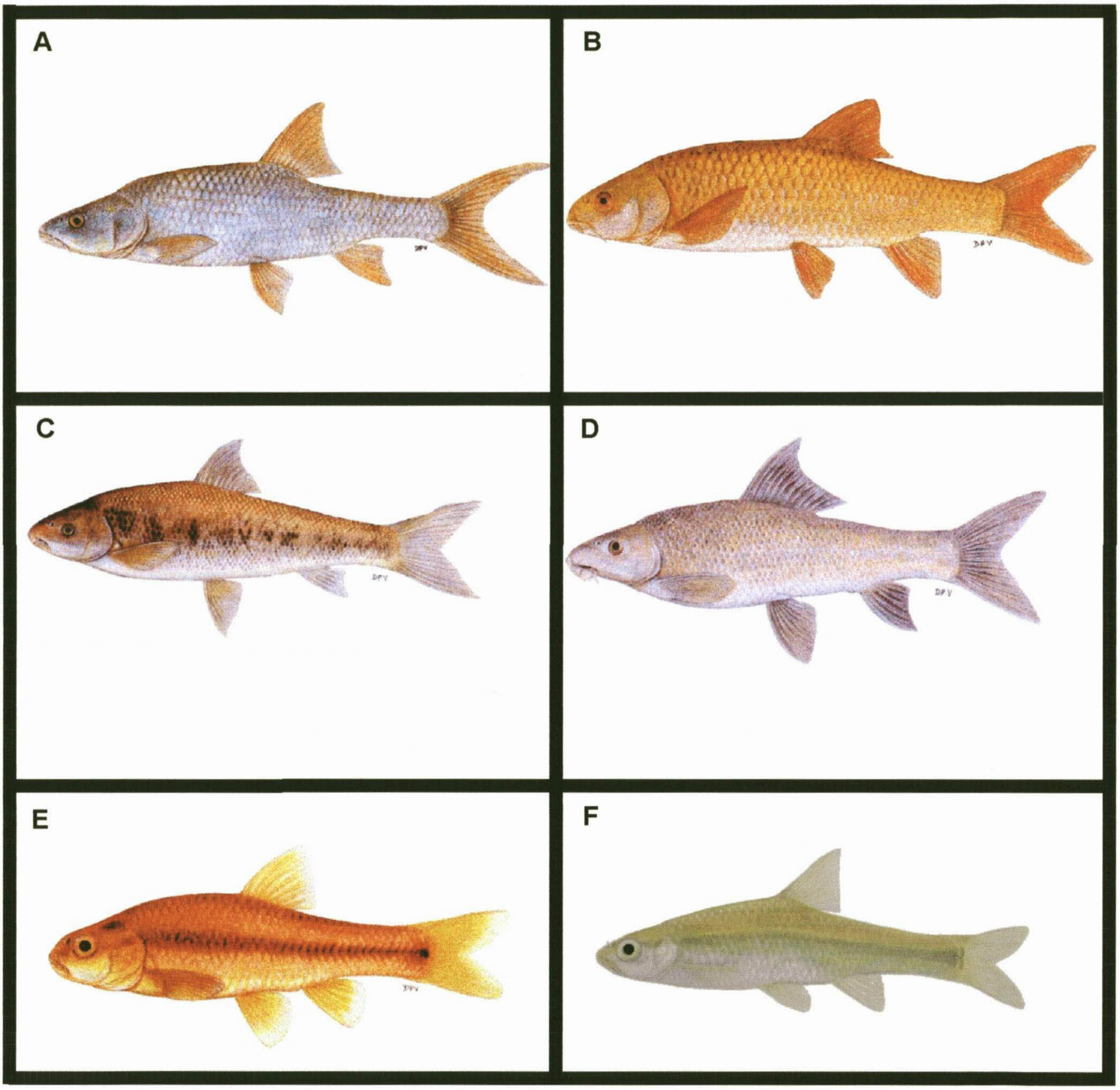


Figure. 3.1. Illustratoins of the fishes from the Modder River. **A** – *Labeobarbus kimberleyensis* (Gilchrist & Thompson, 1913). **B** – *L. aeneus* (Burchell, 1822), **C** – *Labeo umbratus* (Smith, 1841), **D** – *L. capensis* (Smith, 1841), **E** – *Barbus anoplus* (Weber, 1897), **F** – *B. paludinosus* Peters, 1852. Taken from Skelton (1993). (Not to scale).

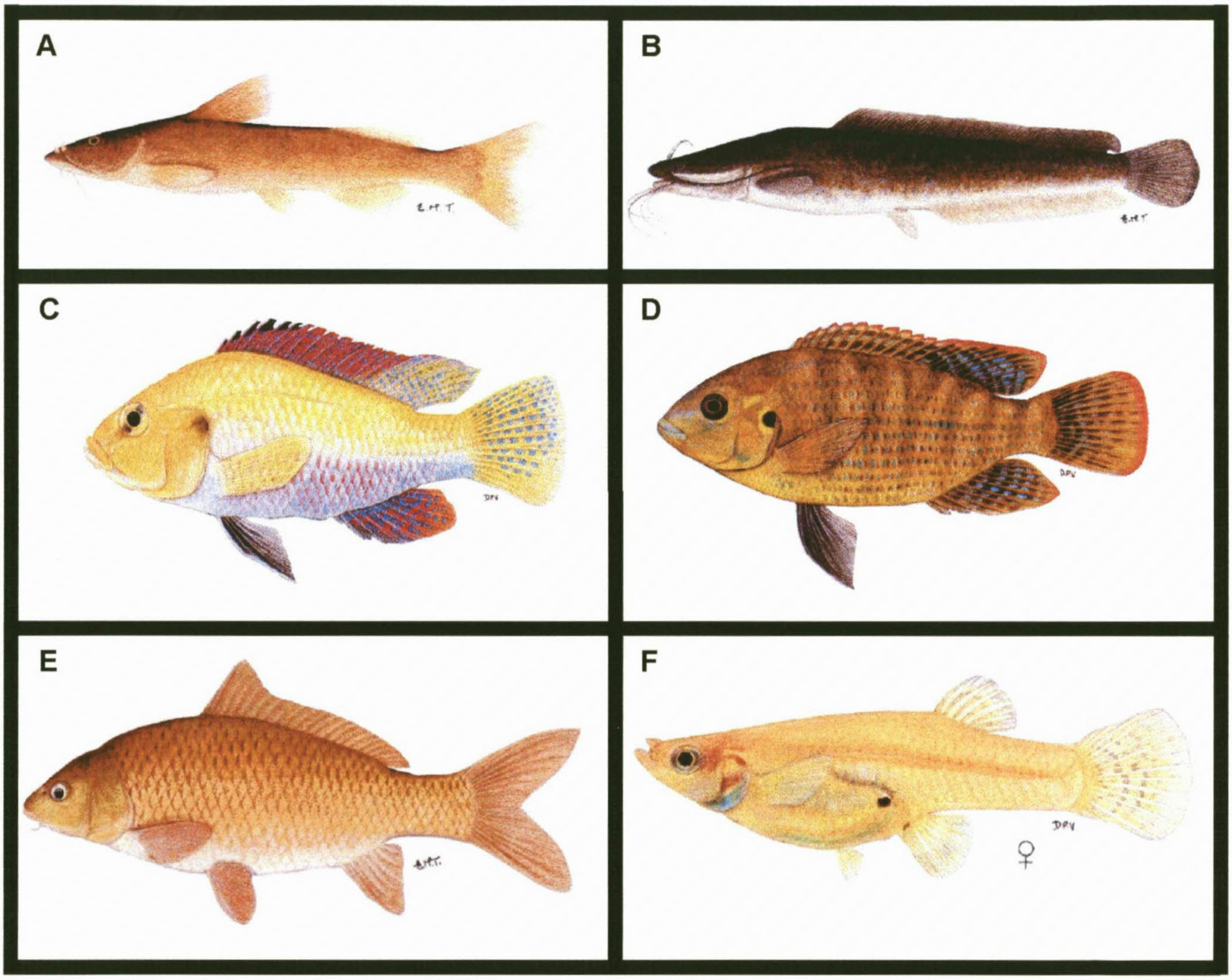


Figure. 3.2. Illustrations of the fishes from the Modder River. **A** – *Austroglanis sclateri* (Boulenger, 1801), **B** – *Clarias gariepinus* (Burchell, 1822), **C** – *Pseudocrenilabrus philander* (Weber, 1897), **D** – *Tilapia sparrmanii* Smith, 1840, **E** – *Cyprinus carpio* Linnaeus, 1758, **F** – *Gambusia affinis* (Baird & Girard, 1853). Taken from Skelton (1993). (Not to scale).

Results

The results of my study are presented in chapters 4-6. Each chapter is concerned with a specific group of parasites, with the systematics and literature of the respective group discussed first, followed by the results of parasites collected from Soetdoring Nature Reserve. This includes diagrams as well as light micrographs. For all groups where measurements are given, these are presented as they appeared in original form. Where measurements were not available, it was omitted or was measured from available drawings.

Diagrams have been redrawn from the original publication, or if not available, redrawn from other authors. For the monogeneans, authors in the past did not provide diagrams of all marginal hooklets. In these cases only those hooklets available are given. More recent cases, where all hooklets were provided, it appears from number I-VII. This does not apply to diagrams of *Quadriacanthus*, where the numbers of the marginal hooklets are given, since the numbering of marginal hooklets from this genus differs from those of *Dactylogyrus* and *Dogielius*.


Chapter 4

The phylum Ciliophora Doflein, 1901

The ciliophorans are a group of acellular organisms, which include free-living, commensalistic and parasitic forms. According to Lom & Dyková (1992) the ciliophorans occurring in or on fish and may range from completely harmless ectocommensals to very dangerous pathogens. Some ectoparasitic species have no host preference, such as *Ichthyopthirius* Fouquet, 1876, which is capable of infecting most teleost fishes. The endocommensal species, however, may be restricted to a few host species. Ciliophorans generally possess one or more diploid micronuclei, which are generative, as well as one or more polyploid macronuclei, which are vegetative. Reproduction takes place either by binary fusion, or sexually through the process of conjugation (Lom & Dyková 1992).

Since Van Leeuwenhoek observed the first acellular organism in 1676, the taxonomy of the protozoans has undergone extensive revision. These will not be discussed in detail, but will be summarised below.

Before the 1970's, all acellular organisms were placed under the phylum Protozoa Goldfuss, 1820, according to the Bütschli-Kahl classification system, and the ciliophorans were all placed in the class Ciliata of the sub-phylum Ciliophora (Corliss 1979). The system of Kahl (1932) was based on somatic ciliation and the appearance of the adults (Lom & Dyková 1992).

The group shows many homogenous characters, which differs from the rest of the Protozoa. At that stage the Ciliata was the only class in the sub-phylum, and based on the diversity of forms and the extent of species which were included in the class, Raabe (1964) suggested that the subphylum be elevated to the rank of phylum. Corliss (1974) supported this suggestion and this led to the elevation from sub-phylum to phylum.

Two major works appeared in 1994, concerning the higher systematics of the Ciliophora. One of these works concerns the anatomy, systematics and biology of the phylum Cilophora (Batisse, Bonhomme-Florentin, Deroux, Fleury, Foissner, Grain, Laval-Peuto, Lom, Lynn, De Puytorac & Tuffrau 1994). The other work is that of Corliss (1994) in which a user-friendly classification for all the protists is proposed. These works differ from each other in that Corliss only mentioned eight classes, with no subphylum division, whereas De Puyterac begins the book with the classification of the Ciliophora with three subphyla, and eleven classes.

The classification of Lom & Dyková (1992) is essentially that of Levine, Corliss, Cox, Deroux, Grain, Honigberg, Leedale, Loeblich, Lom, Lynn, Merinfield, Page, Polyanski, Sprague, Vavra and Wallace (1980). This system is based on the structure of the buccal apparatus, as well as features of the cortex.

The work of Lom & Dyková (1992) is concerned with the protozoan parasites of fishes, which includes three classes, i.e. the Kinetophragminophorea de Puytorac *et al.*, 1974, the Oligohymenophorea de Puytorac *et al.*, 1974, and the Polyhymenophora Jankowski, 1967.

This chapter will deal with two groups of ciliophorans, i.e. the sessiline ciliophorans and the mobiline ciliophorans, both in the subclass Peritrichia. As the aquatic parasitology research group of the University of the Free State has done extensive research on the ciliophorans, this chapter will only be concerned with research done in South Africa. The classification that will be used here is that of Lom & Dyková (1992) (Table 4.1).

Table 4.1. Classification of the ciliophoran parasites of fishes (adapted from Lom & Dyková 1992)

CLASS	SUBCLASS	ORDER	FAMILY
Kinetophragminophorea de Puytorac *et al.*, 1974	Gymnostomata Bütschli, 1889	Pleurostoma	Amphileptidae
	Vestibulifera de Puytorac *et al.*, 1974	Trichostomatida	Balantidiidae
			Pycnotrichidae
	Hypostomata Schewiakoff, 1896	Cyrtophorida	Chilodonellidae
			Hartmannulidae
			Hypocomidae
	Suctoria Claparède & Lachmann, 1858	Suctorida	Dendrostomatidae
			Endosphaeridae
			Trichophryidae
Oligohymenophorea de Puytorac *et al.*, 1974	Hymenostomata Delage & Hérouard, 1896	Hymenostomatida	Tetrahymenidae
			Ophryoglenidae
			Ichthyophthiriidae
		Scuticociliatida	Philasteridae
			Uronematidae
	Peritrichida Steyn, 1859	Sessilina	Epistylidae
			Operculariidae
			Scyphidiidae
			Ellobiophoridae
		Mobilina	Trichodinidae
Polyhymenophora Jankovski, 1967	Spirotricha Bütschli, 1889	Heterotrichida	Sicuophoridae
			Inferostomatidae
			Nathellidae

Sessiline ciliophorans

Class: Oligohymenophorea de Puytorac *et al*, 1974

Subclass: Peritrichida Steyn, 1859

Order: Sessilina Kahl, 1933

These sessiline organisms occur on the gills as well as the skin of both freshwater and marine fish. They attach to the host by means of a scopula, which can either adhere directly to the substrate, or it can be cemented to the substrate. In some cases a stalk is also secreted, which is in most cases non-contractile. If the stalks are contractile, they posses a central spasmoneme, which ensures the contractility of the stalk. According to Lom & de Puytorac (1994), the body of these animals is bell-shaped to cylindrical, ovoid or conical. The peristomal disc is generally well developed. A peristomal lip is situated on the border of the peristome. The adoral spiral with two rows of cilia is situated on the inside of this lip.

Sessiline Ciliophorans known from South Africa

The Genus *Apiosoma* Blanchard, 1885

Generic diagnosis

Species of this genus are solitary and occur mostly as ectoparasites on freshwater fish. According to Viljoen & Van As (1985) the body is cylindrical to elongate cup-shaped. The body tapers sharply and the scopula is small. Some members of this genus posses a non-contractile stalk. The peristomal lip covers the peristomal disc, which is convex, and the adoral cilia, which consists of both haplo- and polykinety. A single contractile vacuole is situated directly below the peristome. The macronucleus is usually conical, and the apex is pointed towards the scopula (Lom & Dyková 1992). In some cases the macronucleus is ellipsoidal. One micronucleus is present, which is situated in the region of the macronucleus (Viljoen & Van As 1985).

Species of *Apiosoma* known from South Africa

Viljoen & Van As (1985) described nine species of the genus *Apiosoma* from fish collected from lakes, rivers, streams and ponds in South Africa. Seven of the species were described as new species by these authors. The two known species collected were *Apiosoma nasalis* (Timofeev, 1962) collected from *Pseudocrenilabrus philander* (Weber, 1897) and *A. piscicola* Blanchard, 1885 collected from *Barbus paludinosus* (Peters, 1852), *B. trimaculatus*, *Labeo cylindricus* Peters, 1852, *Marcusenius macrolepidotus* (Peters, 1852), *Micropterus dolomieu* (Lacepède, 1802), *Oreochromis mossambicus* (Peters, 1852), *P. philander* and *Tilapia rendalli* Dumeril, 1859.

The seven new species described by Viljoen & Van As (1985), included *Apiosoma caulata* Viljoen & Van As, 1985 collected from the skin and gills of *Mesobola brevianalis* (Boulenger, 1908), *A. curvinucleata* Viljoen & Van As, 1985 from the skin of *O. mossambicus*, *A. micralesti* Viljoen & Van As, 1985 collected from the skin of *Micralestes acutidens* (Peters, 1852), *A. mothlapitsis* Viljoen & Van As, 1985 from the skin of *Labeobarbus marequensis* Smith 1841, *A. obliqua* Viljoen & Van As, 1985 from the skin of *L. cylindricus*, *A. phiala* Viljoen & Van As, 1985 collected from the skin and gills of *L. marequensis*, *B. paludinosus*, *B. trimaculatus* Peters, 1852, *B. unitaeniatus* Günther, 1866, *L. capensis* (Smith, 1841), *L. cylindricus*, *Mesobola brevianalis*, *O. mossambicus* and *P. philander* as well as *A. viridis* Viljoen & Van As, 1985 from the skin of *O. mossambicus*, *P. philander*, *T. rendalli* and *T. sparrmanii* Smith, 1840.

The Genus *Scopulata* Viljoen & Van As, 1985

Generic diagnosis

According to Viljoen & Van As (1985) representatives of this genus are ectoparasites of freshwater fish. The genus *Scopulata* was created to accommodate species that do not conform to characters of the genus *Scyphidia* Dujardin, 1841. The body of these ciliophorans is cylindrical with a broad scopula, and the body is not stalked. A prominent unciliated groove encircles the body. The body is also encircled by pellicle striations. When the peristomal lip is expanded, adoral cilia consisting of haplo- and polykinety complete a spiral of more than 360°, as well as a convex peristomal disc is revealed. A contractile vacuole, as well as food vacuoles (in most species) is situated in the region above the groove. The macronucleus is situated below the groove, with only one micronucleus present, either below or alongside the lower part of the macronucleus.

Species of *Scopulata* known from South Africa

Van As & Viljoen (1985) described one new species in 1985, when they created the genus. This species was *Scopulata constricta* Viljoen & Van As, 1985 from the skin of *Oreochromis mossambicus*. Two other species already described by Viljoen & Van As (1983) as *Scyphidia*, were placed in the genus *Scopulata* in 1985. These species were *S. dermata* (Viljoen & Van As, 1983) from the skin of *Marcusenius macrolepidotus*, *Micralestes acutidens*, *B. trimaculatus*, *O. mossambicus*, *P. philander*, *T. rendalli* and *T. sparrmanii*, as well as *S. epibranchialis* (Viljoen & Van As, 1983) collected from the gills and occasionally the skin of *M. dolomieu*, *O. mossambicus* and *P. philander*.

Lom & Dyková (1992), however, provide the following key to the genera of sessiline ciliophorans that are parasitic on fish.

1. a. Ciliophorans attached to the substrate directly by their scopula, mostly circular, often a large diameter, sometimes lobed, occasionally split into long projections... **2**

   b. Ciliophorans attached by semicircular outgrowths of the scopula joined to form circle around secondary lamellae of gills...

   Caliperia Laird, 1953

   c. Ciliophorans attached by means of secreted stalk... **4**

2. a. The locomotory fringe of cilia occurs only in telotrochs... **3**

b. The locomotory fringe is permanent, occurring also in attached ciliophorans... ***Ambiphrya*** Raabe 1952

3. a. Macronucleus is compact, conical or ellipsoidal, the cell shape usually elongated conical... ***Apiosoma*** Blanchard 1885

b. Macronucleus is sausage-shaped, cell shape mostly cylindrical... ***Riboscyphidia*** Jankowski, 1980

4. a. A non-contractile stalk is branched, bearing a small colony of several zooids... ***Epistylis*** Ehrenberg, 1830

b. The non-contractile stalk is short and bears a spoon-like shield sheltering a single zooid... ***Propyxidium*** (Kent, 1881)

c. The stalk is contractile, unbranched, bearing a single zooid or branched, bearing colonies of many zooids...

opportunistic epibionts of the genera ***Vorticella*** (Linnaeus, 1758), ***Zoothamnium*** (Modeer, 1790) and ***Carchesium*** (Linnaeus, 1758).

According to this key, all species, which were formerly placed within the genus *Scopulata*, are now placed within the genus *Apiosoma*. As the classification of Lom & Dyková (1992) is used, for this dissertation the species of *Scopulata* will be treated as species of *Apiosoma*.

A summary of the species of *Apiosoma* occurring in South Africa is given in Table 4.2. The measurements of these species are summarised in Table 4.3.

Table 4.2: Summary of sessiline ciliophoran species that have been recorded from South Africa; selected host and the location on the host (host species in bold represent those occurring in the Modder River).

Sesiline Ciliophorans	Host	Location on host
Apiosoma caulata Viljoen & Van As, 1985 (Figure 4.1A)	*Mesobola brevianalis* (Boulenger, 1908)	Skin and Gills
A. constricta Viljoen & Van As, 1985) (Figure 4.2E)	*Oreochromis mossambicus* (Peters, 1852)	Skin
A. curvinucleata Viljoen & Van As, 1985 (Figure 4.1D)	*O. mossambicus*	Skin
A. dermata Viljoen & Van As, 1983) (Figure 4.2F)	*Barbus trimaculatus* Peters, 1852, ***Pseudocrenilabrus philander*** (Weber, 1897) *T. rendalli* Gilchrist & Thompson, 1917, ***T. sparrmanii*** Smith, 1840	Skin
A. epibranchialis Viljoen & Van As, 1983) (Figure 4.2D)	***P. philander***	Gills and occasionally skin
A. micralesti Viljoen & Van As, 1985 (Figure 4.1C)	*Micralestes acutidens* (Peters, 1852)	Skin
A. mothlapitsis Viljoen & Van As, 1985 (Figure 4.2C)	*Labeobarbus marequensis* (Smith, 1841)	Skin
A. nasalis Timofeev, 1962) (Figure 4.2B)	***P. philander***	Skin and Gills
A. obliqua Viljoen & Van As, 1985 (Figure 4.2A)	*Labeo cylindricus* Peters, 1852	Skin
A. phiala Viljoen & Van As, 1985 (Figure 4.1E)	*L. marequensis*, ***Barbus paludinosus*** Peters, 1852, *B. trimaculatus*, *B. unitaeniatus* Günther, 1866, ***Labeo capensis*** (Smith, 1841), *L. cylindricus*, *M. brevianalis*, *Oreochromis mossambicus*, ***P. philander***	Skin and Gills
A. piscicola (Figure 4.1B) Blanchard, 1885	***B. paludinosus***, *B. trimaculatus*, *L. cylindricus*, ***P. philander***, *T. rendalli*	Skin
A. viridis Viljoen & Van As, 1985 (Figure 4.1F)	***P. philander***, *T. rendalli*, ***T. sparrmanii***	Skin

able 4.3 Summary of the measurements of sessiline ciliophoran species that have been ecorded from South Africa. BD-diameter of body, BL-length of body, MAD diameter of nacronucleus, MAL-length of macronucleus, MID-diameter of micronucleus, MIL-length of nicronucleus, SD-diameter of scopula (or stalk in some cases).

Species	Measurements						
	BL	BD	SD	MAL	MAD	MIL	MID
piosoma caulata iljoen & Van As, 1985	46.4-73.9	31.6-60.6	5.8-11.4	13.8-31.2	15.0-25.6	2.8-8.2	3.1-9.4
. constricta Viljoen & Van As, 1985)	32.6-50.5	21.3-33.8	14.3-28.5	11.7-18.4	12.7-19.4	3.1-3.7	1.9-3.4
. curvinucleata iljoen & Van As, 1985	113.7-171.5	31.3-50.5	8.8-22.1	50.4-70.0	15.6-25.9	—	—
. dermata Viljoen & Van As, 1983)	35.2-56.4	16.8-38.6	14.8-32.8	12.4-20.4	11.4-18.6	2.7-4.1	1.4-2.2
. epibranchialis Viljoen & Van As, 1983)	20.7-49.8	20.1-28.9	10.9-29.1	7.9-17.6	11.3-15.9	2.1-3.9	1.3-3.0
. micralesti iljoen & Van As, 1985	31.2-54.1	19.2-37.4	4.2-9.2	11.2-23.2	11.8-21.0	2.8-7.4	2.7-4.5
. mothlapitsis iljoen & Van As, 1985	20.1-37.8	11.2-25.8	1.5-4.3	6.4-13.0	10.0-16.8	2.0-6.4	2.5-6.7
. nasalis Timofeev, 1962)	27.9-40.0	13.8-8.2	4.8-8.2	8.8-15.1	10.1-12.0	1.8-3.2	1.9-3.1
. obliqua iljoen & Van As, 1985	29.2-53.8	17.3-34.0	2.3-6.3	6.6-14.2	5.9-15.2	1.1-2.5	1.1-3.6
. phiala iljoen & Van As, 1985	22.5-49.8	15.1-34.1	3.4-9.6	9.7-20.5	8.8-19.6	3.9-6.7	1.7-4.6
. piscicola lanchard, 1885	47.0-84.5	17.3-39.6	7.3-19.3	15.0-26.1	7.6-15.8	3.2-6.9	1.6-2.7
. viridis iljoen & Van As, 1985	32.7-90.8	14.3-45.0	—	11.2-17.8	8.5-16.7	—	—

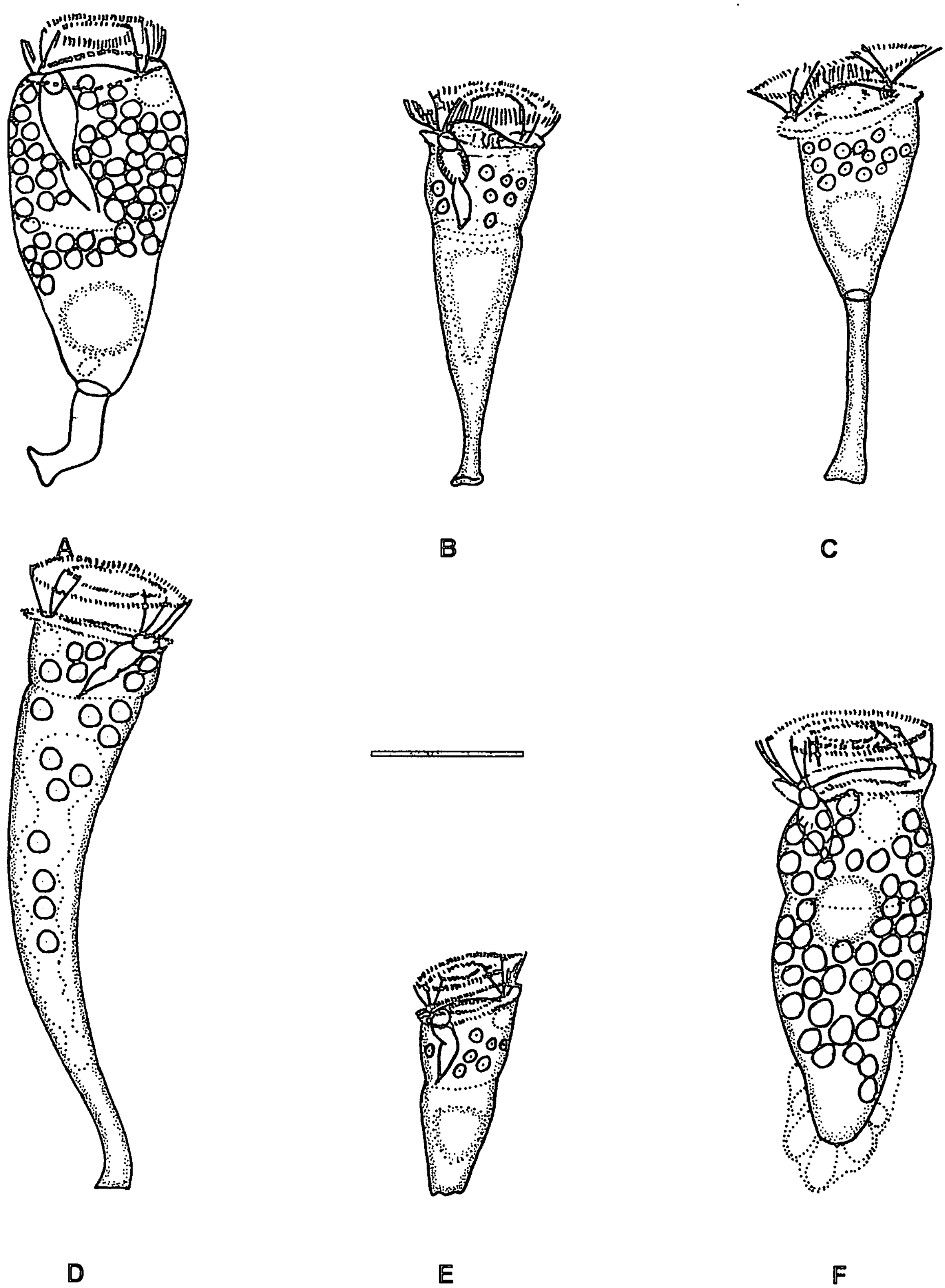


Figure. 4.1. Diagrammatic drawings of sessiline ciliophorans from South Africa. **A** – *Apiosoma caulata* Viljoen & Van As, 1985 (redrawn from Viljoen & Van As 1985). **B** – *A. piscicola* Blanchard, 1885, (redrawn from Viljoen & Van As 1985). **C** – *A. micralesti* Viljoen & Van As, 1985 (redrawn from Viljoen & Van As 1985). **D** – *A. curvinucleata* Viljoen & Van As, 1985 (redrawn from Viljoen & Van As 1985). **E** – *A. phiala* Viljoen & Van As, 1985 (redrawn from Viljoen & Van As 1985). **F** – *A. viridis* Viljoen & Van As, 1985 (redrawn from Viljoen & Van As 1985). Scale bar: 40μm

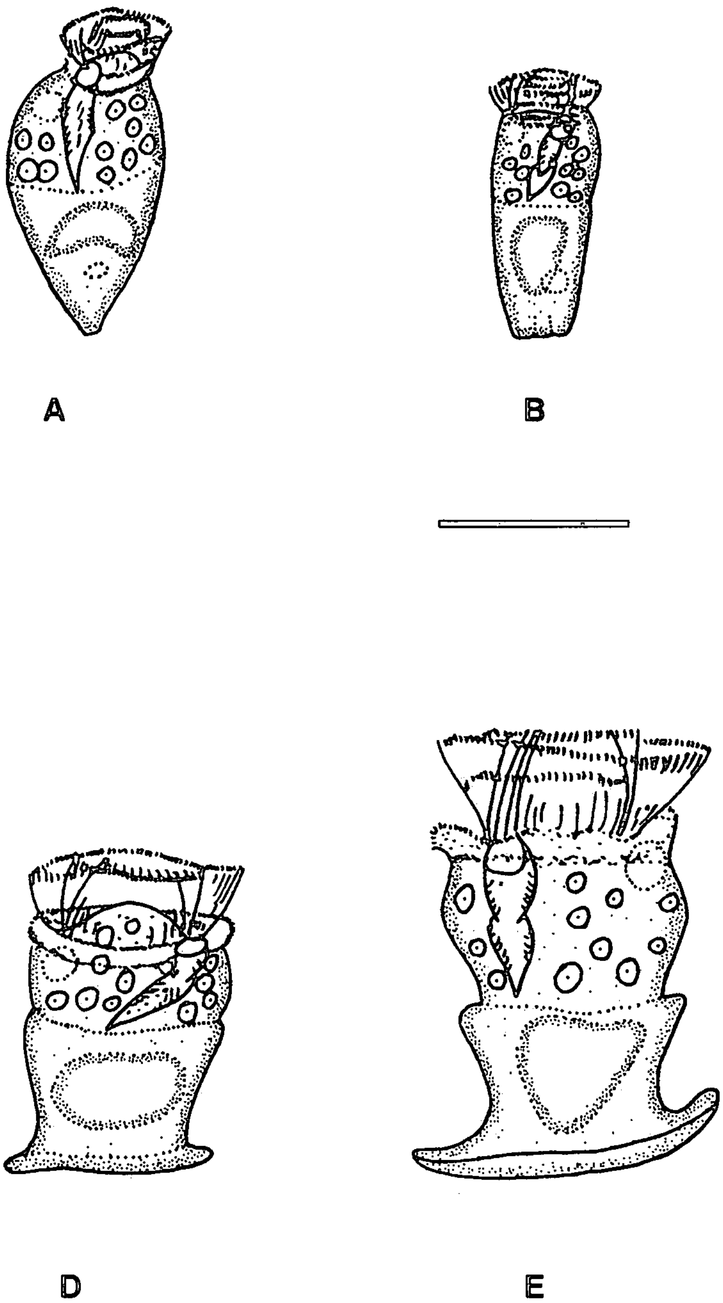


Figure. 4.2. Diagrammatic drawings of sessiline ciliophorans from South Africa. **A** – *Apiosoma obliqua* Viljoen & Van As, 1985 (redrawn from Viljoen & Van As 1985). **B** – *A. nasalis* (Timofeev, 1962) (redrawn from Viljoen & Van As 1985). **C** – *A. mothlapitsis* Viljoen & Van As, 1985 (redrawn from Viljoen & Van As 1985). **D** – *A. epibranchialis* (Viljoen & Van As, 1983) (redrawn from Viljoen & Van As 1985). **E** – *A. constricta* Viljoen & Van As, 1985 (redrawn from Viljoen & Van As 1985). **F** – *A. dermata* (Viljoen & Van As, 1983) (redrawn from Viljoen & Van As 1985). Scale bar: 40µm

Mobiline Ciliophorans

Class: Oligohymenophorea de Puytorac *et al*, 1974

Subclass: Peritrichida Steyn, 1859

Order: Mobilina Kahl, 1933

The Mobilina Kahl, 1933 are constantly moving ciliophorans that can be compared to the telotroch stage of sessiline ciliophorans. Body shape can vary from flat discoid to hemispheric (Lom & Dyková, 1992). The most prominent part of the body is the adhesive disc, which is situated on the aboral side of the protist, and consists of skeletal structures that consist of three rings, which are concentrically arranged. The most prominent is the innermost ring, the denticle ring. The shape and structure of the denticles are very important in distinguishing between the species. The denticle ring consists of a number of denticles, which consists of a blade, a central part and a ray.

The adhesive disc is circular and is supported by the skeletal complex, which consists of the denticle ring surrounded by the striped membrane. Directly underneath the velum, which is formed by a fold in the pellicle, 50-100 marginal cilia occur. Two rows of aboral cilia are present one consisting of short and soft cilia and another row of long movable cilia. The macronucleus is horseshoe-shaped. Mobiline ciliophorans occur on the skin as well as the gills of freshwater and marine fish.

Lom & Dyková (1992) provide the following key to trichodinid genera occurring on fish.

1. a. Adoral spiral makes two and a half to three turns...
   Vauchomia Mueller, 1938

   b. Adoral spiral makes slightly more or slightly less than one turn...
   2

   c. Adoral spiral makes one half to three-quarters of a turn... 3

2. a. Denticles with well-developed rays and blades...

Trichodina Ehrenberg, 1838

b. Blades of denticles stunted...

Hemitrichodina Basson & Van As, 1989

3. a. Denticles with well developed rays... 4

b. Rays stunted to form short crooks or platelets...

Trichodinella Šrámek-Hušek, 1953

c. Rays absent, central part indistinct, blades triangular...

Dipartiella (Raabe, 1959)

3. a. Blades attached almost perpendicular to central part and denticles interlocked only by conical central parts...

Paratrichodina Lom, 1963

b. Blades extend obliquely backward from central part; denticles interlocked by central parts and anterior projections of blades fitting into corresponding notches in blades of preceding denticles...

Tripartiella Lom, 1959

The genera *Trichodina* Ehrenberg, 1838, *Tripartiella* Lom, 1959 and *Trichodinella* Šrámek-Hušek, 1953

Lom (1958) provides a system of uniform specific characters for the description of species, which is still being used, together with the characters suggested by Van As & Basson (1989). These characters include the shape, the dimensions, number, and diameter of the denticles. The number of radial pins of the striped membrane has to be determined between the bordering denticles. For the macronucleus, the diameter, width and the distance between the two terminations are of importance. Shape and placement of the micronucleus is also important.

The Genus *Trichodina* Ehrenberg, 1838

Generic Diagnosis

According to Basson & Van As (1989) the denticles of representatives of this genus consist of blades, central parts and rays. The blades may be straight or curved. The rays display various shapes, which may be rod-like, spine-shaped or needle-shaped. They may also vary in length. There are no anteriorly directed projections present in the central part. The adoral spiral can vary in length, from 360° to 540°.

The genus *Trichodinella* Šrámek-Hušek, 1953

Generic diagnosis

The denticles of species from this genus have a delicate central part. Between the central part and the blade, there is a notch into which a projection of the anterior border of the central part from the following denticle fits well. This causes the denticles to be wedged together by both the central parts and the projections. The rays form a short delicate hook, which is curved along the central part. The adoral spiral may vary from 180° to 270° (Basson & Van As 1989).

The Genus *Tripartiella* Lom, 1959

Generic diagnosis

According to Basson & Van As (1989) the denticle has a delicate central part, with a ray that is in most cases directed backwards and a blade that is also slanted obliquely backwards. The narrow bases of the blades by which they connect to the central part, extends anteriorly and forms projections, which may vary from short and thin, to wide and knee-like. These projections correspond with a notch on the preceding denticle and thus the denticles are wedged together by the central parts as well as the projections. The turn of the adoral spiral may vary from 180° to 290°.

Trichodinid species known from South Africa

The first description of trichodinids from the gills as well as the skin of freshwater fish from South Africa was by Basson, Van As & Paperna (1983). They recorded seven known species of trichodinids namely *Trichodina acuta* Lom, 1961 from *Pseudocrenilabrus philander*, *Tilapia rendalli*, *T. sparrmanii*, *Barbus trimaculatus*, and *Cyprinus carpio* Linnaeus, 1758; *T. heterodentata* Duncan, 1977 from *T. rendalli*, *T. sparrmanii*, *B. paludinosus*, *B. trimaculatus* and *C. carpio*; *T. mutabilis* Kazubski & Migala, 1968 from *B. paludinosus*, *B. trimaculatus* and *Carassius auratus* Linnaeus, 1758 (collected from a fish farm); *T. nigra* Lom, 1960 from *Oreochromis mossambicus*, *P. philander*, *Tilapia sparrmanii*, and *B. paludinosus*; *T. pediculus* Ehrenberg, 1838 from *O. mossambicus*, *Tilapia rendalli*, and *T. sparrmanii* and *Trichodinella epizootica* (Raabe, 1950) from *O. mossambicus*, *T. rendalli* and *C. carpio*.

Two new species were also described by Basson *et al* (1983). These included: *Trichodina centrostrigeata* Basson, Van As & Paperna, 1983 from *O. mossambicus*, *P. philander*, *T. rendalli*, *T. sparrmanii* and *C. carpio* and *Trichodina minuta* Basson, Van As & Paperna, 1983 from *O. mossambicus*, *P. philander*, *T. sparrmanii* and *B. trimaculatus*.
When a reappraisal of previously published material of Basson *et al* (1983) was done, they came to the conclusion that the population of *T. acuta* reported from South Africa in 1983 differed significantly from the original description by Lom (1961). Van As & Basson (1989) then described *Trichodina compacta* Van As & Basson, 1989, which was previously recorded as *T. acuta*.

In the same publication of 1989, Van As & Basson also described *T. uniforma* Van As & Basson, 1989 and *T. kazubski* Van As & Basson, 1989 both of which were previously identified as *T. mutabilis* in 1983 from South Africa. New surveys in southern Africa also revealed that the species that was recorded as *T. pediculus* by Basson *et al* (1983) also differed significantly from populations described from Europe by Kazubski & Migala (1968). As a result Van As &

Basson (1989) described *T. magna* Van As & Basson, 1989 from the populations previously recorded as *T. pediculus.* Two years later, *Trichodina maritinkae* Basson & Van As, 1991 was described from *Clarias gariepinus* (Burchell, 1822) by Basson & Van As (1991).

According to Basson[1] (pers. comm.), however, *T. mutabilis* has indeed been recorded since, from fish supplied to them by dealers in the ornamental fish trade.

In 1993, Basson & Van As recorded the first confirmed European species of *Trichodina* from South Africa. These species were *T. acuta*, and *T. reticulata* Hirschmann & Partsch, 1955, which were collected from fish introduced into South Africa, namely *Carassius auratus* and *Oncorhynchus mykiss.*

In 1987, Basson & Van As did research in South Africa and described six new species of *Tripartiella* from the gills of freshwater fishes, namely *T. clavodonta* Basson & Van As, 1987 from *O. mossambicus*, *P. philander* and *Mesobola brevianalis*; *Tripartiella lechridens* Basson & Van As, 1987 from *L. cylindricus*, *C. carpio*, *O. mossambicus*, *M. brevianalis*, *B. paludinosus*, *B. trimaculatus* and *Micralestes acutidens*; *T. leptospina* Basson & Van As, 1987 from *O. mossambicus*; *T. macrosoma* Basson & Van As, 1987 from *Barbus eutaenia* Boulenger, 1904; *T. nana* Basson & Van As, 1987 from *O. mossambicus* and *T. orthodens* Basson & Van As, 1987 from *T. rendalli swierstrae* Gilchrist & Thompson, 1917.

One species of *Trichodinella* was also described by Basson & Van As (1987), namely *T. crennulata* Basson & Van As, 1987 from *M. acutidens*.
A summary of the trichodinid species occurring in South Africa is given in Table 4.4, and the measurements of these species are given in Table 4.5.

[1] Prof. Linda Basson is a leader in the field of mobiline ciliophorans and is an associated Professor at the University of the Free State, Bloemfontein, South Africa.

Table 4.4. Summary of the trichodinid species that have been recorded from South Africa, and selected hosts species (host species in bold represent those that also occur in the Soetdoring Nature Reserve).

Species	Hosts	Location on Host
Trichodina acuta Lom, 1961 (Figure 4.3A)	*Oncorhynchus mykiss* (Walbaum, 1792)	Skin
T. centrostrigeata Basson, Van As & Paperna, 1983 (Figure 4.3B)	***Pseudocrenilabrus philander*** Weber, 1897, *Tilapia rendalli* Dumeril, 1859, ***T. sparrmanii*** Smith, 1840, ***Cyprinus carpio*** Linnaeus, 1758	Skin
T. compacta Van As & Basson, 1989 (Figure 4.3C)	*Barbus eutaenia* Boulenger, 1904, *B. radiatus* Peters, 1853, *B. trimaculatus* Peters, 1852, ***C. carpio***, *Labeobarbus marequensis* Smith 1841, ***L. kimberleyensis*** (Gilchrist & Thompson, 1913), *Labeo cylindricus* Peters, 1852, ***P. philander***, *T. rendalli rendalli* (Boulenger, 1896), *T. rendalli swierstrae* Gilchrist & Thompson, 1917, ***T. sparrmanii***	Skin
T. heterodentata Duncan, 1977 (Figure 4.3D)	***P. philander***, *T. rendalli*, ***T. sparrmanii***, ***B. paludinosus*** Peters, 1852, *B. trimaculatus*, ***C. carpio***	Skin and Gills
T. kazubski Van As & Basson, 1989 (Figure 4.3E)	***B. paludinosus,*** *B. trimaculatus*	Skin and Gills
T. magna Van As & Basson, 1989 (Figure 4.3F)	***P. philander***, *T. rendalli rendalli*, *T. rendalli swierstrae*, ***T. sparrmanii***	Skin
T. minuta Basson, Van As & Paperna, 1983 (Figure 4.4A)	***P. philander, T. sparrmanii,*** *B. trimaculatus*	Skin and Gills
T. mutabilis Kazubski & Migala (Figure 4.4B)	***Carassius auratus*** Linnaeus, 1758	Skin and Gills
T. nigra Lom, 1960 (Figure 4.4C)	***P. philander, T. sparrmanii, B. paludinosus***	Skin and Gills
T. uniforma Van As & Basson, 1989 (Figure 4.4D)	*C. auratus*	Skin and Gills
T. retucilata Hirschmann & Partsch, 1955 (Figure 4.4E)	*C. auratus*	Skin and Gills
Trichodinella crennnulata Basson & Van As, 1987 (Figure 4.5A)	*Micralestes acutidens* (Peters, 1852)	Gills
T. epizootica (Raabe, 1950) (Figure 4.5B)	*T. rendalli*, ***C. carpio***, ***P. philander***, *B. trimaculatus*, ***B. paludinosus***,	Gills and occasionally skin
Tripartiella clavodonta Basson & Van As, 1987 (Figure 4.5C)	***P. philander***	Gills
T. lechridens Basson & Van As, 1987 (Figure 4.5D)	*L. cylindricus*, ***C. carpio***, ***B. paludinosus,*** *B. trimaculatus*	Gills
T. leptospina Basson & Van As, 1987 (Figure 4.6A)	*Oreochromis mossambicus* (Peters, 1852)	Gills
T. macrosoma Basson & Van As, 1987 (Figure 4.6B)	*B. eutaenia*	Gills
T. nana Basson & Van As, 1987 (Figure 4.6C)	*O. mossambicus*	Gills
T. orthodens Basson & Van As, 1987 (Figure 4.6D)	*T. rendalli swierstrae*	Gills

Table 4.5: Summary of the measurements of trichodinid species that have been recorded from South Africa. AD-diameter of adhesive disc, BD-diameter of body, BM- width of border membrane, BL-length of blade, CW-width of central part, LD-length of denticle, LR-length of ray, ND-number of denticles, RD-diameter of diameter of denticle ring

Species	Measurements								
	BD	AD	BM	RD	ND	LD	LR	CW	BL
Trichodina acuta Lom, 1961	50.0-67.0	39.0-57.0	4.0-5.0	23.0-36.0	18-22	6.0-9.0	5.0-8.0	2.0-3.5	4.5-6.0
T. centrostrigeata Basson, Van As & Paperna, 1983	37.4-54.4	31.2-45.8	2.0-4.4	18.7-33.3	26-30	2.0-6.2	3.2-6.0	1.1-3.0	2.8-6.4
T. compacta Van As & Basson, 1989	40.9-58.9	31.7-49.1	3.8-5.5	18.3-29.7	18-21	3.8-7.3	2.5-4.6	1.8-4.2	2.9-4.7
T. heterodentata Duncan, 1977	47.5-69.1	39.5-59.8	3.2-6.2	23.2-37.8	22-29	5.1-8.6	4.6-8.1	1.6-3.3	3.4-5.5
T. kazubski Van As & Basson, 1989	34.3-54.6	26.7-39.5	3.2-5.9	16.4-26.3	22-26	3.6-5.7	3.6-6.4	1.5-3.2	3.5-5.7
T. magna Van As & Basson, 1989	71.2-118.8	59.7-94.8	6.2-13.9	35.6-57.5	24-27	7.4-13.6	7.7-16.0	3.7-7.4	6.0-10.9
T. minuta Basson, Van As & Paperna, 1983	28.2-38.0	22.4-33.7	2.6-4.1	12.2-18.2	19-22	3.2-5.7	2.6-4.4	1.7-2.7	3.1-4.6
T. nigra Lom, 1960	41.7-56.7	31.7-42.6	4.0-5.9	18.9-23.7	19-22	5.1-7.5	2.5-4.9	1.6-3.0	3.3-5.9
T. reticulata Hirschmann & Partsch, 1955	40.0-55.0	31.0-46.0	3.0-5.0	20.5-29.0	22-27	4.0-6.0	3.5-6.0	1.0-2.0	4.5-6.5
T. uniforma Van As & Basson, 1989	47.9-74.8	37.6-62.5	3.9-7.4	24.5-40.6	24-29	5.2-8.7	5.8-9.5	2.0-3.5	5.5-8.3

Table 4.5. Continued. Summary of the measurements of trichodinid species that have been recorded from South Africa. AD-diameter of adhesive disc, BD-diameter of body, BM- width of border membrane, BL-length of blade, CW-width of central part, LD length of denticle, LR-length of ray, ND-number of denticles, RD-diameter of diameter of denticle ring

Species	Measurements								
	BD	AD	BM	RD	ND	LD	LR	CW	BL
Trichodinella crennnulata Basson & Van As, 1987	20.7-27.2	16.9-23.3	1.6-3.2	8.8-11.2	21-26	2.2-3.6	0.7-1.3	0.7-1.3	3.1-5.6
T. epizootica (Raabe, 1950)	18.2-26.5	14.4-22.5	1.5-2.3	7.4-13.2	20-25	1.8-2.9	0.5-1.5	0.7-1.2	1.7-3.8
Tripartiella clavodonta Basson & Van As, 1987	19.3-25.0	15.7-20.0	1.7-2.6	9.0-12.3	18-24	2.5-3.5	1.5-2.2	0.7-1.4	1.8-3.1
T. lechridens Basson & Van As, 1987	19.1-24.7	15.4-20.4	1.6-2.8	7.1-11.0	20-26	1.8-4.3	0.6-1.7	0.8-1.6	3.0-4.7
T. leptospina Basson & Van As, 1987	18.7-26.2	14.4-22.3	1.7-2.8	6.8-10.1	16-21	2.3-3.7	1.0-2.1	0.7-1.4	2.2-4.2
T. macrosoma Basson & Van As, 1987	18.0-23.4	13.6-19.9	1.7-2.7	6.4-9.3	22-25	2.5-4.0	1.0-2.3	0.9-1.4	2.4-4.3
T. nana Basson & Van As, 1987	16.8-26.1	13.3-21.6	1.0-2.5	6.7-10.8	16-19	2.2-3.6	0.6-1.6	0.8-1.5	1.7-3.3
T. orthodens Basson & Van As, 1987	27.6-36.5	23.0-31.7	2.2-3.6	12.8-16.3	24-28	3.3-4.5	1.8-3.0	1.2-2.6	3.0-5.4

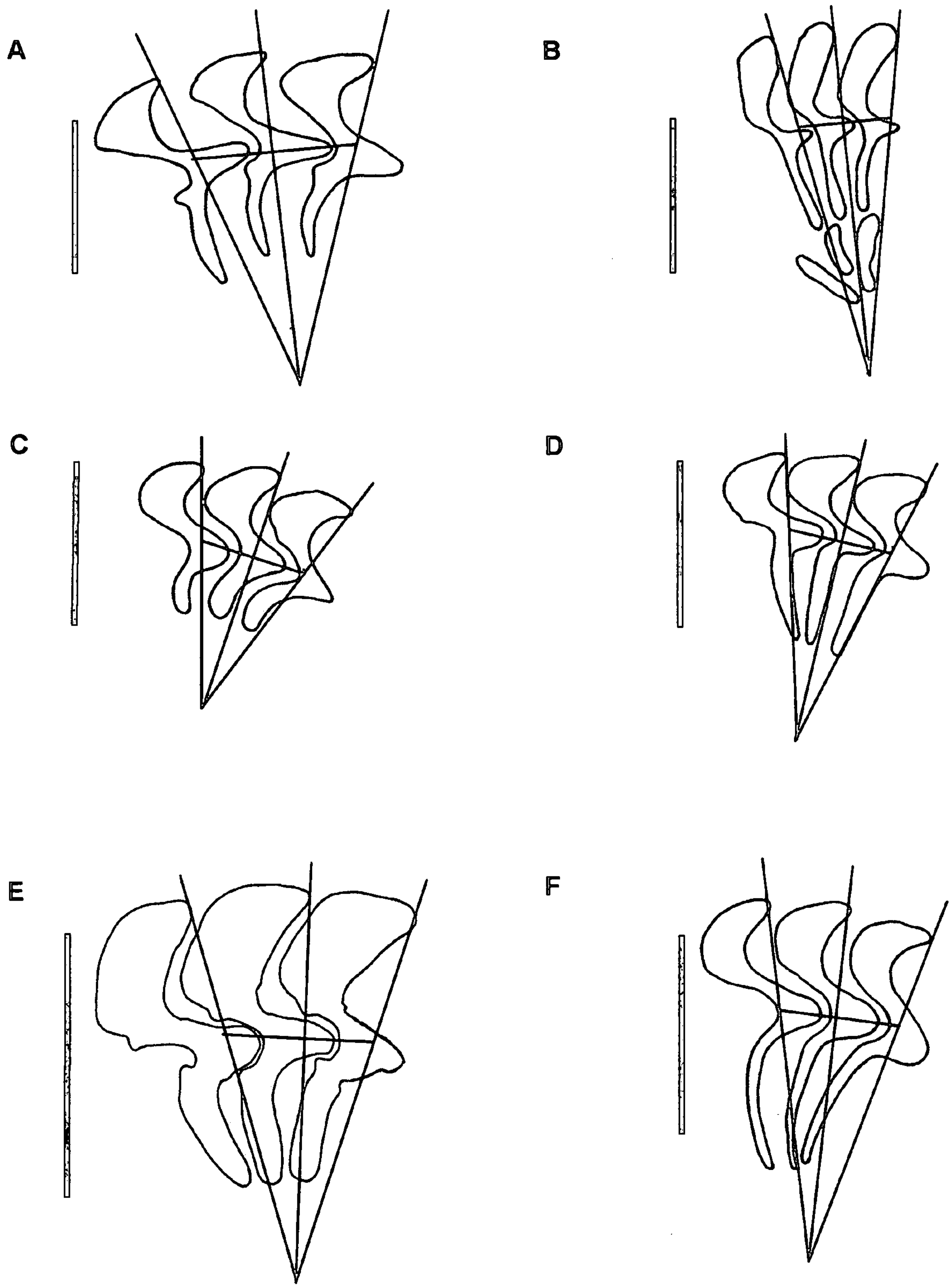


Figure. 4.3. Diagrammatic drawings of the denticles of trichodinids recorded from South Africa. **A** – *Trichodina acuta* Lom, 1961 (redrawn from Basson & Van As 1993). **B** – *T. centrostrigeata* Basson, Van As & Paperna, 1983 (redrawn from Basson, Van As & Paperna 1983). **C** – *T. compacta* Van As & Basson, 1989 (redrawn from Van As & Basson 1989). **D** – *T. heterodentata* Duncan, 1977 (redrawn from Basson, Van As & Paperna 1983). **E** – *T. kazubski* Van As & Basson, 1989 (redrawn from Basson & Van As, 1989). **F** – *T. magna* Van As & Basson, 1989 (redrawn from Van As & Basson 1989). Scale bar: 10µm

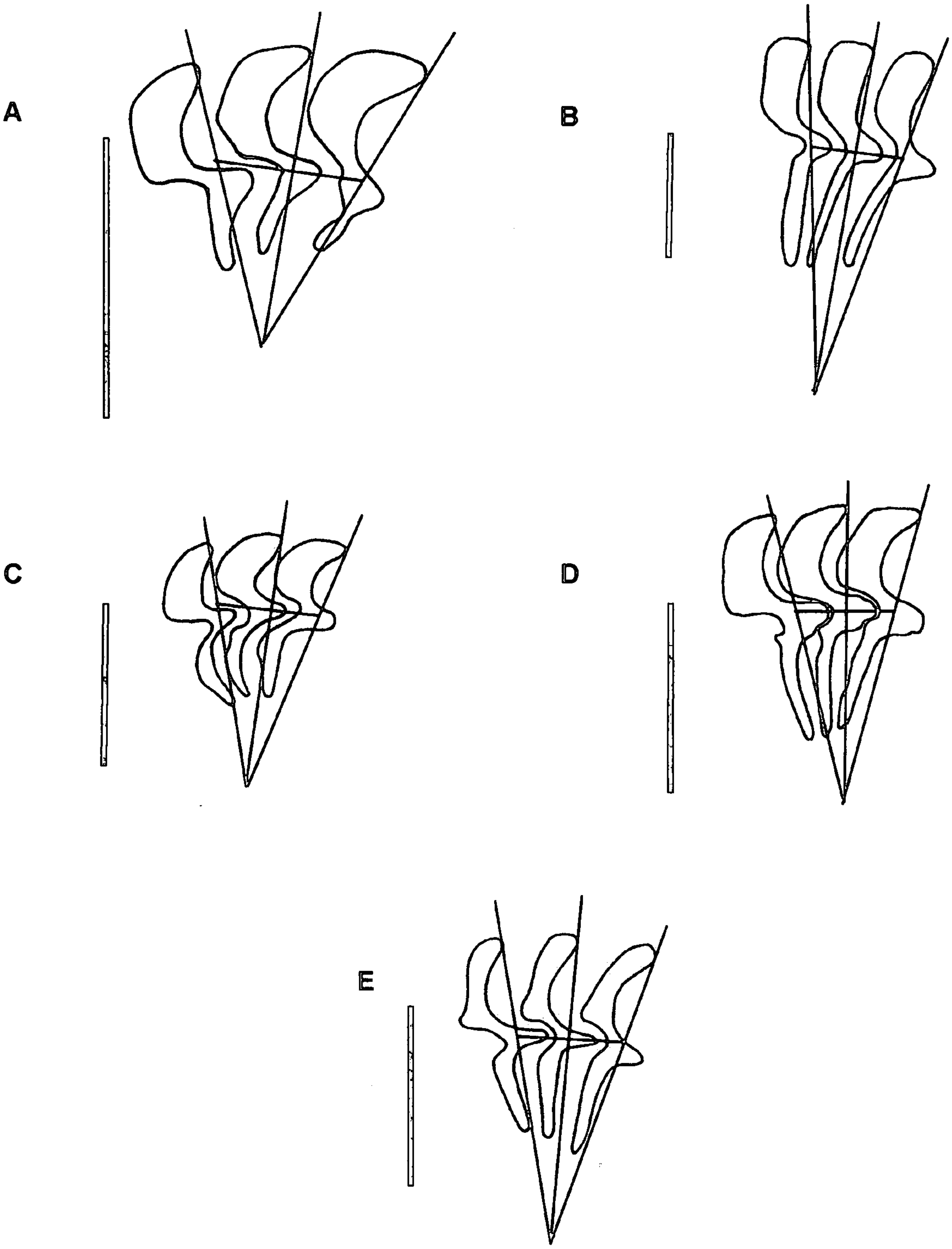


Figure. 4.4. Diagrammatic drawings of the denticles of trichodinids recorded from South Africa. **A** – *Trichodina minuta* Basson, Van As & Paperna, 1983 (redrawn from Basson, Van As & Paperna 1983). **B** – *T. mutabilis* Kazubski & Migala, 1968 (redrawn from Basson, Van As & Paperna 1983). **C** – *T. nigra* Lom, 1960 (redrawn from Basson, Van As & Paperna 1983). **D** – *T. uniforma* Van As & Basson, 1989 (redrawn from Van As & Basson 1989). **E** – *T. reticulata* Hirschmann & Partsch, 1955 (redrawn from Basson & Van As 1993). Scale bar: 10µm

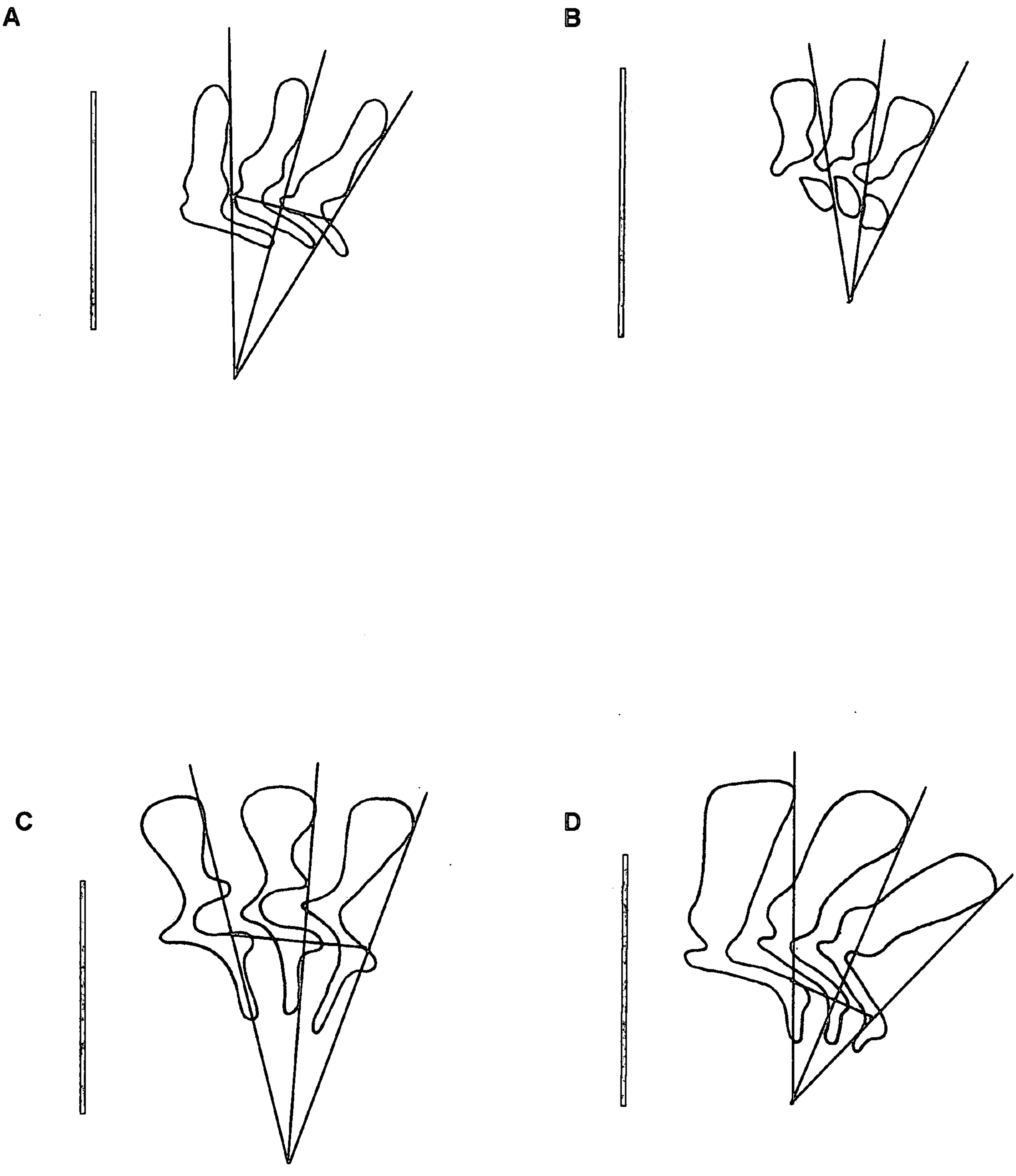


Figure. 4.5. Diagrammatic drawings of the denticles of trichodinids recorded from South Africa. **A** – *Trichodinella crennulata* Basson & Van As, 1987 (redrawn from Basson & Van As 1987). **B** – *T. epizootica* (Raabe, 1950) (redrawn from Basson, Van As & Paperna 1983). **C** – *Tripartiella clavodonta* Basson & Van As, 1987 (redrawn from Basson & Van As & 1987). **D** – *T. lechridens* Basson & Van As, 1987 (redrawn from Basson & Van As 1987). Scale bar: 10µm

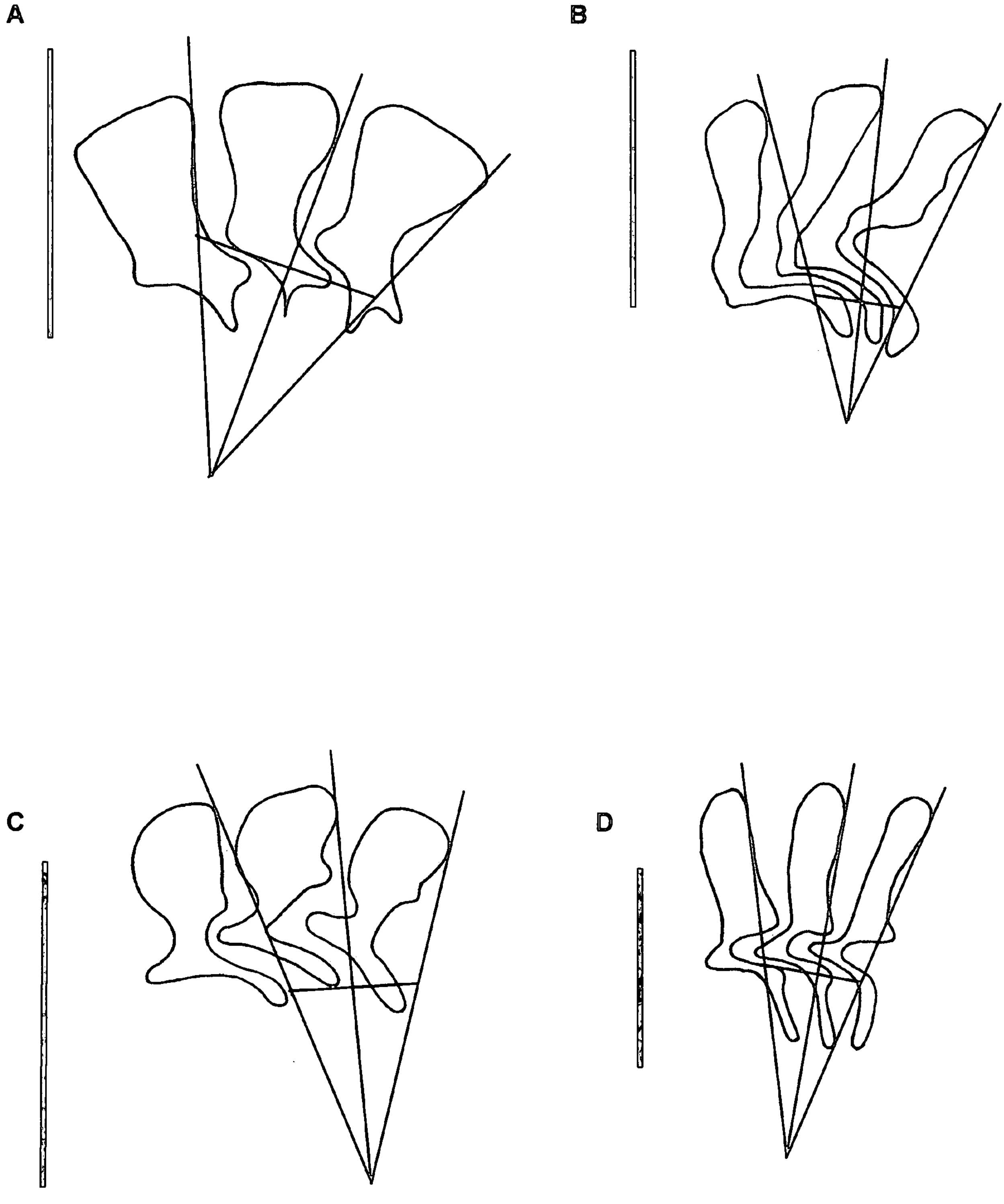


Figure. 4.6. Diagrammatic drawings of the denticles of trichodinids recorded from South Africa. **A** – *Tripartiella leptospina* Basson & Van As, 1987 (redrawn from Basson & Van As 1987). **B** – *T. macrosoma* Basson & Van As, 1987 (redrawn from Basson & Van As 1987). **C** – *T. nana* Basson & Van As 1987 (redrawn from Basson & Van As 1987). **D** – *T. orthodens* Basson & Van As, 1987 (redrawn from Basson & Van As 1987). Scale bar: 5μm

Ciliophoran parasites from Soetdoring Nature Reserve

Two species of *Apiosoma* were collected from fishes of the Soetdoring Nature Reserve. *Apiosoma* sp. A from the skin of *P. philander* and *T. sparrmanii* and *Apiosoma* sp. B. from the gills of *P. philander* and *C. carpio.*

Six species of trichodinid parasites were collected. The species collected represent three genera, i.e. *Trichodina*, *Trichodinella* and *Tripartiella*.

Trichodina sp. A was collected from the gills of *Pseudocrenilabrus philander* and *Trichodina* sp. B from the gills of both *Labeo capensis* and *Cyprinus carpio. Trichodina* sp. C was also collected from the gills of *L. capensis* and *C. carpio.* One species of *Trichodinella* was collected, *Trichodinella* sp. A from the gills of *C. carpio*, *L. capensis* and *L. umbratus.* Two species of *Tripartiella* were collected, i.e. *Tripartiella* sp. A from the gills of *L. capensis* and *L. umbratus*, and *Tripartiella* sp. B from *L. capensis.*

Apiosoma sp. A

Hosts and locality: Pseudocrenilabrus philander and *Tilapia sparrmanii*, Soetdoring Nature Reserve, South Africa (28° 52' S, 26° 0' E).

Infection Site: Skin.

Specimens studied: Morphometric measurements and drawings were made using light microscopy. Reference material (V2001/05/08-05, V2001/03/21-27) in the collection of the Aquatic Parasitology Study group, University of the Free State.

Description:

Stalkless. Body cylindrical (Figure 4.7A1& A2, Figure 4.10A), tapering towards scopula. Length of body 54.7-80.7 (70.4, 9), diameter 19.5-27.5 (23.4, 9). Groove situated at one-third of body length from peristome. Scopula small 10.7-14.7 (12.1, 9) in diameter. Food vacuoles distributed in region above groove. Macronucleus elongated, triangular, situated below groove, length 20.3-33.5

(25.4, 9), diameter 12.4-19.1 (14.4, 9). Micronucleus oval-shaped, situated alongside micronucleus, length 2.2-3.4 (3.1, 1), diameter 1.5-2 (1.7, 2).

Remarks:

Individuals were often observed in clusters on the fish host, which has a colonial appearance. *Apiosoma* sp. A most closely resembles *A. piscicola* based on the shape of the macronucleus, as well as morphometrical data from Viljoen & Van As (1985). Due to the unavailability of observations from live specimens, specific identification is not possible.

Apiosoma sp. B

Hosts and locality: *Pseudocrenilabrus philander* and *Cyprinus carpio*, Soetdoring Nature Reserve, South Africa (28° 52' S, 26° 0' E).

Infection Site: Gills.

Specimens studied: Morphometric measurements and drawings were made using light microscopy. Reference material (2001/03/21-27, V2001/11/22-08) deposited in the collection of the Aquatic Parasitology Study group, University of the Free State.

Description:

Body cylindricl (Figure 4.7B1 & B2, Figure 4.10B), length 32.9-49.7 (39.4, 9), diameter 17.4-28.3 (23.6, 9). Groove centrally placed. Scopula broad, diameter 12.5-22.0 (17.7, 7). Food vacuoles distributed in region above groove. Macronucleus round to oval, situated below groove, length 10.6-19.5 (13.8, 9), diameter 11.5-19.8 (15.4, 9). Micronucleus not observed.

Remarks:

Specimens have a short and stout appearance, and most closely resemble *A. epibranchialis*, on overall dimensions as reported by Viljoen & Van As (1985). Specific identification is, however, not possible as observations from live specimens were not available.

Trichodina sp. A

Host and locality: Pseudocrenilabrus philander, Soetdoring Nature Reserve, South Africa (28° 52' S, 26° 0' E).

Infection Site: Gills.

Specimens studied: Morphometric measurements and drawings were made using light microscopy. Reference material (2001/03/22-13, 2001/03/22-45, 2001/03/22-46, 2001/03/22-50) deposited in the collection of the Aquatic Parasitology Study group, University of the Free State.

Description:

Diameter of body 41.6-52.0 (49.5, 7), adhesive disc cup-shaped, 33.9-43.5 (37.9, 7) in diameter, surrounded by finely striated border membrane, 3.7-5.2 (4.2, 7) wide (Figure 4.10C). Distinctive ridges present in the center of the adhesive disc. Diameter of denticle ring 22.0-28.9 (24.2, 7). Number of denticles 23-26 (25). Length of denticle 3.7-4.4 (4.0, 7): length of ray 3.4-6.3 (4.6, 7): width of central part 1.8-3.3 (2.3, 7): length of blade 5.0-6.3 (5.7, 7). Distal surface of blade slightly rounded, sloping in anterior direction, not parallel to border membrane (Figure 4.8A). Tangent point slightly lower than distal surface. Anterior margin varies, in some cases angular, in others curved. Anterior surface extends to y+1 line, extending past y line in some cases. Blade apophysis more prominent in some cases than in others. Posterior margin forms L- shaped curve, which corresponds to apex of anterior surface. Part connecting blade to central part thinner than blade. Central part extends towards and in some cases beyond y-1 axis, but not more than halfway. Rays straight and extends anteriorly toward the y-axes, tapering to rounded point. Centre ridges varies in thickness and length, thicker than rays.

Remarks:

Based on the above description and morphometrical data, *Trichodina* sp. A can be identified as *Trichodina centrostrigeata*.

The material collected from the Soetdoring Nature Reserve corresponds very closely in morphometrical data to the type population described by Basson *et al* (1983). It is also very similar to another population described by Van As & Basson (1992) from the Zambesi River. *Trichodina centrostrigeata* can easily be distinguished from other species based on the presence of centre ridges, as well as denticle morphology and overall dimensions.

Trichodina sp. B

Host and locality: *Labeo umbratus* and *Cyprinus carpio*, Soetdoring Nature Reserve, South Africa (28° 52' S, 26° 0' E)

Infection Site: Gills

Specimens studied: Morphometric measurements and drawings were made using light microscopy. Reference material (2001/03/21-15, 2001/03/21-30) deposited in the collection of the Aquatic Parasitology Study group, University of the Free State.

Description:

Diameter of disc-shaped body 55.0-59.3 (57.1, 2), adhesive disc concave, 45.3-47.3 (46.3, 2) in diameter, surrounded by finely striated border membrane, 4.9-5.3 (5.1, 2) wide (Figure 4.10D). Diameter of denticle ring 28.7-29.6 (29.1, 2). Number of denticles 23-24. Length of denticle 7.18-7.20 (7.19, 2): length of ray 6.0- 6.5 (6.2, 2): width of central part 3.4-3.7 (3.5, 2): length of blade 3.8-4.2 (4.0, 2). Blade broad, with distal margin curved (Figure 4.8B). Tangent point higher than distal surface. Posterior margin forms indentation, semi-lunar in shape. Anterior margin rounded, with apex slightly protruding, reaching y+1 axis. Connecting part between central part and blade broad, with central part extending more than halfway past y-axis, in some cases completely. Point of central part rounded, and closely associated with following denticle. Connecting part between central part and ray similar in thickness to connecting part between central part and blade, with apophysis of ray present, but not always prominent.

Ray thick and varies in length, tapering to blunt point. Ray directed to center point, almost parallel to y+1 axis.

Remarks:

Based on the above description and overall body dimensions, *Trichodina* sp. B can be identified as *T. heterodentata*.

Trichodina sp. B resembles *T. magna*, but the difference between these species can be seen in the body size of *T. magna*, which is much larger, and the shape of the denticle. The present population corresponds closely to the population described by Basson *et al* (1983) in morphometrical data as well as denticle shape and dimensions.

Trichodina sp. C

Host and locality: Labeo capensis and *Cyprinus carpio*, Soetdoring Nature Reserve, South Africa (28° 52' S, 26° 0' E)

Infection Site: Gills

Specimens studied: Morphometric measurements and drawings were made using light microscopy. Reference material (2001/03/21-30, 2001/03/21, 42, 2001/03/22-44) deposited in the collection of the Aquatic Parasitology Study group, University of the Free State.

Description:

Large trichodinid with disc-shaped body 51.2-72.3 (57.6, 5) in diameter. Adhesive disc concave, 38.7-59.3 (46.0, 5) in diameter, and surrounded by finely striated border membrane 4.7-6.3 (5.8, 5) wide (Figure 4.10E). Diameter of denticle ring 23.8-39.5 (28.9, 5). Number of denticles 21-25 (21). Length of denticle 5.7-8.9 (7.1, 5): length of ray 5.6-9.9 (6.8, 5): width of central part 1.9-2.4 (2.1, 5): length of blade 5.2-7.4 (6.2, 5). Blade broad, with distal margin parallel to border membrane. Anterior side of distal surface rounded (Figure 4.9A). Tangent point slightly lower than distal surface. Posterior margin almost straight up to two thirds of blade length, forming curve into central part. Deepest point where curve begins. Apex of anterior margin rounded. Anterior apophysis of blade not present. Posterior projection of blade absent. Connection between central part and blade thin. Central part delicate and extending more than halfway past y+1 axis. Central part above and below x-axis similar in shape. Rays almost parallel to y-axes, in some cases directed anteriorly, sometimes reaching and extending past y-axes. Rays of same thickness throughout, without apophysis.

Remarks:

Based on the above description and overall body dimensions, *Trichodina* sp. C can be positively identified as *T. mutabilis*.

Trichodina sp. C resembles *T. uniforma* and *T. kazubski*, which were previously mistaken for *T. mutabilis* by Basson *et al* (1983). The shape of the blade and central part of *T. uniforma*, however, differs significantly. In *T. mutabilis*, the apex of the anterior margin is not as prominent as in *T. uniforma* and the curve of the posterior margin also differs. The overall body dimensions of *T. kazubski* is smaller than that of *T. mutabilis*, and the rays are short and straight, as opposed to the anteriorly directed rays of *T. mutabilis*. The population of *T. mutabilis* from Soetdoring Nature Reserve is the first record of this species from a fish host in the wild in South Africa. A population of *T. mutabilis* was found on ornamental fish in South Africa that were originally introduced from the Far East (Basson, pers. comm.). It is also the first record of this species from an indigenous host species.

Tripartiella sp. A

Host and locality: Labeo capensis and L. umbratus, Soetdoring Nature Reserve, South Africa (28° 52' S, 26° 0' E)

Infection Site: Gills

Specimens studied: Morphometric measurements and drawings were made using light microscopy. Reference material (2001/03/21-05, 2001/03/21-42) deposited in the collection of the Aquatic Parasitology Study group, University of the Free State.

Description:

Small trichodinid with bell-shaped body 19.3-24.4 (21.1, 3) in diameter, adhesive disc concave, 14.4-19.8 (17.1, 3) in diameter, surrounded by finely striated border membrane, 2.3-2.8 (2.5, 2) wide. Diameter of denticle ring 8.0-8.2 (8.1, 2). Number of denticles 24-25 (24). Length of denticle 2.0-3.0 (2.5, 2): length of ray 1.0-1.1 (1.0, 2): width of central part 0.88-0.91 (0.9, 2): length of blade 3.8-4.1 (3.9, 2). Blade slender, with distal margin parallel to border membrane. Anterior side of distal surface rounded (Figure 4.9B). Tangent point slightly lower than distal surface. Lateral sides of blade almost parallel. Anterior margin constricts, forms pronounced apophysis, which extends more than halfway past y+1 axis. Posterior projection of blade absent, with posterior margin constricting. Part of blade connecting to anterior apophysis very thin. Connection between blade and central part thin and delicate. Central part small with rounded point and part above x axis similar to the part below x axis. Central part extends almost completely past y-1 axis. Rays short and thin, tapering to sharp tip, almost parallel to y axes, extending beyond line in some cases.

Remarks:

Based on the above description and morphometrical data, *Tripartiella* sp. A can be identified as *T. lechridens*.

Tripartiella lechridens shows some similarity to three species of the genus (Basson & Van As 1987), i.e. *T. bulbosa* (Davis, 1947), *T. bursiformes* (Davis, 1947) and *T. lechridens*. *Tripartiella bulbosa* and *T. bursiformes*, however, have a larger diameter of the adhesive disc than *T. lechridens*. The constriction of the blade in *T. lechridens* is a unique characteristic, which can be used to identify *Tripartiella* sp. A as *T. lechridens*. Morphometrical data from the present population is well within range with those given by Basson & Van As (1987) for *T. lechridens*.

Tripartiella sp. B

Host and locality: Labeo capensis, Soetdoring Nature Reserve, South Africa (28° 52' S, 26° 0' E).

Infection Site: Gills.

Specimens studied: Morphometric measurements were made using light microscopy. Reference material (2001/03/21-43) deposited in the collection of the Aquatic Parasitology Study group, University of the Free State.

A single specimen was recorded, which was in the process of fission. This specimen is provisionally identified as *Tripartiella leptospina*. A comparative description could thus not be given, but some morphometrical data is given.

Diameter of body 16.2, diameter of adhesive disc 13.5, width of border membrane 1.4, diameter of denticle ring, 7.4, number of denticles 20, length of denticle 3.7, length of ray 1.0, width of central part 0.4 and length of blade 2.8.

Remarks:

The single specimen collected in this study, showed some remnants of an old denticle ring, indicating that it was in the process of division. During binary fission, the denticle shape of the newly formed ring on the outside are normally slightly different from that of the adult individual. However, it was provisionally identified as *Tripartiella leptospina* (Basson, pers comm.).

Trichodinella sp. A

Hosts and locality: Cyprinus carpio, *Labeo capensis* and *L. umbratus*, Soetdoring Nature Reserve, South Africa (28° 52' S, 26° 0' E).

Infection Site: Gills.

Specimens studied: Morphometric measurements and drawings were made using light microscopy. Reference material (2001/03/21-01, 2001/03/21-02, 2001/03/21-03, 2001/03/21-29, 2001/03/21-41, 2001/03/21-42, 2001/03/21-43) deposited in the collection of the Aquatic Parasitology Study group, University of the Free State.

Description:

Diameter of body 19.0-22.5 (21.2, 7), adhesive disc cup-shaped, 15.4-20.0 (17.4, 7) in diameter, surrounded by finely striated border membrane, 1.7-2.4 (2.1, 7) wide (Figure 4.10E). Diameter of denticle ring 7.4-9.5 (8.3, 5). Number of denticles 19-21 (19). Length of denticle 1.1-2.0 (1.6, 7): width of central part 1.2-1.8 (1.4, 6): length of blade 3.4-4.1 (3.7, 6). Blade short and slender, with lateral margins almost parallel. Distal margin parallel to border membrane (Figure 4.9C). Tangent point at same level as distal surface. Anterior margin gently curves into well-developed apophysis extending more than halfway past y+1 axis. Posterior margin forms indentation that corresponds with anterior apophysis. Part connecting central part to blade varies, delicate in some cases, broad in others. Central part well developed. Although ray is absent, a small triangular protrusion is visible in some cases.

Remarks:

Based on the above description and morphometrical data, *Trichodinella* sp. A can be identified as *T. epizootica*.

Trichodinella crennulata and *T. epizootica* are the only two species of the genus known from South Africa. *Trichodinella crennulata* differs from *T. epizootica* in the shape of the blade; the projections, as well as the central part complex. Based on these characteristics, as well as morphometrical data, *Trichodinella* sp. A is identified as *T. epizootica* The morphometrical data of the population from Soetdoring Nature Reserve corresponds well with that reported by Basson & Van As (1987).

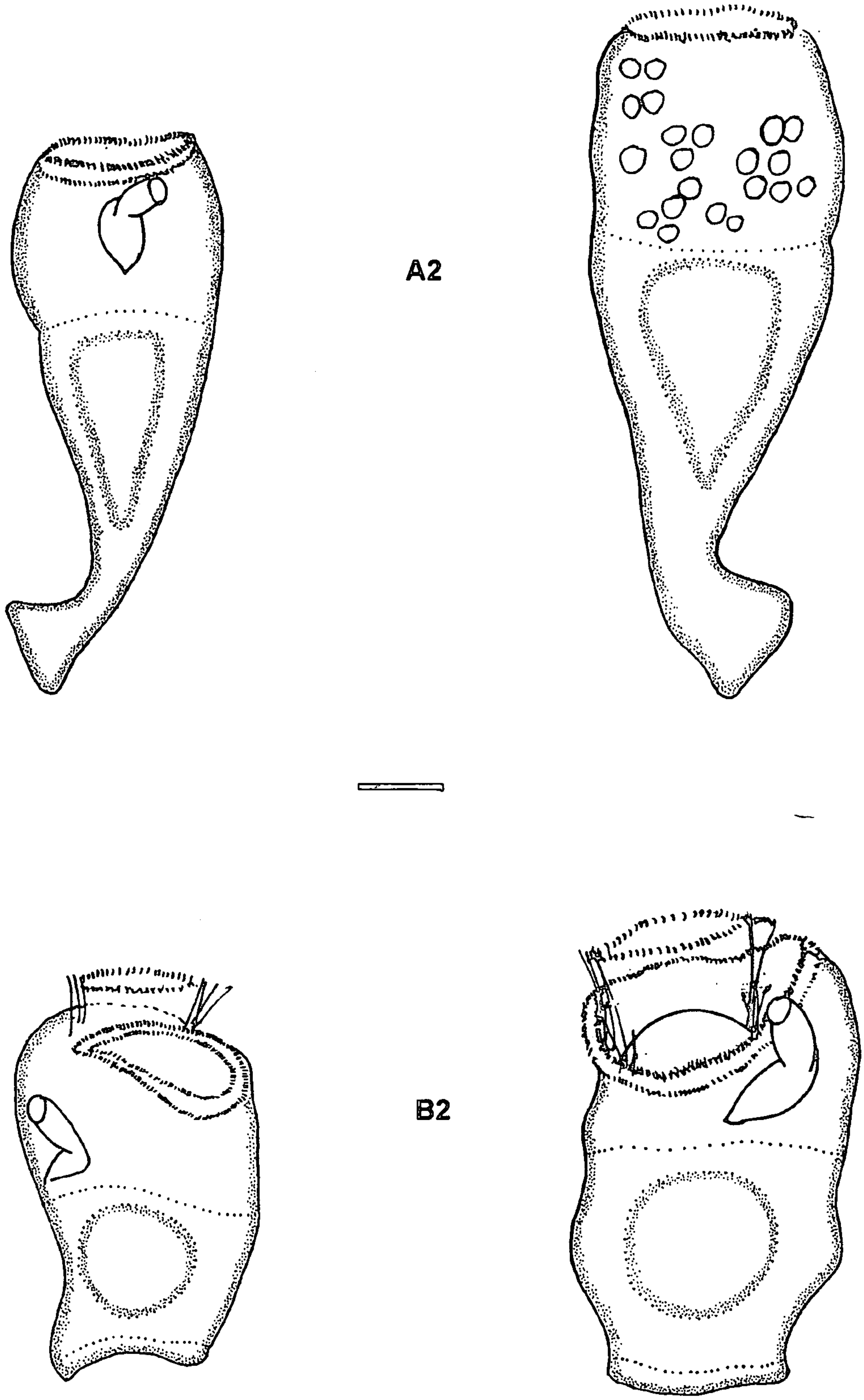


Figure. 4.7. Microscope projection drawings of *Apiosoma* species from the fishes of the Soetdoring Nature Reserve. **A** – *Apiosoma* sp. A. from the skin of *Pseudocrenilabrus philander* (Weber , 1897) and *Tilapia sparrmanii* Smith, 1840. **B** – *Apiosoma* sp. B from the gills of *P. philander* and *Cyprinus* carpio Linnaeus, 1758. Scale bar: 10µm

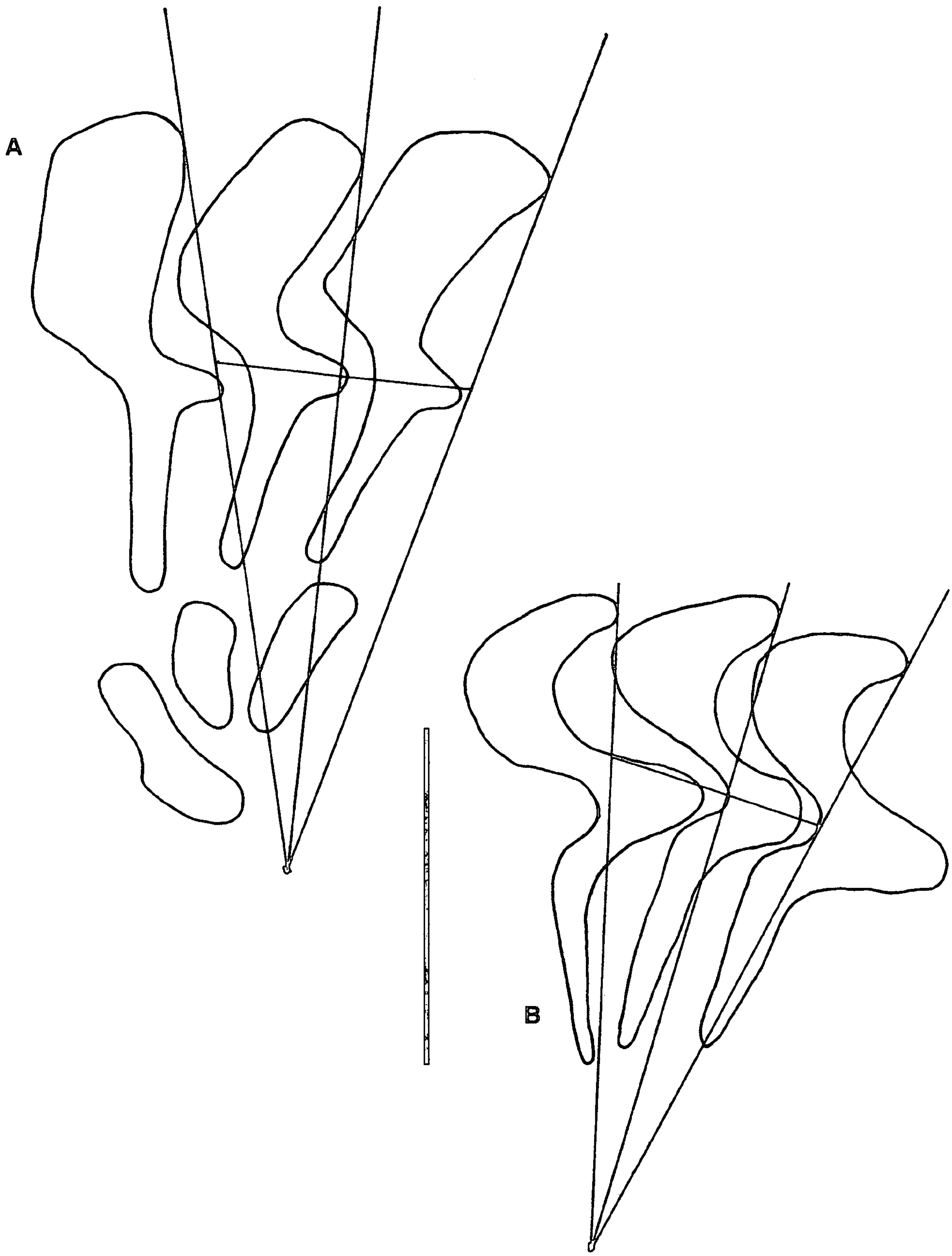


Figure. 4.8. Microscope projection drawings of the denticles of trichodinids from fishes of the Soetdoring Nature Reserve. **A** – *Trichodina centrostrigeata* Basson, Van As & Paperna, 1983 from the gills of *Pseudocrenilabrus philander* (Weber, 1897). **B** – *T. heterodentata* Duncan, 1977 from the gills of *Labeo capensis* (Smith, 1841) and *Cyprinus carpio* Linnaeus, 1758. Scale bar: 10µm

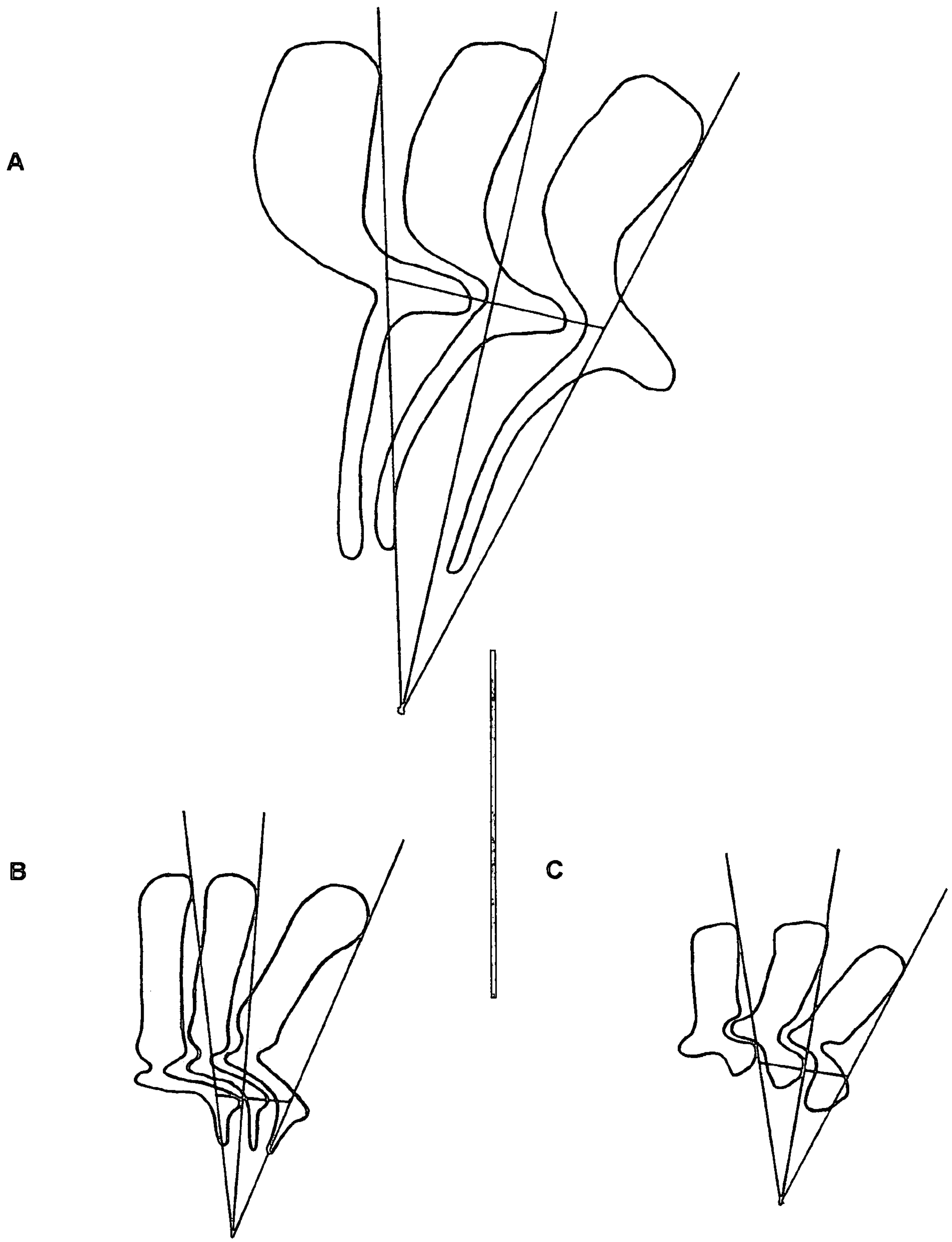


Figure. 4.9. Microscope projection drawings of the denticles of trichodinids from the fish of the Soetdoring Nature Reserve. **A** – *Trichodina mutabilis* Kazubski & Migala, 1968 from the gills of *Cyprinus carpio* Linnaeus, 1758 and *Labeo capensis* (Smith, 1841). **B** – *Tripartiella lechridens* Basson & Van As, 1987 from the gills of *L. umbratus* (Smith, 1841). **C** – *Trichodinella epizootica* (Raabe, 1950) from the gills of *L. capensis*, *L. umbratus* and *C. carpio*. Scale bar: 10µm

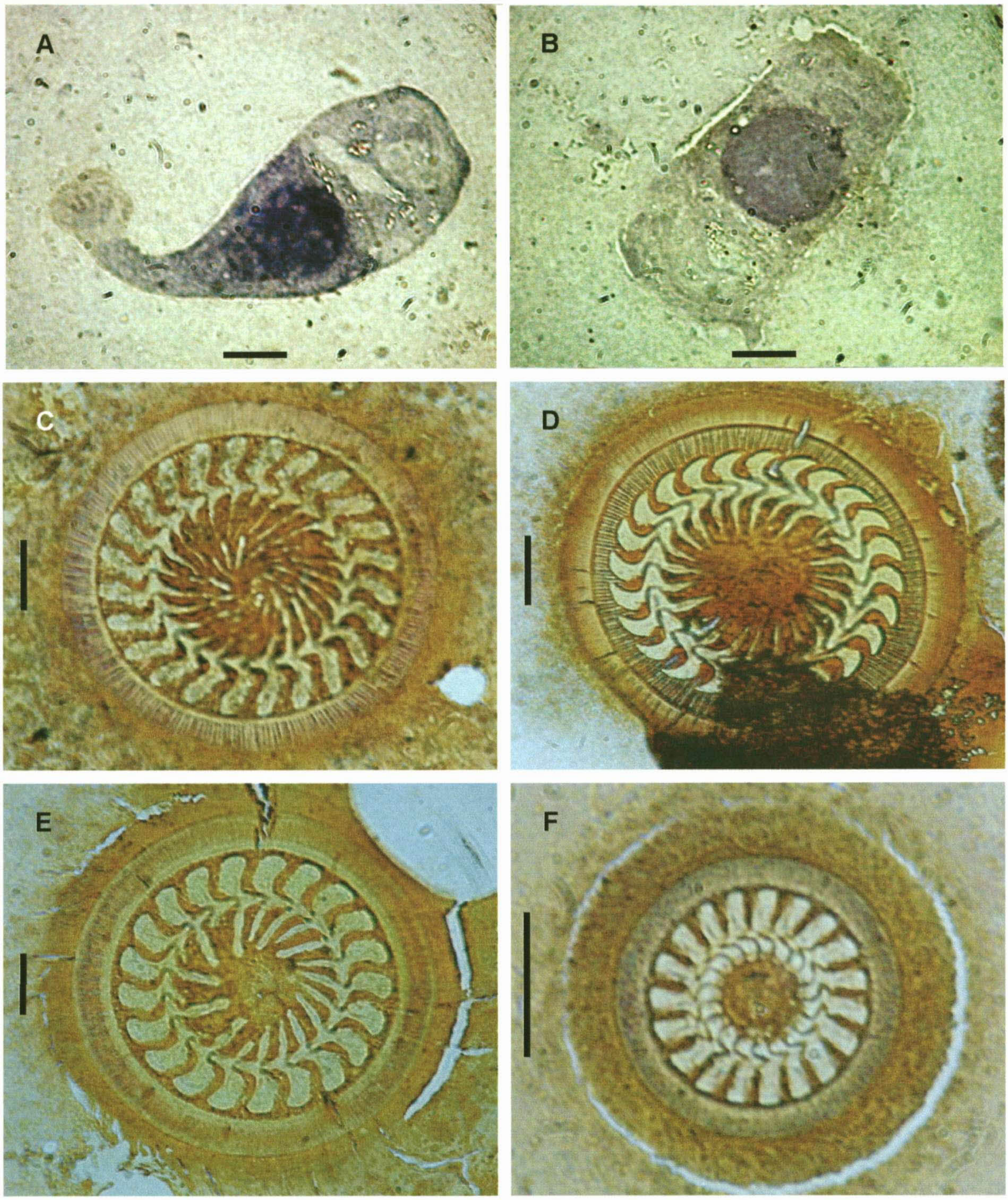


Figure. 4.10. Light micrographs of ciliophorans collected from the fishes from the Soetdoring Nature Reserve. **A** – *Apiosoma* sp. A, **B** – *Apiosoma* sp. B, **C** – *Trichodina centrostrigeata* Basson, Van As & Paperna, 1983, **D** – *T. heterodentata* Duncan, 1977, **E** – *T. mutabulis* Kazubski & Migala, 1968, **F** – *Trichodinella epizootica* (Raabe, 1950). Scale bar: 10µm

Chapter 5

The Class Monogenea (Van Beneden, 1858)

Monogeneans are a group of hermaphroditic flatworms parasitising mostly aquatic vertebrates, and are most often associated with the gill chamber, skin or other organs that are in direct contact with the external environment (Yamaguti 1963a; Euzet & Combes 1998). They occasionally also occur on aquatic invertebrates. Monogeneans are very specific to the site of attachment, and in some cases there is also specificity to certain microhabitats within an attachment site (Euzet & Combes 1988).

The life-cycle of monogeneans is usually very simple, involving an egg, oncomiracidium and the adult. Members of the Gyrodactylidae Cobbold, 1864 however, are viviparous. Generally, the life span of monogeneans can vary from a few days to several years.

Several authors have contributed to the systematics of the Monogenea, which has been emended in several publications since the separation of the monogeneans from other trematodes. A summary of the landmarks in the systematics is presented below.

- Van Beneden (1858) separated the Trematoda into two groups, namely the monogénèses and digénèses.
- Carus (1863) changed the French suffix to a latinised one, referring to the group as Monogenea. As this change is merely a minor orthographic change, authorship should still be attributed to Van Beneden (1858).
- Odhner (1912) divided the monogeneans into two groups, namely the Monopisthocotylea Odhner, 1912 and the Polyopisthocotylea Odhner, 1912, based on the presence or absence of a genito-intestinal tract.
- Bychowsky (1937) elevated the Monogenea from the rank of order, to that of class, based on the opisthaptor of the monogeneans, and the cercomer in the

ontogeny of the cestodes, amphillinideans, and gyrocotylideans. With this elevation, the name was changed to Monogenoidea, but Bychowsky still credited authorship to Van Beneden. Other authors, including Price (1937) objected to this, and accredited authorship to Carus. Some authors adopted the use of Monogenoidea as proposed by Bychowsky, while others still referred to it as the Monogenea.

- ◊ The system of classification by Byckowsky (1937), led to the division of the class into two subclasses, the Polyonchoinea (Bychowsky, 1937), and the Oligonchoinea (Bychowsky, 1937).
- ◊ Lebedev (1988) put forward a classification system, which included a subclass, the Polystomatoinea (Lebedev, 1986), which was previously either placed amongst the higher Monogenea (Oligonchoinea) or the lower Monogenea (Polyonchoinea). Orders were also introduced within the monogenea for the first time.
- ◊ Malmberg (1990) proposed a classification scheme based on the ontogeny of the opisthaptor. This suggested a progressive evolution amongst the monogeneans, resulting in an increase in the number of marginal hooks during evolution. This is contrary to the theories of Bychowsky, Lebedev and Euzet who support the theory of regressive evolution.
- ◊ Justine (1991) performed cladistic studies based on spermatozoan structure and spermiogenesis of monogeneans, and found similarities in the phylogenetic relationships with the classification of Lebedev (1988).
- ◊ Boeger & Kritsky (1993) proposed a classification system based on the phylogenies within the group, after subjecting the monogenean families to cladistic analysis using a variety of anatomical and ultrastructural characters.
- ◊ Lebedev (1995) proposed a classification system, which was similar to that of Boeger & Kritsky (1993), and an emended version of the Lebedev (1988) system.
- ◊ Due to molecular studies suggesting the Monogeneans to be non-monophyletic, Justine (1998) concluded that a reappraisal of morphological

synapomorphies should be undertaken, and that monophyly of the Monogenea be tested on this basis.

- ◊ Boeger & Kritsky (1997) put forward a revised hypothesis of monogenean phylogeny based on new structural and anatomical data.
- ◊ Mollaret, Jamieson & Justine (2000) concluded the Monogenea to be paraphyletic, based on analyses of 28srDNA sequences. They also found both the groups Monopisthocotylea, and Polyopisthocotylea to be monophyletic.
- ◊ Boeger & Kritsky (2001) presented an emended version of the hypothesis of Boeger & Kritsky (1997) for the relationships of family groups of the monogeneans. In this classification, two subclasses were suggested, namely the Polyonchoinea and the Heteronchoinea Boeger & Kritsky, 2001, with the Polystomatoinea and the Oligonchoinea included as infrasubclasses of the Heteronchoinea.
- ◊ Olson & Littlewood (2002) perform further molecular analysis, and came to the conclusion that the Monogenea is indeed monophyletic. This confirms the classification of Boeger & Kritsky (2001).

Controversy still exists as to how the class should be referred to, i.e. Monogenoidea or Monogenea, and many authors still debate which of the names are most acceptable. For the remainder of this dissertation, the classification of Boeger & Kritsky (2001) (Table 5.1) will be used, as it provides the most recent classification based on the phylogeny of the group. In accordance with the Round Table discussion of ICOPA IV, 1978 in Warsaw (Wheeler & Chisholm, 1995), this group will be referred to as the Monogenea (Van Beneden, 1858).

able 5.1: Classification of the Monogenea (adapted from Boeger & Kritsky 2001)

SUBCLASS	INFRA SUBCLASS	ORDER	SUBORDER	INFRA ORDER	SUPER FAMILY	FAMILY
olyonchoinea Bychowsky, 937)		Monocotylidea				Monocotylidae
						Loimoidae
		Capsalidea				Dionchidae
						Capsalidae
		Lagarocotylidea				Lagarocotylidae
		Montchadskyellidea				Montchadskyellidae
		Gyrodactylidea				Tetraonchoididae
						Bothitrematidae
						Anoplodiscidae
						Udonellidae
						Gyrodactylidae
						Acanthocotylidae
		Dactylogyridea	Calceostomatinea			Calceostomatidae
			Neodactylodiscinea			Neodactylodiscidae
			Amphibdellatinea			Amphibdellatidae
			Tetraonchinea			Sundanonchidae
						Tetraonchidae
						Neotetraonchidae
			Dactylogyrinea			Dactylogyridae
						Diplectanidae
						Pseudomurraytrematidae
eteronchoinea, oeger & Kritsky, 001	Polystomatoinea (Lebedev, 1986)	Polystomatidea				Polystomatidae
						Sphyranuridae
	Oligonchoinea (Bychowsky, 1937)	Chimaericolidea				Chimaericolidae
		Diclybothriidea				Diclybothriidae
						Hexabothriidae
		Mazocraeidea	Mazocraeinea			Plectanocotylidae
						Mazoplectidae
						Mazocraeidae
			Gastrocoltylinea	Anthocotylinea		Anthocotylidae
				Gastrocotylina		Pseudodiclidophoridae
					Protomicrocotyloidea	Allodiscocotylidae
						Pseudomazocraeidae
						Chauhaneidae
					Gastrocotyloidea	Bychowskycotylidae
						Gastrocotylidae
						Neothoracocotylidae
						Gotocotylidae
			Discocotylinea			Discocotylidae
						Diplozoidae
						Octomacridae
			Hexostomatinea			Hexostomatidae
			Microcotylinea		Microcotyloidea	Axinidae
						Diplasiocotylidae
						Heteraxinidae
						Microcotylidae
					Allopyragraphoroidea	Allopyragraphoridae
					Diclidophoroidea	Diclidophoridae
					Pyragraphoroidea	Pterinotrematidae
						Rhinecotylidae
						Pyragraphoridae
						Heteromicrocotylidae

Branchial monogeneans from African fishes

Monogeneans of the genera *Dactylogyrus* Diesing, 1850 and *Paradiplozoon* occur on the gills of a wide range of African fishes. In this chapter the dactylogyridean and diplozoid species occurring on the fishes from Africa will be discussed.

Dactylogyridean monogeneans

According to Yamaguti (1963a), the family Dactylogyridae belongs to the superfamily Dactylogyroidea Yamaguti, 1963, and includes species in which there are two or more head organs present. The lobes of the head may or may not be developed. Structures of the haptor include either one or two pairs of anchors, and there are usually 14 marginal hooklets present. All of the species discussed in this chapter are included either in the subfamily Dactylogyrinae Bychowsky 1933, or the Ancyrocephalinae Bychowsky, 1935. The Dactylogyrinae includes all those species with only one pair of anchors present, while the Ancyrocephalinae includes those that possess two pairs of anchors and in which the seminal receptacle is associated with the vagina (Yamaguti 1963a).

Genus *Dactylogyrus* Diesing, 1850

Generic Diagnosis

The genus *Dactylogyrus* according to the amended description by Price (1967) belongs to the subfamily Dactylogyrinae of the family Dactylogyridae. The haptor is armed with a single pair of anchors, which are supported by a haptoral bar. A ventral bar may or may not be present. The marginal hooklets are usually of the same shape, and subequal in size. Four eye-spots are present.

The copulatory complex is composed of a tubular cirrus, which is usually basally articulated to the accessory piece. A vagina may be present or absent, and the position of the vagina is variable. The vas deferens is usually looped around the intestinal limb, and the seminal vesicle is a simple dilation of the vas deferens. One or two prostatic reservoirs may be present.

Dactylogyrus Diesing, 1850 species of African cyprinids

In Africa there are currently 92 known species belonging to the genus *Dactylogyrus*, which are parasites of cyprinid fishes. According to Paperna (1979a), the genus can be divided into three species groups. These groups share some common morphological characters, but still differ morphologically from each other to be ranked as different species (Paperna 1979a). Two of these groups, namely the *Dactylogyrus pseudoanchoratus* Price & Géry, 1968 group, and the *D. afrobarbae* Paperna, 1968 group are known only from African cyprinids fishes. The third species group, *D. varicorhini* Bychowsky, 1957, is common to cyprinid fish from both Africa and Asia.

Species recorded from *Labeo* Cuvier, 1817 hosts

In Africa, there are currently 24 species of *Dactylogyrus* that have been described from *Labeo* species (Table 5.2), or recorded from species of *Labeo* by other authors.

The first of these species was described in 1968, when Paperna described *Dactylogyrus afrobarbae* Paperna, 1968 from *Barbus sublineatus* Daget, 1954 from Ghana. One year later however, Paperna recorded the same species from *Labeo coubie* Rüppel, 1832, also in Ghana. Paperna (1969) described three other species from Ghana, namely *D. digitalis* Paperna, 1969, *D. labeous* Paperna, 1969 and *D. senegalensis* Paperna, 1969. All three species were collected from *L. coubie*. Price, Korach & McPott (1969a) also, described *D. pienaari* Price, Korach & McPott, 1969 from *L. rosae* Steindachner 1894, which is to date the only species described from a *Labeo* species from South Africa.

Four years later, in 1973, Paperna described a number of new species from research done in Africa. Of these species, four were described from *Labeo* species, namely *D. brachydiscus* Paperna, 1973, and *D. longiphallus* Paperna, 1973 from *L. victorianus* Boulenger, 1901, both from Kenya. *Dactylogyrus cyclocirrus* Paperna, 1973 was found on *L. coubie*, from Ghana and *D. helicophallus*, from *Labeo forskalii* Rüppel, 1836 collected from Uganda.

A fifth species was also collected from Kenya, namely *D. brevicirrus* Paperna, 1973 and was found on *Barbus altianalis* Boulenger, 1900. Paperna also recorded this species from *Labeo victorianus* in 1973. *Dactylogyrus brevicirrus* was also recorded from other *Labeo* hosts, namely *L. cylindricus* and *L. forskalii* by Paperna (1979a) from Tanzania and Uganda, respectively. Other authors also reported it from *Labeo* species, namely *L. parvus* Boulenger, 1902, (Guegan, Lambert & Euzet 1988) from Mali and again from *L. parvus* Boulenger, 1902 (Guegan & Lambert 1991), from West Africa.

Paperna (1979a) described a subspecies of *D. pseudoanchoratus* Price & Gery, 1968 from a *Labeo* host, namely *D. p. michronchus* Paperna, 1979 from Tanzania.

Guegan *et al.* (1988) described a number of species from *Labeo* hosts, all from research done in Mali. These species included *D. decaspirus* Guegan, Lambert, Euzet, 1988, *D. falcilocus* Guegan, Lambert & Euzet, 1988, *D. jaculus* Guegan, Lambert, Euzet, 1988, *D. titus* Guegan, Lambert & Euzet 1988, and *D. retroversus* Guegan, Lambert, Euzet 1988, all from *L. coubie*. They also described *D. rastellus* Guegan, Lambert & Euzet, 1988 and *D. tubarius* Guegan, Lambert & Euzet, 1988 from *L. senegalensis* Valenciennes, 1842, and *D. nathaliae* Guegan, Lambert & Euzet, 1988 from a *Labeo* host.

Guegan & Lambert recorded *D. falcilocus* again from Mali in 1990 and in 1991 from Mali and West Africa respectively. These records were from *Labeo coubie*, *L. parvus* and *L. wurtzi* (not in CLOFFA)[1].

[1] Check-List of the Freshwater Fishes of Africa.

Guegan & Lambert (1991) described four more species from *Labeo* hosts. These were *D. gucundus* Guegan & Lambert, 1991, from *L. parvus* in West Africa, *D. longiphalloides* Guegan & Lambert, 1991 from *L. allauadi* Pellegrin, 1933 from Sierra Leone, and two species from *L. rouaneti* Daget, 1962, namely *D. sematus* Guegan & Lambert, 1991, and *D. omega* Guegan & Lambert, 1991, collected in Guinea.

A comparison of the measurements of the species recorded from *Labeo* hosts is given in Table 5.3. Where available the measurements were used from the original descriptions or from redescriptions by other authors. In other cases measurements were made from available drawings.

Table 5.2. Summary of the species of *Dactylogyrus* Diesing, 1850 that have been collected from *Labeo* Cuvier, 1817 hosts and the distribution (adapted from Khalil & Polling 1997).

Species	Host	Distribution
Dactylogyrus afrobarbae Paperna, 1968 (Figure 5.1A, B)	*Labeo coubie* Rüppel, 1832	Ghana
D. brachydiscus Paperna, 1973 (Figure 5.1C-E)	*L. victorianus* Boulenger, 1901	Kenya
D. brevicirrus Paperna, 1973 (Figure 5.1F-H)	*L. cylindricus* Peters, 1968, *L. forskalii* Rüppel 1836, *L. parvus* Boulenger, 1902 and *L. victorianus*	Kenya, Uganda, Tanzania, West Africa and Mali
D. cyclocirrus Paperna, 1973 (Figure 5.2A-C)	*L. coubie, L. cylindricus* and *L. senegalensis* Valienciennes, 1842	Ghana, Tanzania, West Africa, and Kenya
D. decaspirus Guegan, Lambert & Euzet, 1988 (Figure 5.2D-F)	*L. coubie*	Mali and Ghana
D. digitalis Paperna, 1969 (Figure 5.2G-I)	*L. coubie*	Ghana and Mali
D. falcilocus Guegan, Lambert & Euzet, 1988 (Figure 5.3A-C)	*L. coubie, L. parvus* and *L. wurtzi* (not in CLOFFA)	Mali
D. helicophallus Paperna, 1973 (Figure 5.3D-F)	*L. forskalii*	Uganda
D. jaculus Guegan, Lambert & Euzet, 1988 (Figure 5.3G-I)	*L. coubie*	Mali, Ghana
D. jucundus Guegan & Lambert, 1991 (Figure 5.3J-L)	*L. parvus* and *L. rouaneti* Daget, 1962	West Africa and Guinea
D. labeous Paperna, 1969 (Figure 5.4A-C)	*L. coubie* and *L. senegalensis*	Ghana
D. longiphalloides Guegan & Lambert, 1991 (Figure 5.4D-F)	*L. alluaudi* Pellegrin, 1932	Sierra Leone
D. longiphallus Paperna, 1973 (Figure 5.4G-I)	*L. victorianus* and *L. parvus*	Kenya and Uganda
D. nathaliae Guegan, Lambert & Euzet, 1988 (Figure 5.5A-C)	*Labeo sp.*	Mali
D. oligospirophallus Paperna, 1973 (Figure 5.5D-F)	*L. coubie*	Ghana
D. omega Guegan & Lambert, 1991 (Figure 5.5G-I)	*L. rouaneti* Daget, 1962	Guinea
D. pienaari Price, Korach & McPott, 1969 (Figure 5.5J-L)	*L. rosae* Steindachner, 1894	South Africa
D. pseudoanchoratus micronchus Paperna, 1979 (Figure 5.6A-C)	*Labeo sp.*	Tanzania
D. rastellus Guegan, Lambert & Euzet, 1988 (Figure 5.6D-F)	*L. senegalensis*	Mali
D. retroversus Guegan, Lambert & Euzet, 1988 (Figure 5.6G-I)	*L. coubie*	Mali
D. sematus Guegan & Lambert, 1991 (Figure 5.6J-L)	*L. rouaneti*	Guinea
D. senegalensis Paperna, 1969 (Figure 5.7A-C)	*L. coubie* and *L. senegalensis*	Ghana
D. titus Guegan, Lambert & Euzet, 1988 (Figure 5.7D-F)	*L. coubie*	Mali
D. tubarius Guegan, Lambert & Euzet, 1988 (Figure 5.7.G-I)	*L. senegalensis*	Mali

Table 5.3 Summary of the measurements of species of *Dactylogyrus* Diesing, 1850 collected from *Labeo* Cuvier, 1817 species. **AL**-anchor length, **AP**-length of accessory piece, **BL**-length of dorsal bar, **BW**-width of dorsal bar, **C**-length of cirrus, **IR**-length of inner root, **OR**-length of outer root, **S**-shaft length, **T**-length of tip, **TL**-total length, **W**-greatest width

Species	TL	W	AL	S	OR	IR	T	BL	BW	C	A
Dactylogyrus afrobarbae Paperna, 1968	□	□	45	26	1	22	16	33	2	135	42
D. brachydiscus Paperna, 1973	200-220	110-130	28-29	18		13	9	25	□	20-21	6-8
D. brevicirrus Paperna, 1973	230-380	40-100	35-40	20-24	1-4	16-20	10-14	19-21	□	25-30	15-21
D. cyclocirrus Paperna, 1973	420-460	110-140	27-29	11-12		14	7-9	26-28	□	58-60	□
D. decaspirus Guegan, Lambert & Euzet, 1988	250-350	60-80	45-50	32-35	3-5	21-25	17-19	21-29	4-5	250-300	8-10
D. digitalis Paperna, 1969	480-850	100-200	31-38	27-35	3-8	5?	12-18	28-34	4-6	70	40-47
D. falcilocus Guegan, Lambert & Euzet, 1988	280-470	40-80	30-40	23-27	1-2	12-19	11-16	24-28	3-5	17-23	17-25
D. helicophallus Paperna, 1973	180-200	40	33-35	20-22	2	15	14-19	16	□	72-82	20-25
D. jaculus Guegan, Lambert & Euzet, 1988	240-350	40-70	25-35	21-24	1-2	12-16	8-12	14-17	3-4	15-20	24-28
D. jucundus Guegan & Lambert, 1991	250-630	40-120	47-55	26-33	3-6	22-29	17-18	22-26	□	40-47	26-30
D. labeous Paperna, 1969	230-400	40-80	38-43	29-31	3-4	16-21	12-17	20-23	4-5	33-39	30
D. longiphalloides Guegan & Lambert, 1991	250-360	40-80	40-45	24-28	1-3	19-21	12-14	17-20	3-5	40-46	40-46
D. longiphallus Paperna, 1973	190-240	50-80	34-41	20-24	1-4	16-22	11-17	15-24		45-63	32-40
D. nathaliae Guegan, Lambert & Euzet, 1988	400-700	80-130	26-30	24-28	5-7	10-13	10-13	22-26	3-5	60-70	22-30
D. oligospirophallus Paperna, 1973	220-480	50-80	33-40	24-27	2-4	14-20	11-17	18-22	3-4	60-65	□
D. omega Guegan & Lambert, 1991	360-830	70-120	32-36	26-30	3-6	10-14	13-15	24-28	4-6	□	35-42
D. pienaari Price, Korach & McPott, 1969	197-244	79-129	26-32	24	2	9	12	17-22	4	70-80	12-16
D. pseudoanchoratus micronchus Paperna, 1979	220-240	60-100	31-34	22-25	2-4	12-13	9-12	25-26	□	28-38	14-17

Table 5.3 continued: Summary of the measurements of species of *Dactylogyrus* Diesing, 1850 collected from *Labeo* Cuvier, 1817 species. AL-anchor length, AP-length of accessory piece, BL-length of dorsal bar, BW-width of dorsal bar, C-length of cirrus, IR-length of Inner root, OR-length of outer root, S-shaft length, T-length of tip, TL-total length, W-greatest width

Species	TL	W	AL	S	OR	IR	T	BL	BW	C	A
D. rastellus Guegan, Lambert & Euzet, 1988	230-470	40-80	42-48	31-35	2-4	15-19	16-18	17-21		20-27	
D. retroversus Guegan Lambert & Euzet, 1988	230-400	40-80	40-48	26-31	2-3	18-22	17-19	21-26	2-4	30-35	□
D. sematus Guegan & Lambert, 1991	220-670	40-110	39-43	23-27	3-5	18-21	13-15	19-23	3-5	35-42	□
D. senegalensis Paperna, 1969	200-500	50-80	29-33	24-28	1-4	8-13	11-14	17-21	3-4	180	□
D. titus Guegan, Lambert & Euzet, 1988	200-390	40-90	35-40	23-37	1-3	13-18	12-15	17-22	3-4	18-20	14-18
D. tubarius Guegan, Lambert & Euzet, 1988	180-380	40-80	39-44	26-30	3-4	17-22	14-19	22-25	3-4	□	□

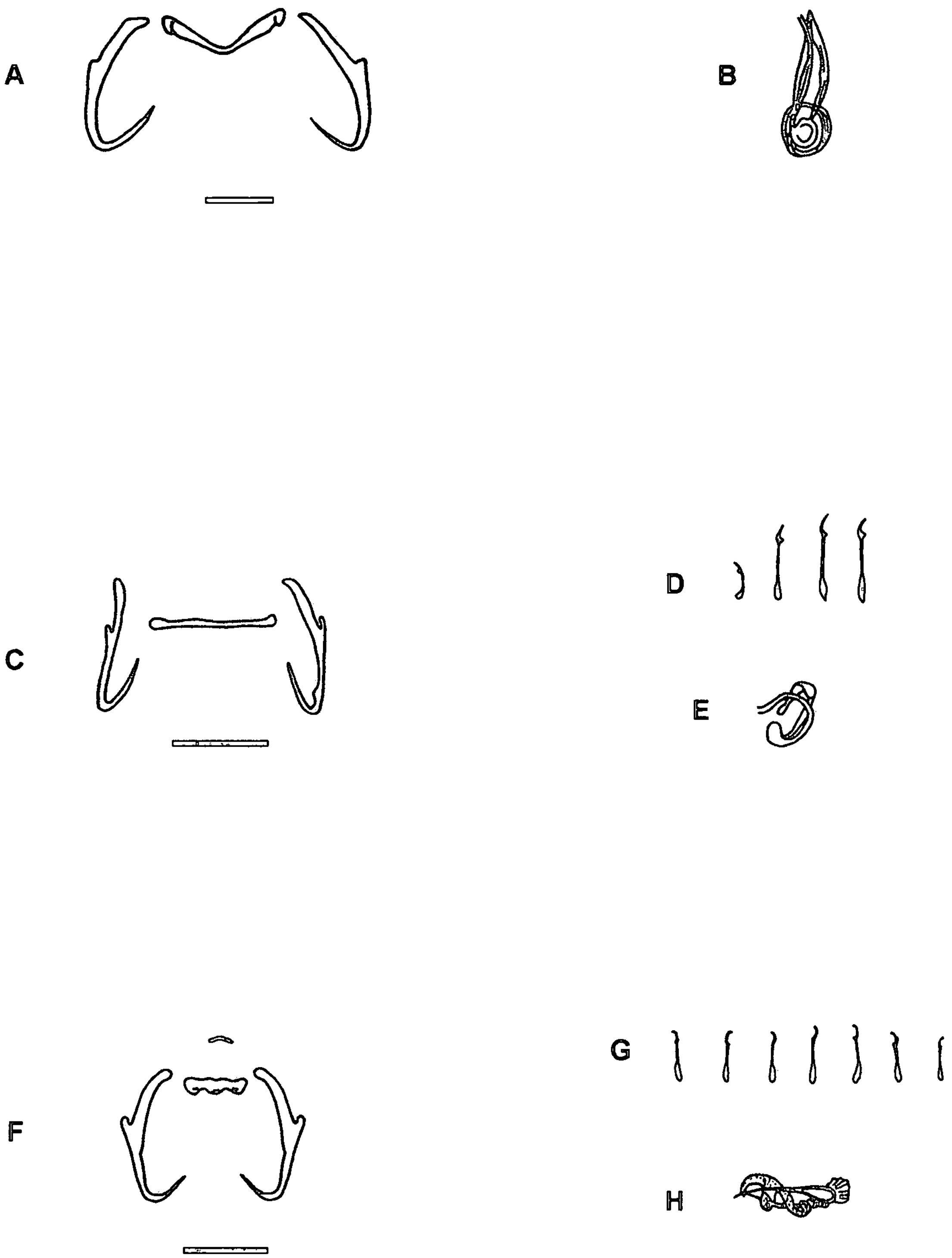


Figure. 5.1. Diagrammatic drawings of *Dactylogyrus* Diesing, 1850 species. **A**, **B** – *Dactylogyrus afrobarbae* Paperna, 1968 (redrawn from Paperna 1968). **A** – anchors and dorsal bar, **B** – cirrus. **C-E** – *D. brachydiscus* Paperna, 1973 (redrawn from Paperna 1979). **C** – anchors and dorsal bar, **D** – marginal hooklets, **E** – cirrus. **F-H** – *D. brevicirrus* Paperna, 1973 (redrawn from Guegan, Lambert & Euzet 1988). **F** – anchors and dorsal bars, **G** – marginal hooklets, **H** – cirrus. Scale bar: 20µm

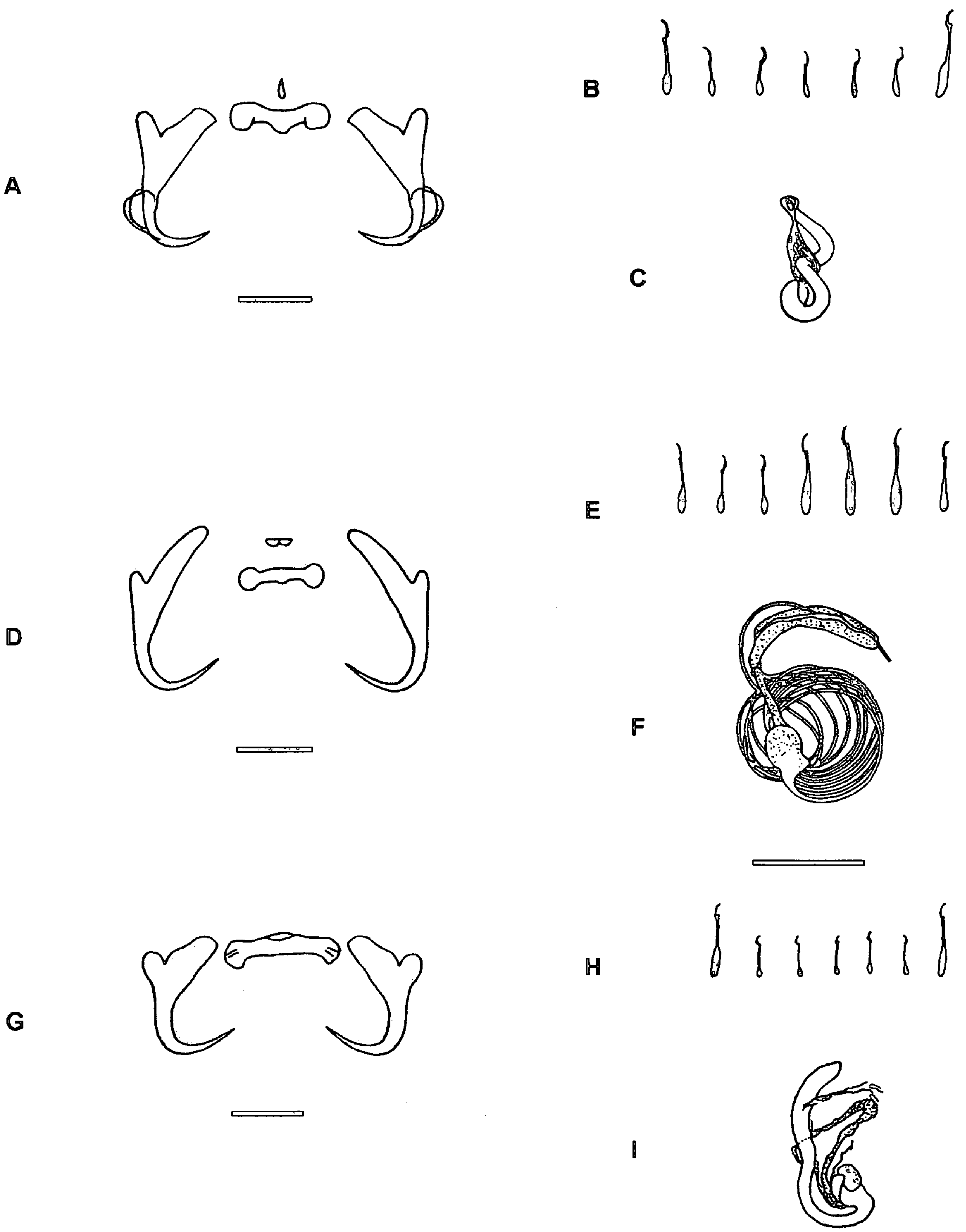


Figure. 5.2. Diagrammatic drawings of *Dactylogyrus* Diesing, 1850 species. **A-C** – *Dactylogyrus cyclocirrus* Paperna, 1973 (redrawn from Guegan, Lambert & Euzet 1988). **A** – anchors and dorsal bars, **B** – marginal hooklets, **C** – cirrus. **D-F** – *D. decaspirus* Guegan, Lambert & Euzet, 1988 (redrawn from Guegan, Lambert & Euzet 1988). **D** – anchors and dorsal bars, **E** – marginal hooklets, **F** – cirrus. **G-I** – *D. digitalis* Paperna, 1969 (redrawn from Guegan, Lambert & Euzet 1988). **G** – anchors and dorsal bar, **H** – marginal hooklets, **I** – cirrus. Scale bar: 20µm

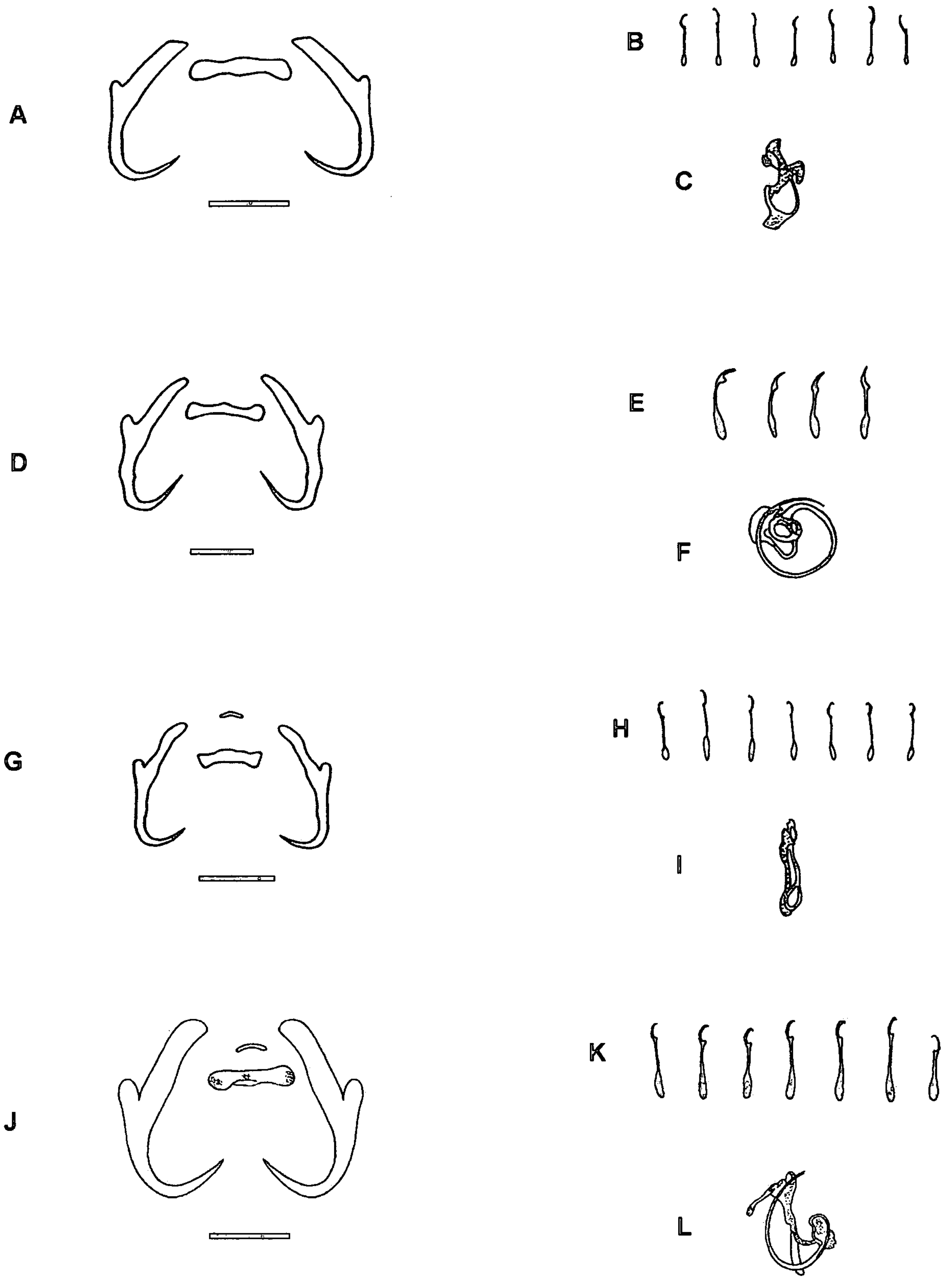


Figure. 5.3. Diagrammatic drawings of *Dactylogyrus* Diesing, 1850 species. **A-C** – *Dactylogyrus falcilocus* Guegan, Lambert & Euzet, 1988 (redrawn from Guegan, Lambert & Euzet 1988). **A** – anchors and dorsal bar, **B** – marginal hooklets, **C** – cirrus. **D-F** – *D. helicophallus* Paperna, 1974 (redrawn from Paperna 1979). **D** – anchors and dorsal bar, **E** – marginal hooklets, **F** – cirrus. **G-I** – *D. jaculus* Guegan, Lambert & Euzet, 1988 (redrawn from Guegan, Lambert & Euzet 1988). **G** – anchors and dorsal bars, **H** – marginal hooklets, **I** – cirrus. **J-L** - *D. jucundus* Guegan & Lambert, 1991 (redrawn from Guegan & Lambert 1991). **J** – anchors and dorsal bars, **K** – marginal hooklets, **L** - cirrus. Scale bar: 20µm

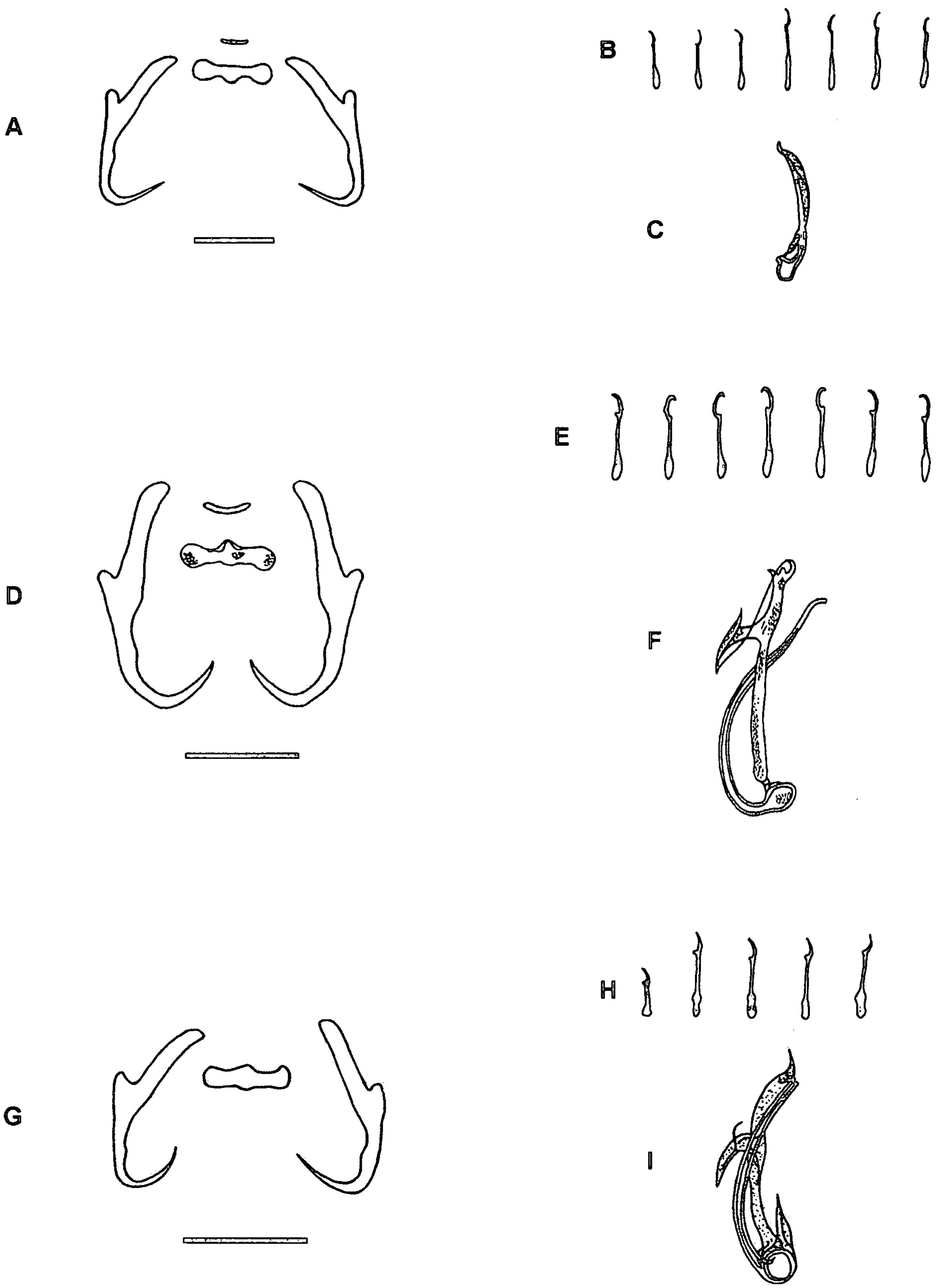


Figure. 5.4. Diagrammatic drawings of *Dactylogyrus* Diesing, 1850 species. **A-C** – *Dactylogyrus labeous* Paperna, 1969 (redrawn from Guegan, Lambert & Euzet 1988). **A** – anchors and dorsal bars, **B** – marginal hooklets, **C** – cirrus. **D-F** – *D. longiphalloides* Guegan & Lambert, 1991 (redrawn from Guegan & Lambert 1991). **D** – anchors and dorsal bars, **E** – marginal hooklets, **F** – cirrus. **G-I** – *D. longiphallus* Paperna, 1973 (redrawn from Paperna 1979). **G** – anchors and dorsal bar, **H** – marginal hooklets, **I** – cirrus. Scale bar: 20μm

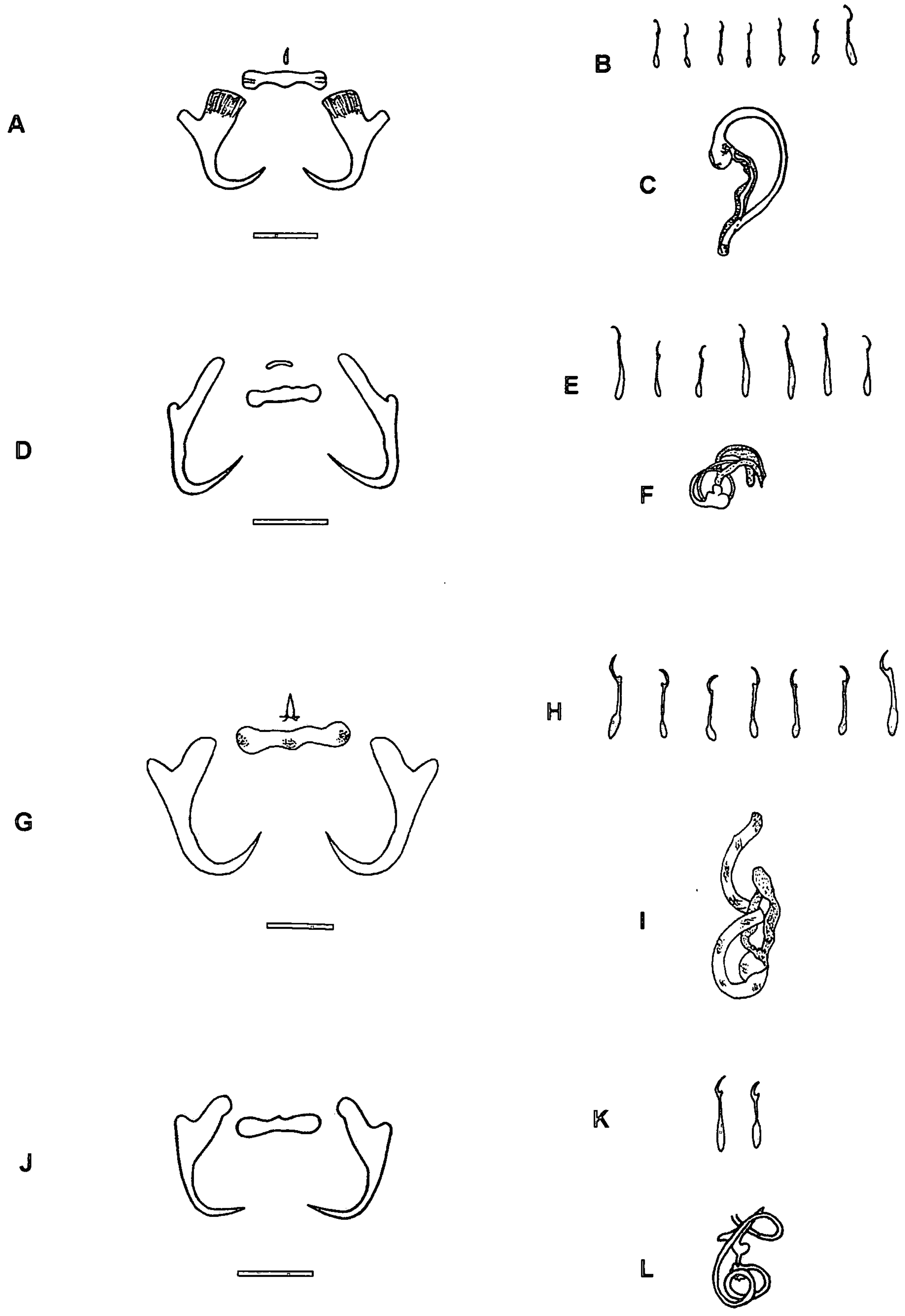


Figure. 5.5. Diagrammatic drawings of *Dactylogyrus* Diesing, 1850 species. **A-C** – *Dactylogyrus nathaliae* Guegan, Lambert & Euzet, 1988 (redrawn from Guegan, Lambert & Euzet 1988). **A** – anchors and dorsal bars, **B** – marginal hooklets, **C** – cirrus. **D-F** – *D. oligospirophallus* Papena, 1973 (redrawn from Paperna 1979). **D** – anchors and dorsal bars, **E** – marginal hooklets, **F** – cirrus. **G-I** – *D. omega* Guegan & Lambert, 1991 (redrawn from Guegan & Lambert 1991). **G** – anchors and transvers bars, **H** – marginal hooklets, **I** – cirrus. **J-L** – *D. pienaari* Price, Korach & McPott, 1969 (redrawn from Price, Korach & McPott 1969). **J** – anchors and dorsal bar, **K** – marginal hooklets, **L** – cirrus. Scale bar: 20µm

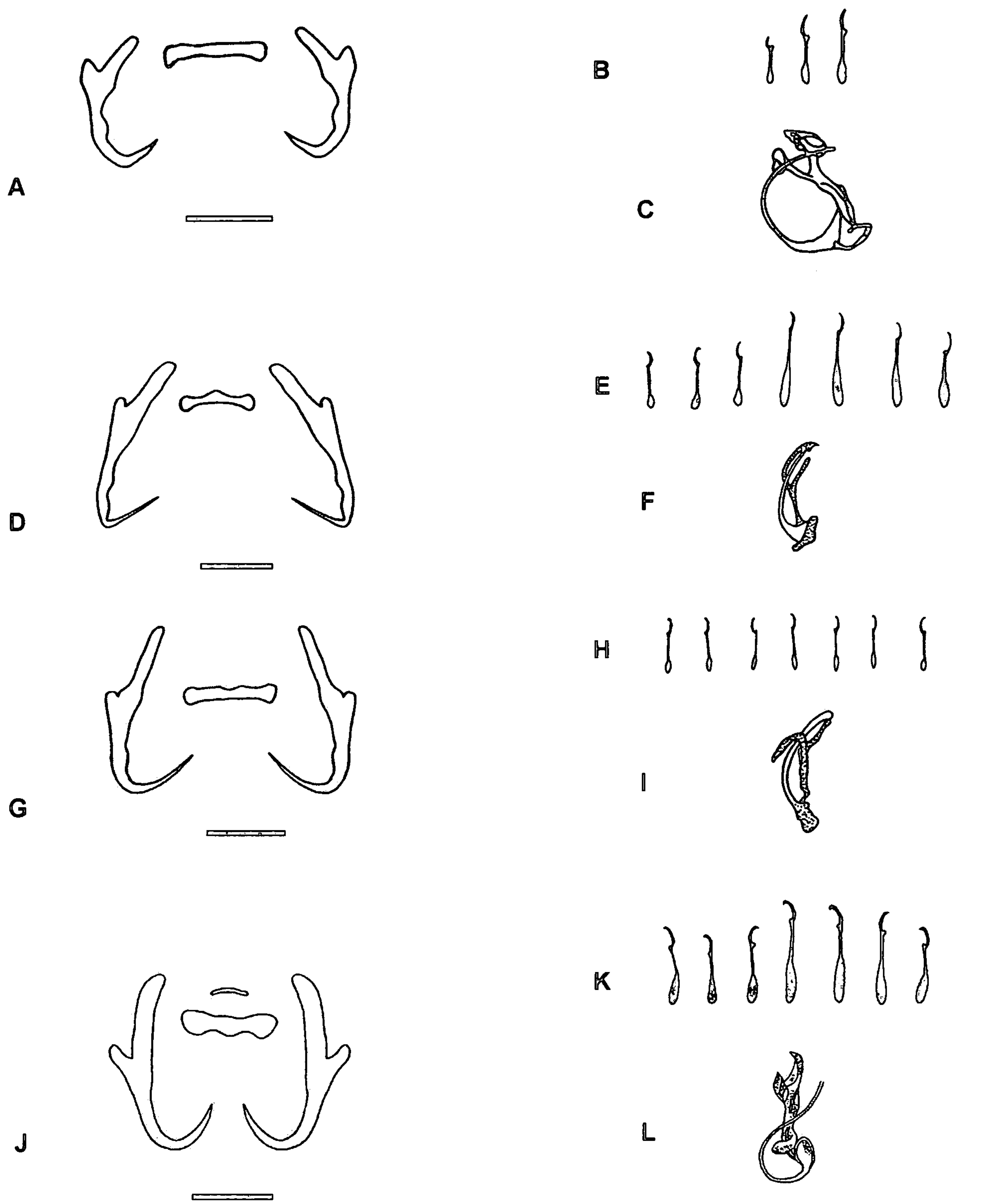


Figure. 5.6. Diagrammatic drawings of *Dactylogyrus* Diesing, 1850 species. **A-C** – *Dactylogyrus pseudoanchoratus micronchus* Paperna, 1979 (redrawn from Paperna 1979). **A** – anchors and dorsal bar, **B** – marginal hooklets, **C** – cirrus. **D-F** – *D. rastellus* Guegan, Lambert & Euzet, 1988 (redrawn from Guegan, Lambert & Euzet 1988). **D** – anhors and dorsal bar, **E** – marginal hooklets, **F** – cirrus. **G-I** – *D. retroversus* Guegan, Lambert & Euzet, 1988 (redrawn from Guegan, Lambert & Euzet 1988). **G** – anchors and dorsal bar, **H** – marginal hooklets, **I** – cirrus. **J-L** – *D. sematus* Guegan & Lambert, 1991 (redrawn from Guegan & Lambert 1991). **J** – anchors and dorsal bars, **K** – marginal hooklets, **L** – cirrus. Scale bar: 20μm

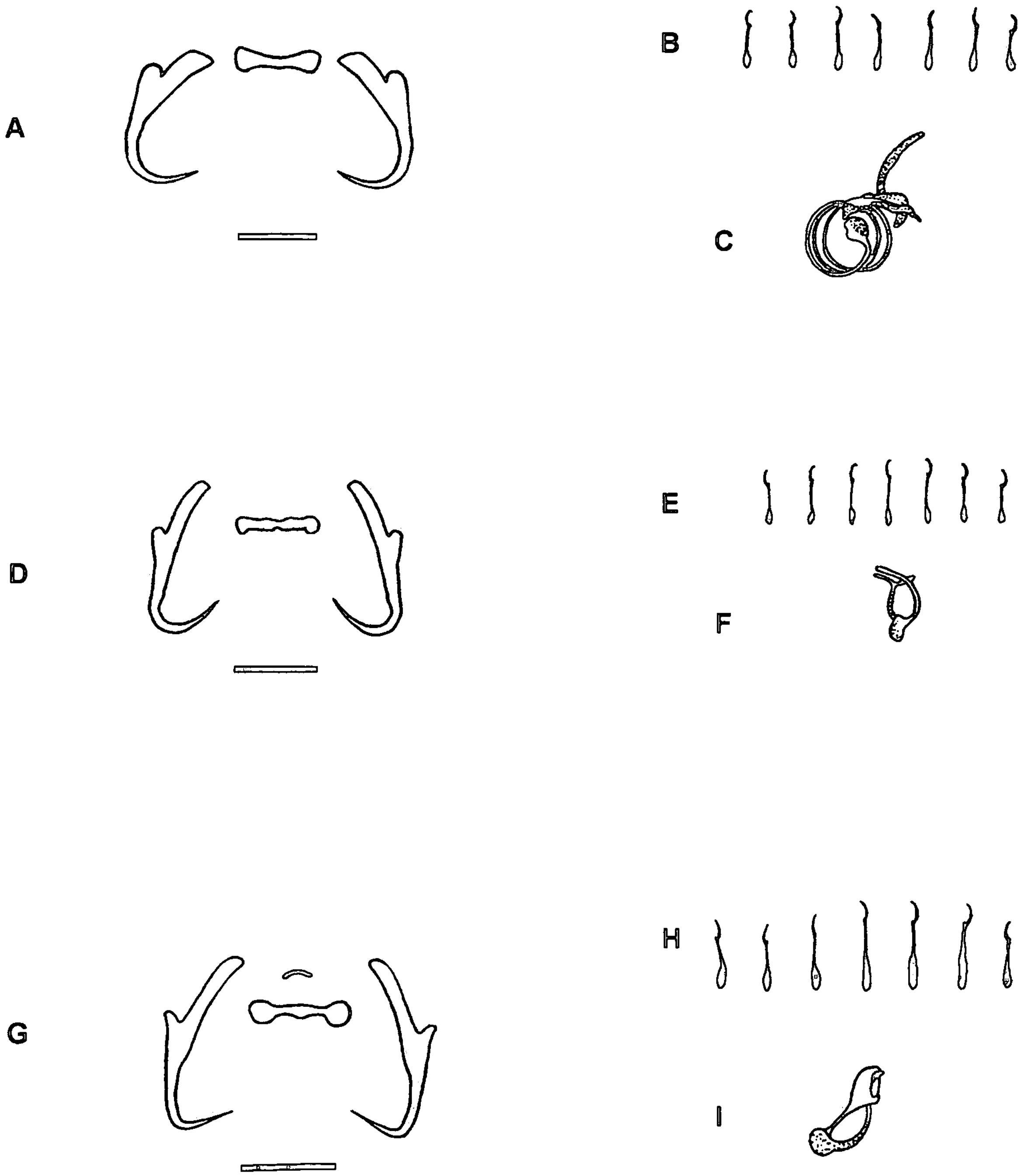


Figure. 5.7. Diagrammatic drawings of *Dactylogyrus* Diesing, 1850 species. **A-C** – *Dactylogyrus senegalensis* Paperna, 1969 (redrawn from Guegan, Lambert & Euzet 1988). **A** – anchors and dorsal bar, **B** – marginal hooklets, **C** – cirrus. **D-F** – *D. titus* Guegan, Lambert & Euzet, 1988 (redrawn from Guegan, Lambert & Euzet 1988). **D** – anchors and dorsal bar, **E** – marginal hooklets, **F** – cirrus. **G-I** – *D. tubarius* Guegan, Lambert & Euzet, 1988 (redrawn from Guegan, Lambert & Euzet 1988). **G** – anchors and transvers bars, **H** – marginal hooklets, **I** – cirrus. Scale bar: 20µm

Dactylogyrus **species known from South African hosts, other than** ***Labeo*** Cuvier, 1817 **species**

Twelve species of *Dactylogyrus* have been recorded from South Africa (see Table 5.4). Of these species, *D. pienaari* (mentioned above) has been described from a *Labeo* host. The remaining eleven species is known from other cyprinid hosts.

Two of the species that were described from South Africa were described in 1969, namely *D. jubbstrema* Price, Korach & McPott 1969 from *Glossogobius giuris* Hamilton, 1822, and *D. myersi* Price, McClellan, Druckenmiller & Jacobs 1969 from *Barbus trimaculatus* (Price et al, 1969a; Price et al, 1969b). The other three were described by Mashego in 1983, two from *Barbus palidinosus*, namely *D. teresae* Mashego, 1983 and *D. dominici* Mashego, 1983, and one from *Barbus neefi* Greenwood, 1962, namely *D. enidae* Mashego, 1983.

Price *et al.* (1969b) recorded *D. varicorhini* Bychowsky, 1957 from *Labeobarbus kimberleyensis*. This species was originally described by Bychowsky (1957), from *Varicorhinus capoeta* (Güldenstädt, 1772) from the Vazrob River, near Stalinabad. Price *et al.* (1969b) did not give a description or measurements and according to Paperna (1979a) this might well be another species because of the morphological similarities in the specific species group.

The remaining species that were recorded from South Africa are all species that were originally described from Uganda from *Barbus* and *Labeobarbus* hosts. They were recorded again from South Africa in 1983 by Mashego. These include, *D. allolongionchus* Paperna, 1973, *D. afrosclerovaginus* Paperna 1973, *D. afrolongicornis afrolongicornis* Paperna, 1973, *D. a. alberti* Paperna 1973, all from *B. trimaculatus*, as well as a species described by Paperna and Thurston (1968b), namely *D. spinicirrus* Paperna & Thurston (1968b), from *L. marequensis* (Smith, 1841).

Table 5.4. Summary of the species of *Dactylogyrus* Diesing, 1850 from other cyprinids hosts in South Africa (adapted from Khalil & Polling 1997).

Species	Host
D. afrolongicornis afrolongicornis Paperna, 1973 (Figure 5.8A-C)	*Barbus trimaculatus* Peters, 1852
D. afrolongicornis alberti Paperna, 1973 (Figure 5.8D-F)	*B. trimaculatus*
D. afrosclerovaginus Paperna, 1973 (Figure 5.8G-I)	*B. paludinosus* Peters, 1852
D. allolongionchus Paperna, 1973 (Figure 5.8J-L)	*B. trimaculatus*
D. dominici Mashego, 1983 (Figure 5.9A-C)	*B. neefi* Greenwood, 1962
D. enidae Mashego, 1983 (Figure 5.9D-F)	*B. paludinosus*
D. jubbstrema Price, Korach & McPott, 1969 (Figure 5.9G-I)	*Glossogobius giuris* Hamilton, 1822
D. myersi Price, McClellan, Druckenmiller & Jacobs, 1969 (Figure 5.10A-C)	*B. trimaculatus*
D. spinicirrus (Paperna & Thurston, 1968b) (Figure 5.10D-F)	*Labeobarbus marequensis* (Smith, 1841)
D. teresae Mashego, 1983 (Figure 5.10G-I)	*B. paludinosus*

A comparison of the measurements of the species recorded from other cyprinid hosts from South Africa is given in Table 5.5.

Table 5.5. Measurements of species of *Dactylogyrus* Diesing, 1850 collected from South Africa. AL-anchor length, AP-length of accessory piece, BL-length of dorsal bar, BW-width of dorsal bar, C-length of cirrus, IR-length of inner root, OR-length of outer root, S-shaft length, T-length of tip, TL-total length, W-greatest width

Species	TL	W	AL	S	OR	IR	T	BL	BW	C	AP
D. afrolongicornis afrolongicornis Paperna, 1973	280	100	35-36	20-22	5	17	12-17	51-63	2	42	32
D. afrolongicornis alberti Paperna, 1973	230-310	50-100	38-43	22-28	1-5	17-23	12-17	51-63	5-10	25-30	20-26
D. afrosclerivaginus Paperna, 1973	130-400	45-100	36-41	27-32	2-4	13-16	7-12	38-40	2-4	22-30	16-32
D. allolongionchus Paperna, 1973	200-310	80-160	□	42-54	3-6	11-19	16-20	36-51	3-7	22-25	17-22
D. dominici Mashego, 1983	218-419	31-75	58-80	40-54	2	23	40-54	43-58	4-5	25-45	15-19
D. enidae Mashego, 1983	171-281	31-38	68-81	50-56	3-9	21-31	19	31-43	4-6	21-25	19
D. jubbstrema Price, Korach & McPott, 1969	190-226	50-60	32-38	18	3	18	15	15-18	4	21-25	14-17
D. myersi Price, McClellan, Druckenmiller & Jacobs	363-463	56-110	150-158	100	6	100	50-56	38-44	□	25-38	16-25
D. spinicirrus (Paperna & Thurston, 1968b)	400-450	□	70-80	□	5-8	16-18	□	31-35	□	78	25
D. teresae Mashego, 1983	238-413	38-69	100-106	69-75	6-8	23-29	13-19	44-50	4-6	28-31	14-19

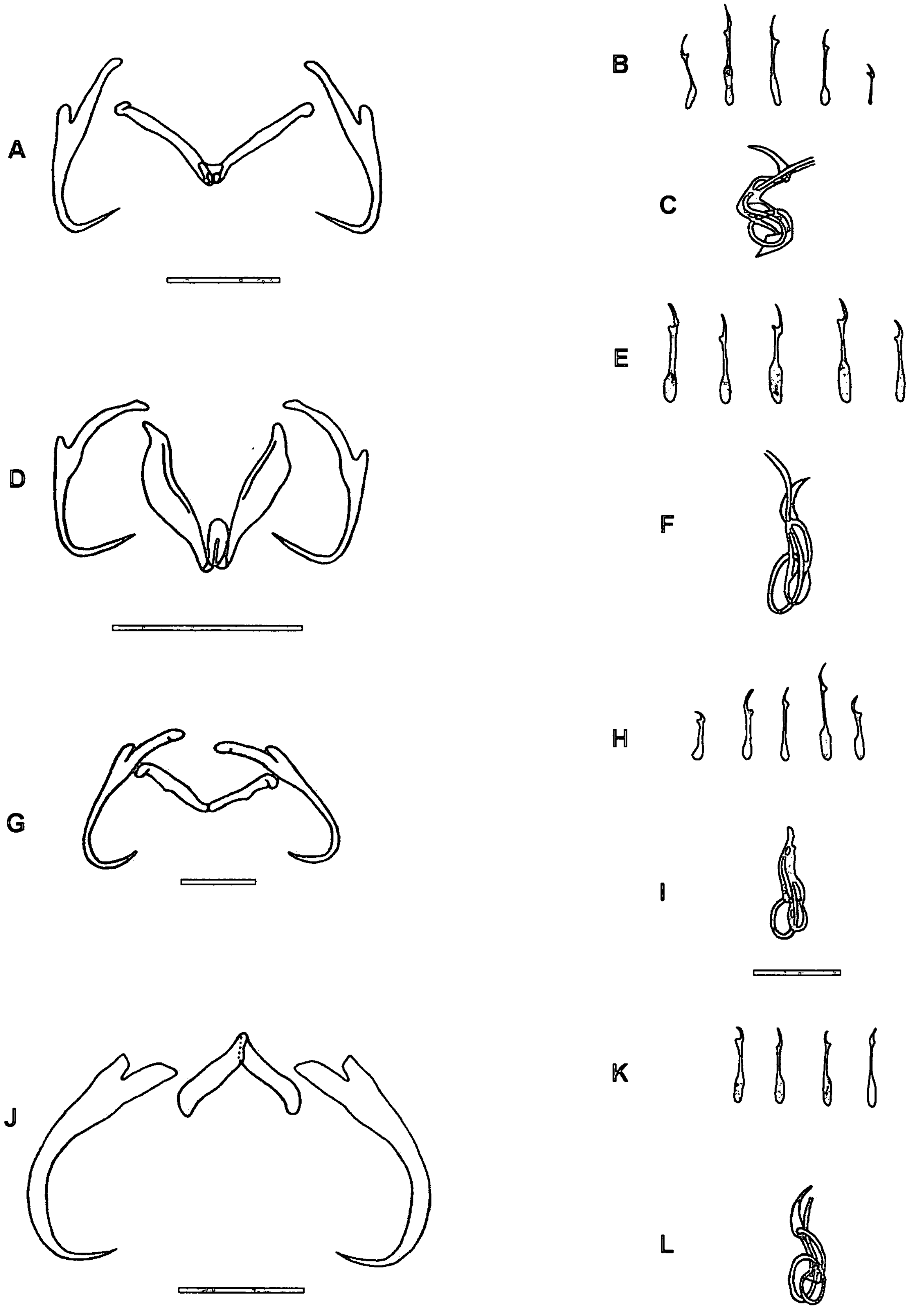


Figure. 5.8. Diagrammatic drawings of *Dactylogyrus* Diesing, 1850 species. **A-C** – *Dactylogyrus afrolongicornis afrolongicornis* Paperna, 1973 (redrawn from Paperna 1979). **A** – anchors and dorsal bar, **B** – marginal hooklets, **C** – cirrus. **D-F** – *D. afrolongicornis alberti* Papena, 1973 (redrawn from Paperna 1979). **D** – anchors and dorsal bar, **E** – marginal hooklets, **F** – cirrus. **G-I** – *D. afrosclerovaginus* Paperna, 1973 (redrawn from Paperna 1979). **G** – anchors and transvers bar, **H** – marginal hooklets, **I** – cirrus. **J-L** – *D. allolongionchus* Paeprna, 1973 (redrawn from Paperna 1979). **J** – anchors and dorsal bar, **K** – marginal hooklets, **L** – cirrus. Scale bar: 20μm

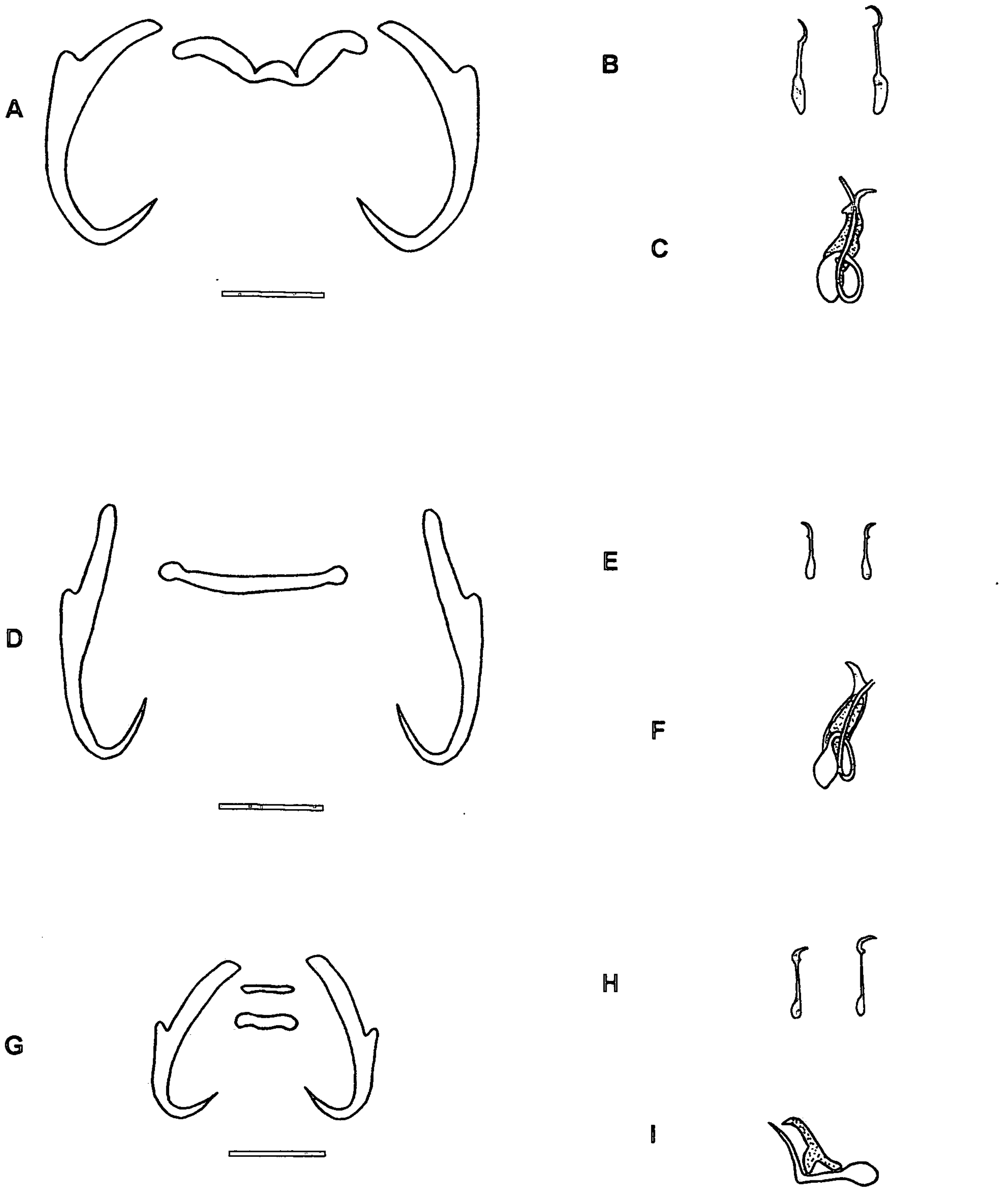


Figure. 5.9. Diagrammatic drawings of *Dactylogyrus* Diesing, 1850 species. **A-C** – *Dactylogyrus domonici* Mashego, 1983 (redrawn from Mashego 1983). **A** – anchors and dorsal bar, **B** – marginal hooklets, **C** – cirrus. **D-F** – *D. enidae* Mashego, 1983 (redrawn from Mashego 1983). **D** – anchors and dorsal bar, **E** – marginal hooklets, **F** – cirrus. **G-I** – *D. jubbstrema* Price, Korach & McPott, 1969 (redrawn from Price, Korach & McPott 1969). **G** – anchors and transvers bars, **H** – marginal hooklets, **I** – cirrus. Scale bar: 20µm

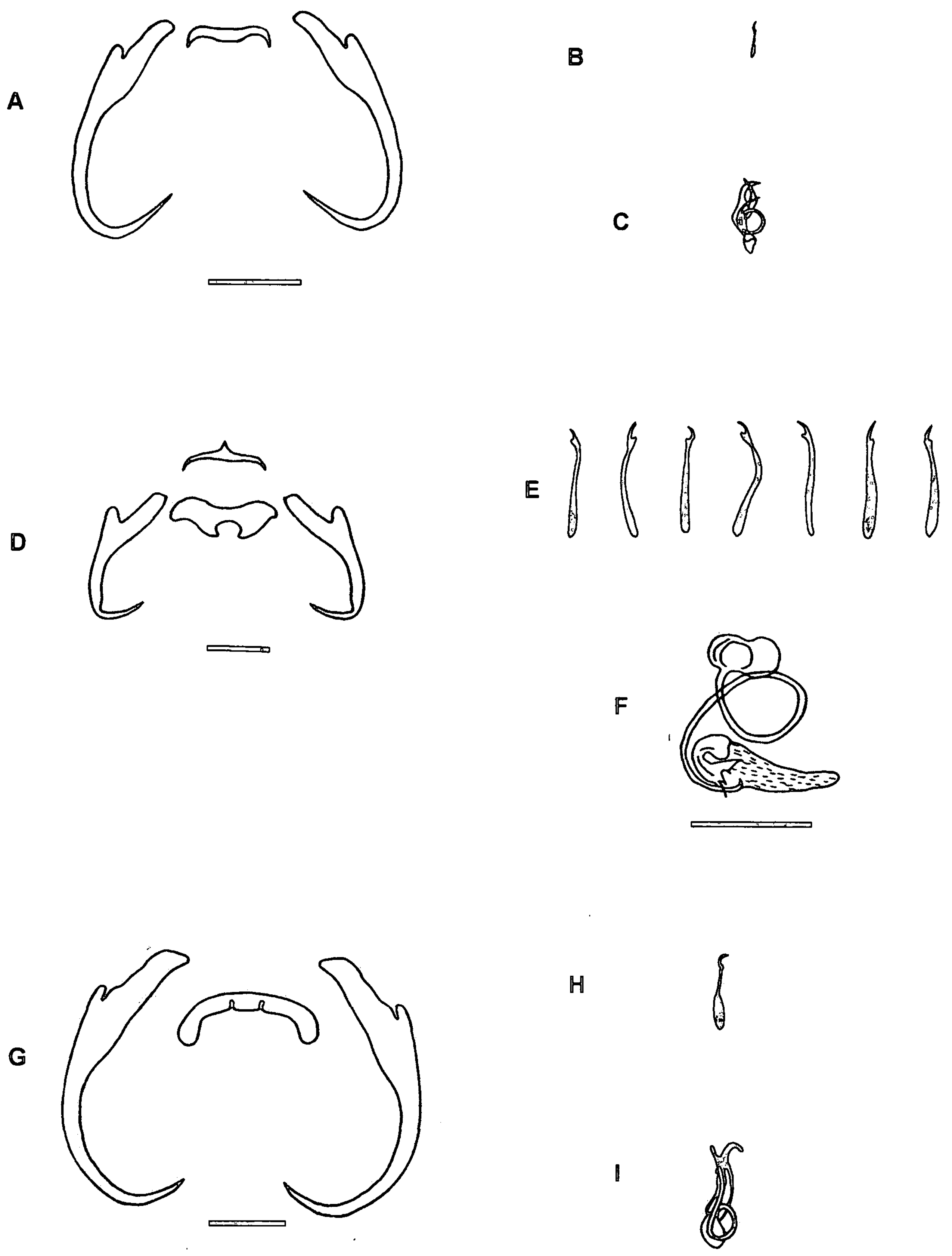


Figure. 5.10. Diagrammatic drawings of *Dactylogyrus* Diesing, 1850 species. **A-C** – *Dactylogyrus myersi* Price, McClellan, Druckenmiller & Jacobs, 1969 (redrawn from Price, McClellan, Druckenmiller & Jacobs 1969). **A** – anchors and dorsal bar, **B** – marginal hooklets, **C** – cirrus. **D-F** – *D. spinicirrus (*Paperna & Thurston, 1968) (redrawn from Paperna & Thurston 1968). **D** – anchors and dorsal bars, **E** – marginal hooklets, **F** – cirrus. **G-I** – *D. teresae* Mashego, 1983 (redrawn from Mashego 1983). **G** – anchors and transvers bar, **H** – marginal hooklets, **I** – cirrus. Scale bar: 20μm

Species recorded from *Cyprinus carpio* Linnaeus, 1758

To date, no *Dactylogyrus* species collected from *Cyprinus carpio* have been reported from Africa. The carp is an introduced species, thus the species of *Dactylogyrus* that have been recorded from carp from other parts of the world will be discussed.

According to Yamaguti (1963a) there are eight species of *Dactylogyrus* that have been recorded from *C. carpio*. The first of these was *D. auriculatus* (Nordmann, 1832) from Europe, recorded from *C. carpio*, *Phoxinus phoxinus* Linnaeus, 1758 and *Abramis brama* Linnaeus, 1758. This is also the type species of the genus. The species was redescribed by various authors, namely Roman (1953), Ergens (1956), Prost (1957) and Lucky (1959). Diesing (1850) also described another species, namely *D. dujordinianus* (Diesing, 1850) from Europe.

In 1924, Nybelin described *D. vastator* Nybelin 1924, which was recorded from Europe, Japan and Siberia from *C. carpio*, *Carassius auratus* and *C. carassius*. This species was, however, synonymised with *D. intermedius* Wegener, 1909 by Nybelin (1937), which was described from Europe.

Yamaguti (1963a) lists the following species that have also been recorded from *C. carpio* (references are, however, not provided): *D. cyprini* Buschkiel, 1930 from *C. carpio* from Java, *D. extensus* Mueller & Van Cleave 1932, from *C. carpio* from North America and from Europe, *D. solidus* Achmerow, 1948. *Dactylogyrus extensus* was redescribed by various other authors, i.e. Mueller (1936), Fantham & Porter (1948), Mizelle & Klucka (1953), and Paperna (1959) and was synonymised with *D. solidus* by Ergens (1956).

In 1952 Achmerov described another species, this time from *C. c. haematopterus*, from Russia, namely *D. falciformes* Achmerow, 1952. Three years later, Gussev described *D. achmerowi*, from carp in the Lake Khanka basin (Gussev 1955).

Comparative measurements of these species are given in Table 5.6.

Table 5.6: Measurements of species of *Dactylogyrus* Diesing, 1850 collected from *Cyprinus carpio* Linnaeus 1758. **AL**-anchor length, **AP**-length of accessory piece, **BL**-length of dorsal bar, **BW**-width of dorsal bar, **C**-length of cirrus **IR**-length of inner root. **OR**-length of outer root, **S**-shaft length, **T**-length of tip

Species	AL	S	OR	IR	T	BL	BW	C	AP
Dactylogyrus achmerowi Gussev, 1955 (Figure 5.11A, B)	68	55	5	11	5	38	5	45	61
D. auriculatus (Nordmann, 1932) (Figure 5.11C, D)	51	52	8	17	22	34	11	474	161
D. extensus (Mueller & Van Cleave, 1932) (Figure 5.11E, F)	72	66	9	16	19	44	12	77	69
D. falciformes Achmerow, 1952 (Figure 5.12A, B)	38	42	3	17	31	33	5	213	60
D. vastator Nybelin 1924 (Figure 5.12C, D)	49	43	8	14	7	39	5	46	57

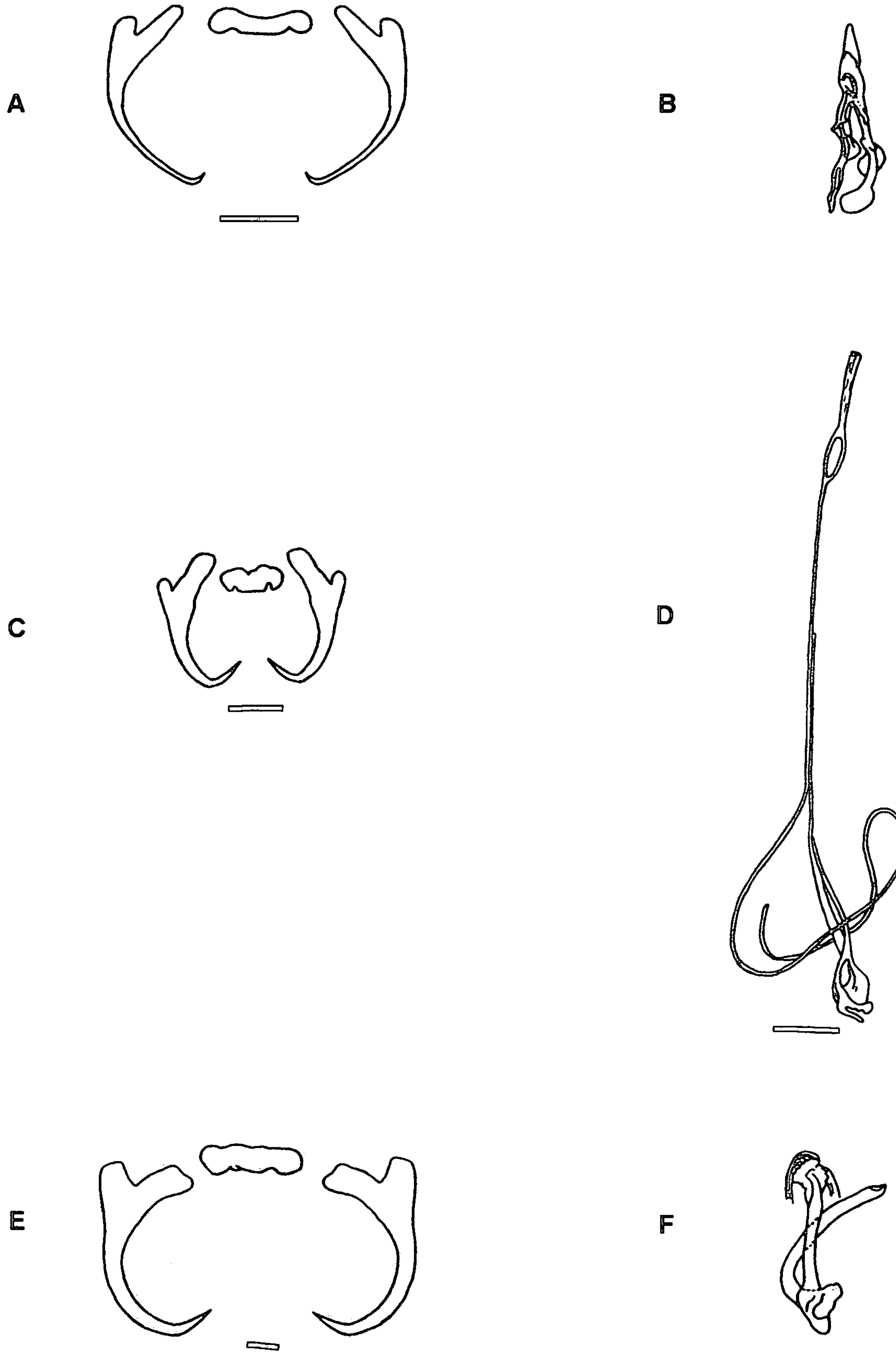


Figure. 5.11. Diagrammatic drawings of *Dactylogyrus* Diesing, 1850 species. **A**, **B**, – *Dactylogyrus achmerowi* Nordmann, 1832 (redrawn fromYamaguti 1963a). **A** – anchors and dorsal bar, **B** – cirrus. **C**, **D**,– *D. auriculatus* Gussev, 1955 (redrawn from Yamaguti 1963a). **C** – anchors and dorsal bar, **D** – cirrus. **E**, **F** – *D. extensus* (Mueller & Van Cleave, 1932 (redrawn from Yamaguti 1963a). **E** – anchors and dorsal bar, **F** – cirrus. Scale bar: 20μm

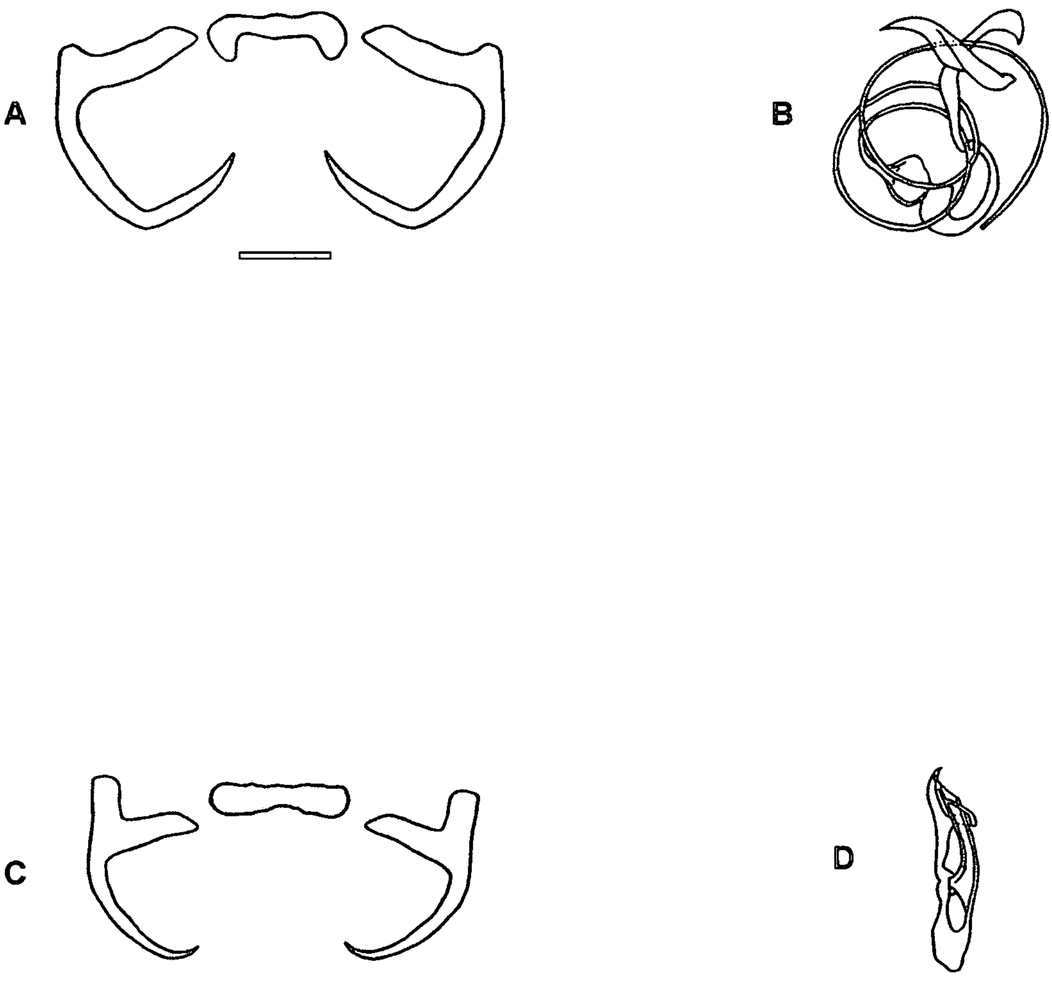


Figure. 5.12. Diagrammatic drawings of *Dactylogyrus* Diesing, 1850 species. **A**, **B**, – *Dactylogyrus falciformes* Achmerov, 1952 (redrawn from Yamaguti 1963a). **A** – anchors and dorsal bar, **B** – cirrus. **C**, **D** – *D. vastator* Nybelin, 1924 (redrawn from Yamaguti 1963a). **C** – anchors and dorsal bar **D** – cirrus. Scale bar: 20μm

The Genus *Dogielius* Bychowsky 1936

Generic Diagnosis

According to the amended generic diagnosis of Price & Yurkiewicz (1968), *Dogielius* belongs to the subfamily Dactylogyrinae. One pair of anchors is present on the haptor, and a simple dorsal bar supports the basis. Fourteen marginal hooks are present, and all are similar in shape. Four eyespots are present. The copulatory complex consists of a basally articulating accessory piece and a tubular cirrus. A double prostatic reservoir is present. The seminal vesicle is a simple dilation of the vas deferens, which is not looped around the intestinal limb, as opposed to *Dactylogyrus*. The testis is postovarian, but might overlap the ovary in the dorsal view. The vagina opens ventrally, to the right of the median line.

Species of *Dogielius* recorded from *Labeo* hosts

Twenty-two species of *Dogielius* are known from African freshwater fishes, and of these, 15 have been described from *Labeo* hosts.

The first of these was *D. junorstrema* Price & Yurkiewicz, 1969, which was described by Price & Yurkiewicz in 1968 from *Labeo ruddi* Boulenger, 1907, from Zimbabwe. Paperna (1969) described *D. tropicus* Paperna, 1969 from *L. coubie* in Ghana. Paperna also recorded the same species from *L. senegalensis* Valencienes, 1842 in the same year.

In 1973, Paperna described *D. dublicornis* Paperna, 1973 from *L. cylindricus* from Tanzania. Paperna (1979a) described two subspecies of *D. junorstrema* from *Labeo* species, one from Tanzania, namely *D. j. ruahae* Paperna, 1979 and one from Kenya, namely *D. j. victorianus* Paperna 1979. The former was collected from *L. cylindricus* and the latter from *L. victorianus*.

Guegan, Lambert & Euzet described eight species from *Labeo* in 1989, all from research done in Mali. Six of these species were described from *L. coubie*, i.e.

D. anthocolpus Guegan, Lambert & Euzet, 1989, *D. clavipenis* Guegan, Lambert & Euzet, 1989, *D. complicatus* Guegan, Lambert & Euzet, 1989, *D. flagellatus* Guegan, Lambert & Euzet, 1989, *D. grandijugus* Guegan, Lambert & Euzet, 1989 and *D. harpagatus* Guegan, Lambert & Euzet, 1989. The remaining two species were described from *L. senegalensis*, namely *D. flosculus* Guegan, Lambert & Euzet, 1989, and from *L. parvus*, namely *D. parvus* Guegan, Lambert & Euzet, 1989.

Two years later, Guegan & Lambert (1991) described another two species, both from West Africa. One species was described from *L. allauadi* namely *D. kabaensis* Guegan & Lambert, 1991, and one from *L. parvus*, namely *D. rosumplicatus* Guegan & Lambert, 1991.

A summary of the species of *Dogielius* occurring on *Labeo* hosts is given in Table 5.7 and a comparison of the measurements are given in Table 5.8.

Table 5.7. Summary of the species of *Dogielius* Bychowsky, 1936, collected from *Labeo* Cuvier, 1817 species in Africa

Species	Host	Distribution
Dogielius anthocolpus Guegan, Lambert & Euzet, 1989 (Figure 5.13A-C)	*Labeo coubie* Rüppel, 1832	Mali
D. clavipenis Guegan, Lambert & Euzet, 1989 (Figure 5.13D-F)	*L. coubie*	Mali
D. complicatus Guegan, Lambert & Euzet, 1989 (Figure 5.14A-C)	*L. coubie*	Mali
D. dublicornis Paperna, 1973 (Figure 5.14D-F)	*L. cylindricus* Peters, 1868	Tanzania
D. flagellatus Guegan, Lambert & Euzet, 1989 (Figure 5.15A-C)	*L. coubie*	Mali
D. flosculus Guegan, Lambert & Euzet, 1989 (Figure 5.15D-F)	*L. senegalensis* Valenciennes, 1842	Mali
D. grandijugus Guegan, Lambert & Euzet, 1989 (Figure 5.16A-C)	*L. coubie*	Mali
D. harpagatus Guegan, Lambert & Euzet, 1989 (Figure 5.16D-F)	*L. coubie*	Mali
D. junorstrema Price &Yurkiewicz, 1968 (Figure 5.17A-C)	*L. ruddi* Boulenger, 1907	Zimbabwe
D. j. ruahae Paperna, 1979 (Figure 5.17D-F)	*L. cylindricus*	Tanzania
D. j. victorianus Paperna, 1979 (Figure 5.18A-C)	*L. victorianus* Boulenger, 1901	Kenya
D. kabaensis Guegan & Lambert, 1991 (Figure 5.18D-F)	*L. alluaudi* Pellegrin, 1933	West Africa
D. parvus Guegan, Lambert & Euzet, 1989 (Figure 5.19A-C)	*L. parvus* Boulenger, 1902	Mali
D. rosumplicatus Guegan & Lambert, 1991 (Figure 5.D-F)	*L. parvus*	West Africa and Guinea
D. tropicus Paperna, 1969 (Figure 5.19G-I)	*L. coubie*	Ghana

Table 5.8. Measurements of *Dogielius* Bychowsky, 1936, collected from *Labeo* Cuvier, 1817 species in Africa. **AL**-anchor length, **AP**-length of accessory piece, **BL**-length of dorsal bar, **C**-length of cirrus, **S+OR**-shaft + outer root length, **T**-length of tip, **TL**-total length, **W**-greatest width.

Species	TL	W	AL	S+OR	T	BL	C	AP
D. anthocolpus Guegan, Lambert & Euzet, 1989	300-450	60-100	38-41	45-50	26-29	63-70	50	50-60
D. clavipenis Guegan, Lambert & Euzet, 1989	250-350	60-100	33-36	34-37	28-30	57-60	30	–
D. complicatus Guegan, Lambert & Euzet, 1989	350-550	110-150	47-52	45-51	25-27	62-67	310-410	80-90
D. dublicornis Paperna,1973	150-200	80	22	29	16	50-54	39	33
D. flagellatus Guegan, Lambert & Euzet, 1989	300-430	80-100	36-40	34-38	30-33	61-70	150-200	46-56
D. flosculus Guegan, Lambert & Euzet, 1989	250-350	60-100	40-46	42-49	23-29	45-50	50	37-47
D. grandijugus Guegan, Lambert & Euzet, 1989	260-450	60-110	33-37	36-41	39-43	80-100	–	32-40
D. harpagatus Guegan, Lambert & Euzet, 1989	220-350	60-80	28-32	31-37	21-25	44-51	25-30	31-38
D. junorstrema Price & Yurkiewicz, 1968	178-243	46-72	32	32	19	47-55	19-24	17-22
D. j. ruahae Paperna, 1979	150-210	70-10	19	24	14	42-48	22-30	16-25
D. j. victorianus Paperna, 1979	140-230	50-80	19	28	14	44-49	36-42	33-43
D. kabaensis Guegan & Lambert, 1991	330-420	60-80	30-36	41-45	14-17	50-56	22-30	19-22
D. parvus Guegan, Lambert & Euzet, 1989	250-350	60-90	29-33	33-38	18-22	38-47	25-30	31-34
D. rosumplicatus Guegan & Lambert, 1991	330-450	70-90	32-36	41-45	15-18	50-57	25-30	30-36
D. tropicus Paperna, 1969	250-400	70-100	35-40	39-45	21-26	55-65	35-40	32-36

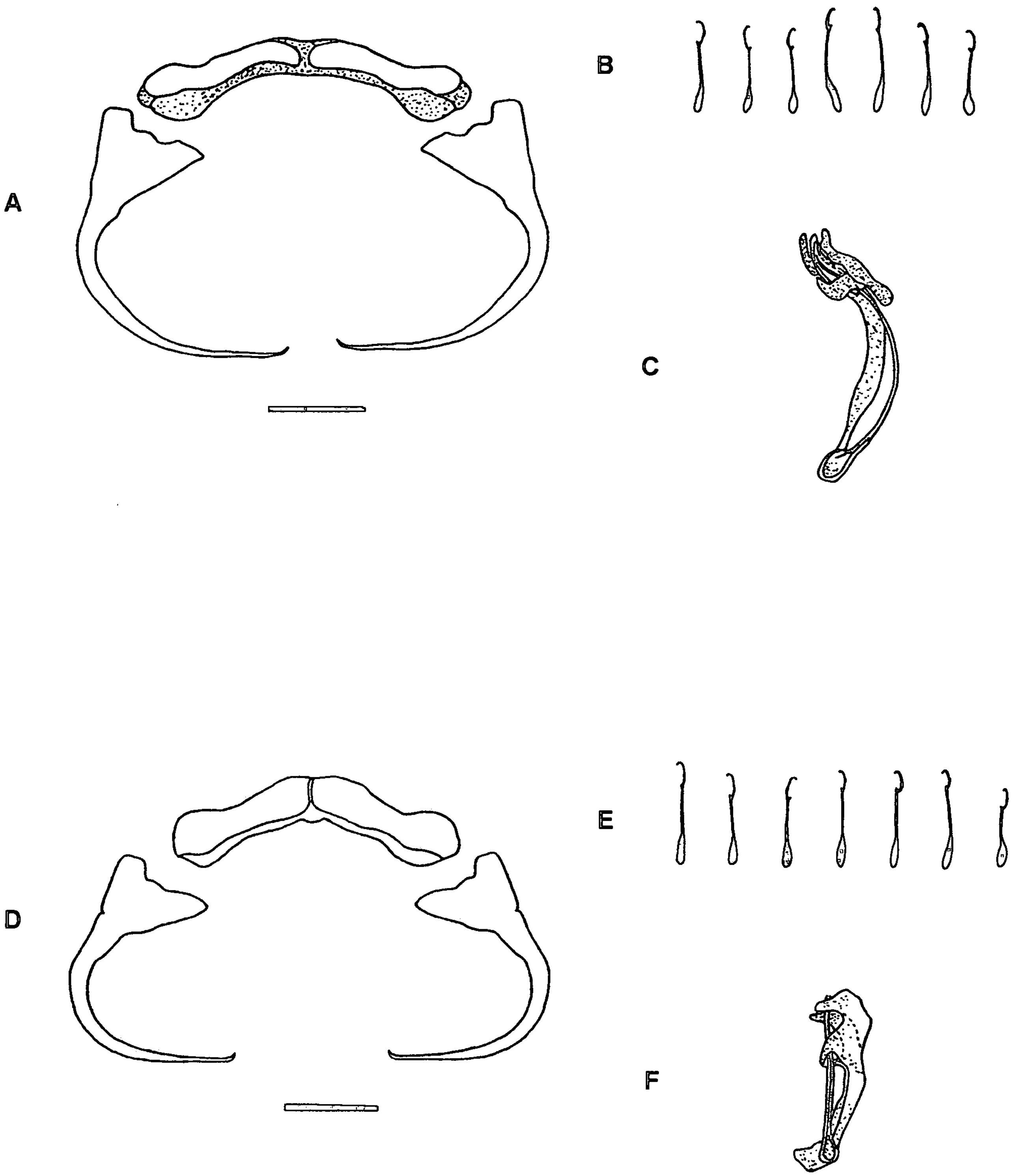


Figure. 5.13. Diagrammatic drawings of *Dogielius* Bychowsky, 1936 species. **A-C** – *Dogielius anthocolpus* Guegan, Lambert & Euzet, 1989 (redrawn from Guegan, Lambert & Euzet 1989). **A** – anchors and dorsal bar, **B** – marginal hooklets, **C** – cirrus. **D-F** – *D. clavipenis* Guegan, Lambert & Euzet, 1989 (redrawn from Guegan, Lambert & Euzet 1989). **D** – anchors and dorsal bar, **E** – marginal hooklets, **F** – cirrus. Scale bar: 20μm

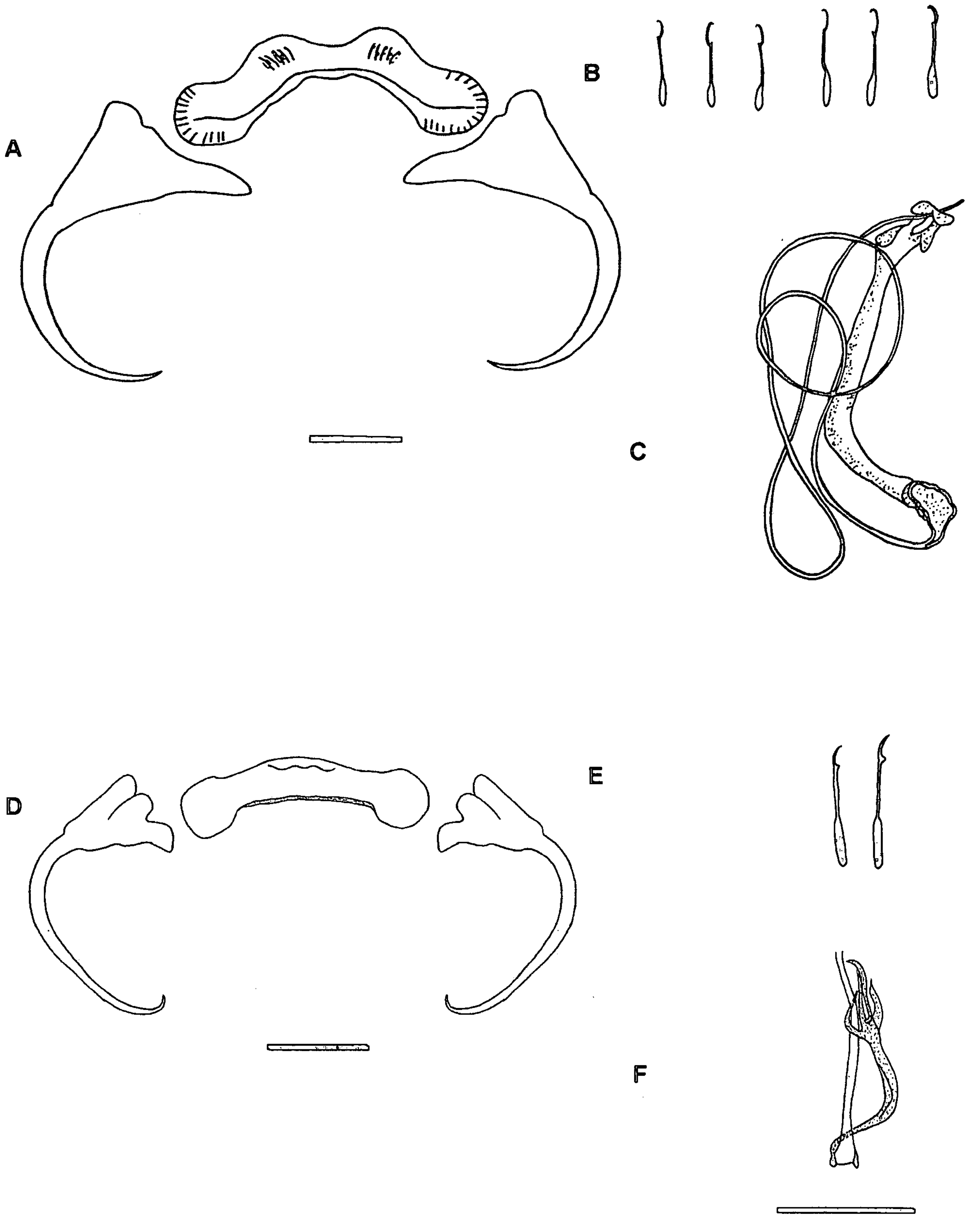


Figure. 5.14. Diagrammatic drawings of *Dogielius* Bychowsky, 1936 species. **A-C** – *Dogielius complicatus* Guegan, Lambert & Euzet, 1989 (redrawn from Guegan, Lambert & Euzet 1989). **A** – anchors and dorsal bar, **B** – marginal hooklets, **C** – cirrus. **D-F** – *D. dublicornis* Paperna, 1973 (redrawn from Paperna 1979). **D** – anchors and dorsal bar, **E** – marginal hooklets, **F** – cirrus. Scale bar: 20μm

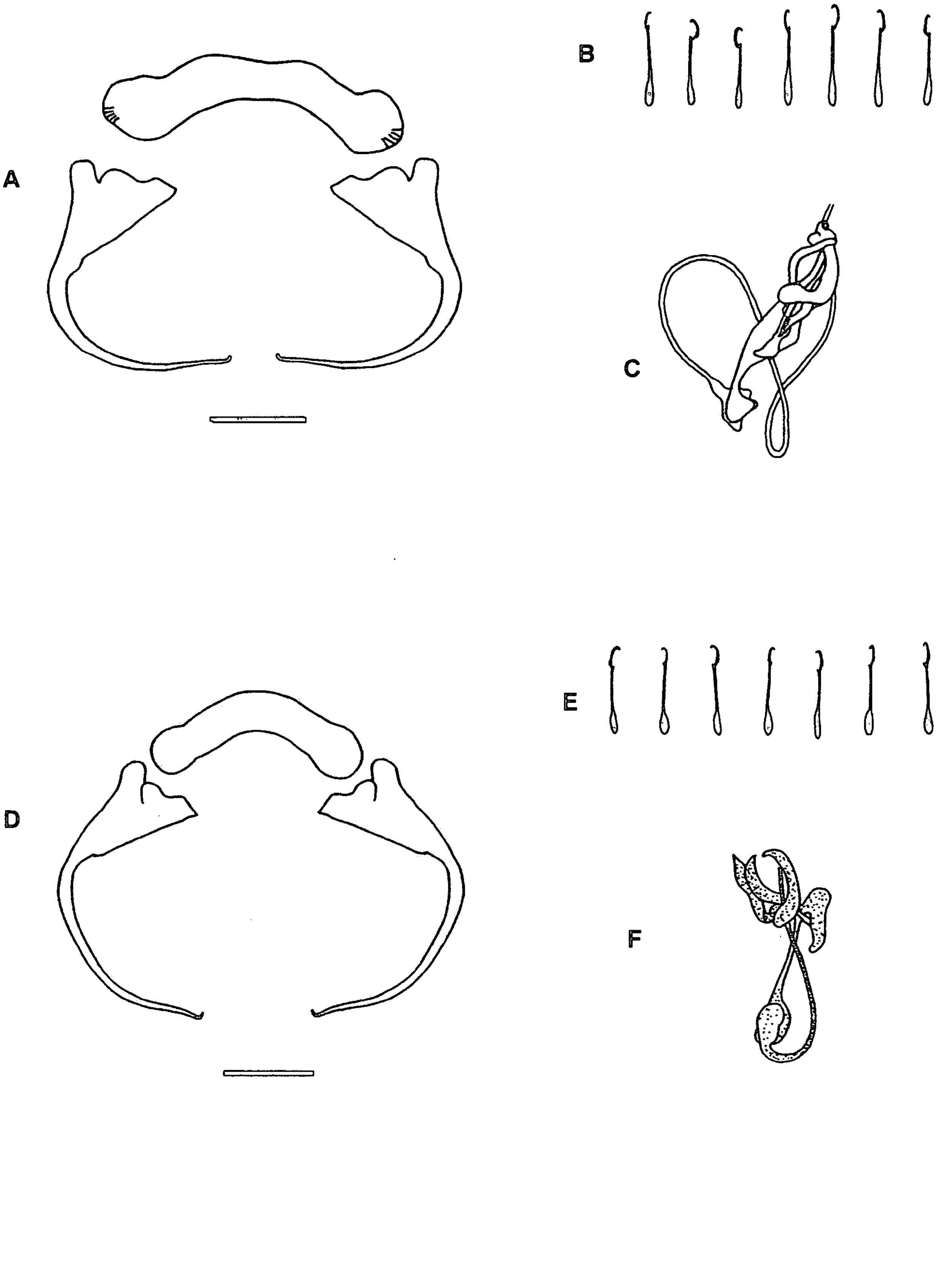


Figure. 5.15. Diagrammatic drawings of *Dogielius* Bychowsky, 1936 species. **A-C** – *Dogielius flagellatus* Guegan, Lambert & Euzet, 1989 (redrawn from Guegan, Lambert & Euzet 1989). **A** – anchors and dorsal bar, **B** – marginal hooklets, **C** – cirrus. **D-F** – *D. flosculus* Guegan, Lambert & Euzet, 1989 (redrawn from Guegan, Lambert & Euzet 1989). **D** – anchors and dorsal bar, **E** – marginal hooklets, **F** – cirrus. Scale bar: 20µm

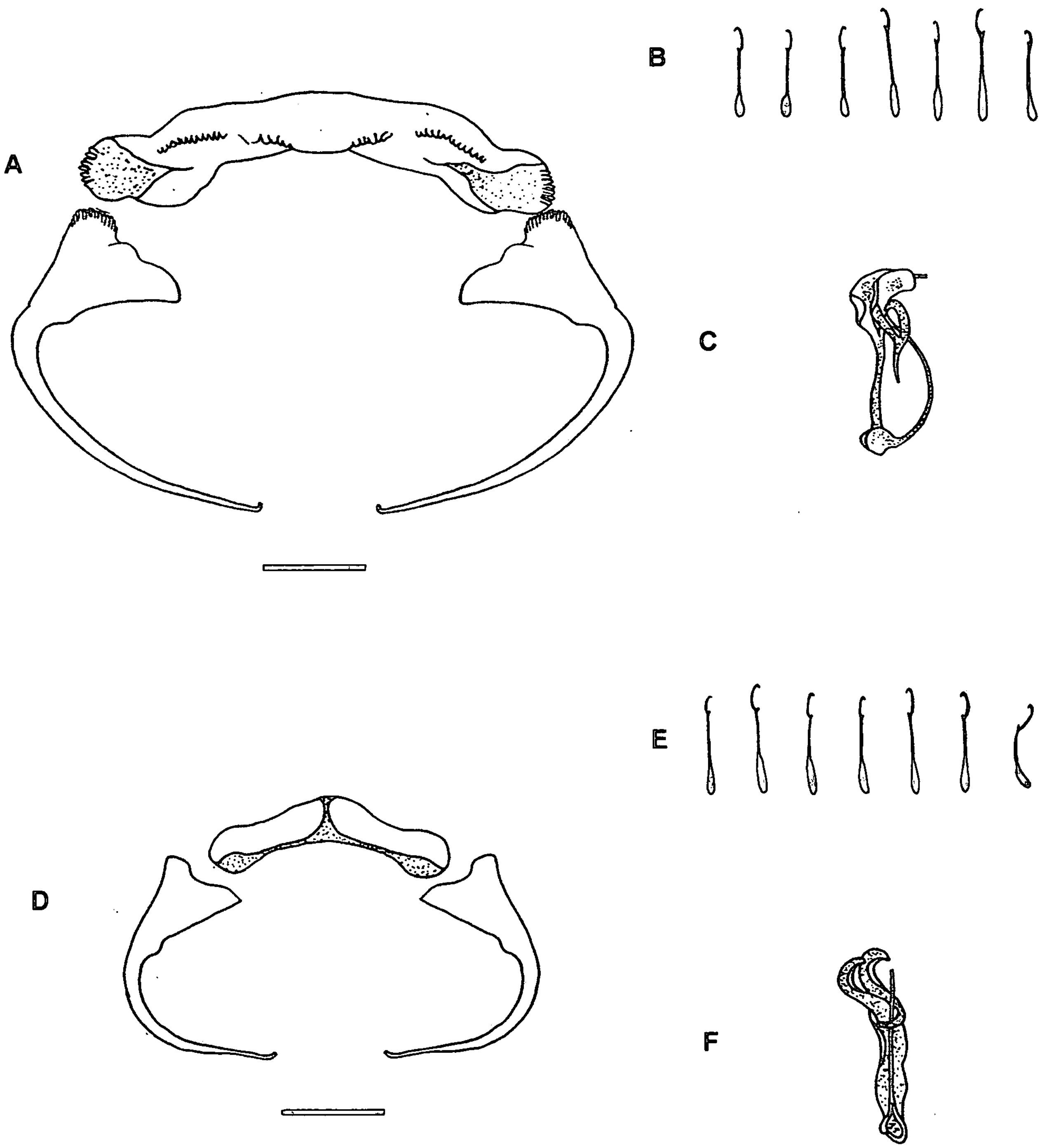


Figure. 5.16. Diagrammatic drawings of *Dogielius* Bychowsky, 1936 species. **A-C** – *Dogielius grandijugus* Guegan, Lambert & Euzet, 1989 (redrawn from Guegan, Lambert & Euzet 1989). **A** – anchors and dorsal bar, **B** – marginal hooklets, **C** – cirrus. **D-F** – *D. harpagatus* Guegan, Lambert & Euzet, 1989 (redrawn from Guegan, Lambert & Euzet 1989). **D** – anchors and dorsal bar, **E** – marginal hooklets, **F** – cirrus. Scale bar: 20μm

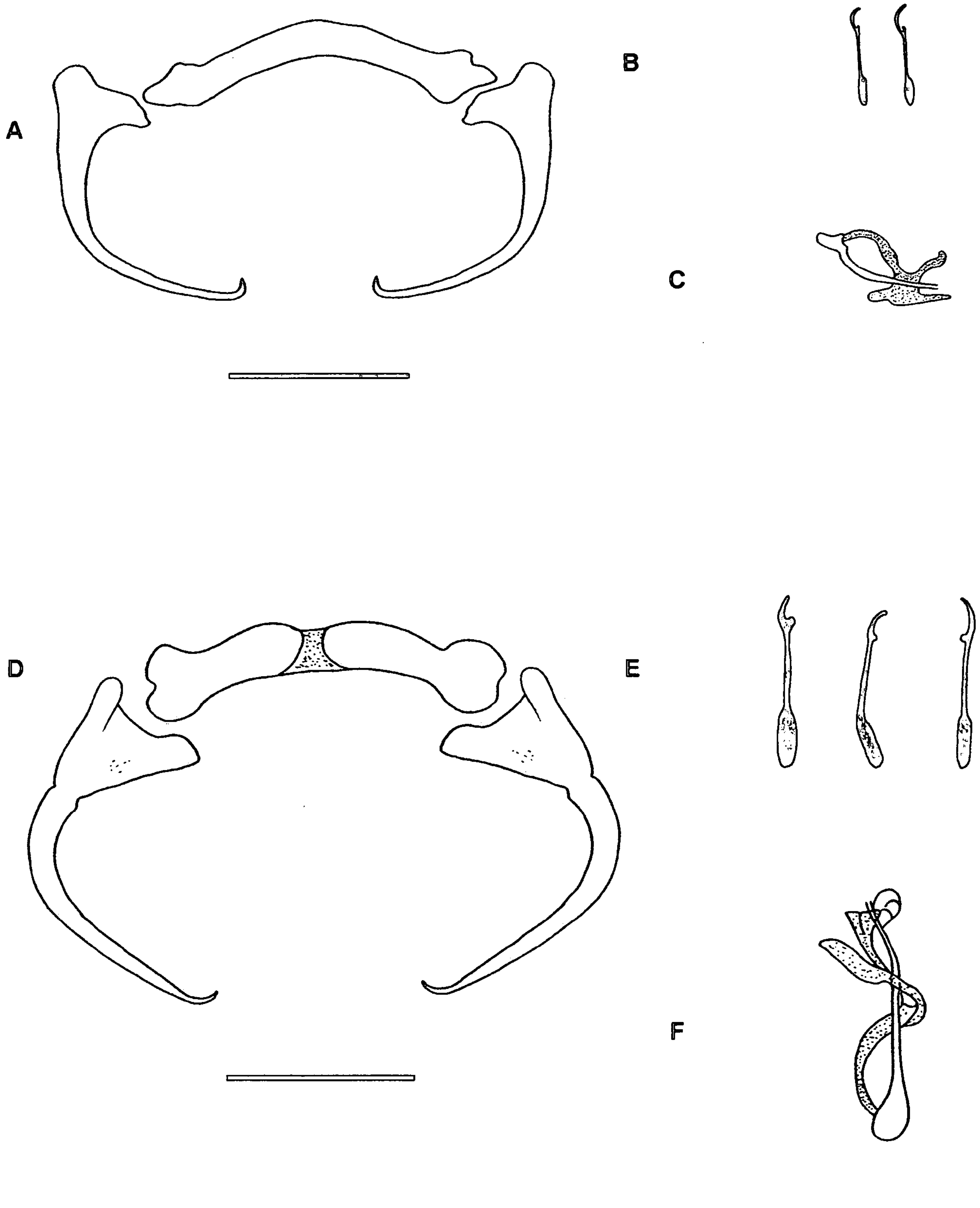


Figure. 5.17. Diagrammatic drawings of *Dogielius* Bychowsky, 1936 species. **A-C** – *Dogielius junorstrema* Price & Yurkiewicz, 1968 (redrawn from Price & Yurkiewicz 1968). **A** – anchors and dorsal bar, **B** – marginal hooklets, **C** – cirrus. **D-F** – *D. junorstrema ruahae* Paperna, 1979 (redrawn from Paperna 1979). **D** – anchors and dorsal bar, **E** – marginal hooklets, **F** – cirrus. Scale bar: 20µm

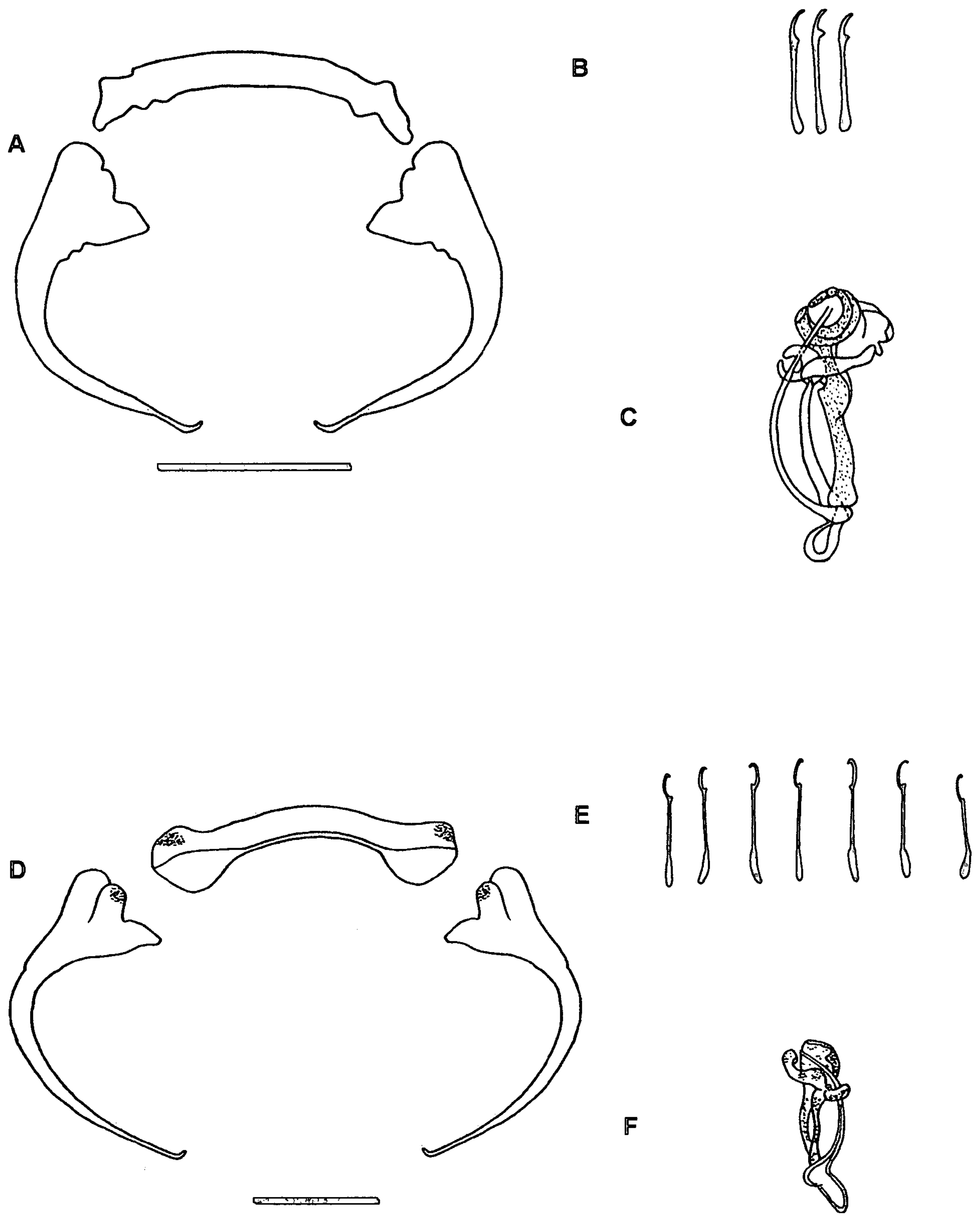


Figure. 5.18. Diagrammatic drawings of *Dogielius* Bychowsky, 1936 species. **A-C** – *Dogielius junorstrema victorianus* Paperna, 1979 (redrawn from Paperna 1979). **A** – anchors and dorsal bar, **B** – marginal hooklets, **C** – cirrus. **D-F** – *D. kabaensis* Guegan & Lambert, 1991 (redrawn from Guegan & Lambert 1991). **D** – anchors and dorsal bar, **E** – marginal hooklets, **F** – cirrus. Scale bar: 20µm

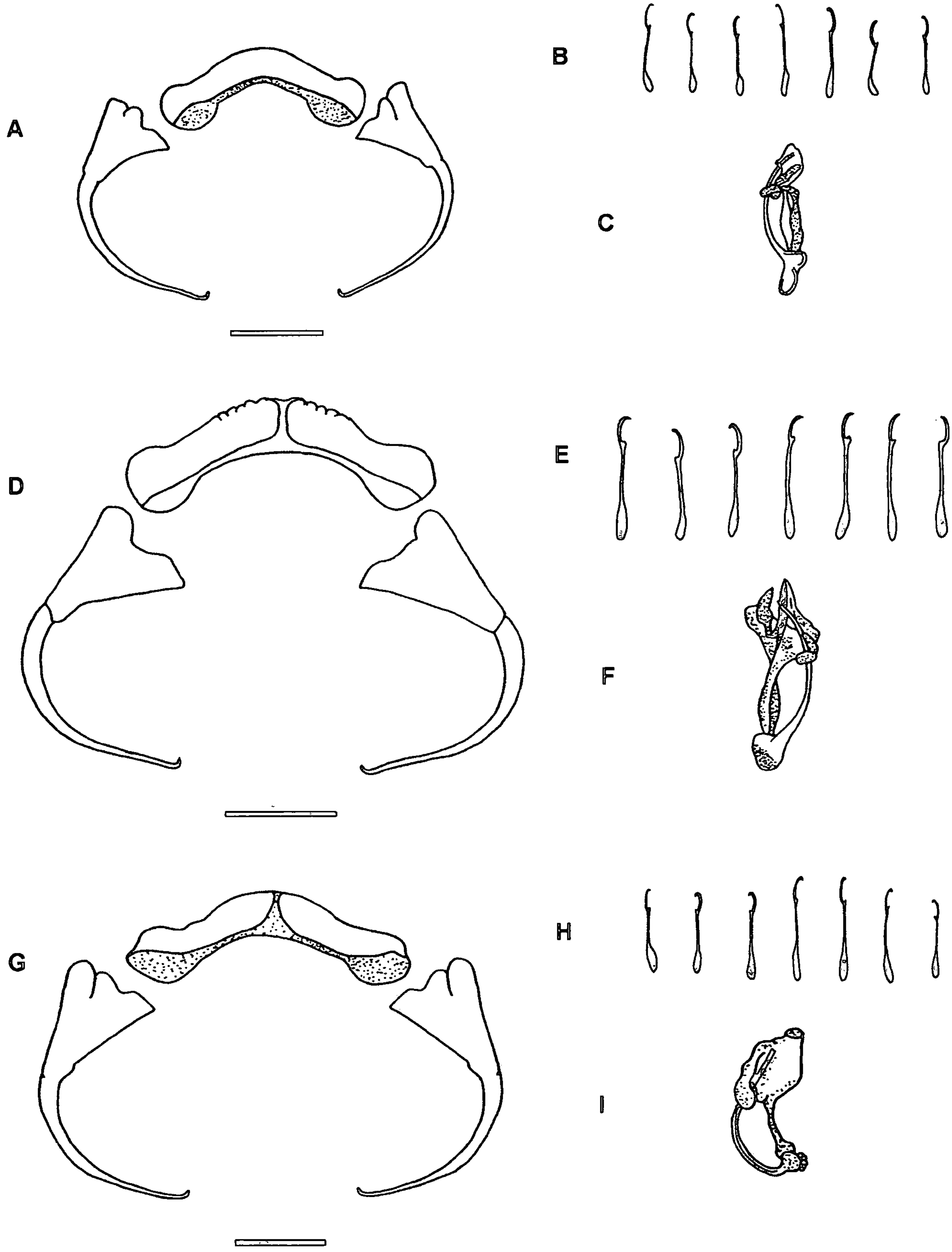


Figure. 5.19. Diagrammatic drawings of *Dogielius* Bychowsky, 1936 species. **A-C** – *Dogielius parvus* Guegan, Lambert & Euzet, 1989 (redrawn from Guegan, Lambert & Euzet 1989). **A** – anchors and dorsal bar, **B** – marginal hooklets, **C** – cirrus. **D-F** – *D. rosumplicatus* Guegan & Lambert 1991 (redrawn from Guegan & Lambert 1991). **D** – anchors and dorsal bar, **E** – marginal hooklets, **F** – cirrus. **G-I** – *D. tropicus* Paperna, 1969 (redrawn from Guegan & Lambert 1991). **G** – anchors and dorsal bar, **H** – marginal hooklets, **I** – cirrus. Scale bar: 20µm

Dactylogyridean species from *Clarias gariepinus* (Burchell, 1822)

In Africa, the genus *Quadriacanthus* Paperna, 1961, comprises 24 species which parasitise the gills of siluriform fishes, except for one species described from a representative of the Cichlidae (Paperna, 1979a). The latter, however, (*Quadriacanthus tilapiae* Paperna, 1973), is considered an accidental infestation (Kritsky & Kulo 1988; Lim, Timofeeva & Gibson 2001). The remaining species of *Quadriacanthus* have all been described from three host genera, namely *Clarias*, *Heterobranchus* Geoffroy-Saint-Hillaire, 1809 and *Bagrus* Forsskål, 1775.

The Genus *Quadriacanthus* Paperna, 1961

Generic Diagnosis

The genus *Quadriacanthus*, as initially described by Paperna (1961) belongs to the family Dactylogyridae Bychowsky, 1933 and the subfamily Ancyrocephalinae, Bychowsky, 1937. Kritsky & Kulo (1988), however, emended this description. They divided the body into four regions, namely a cephalic region, a trunk, peduncle and haptor. The tegument is thin and smooth and there are four pairs of cephalic lobes present, two lateral and two terminal. Four pairs of head organs are present. The cephalic glands are unicellular and comprise two bilateral groups, situated posterolateral to the pharynx. Eyes may be present or absent, and the granules are scattered in the cephalic region.

The mouth is situated subterminally and midventrally. A muscular, glandular pharynx is present, leading to a short oesophagus. Two intestinal caeca are present, which confluent posterior to the gonads which are situated intercaecally and overlap with the testis dorsal to the ovary. The seminal vesicle is a dilation of the vas deferens, and is situated diagonally to the left of the midline in the anterior trunk, with the vas deferens looping around the left intestinal caecum. Two C-shaped prostatic reservoirs are present, the one wrapping around the other. The copulatory complex consists of a basally articulated cirrus, and the accessory piece. A short oviduct and delicate uterus is present. The vagina opens on the sinistral side of the body, and the seminal receptacle is situated ventral to the anterior end of the ovary, and is intercaecal. Well-developed vitellaria is dispersed in two bilateral bands, extending with intestinal caeca.

The haptor is armed with dorsal, as well as ventral anchors, each with a basal accessory sclerite. A dorsal bar with expanded midregion and bilateral arms is present. There is also a ventral bar consisting of two medially articulating components. A posterior muscle pad is situated between the bars. Fourteen marginal hooklets are present, with an ancyrocephaline distribution. Hook pair six posses an elongated proximal dilation of the shank, while pairs one and seven have a short proximal dilation of the shank. In pairs two, three, four and five, the dilated shank is absent.

Species of *Quadriacanthus* Paperna, 1961 recorded from African siluriform fishes

Paperna (1961) created the genus *Quadriacanthus* to accommodate *Quadriacanthus clariadis*, which he described from *Clarias gariepinus*, from Lake of Galilee in Israel. Paperna (1965) then described another species of *Quadriacanthus* from *Clarias walkeri* Gunther, 1896 namely *Q. voltaensis*, from Ghana.

Eight years later, Paperna (1973) described *Q. tilapiae* Paperna, 1973, from a single specimen, which was found on *Oreochromis esculentus* Graham, 1928 from Uganda. This species has not been recorded since the initial description, and Kritsky & Kulo (1988) believe that this species is a synonym of *Q. bagrae* Paperna, 1979.

In the late seventies, Paperna (1979a) subdivided *Quadriacanthus clariadis* into three subspecies, namely *Q. c. allobychowskiella* Paperna, 1979 parasitising *Clarias gariepinus* from Uganda, *Q. c. bagrae* Paperna, 1979 parasitising *Bagrus bajad* (Forsskål, 1775), also from Uganda and *Q. c. clariadis* from Israel. In

1986, El-Naggar & Serag described another species from Egypt, namely *Q. aegypticus* El-Naggar & Serag, 1986, also from *Clarias gariepinus*.

In a comprehensive study on the African species, the three subspecies described by Paperna were, however, raised to species level by Kritsky & Kulo (1988). They also gave a redescription of the genus, and *Q. clariadis*, and described three new species from Egypt, namely *Q. ashuri* Kritsky & Kulo, 1988, *Q. papernai* Kritsky & Kulo, 1988, and *Q. numidus* Kritsky & Kulo, 1988, all from work done on *Clarias gariepinus*. Two undescribed species were discovered amongst the specimens that were labelled as paratype material of *Q. clariadis*.

Birgi (1988) described four new species, three from *Clarias jaensis* Boulenger, 1909 and one from *Clarias pachynema* Boulenger, 1903. All of these species were described from Cameroon waters.

During 1995, Douëllou & Chishawa recorded three known species from research done in Zimbabwe, namely *Q. aegypticus, Q. bagrae* Paperna, 1979, and *Q. numidus*, collected from *Clarias gariepinus*.

In the late nineties, N' Douba, Lambert & Euzet (1999) did research in the Ivory Coast on *Heterobranchus isopterus* Bleeker, 1863 and *H. longifilis* Valenciennes, 1840 and described seven new species. Two new species were described by N'Douba & Lambert also from the Ivory Coast in 2001, namely *Q. eboreus* N'Douba & Lambert, 2001, and *Q. ivoiriensis* N'Douba & Lambert, 2001, both parasitising *Clarias ebriensis* Pellegrin, 1920.

The African species of *Quadriacanthus* is summarised in Table 5.9. Comparative measurements of the species recorded from *C. gariepinus* are given in Table 5.10.

Table 5.9. Summary of the known African species of *Quadriacanthus* Paperna, 1961, the hosts and distribution

Species	Host	Distribution
Q. aegypticus El-Naggar & Serag, 1986 (Figure 5.20A-D)	*Clarias gariepinus* (Burchell, 1822)	Egypt and Zimbabwe
Q. agnebiensis N'Douba, Lambert & Euzet, 1999	*Heterobranchus isopterus* Bleeker, 1863	Ivory Coast
Q. allobychowskiella Paperna, 1979 (Figure 5.20E-H)	*Clarias gariepinus*	Uganda and Egypt
Q. ashuri Kritstky & Kulo, 1988 (Figure 5.21A-D)	*Clarias gariepinus*	Egypt
Q. ayameensis N'Douba, Lambert & Euzet, 1999	*Heterobranchus isopterus*	Ivory Coast
Q. bagrae Paperna, 1979 (Figure 5.21E-H)	*Bagrus bajad* (Forsskål, 1775)	Uganda, Tanzania, Zimbabwe and Egypt
Q. clariadis Paperna, 1961 (Figure 5.22A-D)	*Clarias gariepinus*	Uganda, Zimbabwe, Ghana and Egypt
Q. dageti Birgi, 1988	*Clarias jaensis* Boulenger, 1909	Cameroon
Q. eboreus N'Douba & Lambert ,2001	*Clarias ebriensis* Pellegrin, 1920	Ivory Coast
Q. goureni N'Douba, Lambert & Euzet, 1999	*Heterobranchus isopterus*	Ivory coast
Q. ivoiriensis N'Douba & Lambert, 2001	*Clarias ebriensis*	Ivory Coast
Q. lavequei Birgi, 1988	*Clarias pachynema* Boulenger 1903	Cameroon
Q. longifilisi N'Douba, Lambert & Euzet, 1999	*Heterobranchus longifilis* Valenciennes, 1840	Ivory Coast
Q. macrocirrus N'Douba, Lambert & Euzet, 1999	*Heterobranchus isopterus*	Ivory Coast
Q. numidus Kritsky & Kulo, 1988 (Figure 5.22E-H)	*Clarias gariepinus*	Egypt and Zimbabwe
Q. nyongensis Birgi, 1988	*Clarias jaensis*	Cameroon
Q. papernai Kritsky & Kulo, 1988 (Figure 5.23A-D)	*Clarias gariepinus*	Egypt
Q. simplex N'Douba, Lambert & Euzet, 1999	*Heterobranchus isopterus*	Ivory Coast
Q. teugelsi Birgi, 1988	*Clarias jaensis*	Cameroon
Q. thysi N'Douba, Lambert & Euzet, 1999	*Heterobranchus longifilis*	Ivory Coast
Q. tilapiae Paperna, 1973	*Oreochromis esculentus* (Graham, 1928)	Uganda
Q. voltaensis Paperna, 1979 (Figure 5.23E-H)	*Clarias walkeri* Gunther, 1896	Ghana and Egypt
Q. spp. 1 & 2 Kritsky & Kulo, 1988	*Heterobranchus isopterus*	Ghana

Table 5.10. Measurements of *Quadriacanthus* Paperna, 1961 species collected from *Clarias gariepinus* (Burchell, 1822). AP-length of accessory piece, C-length of cirrus, DA-length of dorsal anchor, DB-length of dorsal bar, DAB-base width of dorsal bar, TL-total length, VA-length of ventral anchor, VB-length of ventral bar, VAB-base width of ventral anchor, W-greatest width

Species	TL	W	VA	VAB	DA	DAB	VB	DB	C	AP
Q. aegypticus El-Naggar & Serag, 1986	313-502	76-105	36-44	13-18	43-51	13-18	39-53	45-74	40-52	33-49
Q. allobychowskiella Paperna, 1979	380-499	88-105	26-31	8-15	44-51	15-18	44-56	51-74	41-48	30-43
Q. ashuri Kritstky & Kulo 1988	340-431	101-165	35-38	12-14	37-42	12-14	33-45	56-75	38-43	28-29
Q. bagrae Paperna, 1979	287-481	80-126	30-34	9-12	33-42	12-16	42-64	51-78	23-27	17-21
Q. clariadis Paperna, 1961	343-444	71-134	29-34	9-11	47-72	12-15	42-65	52-72	22-31	17-26
Q. numidus Kritsky & Kulo, 1988	346-432	80-121	40-44	10-13	43-47	12-15	44-48	44-47	28-32	20-24
Q. papernai Kritsky & Kulo, 1988	329-461	78-108	33-41	8-13	34-37	9-13	24-33	40-49	35-43	29-37
Q. voltaensis Paperna, 1979	□	□	30-34	9-12	33-42	12-16	42-64	51-78	23-27	17-21

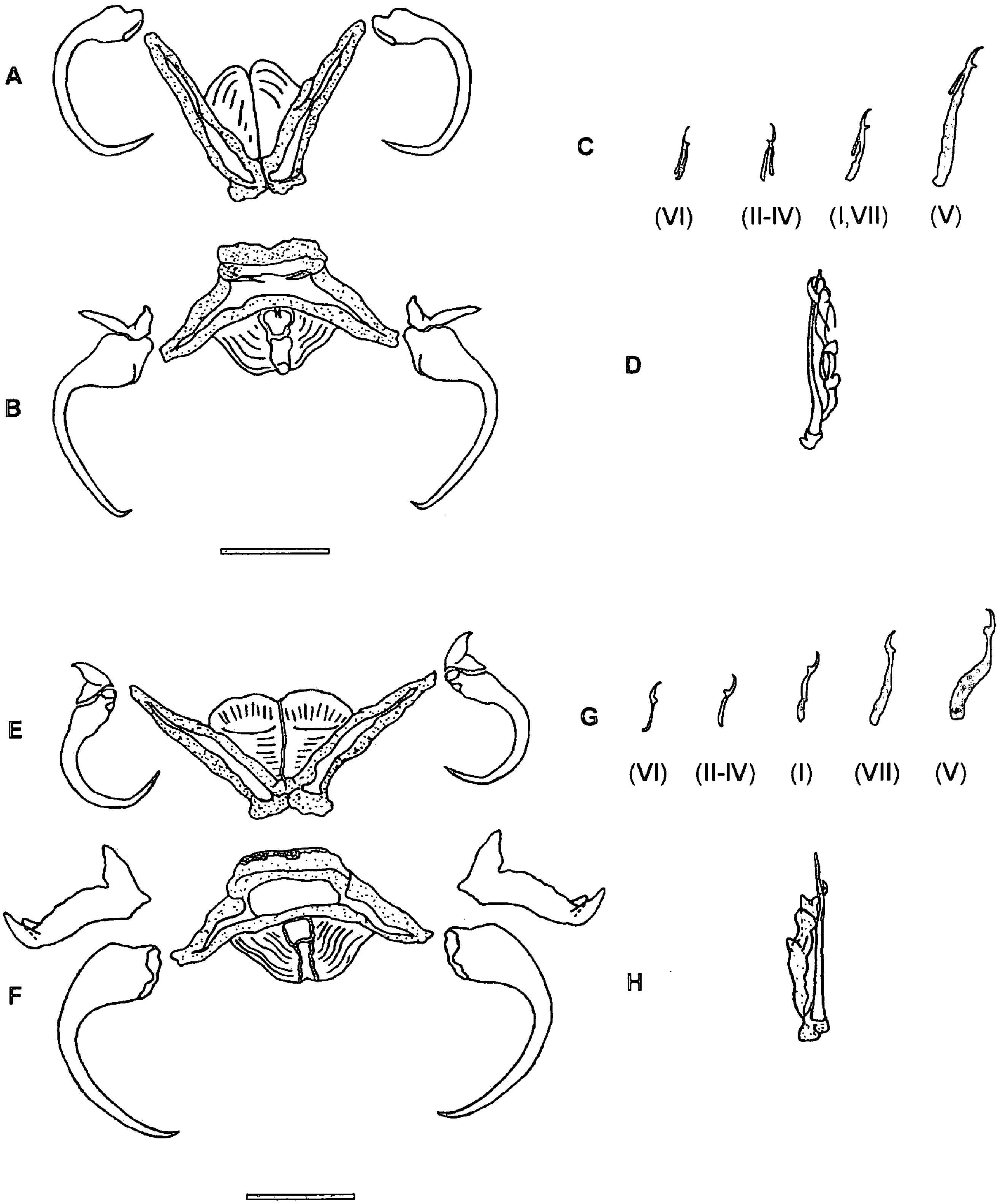


Figure. 5.20. Diagrammatic drawings of haptoral structures and cirrus of *Quadriacanthus* Paperna, 1961 species. **A-D** – *Q. aegypticus* El-Naggar & Serag, 1986 (redrawn from Kritsky & Kulo 1988). **A** – ventral bar and anchors, **B** – dorsal bar and anchors, **C** – marginal hooklets, **D** – cirrus. **E-H** – *Q. allobychowskiella* Paperna, 1979 (redrawn from Kritsky & Kulo 1988). **E** – ventral bar and anchors, **F** – dorsal bar and anchors, **G** – marginal hooklets, **H** – cirrus. Scale bar: 25µm

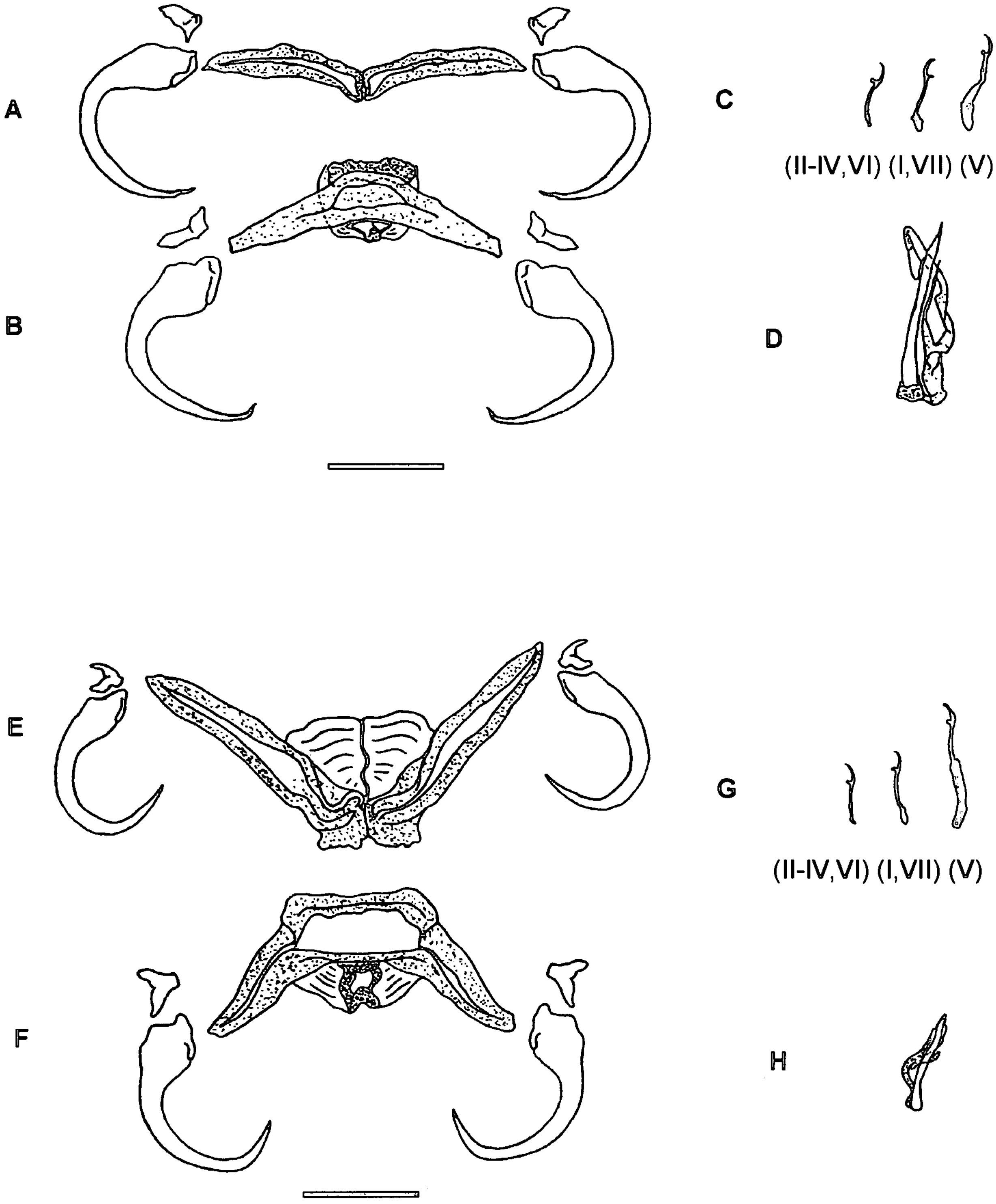


Figure. 5.21. Diagrammatic drawings of haptoral structures and cirrus of *Quadriacanthus* Paperna, 1961 species. **A-D** – *Q. ashuri* Kritsky & Kulo, 1988 (redrawn from Kritsky & Kulo 1988). **A** – ventral bar and anchors, **B** – dorsal bar and anchors, **C** – marginal hooklets, **D** – cirrus. **E-H** – *Q. bagrae* Paperna, 1979 (redrawn from Kritsky & Kulo 1988). **E** – ventral bar and anchors, **F** – dorsal bar and anchors, **G** – marginal hooklets, **H** – cirrus. Scale bar: 25μm

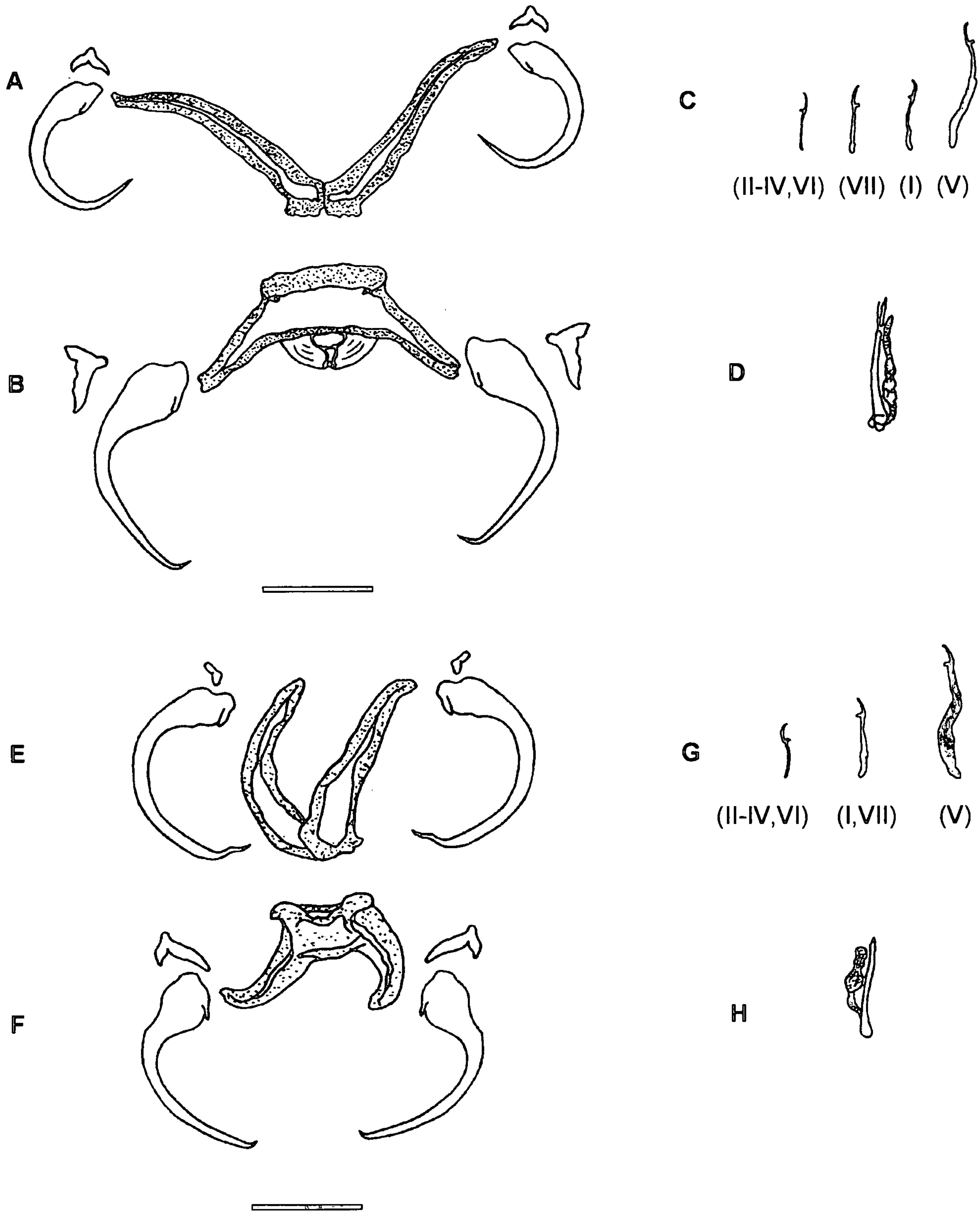


Figure. 5.22. Diagrammatic drawings of haptoral structures and cirrus of *Quadriacanthus* Paperna, 1961 species. **A-D** – *Q. clariadis* Paperna, 1961 (redrawn from Kritsky & Kulo 1988). **A** – ventral bar and anchors, **B** – dorsal bar and anchors, **C** – marginal hooklets, **D** – cirrus. **E-H** – *Q. numidus* Kritsky & Kulo, 1988 (redrawn from Kritsky & Kulo 1988). **E** – ventral bar and anchors, **F** – dorsal bar and anchors, **G** – marginal hooklets, **H** – cirrus. Scale bar: 25μm

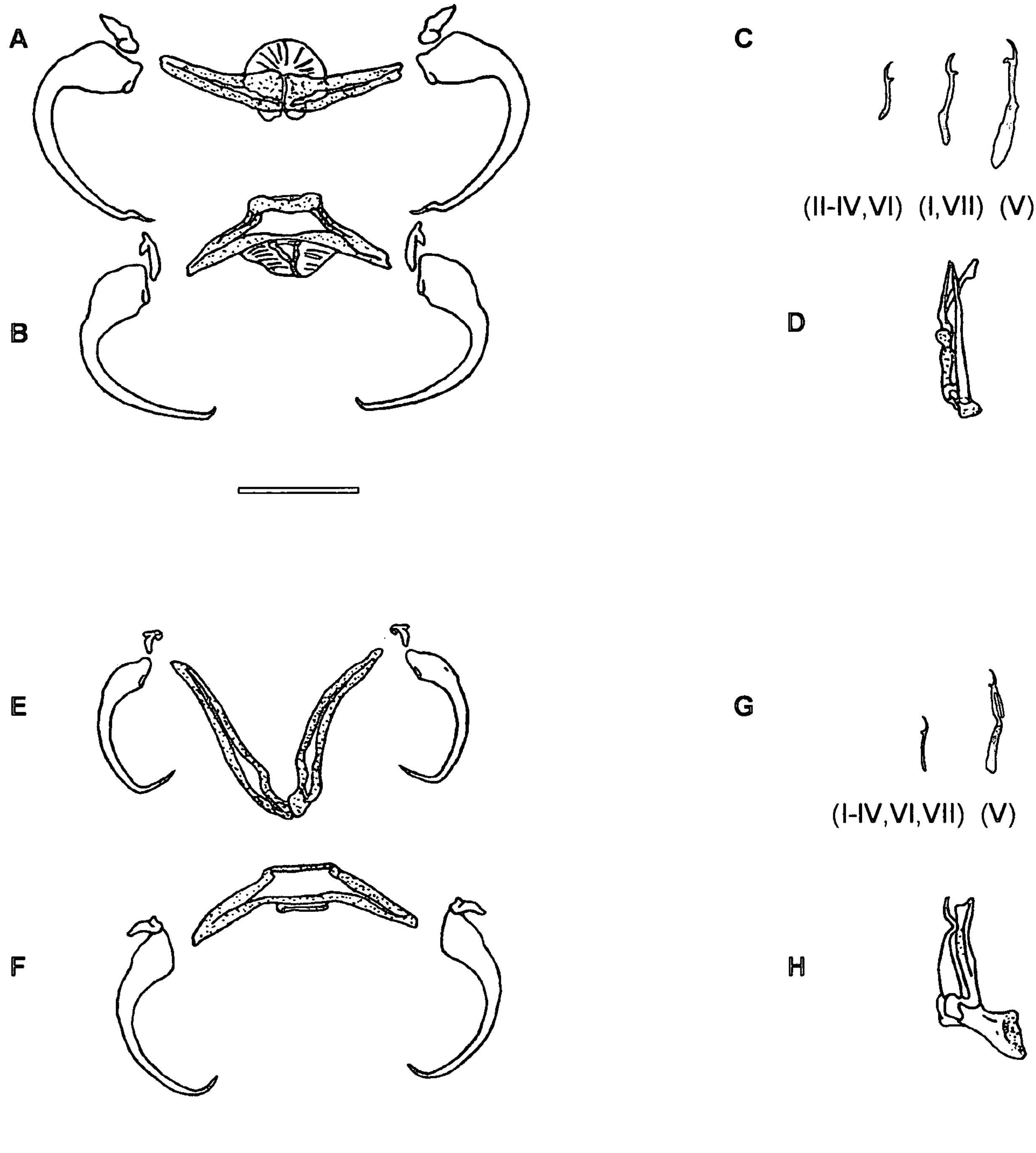


Figure. 5.23. Diagrammatic drawings of haptoral structures and cirrus of *Quadriacanthus* Paperna, 1961 species. **A-D** – *Q. papernai*, Kritsky & Kulo, 1988 (redrawn from Kritsky & Kulo 1988). **A** – ventral bar and anchors, **B** – dorsal bar and anchors, **C** – marginal hooklets, **D** – cirrus. **E-H** – *Q. voltaensis* Paperna, 1979 (redrawn from Kritsky & Kulo 1988). **E** – ventral bar and anchors, **F** – dorsal bar and anchors, **G** – marginal hooklets, **H** – cirrus. Scale bar: 25μm

Diplozoid monogeneans

Diplozoid monogeneans are characterised by adult worms that are in permanent fusion in the form of a cross (Yamaguti 1963a), and the absence of copulatory organs. According to Khotenovsky (1985) the body of these worms can be divided into two regions, an anterior part, ahead of the region of fusion, and a posterior part, behind the region of fusion. There are usually four pairs of clamps present on the haptor, and one pair of crooked anchors. Currently, there are two species of *Paradiplozoon* Achmerov, 1974 known from Africa.

The Genus *Paradiplozoon* Achmerov, 1974

Generic Diagnosis

According to Khotenovsky (1985), *Paradiplozoon* Achmerov, 1974 species differ from other diplozoids in that they have no enlargements in the posterior part of the body. The posterior part can also be divided into two regions, and in the anterior region folds may be present or absent, which vary in size between species. Gonads are situated in the anterior region of the posterior part of the body. The testes are single and protuberant. The uterus outlet is lateral, and situated on the border between the two sections of the posterior part of the body.

Paradiplozoon Achmerov, 1974 species from African fishes

Thomas (1957) described the first diplozoid species from Africa. This species was described from Ghana, namely *Diplozoon ghanense* Thomas, 1957 from *Alestes macrolepidotus*. In 1963 Fischtkal & Kuntz described *D. aegyptensis* Fischtkal & Kuntz, 1963 collected from *Labeo forskalii* from Egypt. Khotenovsky (1985) later placed both these species in the genus *Paradiplozoon*, on the grounds that there are no enlargements present in the posterior part of the body. Measurements comparing the known species are given in Table 5.11.

Table 5.11. Measurements of *Paradiplozoon* Achmerov, 1974 species known from Africa. **AL**-anterior length, **AW**-anterior width, **CL**-clamp length, **CW**-clamp width, **EL**-length of egg, **EW**-egg width, **PL**-posterior length, **PW**-posterior width, **TL**-total length

Species	TL	AL	AW	PL	PW	CL	CW	EL	EW
P. ghanense (Thomas, 1957)	3210-3830	1860-2540	540-740	380-480	380-480	120-160	100-110	260-	1150
P. aegyptensis (Fischthal & Kuntz, 1965)	3620-5767	1879-3452	299-836	867-1871	130-245	65-79	92-102	81-132	254-313

Branchial monogeneans from Soetdoring Nature Reserve

Five species of monogeneans were collected from the fish of the Soetdoring Nature reserve, which include two *Dactylogyrus* species, one *Dogielius*, one *Quadriacanthus* and one *Paradiplozoon* species. A new species of *Dactylogyrus* was collected from *Labeo capensis*. *Dactylogyrus* sp. A was collected from carp (*C. carpio*). A new species of *Dogielus* was also collected from *L. capensis*. *Quadriacanthus* sp. B was collected from *Clarias gariepinus*. A previously recorded but undescribed species of *Paradiplozoon* from the Orange River system was also collected from *L. capensis*.

Dactylogyrus **sp. A**

Host and locality: Cyprinus carpio Soetdoring Nature Reserve, South Africa (28° 52' S, 26° 0' E)

Infection Site: Gills

Specimens studied: Morphometric measurements and drawings made using light microscopy. Reference material (V2002/04/16-04, V2002/04/16-05, V2002/04/16-06, V2002/04/16-07) deposited in the collection of the Aquatic Parasitology Study group, University of the Free State.

Description

Large worms, measuring 1021.6±49.8 (1079.2-968.0) long and 306.7±30.8 (266.6-340.3) wide (Figure 5.26A). Anchors large (Figure 5.24A, Figure 5.26B), with total length of 72.2±2.2 (69.3-74.6); base width 27.8±1.0 (26.4-28.9); inner and outer root relatively square, inner root 20.7±1.5 (19.0-22.4) long, outer root 11.1±1.9 (8.5-12.7) long; shaft length 70.3±1.1 (69.0-71.3); length of tip 18.3±1.5 (16.7-20.4); dorsal bar simple (Figure 5.24B, Figure 5.26C); length 46.9±1.5 (45.2-48.9), width 8.8±1.8 (7.4-11.5); marginal hooklets (Figure 5.25A, Figure 5.26D) equal in shape, pair I, 33.9±0.6 (33.5-34.9), pairs II, IV, VII 30.9±1.5 (27.7-32.0), pair III, 31.8±2.5 (28.1-33.3), pair V, 28.4±0.8 (27.7-29.5), pair VI, 31.5±0.6 (30.6-32.0) long. Copulatory complex (Figure 5.25B, Figure 5.26E) consisting of curved penis 66.1±4.5 (62.0-71.8) long, and accessory piece 82.2±7.0 (71.8-87.1) long, with distal part slightly enlarged and branched.

Remarks:

Based on the above description and morphometrical data, *Dactylogyrus* sp A can be identified as *D. extensus* (Figure 5.24, Figure 5.25, Figure 5.26 & Table 5.12).

In comparing the present material with the European populations of *D. extensus* (Table 5.13) the only marked difference is the size of the cirrus and accessory piece. *Dactylogyrus auriculatus* shows the closest resemblance to *D. extensus*, but differs from it in the shape of the copulatory complex (Figure 5. 25B, Figure 5.26E).

Table 5.12. Comparison of the European population of *Dactylogyrus extensus* (Mueller & Van Cleave, 1932) with the population from Soetdoring Nature Reserve. **AL**-anchor length, **BL**-length of dorsal bar, **BW**-width of dorsal bar, **IR**-length of inner root, **OR**-length of outer root, **S**-shaft length, **T**-length of tip.

Population	AL	S	OR	IR	T	BL	BW	C	AP
Europe	72	66	9	16	19	44	12	77	69
Soetdoring	72	70	11	20	18	47	9	66	82

A

B

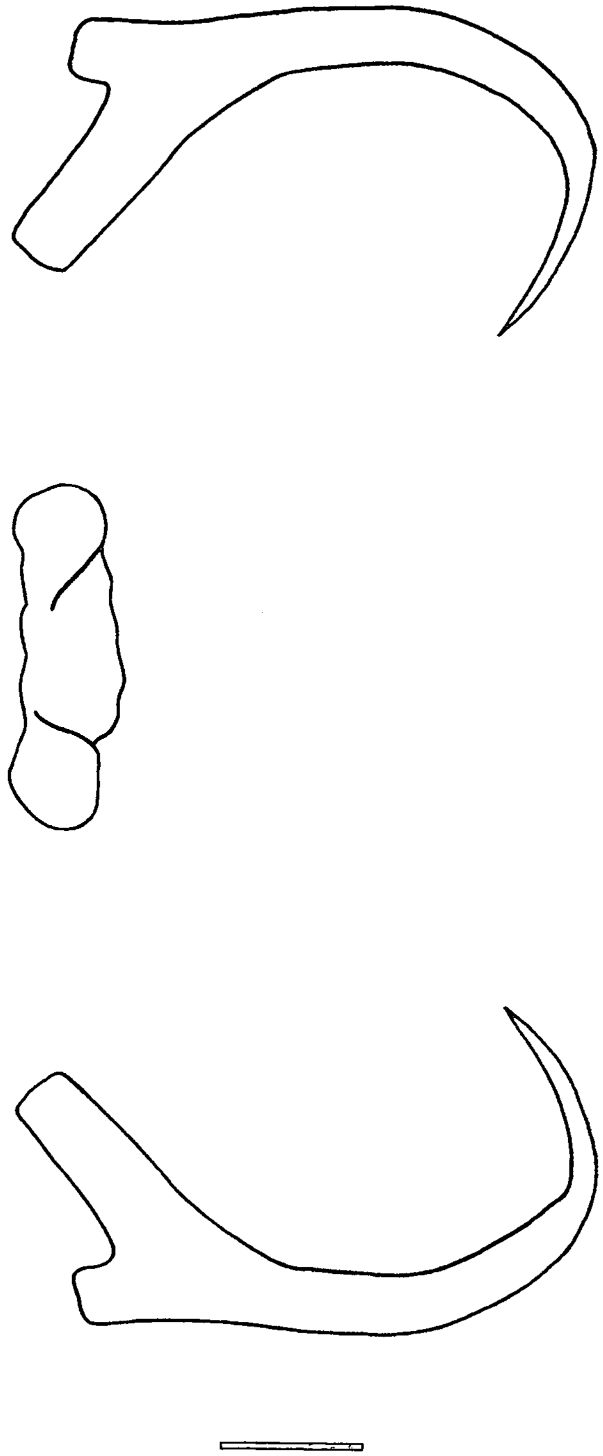


Figure 5.24. Microscope projection drawings of *Dactylogyrus extensus* (Mueller & Van Cleave, 1932) from *Cyprinus carpio* Linnaeus, 1758 collected from the Soetdoring Nature Reserve. **A** - anchors, **B** - dorsal bar. Scale bar: 20μm

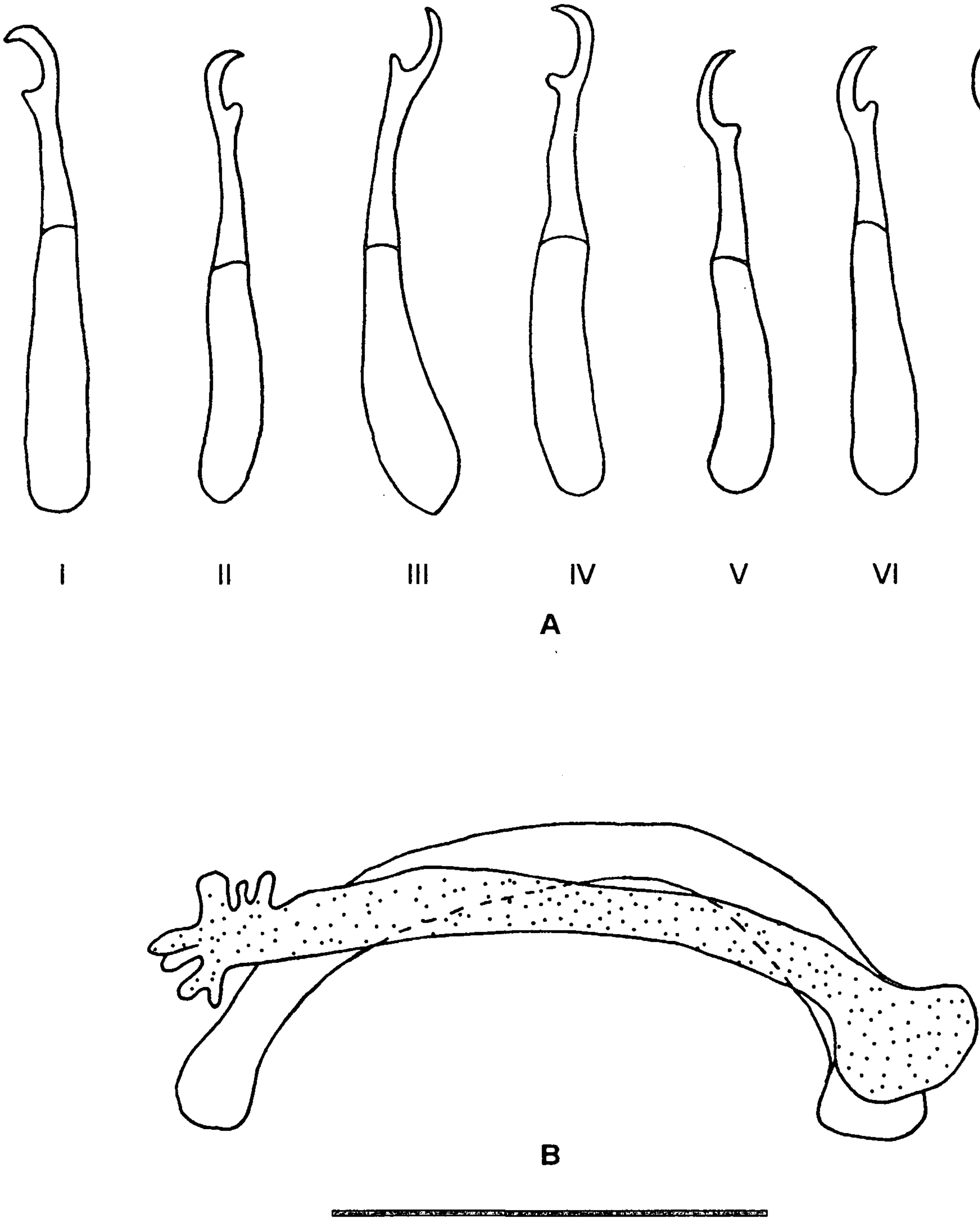


Figure 5.25. Microscope projection drawings of *Dactylogyrus extensus* (Mueller & Van Cleave, 1932) from the gills of *Cyprinus carpio* Linnaeus, 1758 collected from the Soetdoring Nature Reserve. **A** – marginal hooklets, **B** – cirrus. Scale bar: 30µm

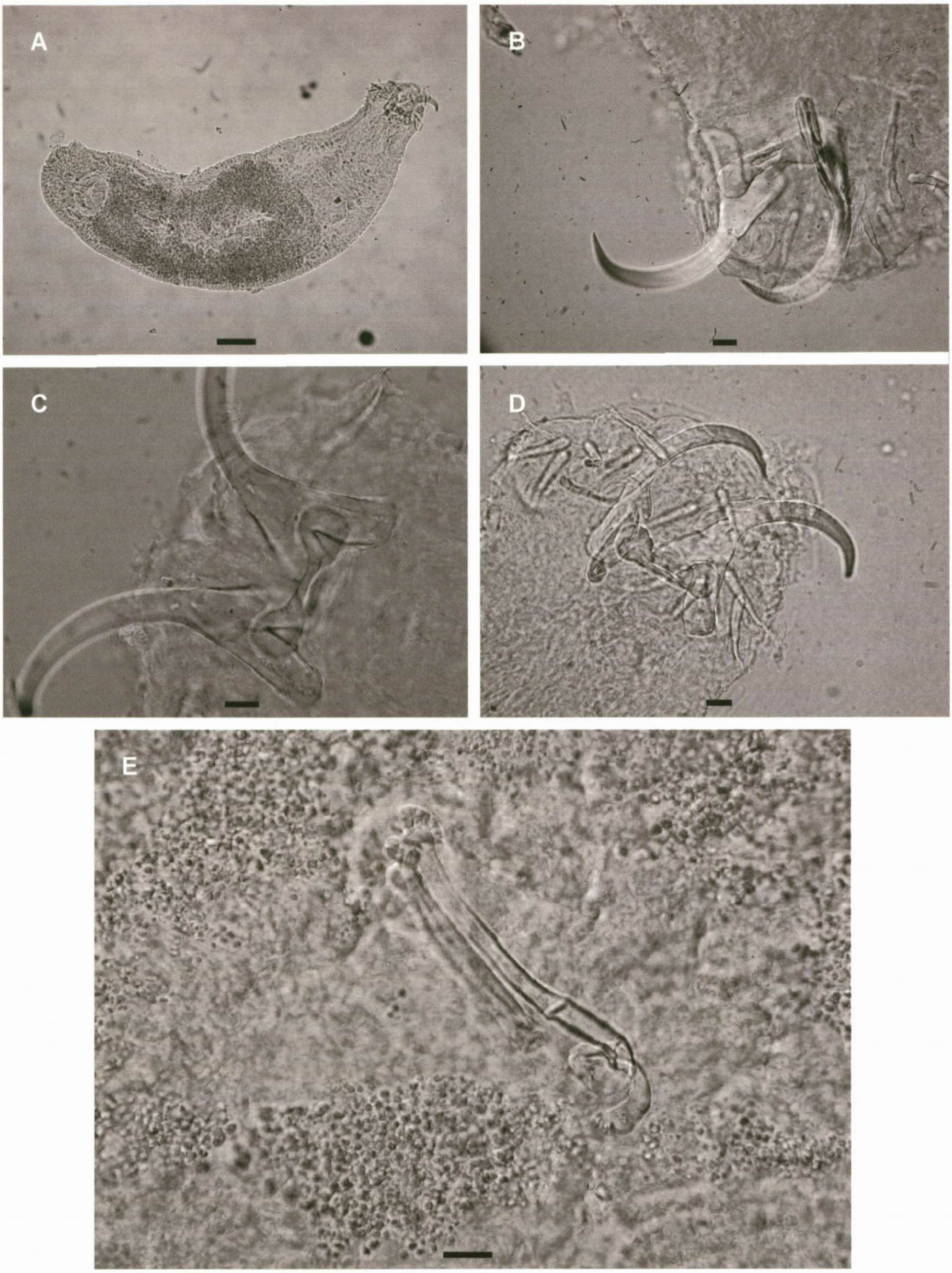


Figure. 5.26. Light micrographs of *Dactylogyrus extensus* (Mueller & Van Cleave, 1932) collected from the gills of *Cyprinus carpio* Linnaeus, 1758. **A** – whole mount, **B** – anchors, **C** – transverse bar, **D** – marginal hooklets, **E** – cirrus. Scale bar A: 100µm, B-E: 10µm

Dactylogyrus freistatensis n. sp.

Host and locality: Labeo capensis, Soetdoring Nature reserve, South Africa (28° 52' S, 26° 0' E)

Infection Site: Gills

Specimens studied: Morphometric measurements and drawings (Figure 5.27, Figure 5.28, Figure 5.29 & Table 5.13) made using light microscopy. Reference material (V2002/05/16-01, V2002/05/16-02, V2002/05/16-03, V2002/05/16-04 V2002/05/16-05, V2002/05/16-06, V2002/05/16-07) deposited in the collection of the Aquatic Parasitology Study group, University of the Free State.

Description:

Small worms, measuring 326.4±21.8(294.9-356.8) long and 76.1±2.0 (73.3-77.5) wide (Figure 5.29A). Anchors relatively large (Figure 5.27A, Figure 5.29B), with total length of 45.0±1.7 (42.0-46.8); base width 8.6±0.9 (7.4-9.9); inner root 20.1±1.2 (18.2-21.7) long, outer root 1.8±0.8 (1.1-3.0) long; shaft length 28.4±1.0 (27.1-29.6); length of tip 10.5±1.0 (9.5-12.2); dorsal bar (Figure 5.27C, Figure 5.29B) length 21.1±1.5 (19.5-23.7), width 3.7±0.9 (3.3-4.6); vestigial ventral bar 10.0± 0.9 (9.0-11.1)(Figure 5.27B); marginal hooklets (Figure 5.28A, Figure 5.29C) with proximal dilation of shank at 1/3 of length, pair I 17.3±1.2 (15.4-18.8) pair II 15.1±0.9 (14.0-16.5) III 15.4±1.2 (14.1-16.8), pair IV 19.4±1.3 (17.3-21.1), pair V 18.7±0.6 (17.9-19.3), pair VI 17.7±1.2 (16.2-19.2), pair VII 18.7±1.6 (16.1-20.1) long. Copulatory complex (Figure 5.2B, C, Figure 5.29D) consisting of penis 117.7±14.5 (98.13-132.7) long making varying spirals and forming bulb like structure at proximal end, and accessory piece 13.8±0.8 (13.1-15.1) long with enlarged basal part, ending in small fork (Figure 5.28B); vagina consists of long twisted tube (Figure 5.28C).

Etymology: The specific name is derived from the Sotho name for the Free State province (Freistata) in which the Soetdoring Nature Reserve is situated.

Remarks:

The specimens collected from *Labeo capensis* resemble *D. senegalensis* in the shape of the penis and vagina, but differ from it in the shape of the accessory piece, and the absence of a vestigial ventral bar in *D. senegalensis*. It also resembles *D. labeous*, *D. jubbstrema* and *D. brevicirrus* in the shape of the dorsal bar, and the vestigial ventral bar, but differs from these species in the shape of the cirrus and accessory piece. *Dactylogyrus freistatensis* n. sp. does not resemble any of the *Dactylogyrus* species previously recorded from South Africa.

Table 5.13. Comparison of *D. freistatensis* n.sp. collected from Soetdoring Nature Reserve with resembling species of *Dactylogyrus* Diesing, 1850. AL-anchor length, AP-length of accessory piece, BL-length of dorsal bar, BW-width of dorsal bar, C-length of cirrus, IR-length of inner root, OR-length of outer root, T-length of tip, TL-total length, S-shaft length, W-greatest width

Species	TL	W	AL	S	OR	IR	T	BL	BW	C	A
D. freistatensis n. sp.	295-357	73-78-	42-47	27-30	1-3	18-22	10-12	20-24	3-5	98-133	13-15
D. brevicirrus Paperna, 1973	230-380	40-100	35-40	20-24	1-4	16-20	10-14	19-21		25-30	15-21
D. jubbstrema Price, Korach & McPott, 1969	190-226	50-60	32-38	18	3	18	15	15-18	4	21-25	14-17
D. labeous Paperna, 1969	230-400	40-80	38-43	29-31	3-4	16-21	12-17	20-23	4-5	33-39	30
D. senegalensis Paperna, 1969	200-500	50-80	29-33	24-28	1-4	8-13	11-14	17-21	3-4	180	

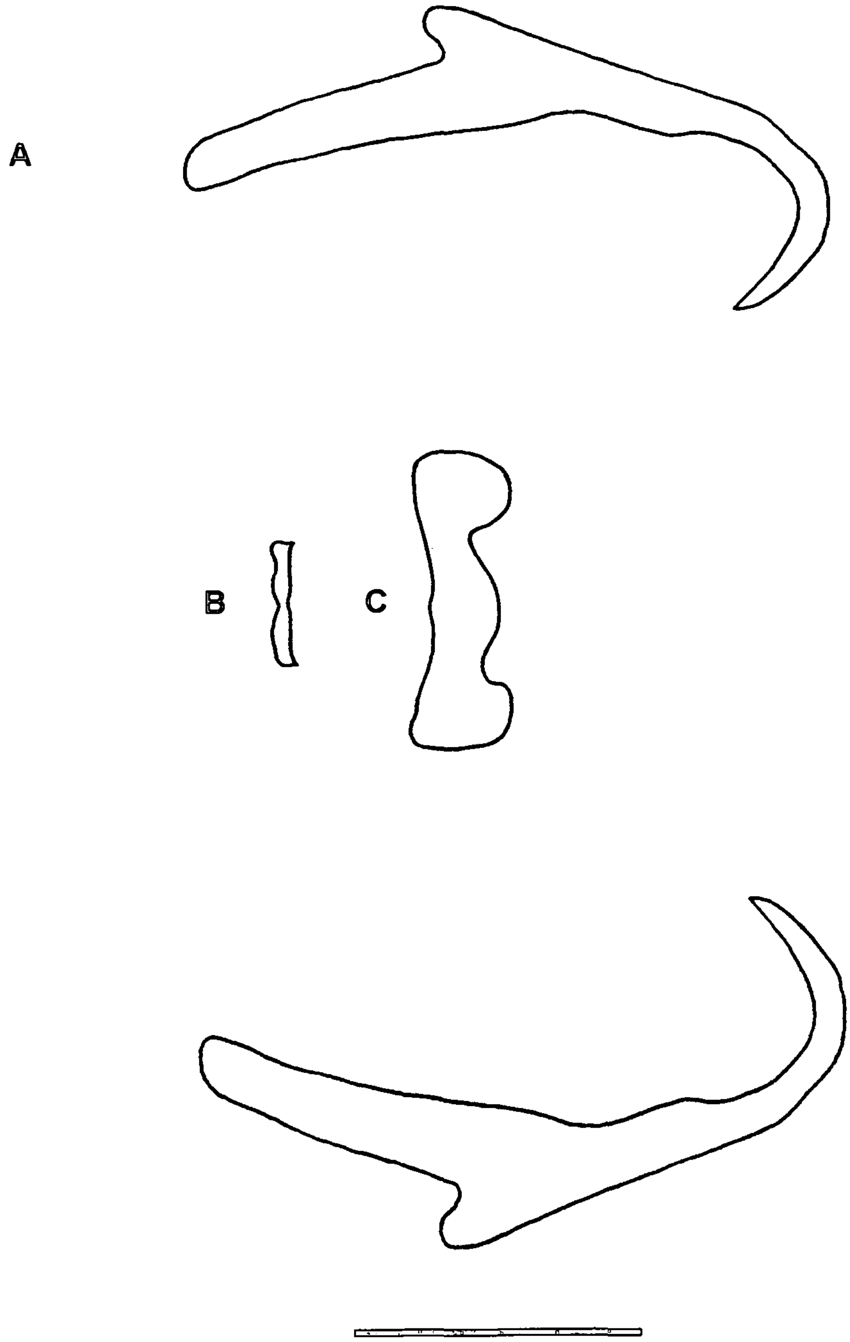


Figure 5.27. Microscope projection drawing of *Dactylogyrus freistatensis* n. sp. From the gills of *Labeo capensis* (Smith, 1841) collected from the Soetdoring Nature Reserve. **A** – anchors, **B** – vestigial ventral bar, **C** – transverse bar. Scale bar: 20µm

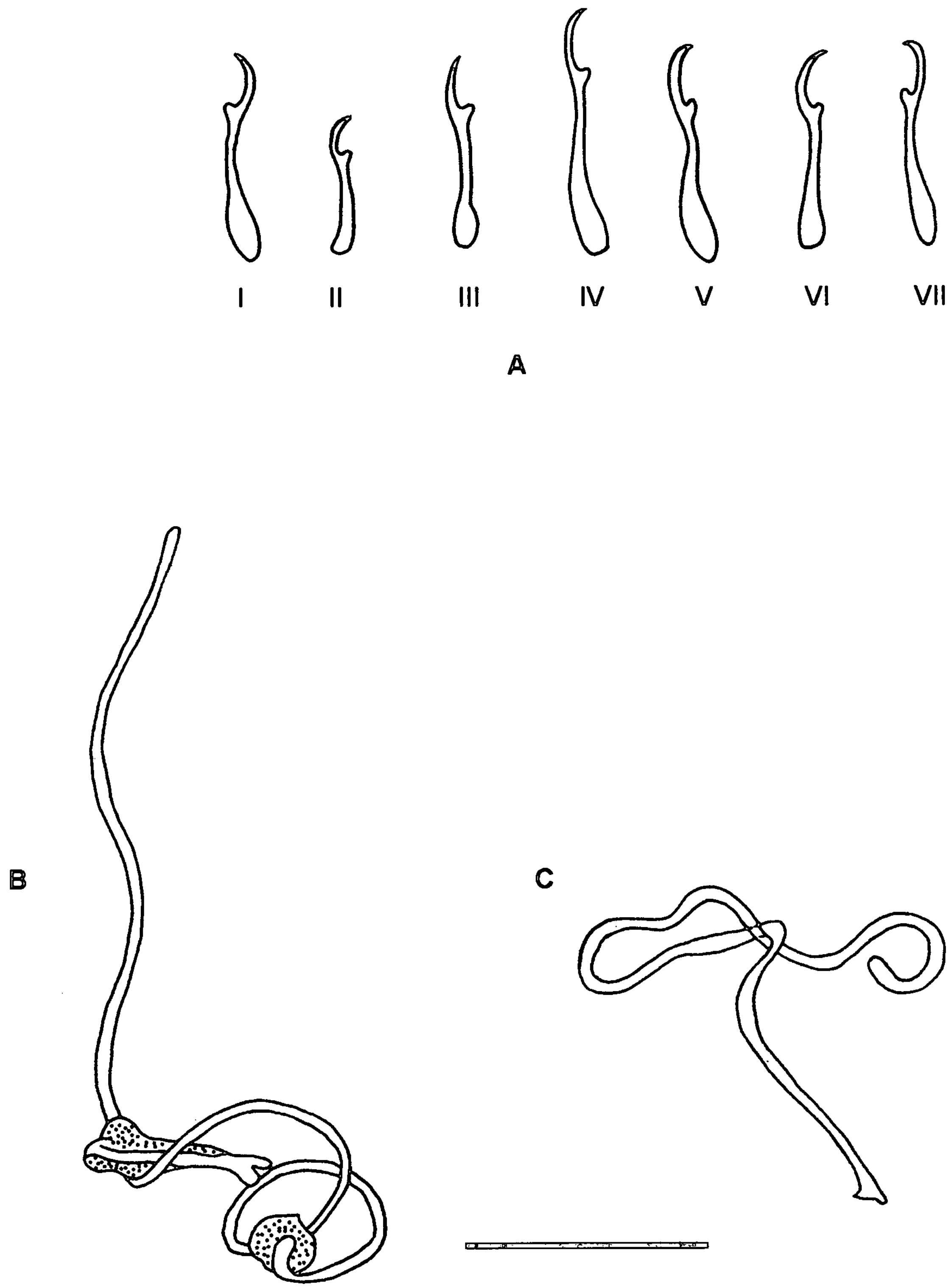


Figure 5.28. Microscope projection drawings of *Dactylogyrus freistatensis* n. sp. from the gills of *Labeo capensis* (Smith, 1841) collected from the Soetdoring Nature Reserve. **A** – marginal hooklets, **B** – cirrus, **C** – vagina. Scale bar: 20µm

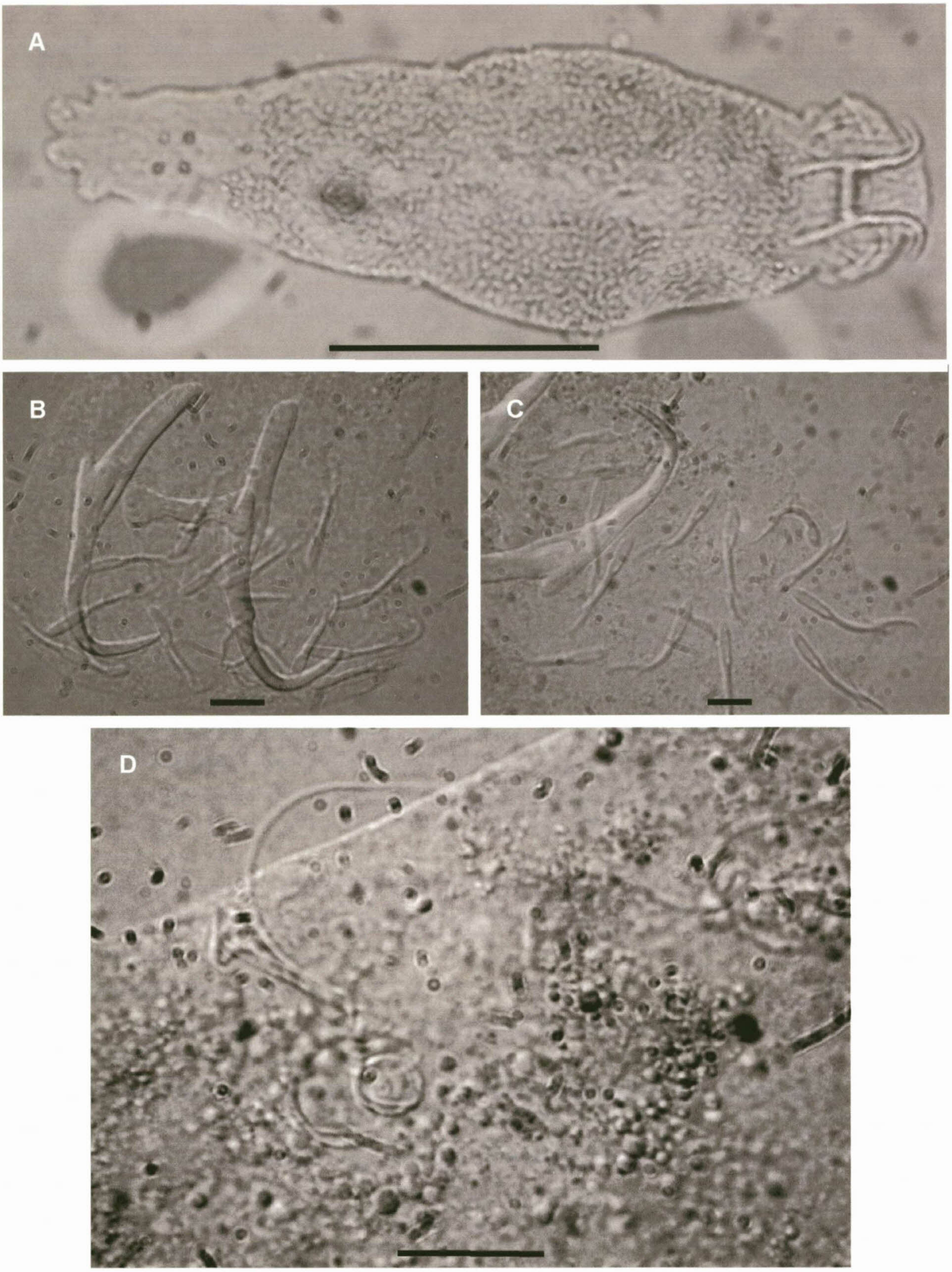


Figure. 5.29. Light micrographs of *Dactylogyrus freistatensis* n.sp. collected from the gills of *Labeo capensis* (Smith, 1841). **A** – whole mount, **B** – anchors, transverse bar and marginal hooklets, **C** – marginal hooklets, **D** – cirrus. Scale bar A: 100µm, B-D: 10µm

Dogielius capensis n. sp.

Host and locality: Labeo capensis, Soetdoring Nature reserve, South Africa (28° 52' S, 26° 0' E)

Infection Site: Gills

Specimens studied: Morphometric measurements and drawings (Figure 5.30, Figure 5.31, Figure 5.32 & Table 5.14) made using light microscopy. Reference material (V2002/05/16-08, V2002/05/16-09) deposited in the collection of the Aquatic Parasitology Study group, University of the Free State.

Description:

Small worms (Figure 5.32A) measuring 345.6±13.0 (336.4-354.7) long and 101.2±19.6 (87.3-115.1) wide. Anchors small (Figure 5.30A, Figure 5.32B), with total length of 28.3±1.9 (27.0-29.7) ending with sharp curve; length of shaft + inner root 38.1±6.0 (33.4-42.3); length of tip 17.4±1.7 (16.2-18.6); dorsal bar (Figure 5.30B, Figure 5.32C) 42.0±9.3 (35.4-48.6) long, 5.5±1.7 (4.3-6.7) wide; marginal hooklets uniform in shape forming small bulb at proximal end of shank (Figure 5.31A, Figure 5.32D), pair I 13.4±1.4 (12.4-15.5), pair II 14.0±2.0 (12.6-15.5), pair III 18.9±1.6 (17.8-20.1), pair IV 17.8±1.5 (16.7-18.9), pair V 19.2±0.1 (19.2-19.3), pair VI 20.7±2.3 (19.0-22.3), pair VII 21.1±2.8 (19.1-23.0) long. Copulatory complex consisting of curved penis 25.2 long and accessory piece 34.5 long, which folds around penis at distal end (Figure 5.31B, Figure 5.32E).

Etymology: The specific name is derived from the specific name of the host, *Labeo capensis*.

Remarks:

This species closely resembles *D. tropicus*, *D. flosculus*, *D. parvus* and *D. kabaensis* in the shape of the roots of the anchors, as well as the shape of the dorsal bar. *Dogielius capensis*, however, differs from these species in the shape of the penis and the accessory piece. *Dogielius capensis* is the first species of *Dogielius* recorded from South Africa.

Table 5.14. Comparison of *Dogielius capensis* n. sp. from Soetdoring Nature Reserve with resembling species of *Dogielius* Bychowsky, 1936. AL-anchor length, AP-length of accessory piece, BL-length of dorsal bar, C-length of cirrus, S+OR-shaft + outer root length, T-length of tip, TL-total length, W-greatest width

Species	TL	W	AL	S+OR	T	BL	C	AP
D. capensis **n. sp.**	334-355	87-115	27-30	33-42	16-19	35-39	25	34
D. flosculus Guegan, Lambert & Euzet, 1989	250-350	60-100	40-46	42-49	23-29	45-50	50	37-47
D. kabaensis Guegan & Lambert, 1991	330-420	60-80	30-36	41-45	14-17	50-56	22-30	19-22
D. parvus Guegan, Lambert & Euzet, 1989	250-350	60-90	29-33	33-38	18-22	38-47	25-30	31-34
D. tropicus Paperna, 1969	250-400	70-100	35-40	39-45	21-26	55-65	35-40	32-36

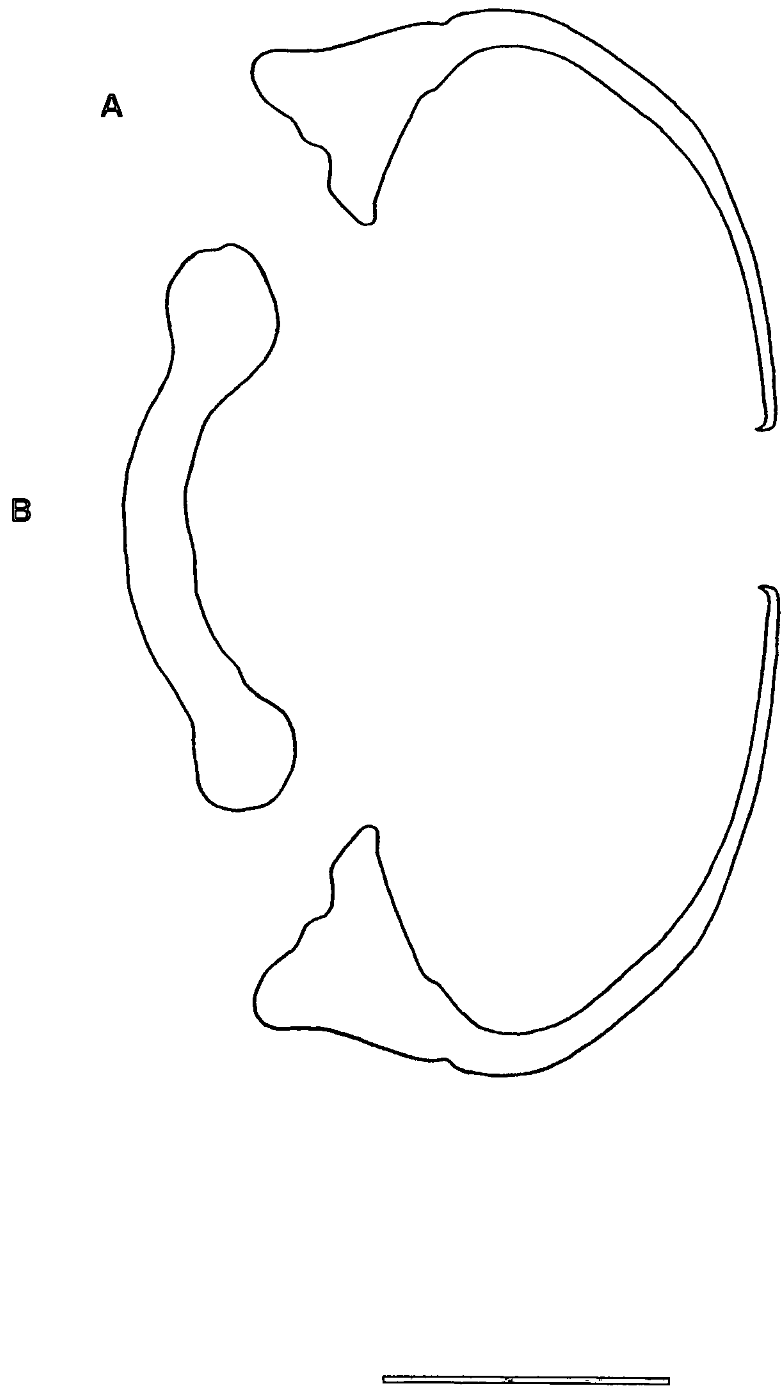


Figure 5.30. Microscope projection drawing of *Dogielius capensis* n. sp. from the gills of *Labeo capensis* (Smith, 1841) collected from the Soetdoring Nature Reserve. **A** – anchors, **B** – transverse bar. Scale bar: 20µm

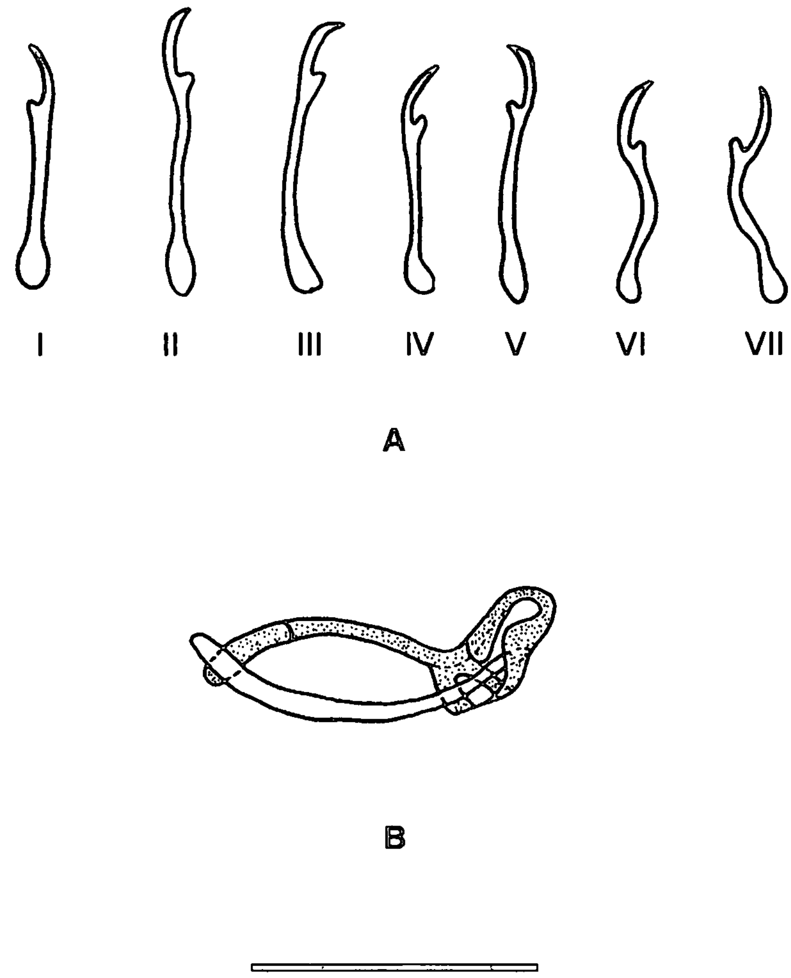


Figure 5.31. Microscope projection drawings of *Dogielius capensis* n. sp. from the gills of *Labeo capensis* (Smith, 1841) collected from the Soetdoring Nature Reserve. **A** – marginal hooklets, **B** – cirrus. Scale bar: 20µm

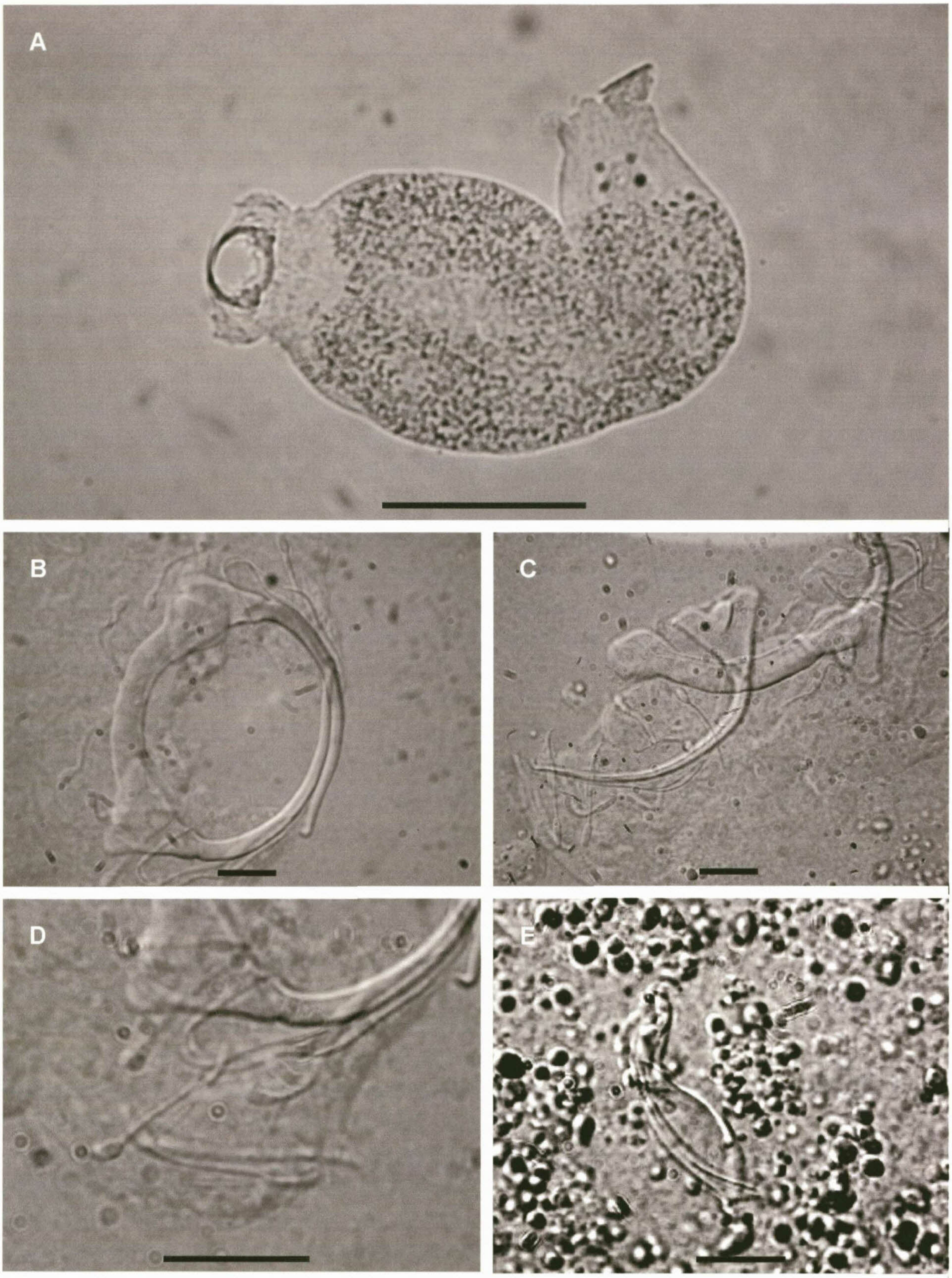


Figure. 5.32. Light micrographs of *Dogielius capensis* n.sp. collected from the gills of *Labeo capensis* (Smith, 1841). A – whole mount, B – anchors, C – transverse bar, D – marginal hooklets, E – cirrus. Scale bar A: 100µm, B-E: 10µm

Quadriacanthus sp. A

Host and locality: Clarias gariepinus, Soetdoring Nature reserve, South Africa (28° 52' S, 26° 0' E)
Infection Site: Gills
Specimens studied: Morphometric measurements and drawings made using light microscopy. Reference material (V2001/09/25-11, V2001/09/26-05, V2002/04/16-02, V2002/04/16-08, V2002/04/16-10, V2002/04/16-12) deposited in the collection of the Aquatic Parasitology Study group, University of the Free State.

Description

Large worms (Figure 5.35A) 629.4±167.4 (434.7–881.3) long, and 156.2±37.4 (108.4–222.3) wide. Ventral anchor (Figure 5.33A, Figure 5.35B) 41.2±2.2 (38.5–45.4) long with short superficial root; small base 11.8±1.7 (9.5–13.6) wide; shaft curved with elongate tip 14.0±1.7 (12.3–16.6) long; accessory sclerite small 11.4±1.2 (9.7–13.2) long, with subequal winglike processes; dorsal anchor (Figure 5.33B, Figure 5.35C) 53.8±3.9 (48.1–59.4) long, with short roots, shaft bent proximally, short tip 4.3±0.7 (3.4–5.5) long, accessory sclerite 19.0±1.3 (17.2–21.2) long, and 9.4±1.3 (7.7–11.9) wide with subequal wings, anchor base 16.5±1.9 (13.5–19.7) wide. Ventral bar component (Figure 5.33A, Figure 5.35D) 50.5±3.2 (46.3–56.3) long, and 9.6±1.0 (7.8–11.2) at greatest width; dorsal bar (Figure 5.33B, Figure 5.35E) 39.4±5.9 (33.8–49.4) long, and 16.6±1.6 (15.0–20.2) at greatest width, median process 19.3±1.4 (17.3–21.8) long. Marginal hooklets (Figure 5.34A) with delicate point and protruding thumb; pair I, 14.0±1.3 (12.2–15.7), pair II, III, IV, 15.2±1.5 (12.8–17.9), pair V, 34.4±2 (31.1-37.3), pair VI, 21.1±1.7 (18.9–23.9), pair VII, 20.2±1.7 (17.9–22.8) long. Cirrus (Figure 5.34B, Figure 5.35F) 55.1±10.0 (44.1–68.2) long, comprising long tapered tube with narrow base; accessory piece 61.7±10.5 (48.9–73.7) long, forming two bulbs, at 1/3 and 2/3's of length, ending in two distinct hooks.

Remarks:

Based on the above description and morphometrical data, *Quadriacanthus* sp. A can be identified as *Q. aegypticus* (Figure 5.33, Figure 5.34, Figure 5.35 & Table 5.15).

Two populations of *Q. aegypticus* could be distinguished based on the size of the cirrus and accessory piece (Table 5.15). The length of the cirrus of one group falls well within the range given for *Q. aegypticus* by Kritsky & Kulo (1988), while the second group has a cirrus and accessory piece that is approximately 20µm longer. The material collected from Soetdoring Nature Reserve differs from the material from Egypt only in the longer length of marginal hooklet pairs I and VII. *Quadriacanthus aegypticus* can be distinguished from the other species of *Quadriacanthus* by the shape of the accessory piece, which ends in two distinct hooks. N'Douba, Lambert & Euzet (1999) described the accessory piece as ending in two hooks, although in their drawing of the copulatory complex this shape could not be distinguished. Kritsky & Kulo (1988) did not mention this characteristic of the accessory piece, but from their drawing this characteristic can clearly be seen. *Quadriacanthus aegypticus* also resembles *Q. clariadis*, but differs from it in the shape and size of the cirrus and accessory piece. *Q. aegypticus* is the first species of *Quadriacanthus* recorded from South Africa.

Table 5.15. Comparison of the Egyptian population of *Quadriacanthus aegypticus* El-Naggar & Serag, 1986 with the population from Soetdoting Nature reserve. **AP**-length of accessory piece, **C**-length of cirrus, **DA**-length of dorsal anchor, **DAB**-base width of dorsal bar, **DB**-length of dorsal bar, **TL**-total length, **VA**-length of ventral anchor, **VAB**-base width of ventral anchor, **VB**-length of ventral bar, **W**-greatest width

Population	TL	W	VA	VAB	DA	DAB	VB	DB	C	AP
Egypt	313-502	76-105	36-44	13-18	43-51	13-18	39-53	45-74	40-52	33-49
Soetdoring Nature Reserve	434-881	108-222	39-45	10-15	48-59	14-20	46-56	34-49	44-68	49-74

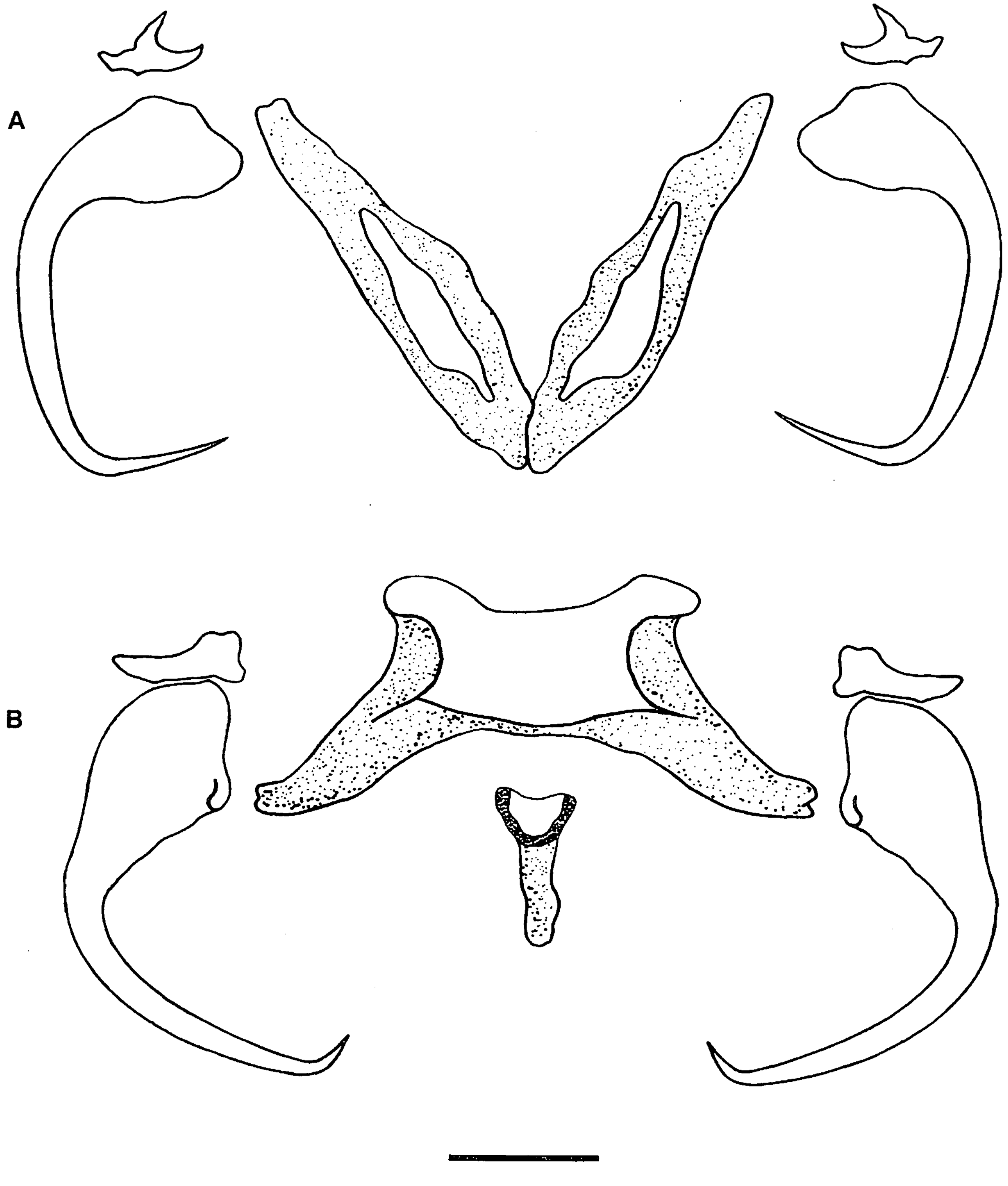


Figure 5.33. Microscope projection drawings of *Quadriacanthus aegypticus* El-Naggar & Serag, 1986 from the gills of *Clarias gariepinus* (Burchell, 1822) collected from the Soetdoring Nature Reserve. **A** – ventral bar and anchors, **B** – dorsal bar and anchors. Scale bar: 20µm

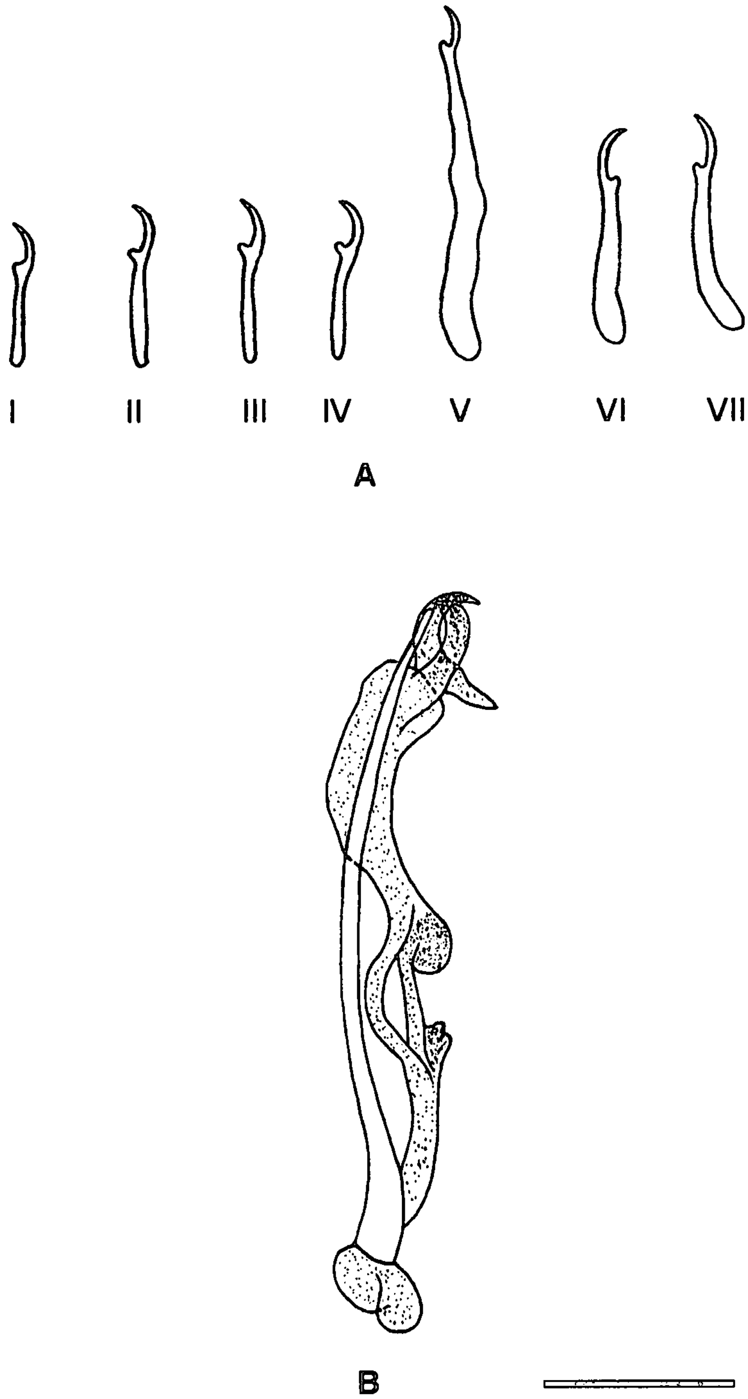


Figure 5.34. Microscope projection drawings of *Quadriacanthus aegypticus* El-Naggar & Serag, 1986 from the gills of *Clarias gariepinus* (Burchell, 1822) collected from the Soetdoring Nature Reserve. **A** – marginal hooklets, **B** – cirrus. Scale bar: 20µm

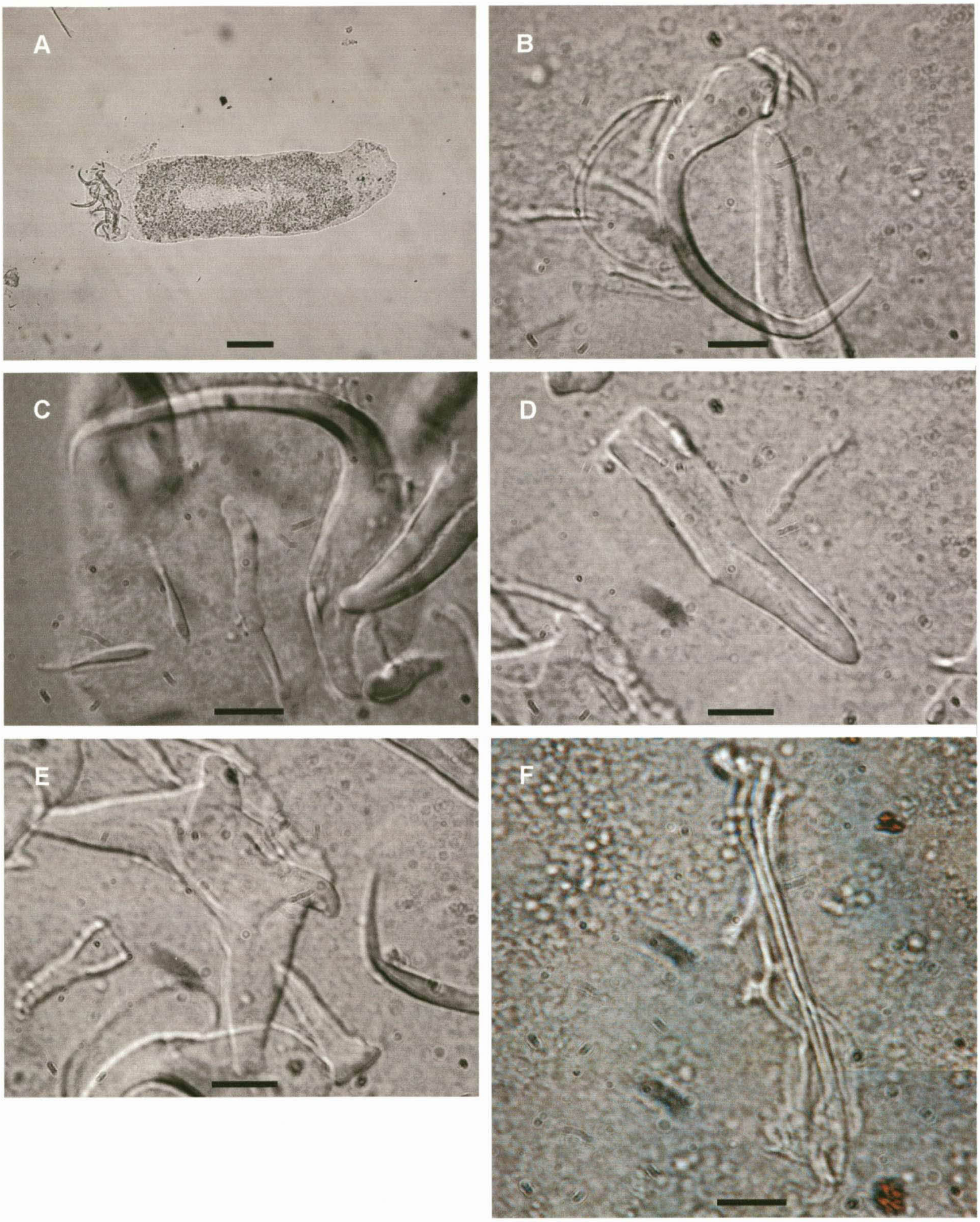


Figure. 5.35. Light micrographs of *Quadriacanthus aegypticus* El Naggar & Serag, 1986. **A** – whole mount, **B** – ventral anchor, **C** – dorsal anchor, **D** – ventral bar component, **E** – dorsal bar, **F** – cirrus. Scale bar A: 100µm, B-F: 10µm

Paradiplozoon modderensis n. sp.

Host and locality: Labeo capensis, Soetdoring Nature reserve, South Africa (28° 52' S, 26° 0' E)

Infection Site: Gills

Specimens studied: Morphometric measurements and drawings (Figure 5.36, Figure 5.37, Figure 5.38, Figure 5.39 & Table 5.16) made using light microscopy. Reference material (V2001/03/21-05, V2002/03/13-05, V2002/07/11-01, V2001/11/26-05, V2001/11/27-02) deposited in the collection of the Aquatic Parasitology Study group, University of the Free State.

Description:

Adults united in pairs in permanent copula in the form of a cross (Figure 5.36A, Figure 5.39A). Total body length 3734.4±395.6 (2880.0-4180.0), length of anterior part 2312.2±319.1 (1750.0-2660.0), width 912.2±231.3 (550.0-1290.0), length of posterior part 1308.5±151.0 (1110.0-1510.0), width 420.0±86.1 (310.0-570.0). Prohaptor consists of a pair of cup-shaped buccal suckers (Figure 5.36B), 82.0±5.8 (72.3-93.9) in diameter. Four pairs of clamps present on the haptor (Figure 5.37A, Figure 5.39B), all equal in size 99.7±4.3 (93.5-105.7) in length and 48.3±3.3 (41.2-52.9) wide. Each clamp consists of dorsal and ventral sclerites, which is strengthened by median U-shaped piece. Each dorsal sclerite with well-developed spur 39.8±2.5 (35.8-44.5) long. Two small crooked anchors (Figure 5. 37B) present between rows of clamps. Mouth opening subterminal, between buccal suckers. Pharynx (Figure 5.36B) oval shaped, 71.9±5.6 (65.1-79.5) long. Intestine not bifurcate, but with numerous diverticula. Testis single, lobed, 219.3±74.4 (166.3-325.3) long and 84.9±2.3 (81.9-86.7) wide (Figure 5.38), situated posterior to, but in close contact with much folded ovary, 248.8±39.7 (204.8-301.2) long and 113.3±2.3 (84.3-127.7) wide (Figure 5.38). Eggs large, 309.0±70.7 (250.3-387.5) long and 119.7±15.6 (103.7-134.9) wide with very long and coiling filament (Figure 5.37C, Figure 5.39C).

Etymology: The specific name is derived from the Modder River from where the fish hosts were collected.

Remarks:

Paradiplozoon modderensis resembles both *P. ghanense* and *P. aegyptensis*, but differs from them in the position of the testis and ovaries. In the case of *P. ghanense*, the testis and ovary are located completely in the area of fusion and in *P. aegyptensis*, the ovaries are also located in the area of fusion and the testis are located only partially in the area of fusion. The testis and ovaries *of P. modderensis* are located completely within the posterior part of the body. *Paradiplozoon modderensis* also differs from the other two known species in the size of the eggs and the haptoral clamps.

Table 5.16. Comparison of *Paradiplozoon modderensis* n. sp from the Soetdoring Nature Reserve with the known species of *Paradiplozoon* Achmerov, 1974 from Africa. AL-anterior length, AW-anterior width, CL-clamp length, CW-clamp width, EL-length of egg, EW-egg width, PL-posterior length, PW-posterior width, TL-total length

Species	TL	AL	AW	PL	PW	CL	CW	EL	EW
P. modderensis n. sp.	2880-4180	1750-2660	550-1290	1110-1510	310-570	94-106	41-53	250-388	104-135
P. ghanense Thomas, 1957	3210-3830	1860-2540	540-740	380-480	380-480	120-160	100-110	260	115
P. aegyptensis Fischthal & Kuntz	3620-5767	1879-3452	299-836	867-1871	130-245	65-79	92-102	81-132	254-313

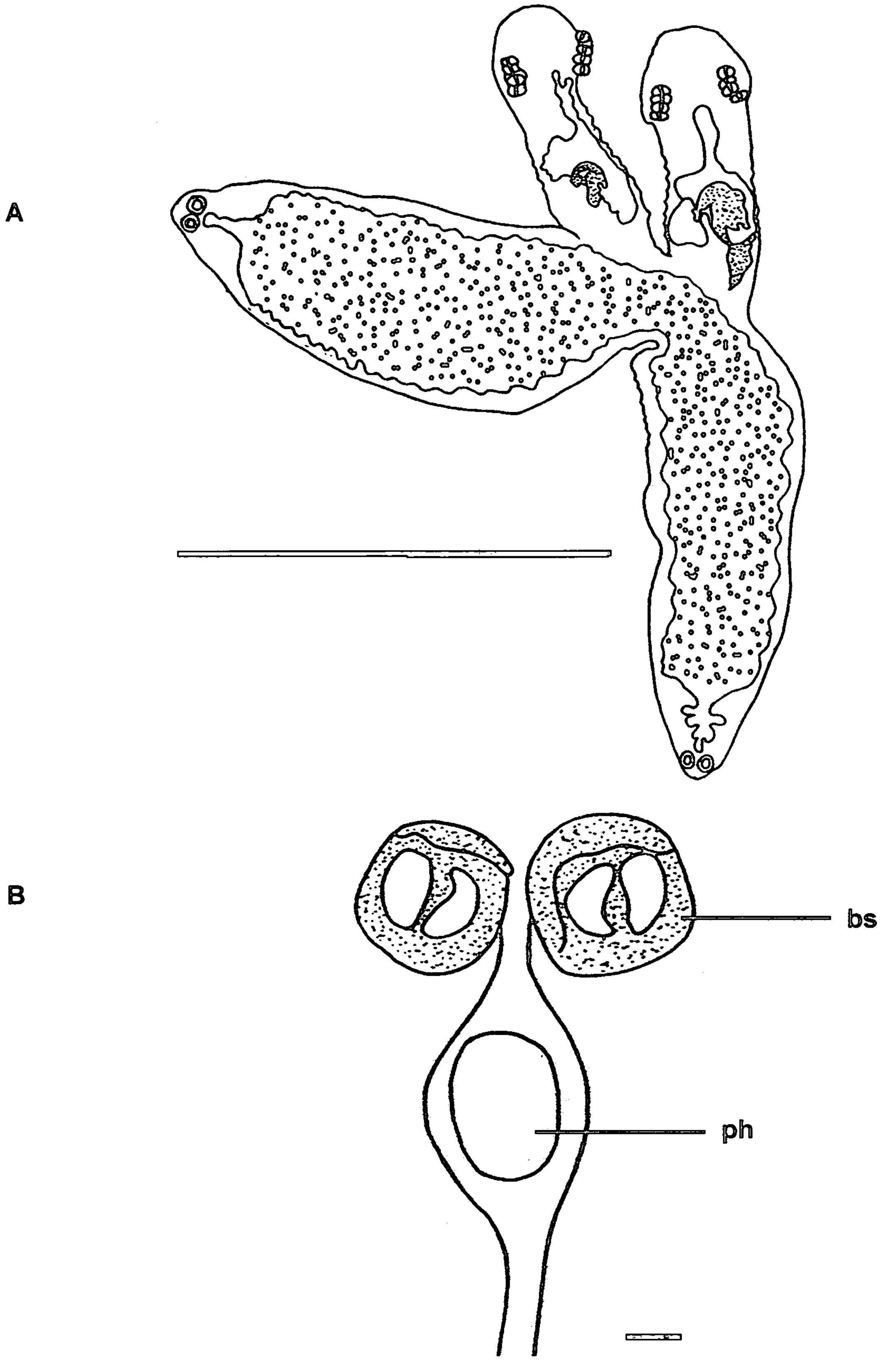
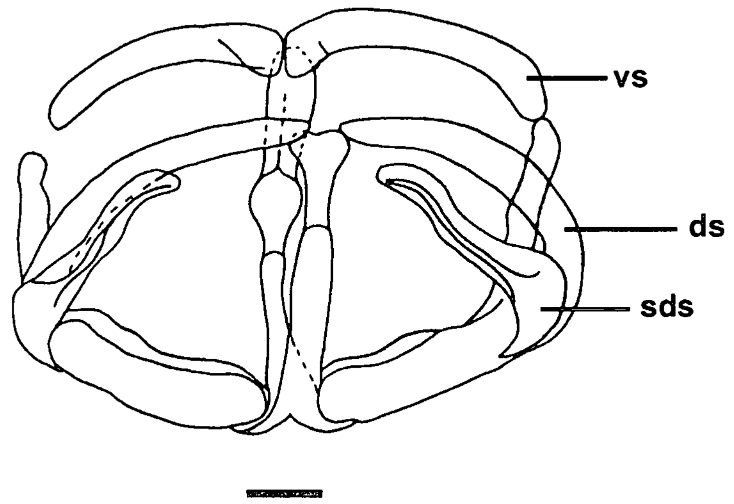
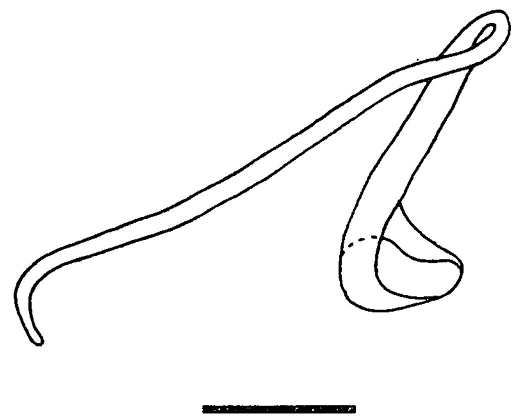


Figure 5.36. Microscope projection drawings of *Paradiplozoon modderensis* n. sp. from the gills of *Labeo capensis* (Smith, 1841) collected from the Soetdoring Nature Reserve. **A** – whole mount. Scale bar: 1mm. **B** – buccal suckers, pharynx and esophagus. Scale bar: 20μm. **bs**-buccal suckers, **ph**-pharynx

A



B



C

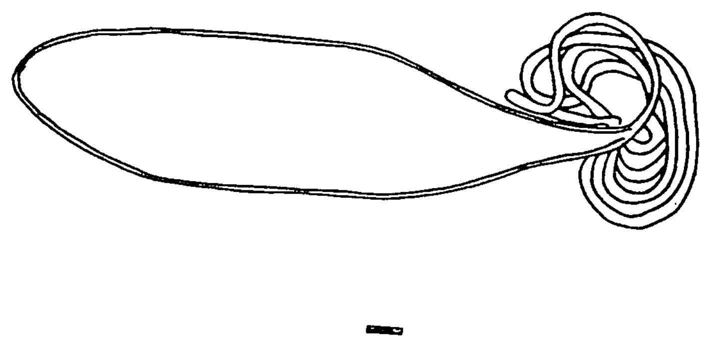


Figure 5.37. Microscope projection drawings of *Paradiplozoon modderensis* n. sp. from the gills of *Labeo capensis* (Smith, 1841) collected from the Soetdoring Nature Reserve. **A** – clamp, **B** – crooked anchor, **C** – egg. Scale bar: 10µm. **ds**-dorsal sclerite, **sds**-spur of dorsal sclerite, **vs**-ventral sclerite

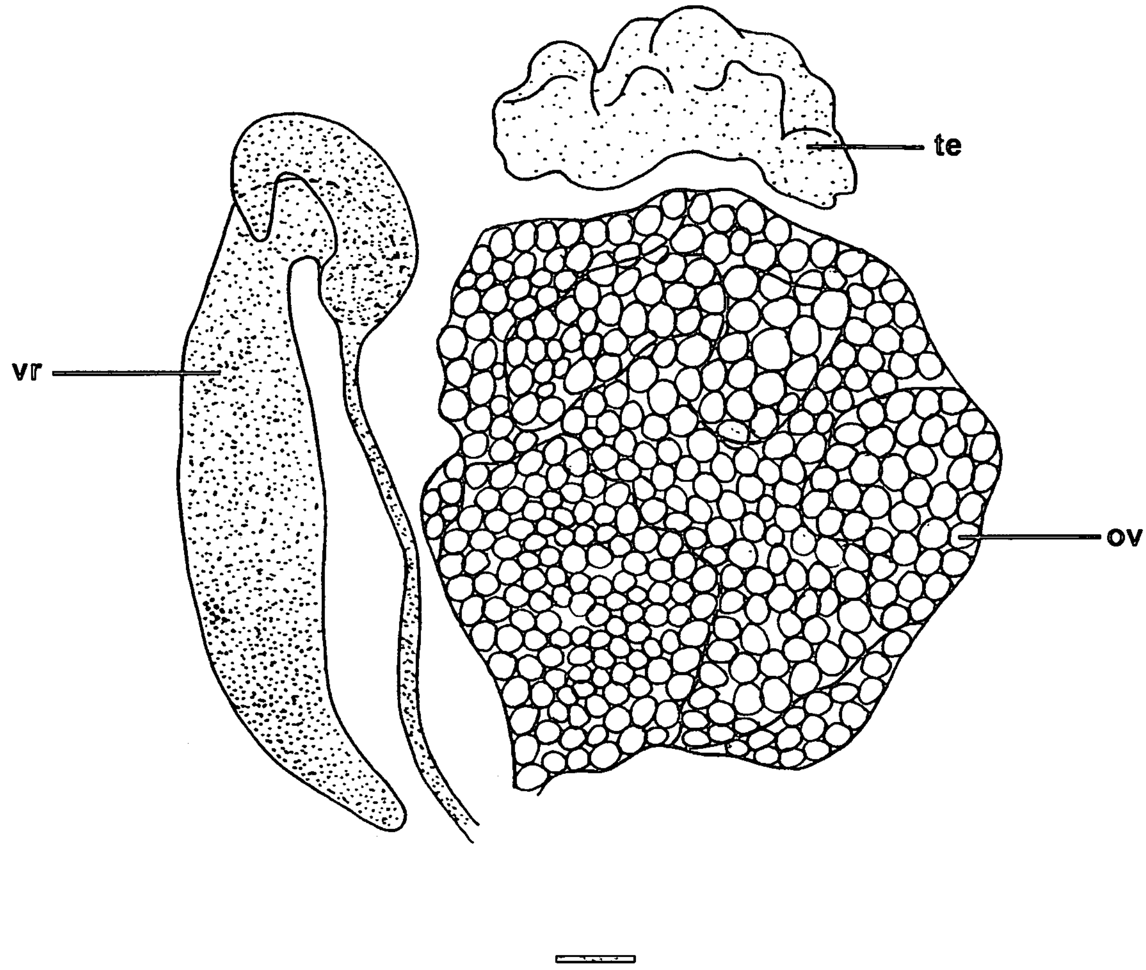


Figure 5.38. Microscope projection drawings of the reproductive system of *Paradiplozoon modderensis* n. sp. from the gills of *Labeo capensis* (Smith, 1841) collected from the Soetdoring Nature Reserve. Scale bar: 20μm. **ov**-ovary, **te**-testis, **vr**-vitteline reservoir

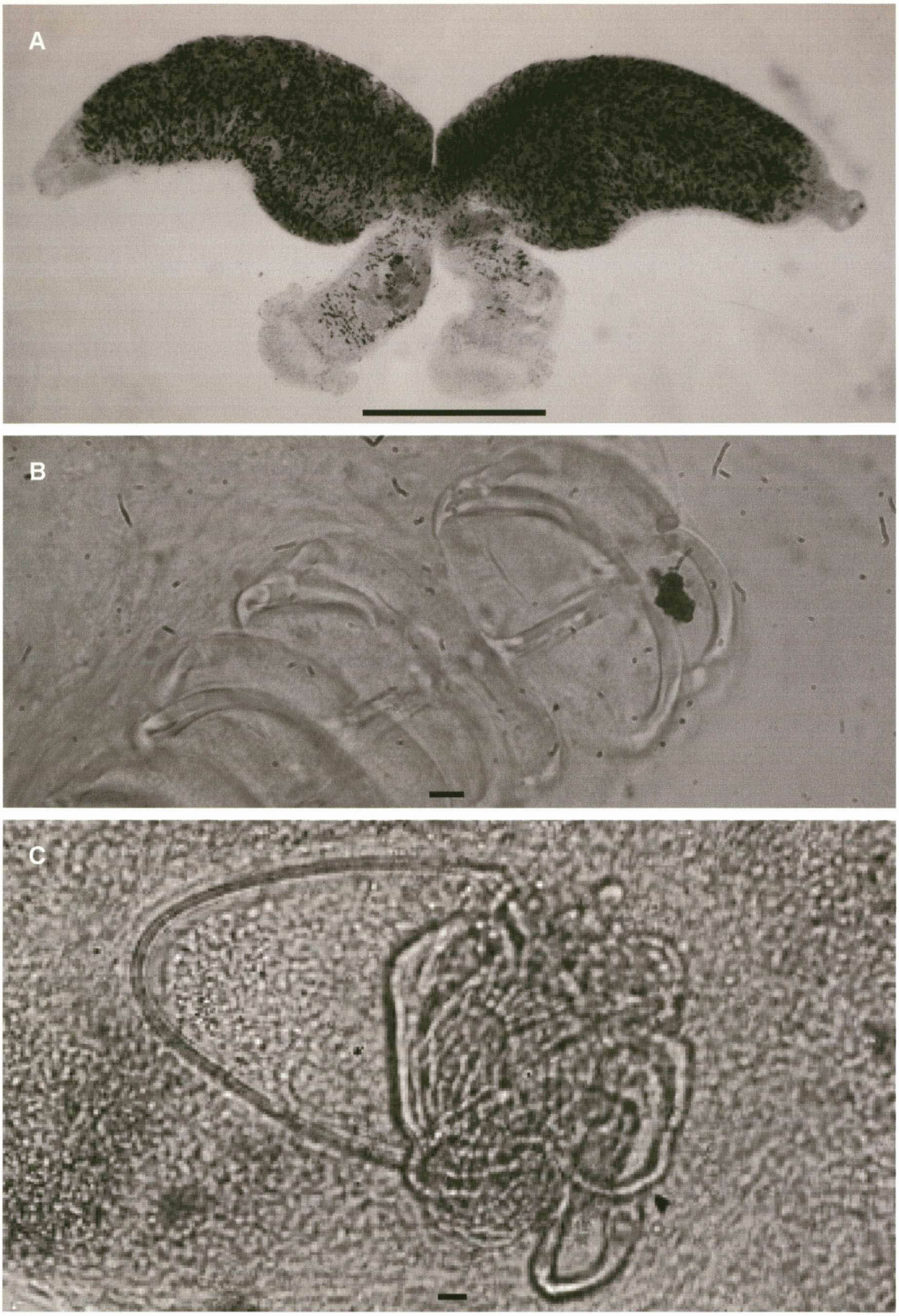


Figure. 5.39. Light micrographs of *Paradiplozoon modderensis* n.sp. collected from the gills of *Labeo capensis* (Smith 1841). **A** – whole mount, **B** – clamps, **C** – egg. Scale bar A: 1mm, B, C: 10µm

Chapter 6

The parasitic Crustacea

Subclass Branchiura Thorell, 1864

The branchiurans, or commonly known as fish lice, are all parasites of fish from freshwater, marine, and brackish habitats (Van As & Van As 2001a). Fish lice occur on the skin and fins, in the branchial chambers and mouth cavities of their hosts. Both the males and females are parasitic, but some retain the ability to leave the host and swim freely, which the female must do in order to lay her eggs (Fryer 1982).

Up to 1854, the Branchiura Thorell, 1864 was not recognised as a separate group, but treated as part of the copepods. Since then the taxonomic position of the group within the Copepoda Milne Edwards, 1840 has changed numerous times. A brief summary of the milestones is presented below.

- Zenker (1854) questioned the placement of the branchiurans within the copepods and placed the group within the Phyllopoda.
- Thorell (1864) suggested the name Branchiura for organisms which display characteristics of the group. He also suggested that these characteristics show similarities with the cladocerans.
- Claus (1875) again placed the Branchiura within the Copepoda, based on a comprehensive study on the development of the larvae, as well as the anatomy and morphology of the group.
- Wilson (1902) accepted the classification of Claus (1875). The characters of the appendages, proboscis and ovary are perceived as evidence for the separation of the Argulidae from the class Branchiopoda, and are subsequently placed within the Copepoda.
- Grobben (1908) suggested that the ovary might have a paired origin, in contrast with Wilson (1902), which suggested that the ovary is single.

- Martin (1932) confirmed the paired origin of the ovary and also showed that the compound eye differs completely from that of the copepods. Martin also showed significant differences with the Cladocera, and elevated the Branchiura to the level of subclass under the Crustacea.
- Yamaguti (1963b) reviewed the subclasses Branchiura and Copepoda, and divided the Branchiura into two families, the Dipteropeltidae Yamaguti, 1963 and Argulidae Muller, 1785 and placed both in the order Argulidea. The Argulidae is further divided into three subfamilies, namely Argulinae Yamaguti, 1963, Chonopeltinae Yamaguti, 1963 and Dolopsinae Yamaguti, 1963.
- Fryer (1969) rejected the classification of Yamaguti, mainly because major similarities of the subfamilies are not recognised.

Presently, the Branchiura is classified as a subclass of the Maxillopoda Dahl, 1956, and comprise of a single family, the Argulidae (see Table 6.1). Some authors still recognise the Dipteropeltidae, but this is not widely accepted.

Subclass: Branchiura Thorell, 1864

Order: Arguloida Rafinesque, 1815

Family: Argulidae Muller, 1785

The Argulidae comprise of four genera, namely *Argulus* Muller, 1785, *Dolops* Audouin, 1837, *Chonopeltis* Thiele, 1900 and *Dipteropeltis* Calman, 1912. According to Van As & Van As (2001a) the genera are distinguished from each other on the form of the maxillules, which are either formed into hooks (in the case of *Dolops*) or suckers (in the case of *Argulus* and *Chonopeltis*). The presence or absence of a mouth tube and stylet as well as characteristics of the antennule and antennae are used to differentiate between *Argulus* and *Chonopeltis*. Only one species of *Dipteropeltis* is known, which was described only from the female and has not been recorded since the original description from South American waters (Van As & Van As 2001a). The genus *Dolops* is represented by 11 species of which only *Dolops ranarum* Stuhlman, 1891 has a pan-African distribution. Fourteen species of *Chonopeltis* are known from African freshwater habitats. The genus is also endemic to Africa. Nearly 150 species of *Argulus* are known worldwide, most of them from freshwater habitats (Rushton-Mellor 1994). At least 35 species have been described from Africa.

The genus *Argulus* Muller, 1785

Generic diagnosis

Carapace trifoliate with distinct anterior lobe. In some cases carapace covers whole cephalothorax, in others only the first two legs are covered. Respiratory areas of two to three differentiated areas situated ventrally on lateral carapace lobe. Paired antennules consist of two segments, with terminal segment ending in a sclerotized hook. Maxillules present as hooks in larval form, which develops into large suckers. Maxillae with four podomeres. Basal plate covered by scales and spines with posterior and anterior projections. Stylet anterior to extended mouth tube. Spermatophore absent (Van As & Van As, 2001a).

Species of *Argulus* known from South Africa

Extensive research has been done on the genus *Argulus* in South Africa by authors such as: Kruger, Van As & Saayman (1983), Avenant-Oldewage & Swanepoel (1993), Van As & Van As (1993), Avenant-Oldewage (1994), Avenant-Oldewage & Oldewage (1995), Lutsch & Avenant-Oldewage (1995), Van As & Van As (1999), Van As, Van Niekerk & Olivier (1999), Van As & Van As (2001a), Van As & Van As (2001b), Van As, Van As, Christison & Cyprus (2001).

Six species of *Argulus* have been recorded from South Africa, with four of these from marine habitats. The remaining two species are freshwater species, namely *A. japonicus* Thiele, 1900, which is an introduced species and *A. capensis* Barnard, 1955 described from *Sandelia capensis* (Cuvier, 1829) by Barnard (1955) from the western Cape rivers. This description, however, was based on a single female specimen, and has not been recorded since the original description.

Subclass Copepoda Milne Edwards, 1940

Parasitic copepods have a variety of body forms and hosts, including freshwater and marine fishes, as well as invertebrates such as tunicates and polychaetes. According to McLaughlin (1980) some species display great diversity in body forms, and it is often difficult to recognise the adult parasite as a copepod.

In many species it is only the female that has undergone extensive morphological change and is parasitic, while the male remains free-living and retains a unmodified copepod appearance. The life cycle of copepods involves young that hatch as nauplius larvae. There are usually five or six naupliar stages, which is followed by four copepodite stages before adulthood is reached (McLaughlin 1980).

According to Huys & Boxshall (1991) the diversity of body form and biology of the copepods lead to considerable confusion among early systematists. Due to this confusion, parasitic forms and free-living forms were classified in separate higher taxa. Thorell (1859) recognised the affinity between free-living and parasitic copepods and this marked the beginning of the search for a natural system of phylogenetic relationships of the Copepoda (Huys & Boxshall 1991). Due to the large number of classification schemes that have been proposed, (they will not all be discussed here) a brief summary is presented below (adapted from Huys & Boxshall 1991).

- The classification systems of Latreille (1802), Lamarck (1818), Milne Edwards (1840), Dana (1846, 1848), Baird (1850), Zenker (1854) and Claus (1857) all placed the copepods in various orders and subclasses of the Crustacea, but neither of them considered the free-living and parasitic forms in the same group.

- Thorell (1859) placed free-living and parasitic copepods in a single group for the first time, and formed three groups based on the oral appendages, namely the Gnathostoma Thorell, 1859, Poecilostoma Thorell, 1859, and Siphonostoma Thorell, 1859.
- Claus (1863) adopted the name Copepoda for the Entomostraca and divided the copepods into the Copepoda Carcinoidea which comprises the free-living forms, as well as the temporary parasites, and the Copepoda Parasitica which comprised the species with modified bodies, which are permanent parasites.
- Gerstaecker (1866-1879) recognised that semi-parasitic and parasitic families do not belong in the same group and suggests lineages leading from free-living forms to commensals and semi-parasites, to highly evolved parasites.
- Giesbrecht (1882) rejected the use of mouthpart structure and number of genital apertures, but used tagmosis to divide the copepods into the Gymnoplea Giesbert, 1882 and Podoplea Giesbert, 1882.
- Sars (1901) rejected the classification of Giesbrecht, and divided the Copepoda into seven suborders (Calanoida Sars, 1903, Harpacticoida Sars, 1903, Cyclopoida Burmeister, 1834, Notodelphyoida Sars, 1903, Monstrilloida, Sars, 1903, Caligoida Sars, 1903 and Lernaeoida Sars, 1903) based on seven genera, which Sars believed to be representing types of copepods.
- Calman (1909) classified the Copepoda as a subclass of the Crustacea, but continued to include the Branchiura as an order.
- Wilson (1910) supported the Sarsian system, but suggested the transfer of the Lernaeidae Cobbold, 1879 to the Caligoida.
- Brehm (1927) combined the best characteristics of the systems of Giesbrecht, Sars and Wilson.
- Oakley (1930) pointed out flows in the Sarsian scheme regarding the Lernaeoida, but suggests a few other alterations, including a new subdivision of the Copepoda into the Cyclopiformes Oakley, 1930 and the Caligiformes Oakley, 1930.

- Gurney (1933) established a new order, the Misophrioida Gurney, 1933, which contained the Misophriidae Brady, 1878.
- Monod & Dolfuss (1932) adopted the system proposed by Oakley (1930), were the Cyclopiformes contained the orders Monstrilloida, Calanoida, Harpacticoida, Cyclopoida and Notodelphyoida, and the Caligiformes contained the families Caligidae Burmeister, 1835, Dichelesthiidae Dana, 1853, Sphyriidae Wilson, 1919, Lernaeidae, Lernaeopodidae Olsson, 1869, Choniostomatidae and the Herpyllobiidae Hansen, 1892.
- Wilson (1932) recognised seven suborders of true copepods, namely the Calanoida, Harpacticoida, Cyclopoida, Notodelphyoida, Monstrilloida, Caligoida, Lernaeopodoida and included the Branchiura as the suborder Arguloidea.
- Heegard (1947) suggested that evolutionary radiation in all directions had taken place from the Cyclopoida, towards the other suborders, as well as the parasitic copepods. He divided the parasitic copepods into the Pectinata and Fisculata, based on the structure of the mandibles.
- Lang (1948) challenged the Sarsian system with the rejection of the Notodelphyoida, and suggested that the Copepods should be divided into four suborders, the Progymnoplea Lang, 1948, Gymnoplea, Propodoplea Lang, 1948, and the Podoplea. The system of Lang contained most of the elements of modern copepod classification, but did not consider parasitic copepods in detail.
- Yamaguti (1963b) placed parasitic copepods on vertebrate hosts in six orders, i.e. the Cyclopidea Yamaguti, 1963, Lernaeopodidea Yamaguti, 1963, Andreinidea Yamaguti, 1963 , Philichthyidea Yamaguti, 1963, Sarcotacidea Yamaguti, 1963 and the Caligidea Stebbing, 1910.
- Kabata (1979) recognised two lineages, namely Gymnoplea and Podoplea and produced a comprehensive classification of the Copepoda, based on a reassessment of parasitic copepods of fishes. He also placed the fish parasite families in the appropriate orders.

- Boxshall (1979) established a new order of Podoplea, the Mormonilloida Boxshall, 1979.
- Marcotte (1982) concluded that the ancestral copepod was benthic or semibenthic. He considered the evolution of the Cyclopoida, Poecilostomatoida Thorell, 1859, and Siphonostomatoida Thorell, 1859 into planktonic and parasitic habitats to be the final great radiation.
- Fosshagen & Iliffe (1985) established a new order within the Gymnoplea, namely the Platycopioida Fosshagen, 1985.
- Starobogatov (1986) proposed a classification scheme of the Crustacea, which differed entirely from the other schemes. The principle on which his system is based was criticised by Boxshall & Huys (1989).
- Boxshall (1986) proposed a phylogenetic system for copepod orders, based on the work of Kabata (1979).
- Huys (1988) introduced a separate order within the Podoplea, the Gelyelloida Huys, 1988.
- Ho (1990) considered ten orders in a phylogenetic analysis of the Copepoda, using cladistic methods, and generated a consensus tree showing the phylogenetic relationships of the orders.
- Huys & Boxshall (1991) proposed a new classification system for the Copepoda (Table 6.1). In this system, the phylogenetic relationships of the orders are based on an analysis of 54 morphological characters.

Table 6.1. Classification of the Branchiura Thorell, 1864 and Copepoda Milne Edwards, 1840 (orders that contain parasitic representatives) within the class Maxillopoda Dahl, 1956 (adapted from Huys & Boxshall 1991)

Subclass	Infraclass	Superorder	Order	Family
Branchiura			Arguloida Rafinesque, 1815	Argulidae
Copepoda Milne Edwards, 1840	Progymnoplea Lang,1948		Platycopioida Fosshagen, 1985	
	Neocopepoda Huys & Boxshall, 1991	Gymnoplea Giesbrecht, 1882	Calanoidea Sars, 1903	
		Podoplea Giesbrecht, 1882	Misophrioida Gurney, 1933	
			Cyclopoida Burmeister, 1834	Archinotodelphyidae
				Ascidicolidae
				Chordeumiidae
				Cucumaricolidae
				Cyclopidae
				Cyclopinidae
				Lernaeidae
				Mantridae
				Notodelphyidae
				Oithonidae
				Ozmanidae
				Thespesiopsyllidae
			Gelyelloida Huys, 1988	
			Mormonilloida Boxshall, 1979	
			Harpacticoida Sars, 1903	
			Poecilistomatoida Thorell, 1859	Anomoclausiidae
				Anomopsyllidae
				Antheacheridae
				Anthessiidae
				Bomolochidae
				Catiniidae
				Chondracanthidae
				Clausidiidae
				Clausiidae
				Corallovexiidae
				Corycaeidae
				Echiurophilidae
				Erebonasteridae
				Ergasilidae
				Eunicicolidae
				Gastrodelphyidae
				Lamippidae
				Lichomolgidae
				Mesoglicolidae
				Myicolidae
				Mytilicolidae
				Nereicolidae
				Oncaeidae
				Paralubbockiidae
				Pharodidae
				Philichtyidae
				Philoblennidae
				Phyllodicolidae
				Pseudanthessiidae
				Rhynchomolgidae
				Sabelliphilidae
				Sapphirinidae
				Serpulidicolidae
				Shiinoidae
				Spiophanicolidae
				Splanchnotrophidae
				Synaptiphilidae

Table 6.1 continued. Calssification of the Branchiura Thorell, 1864 and Copepoda Milne Edwards, 1840 (orders that contain parasitic representatives) within the class Maxillopoda Dahl, 1956 (adapted from Huys & Boxshall 1991)

Subclass	Infraclass	Superorder	Order	Family
				Taeniacanthidae
				Tegobomolochidae
				Telsidae
				Tuccidae
				Urocopiidae
				Vahiniidae
				Vaigamidae
				Ventriculinidae
				Xarifiidae
			Siphonostomatoida Thorell, 1859	Artotrogidae
				Asterocheridae
				Brychiopontiidae
				Caligidae
				Calverocheridae
				Cancerillidae
				Cecropidae
				Dichelesthiidae
				Dinopontiidae
				Dirivultidae
				Dissonidae
				Ecbathyriontidae
				Entomolepidae
				Eudactylinidae
				Euryphoridae
				Hatschekiidae
				Herpyllobiidae
				Hyponeoidae
				Kroyeriidae
				Lernaeopodidae
				Lernanthropidae
				Megapontiidae
				Micropontiidae
				Nanaspididae
				Nicothoidae
				Pandaridae
				Pennellidae
				Pontoeciellidae
				Pseudocycnidae
				Rataniidae
				Sphyriidae
				Sponginticolidae
				Spongiocnizontidae
				Stellicomitidae
				Tanypleuridae
				Trebiidae
				Xenocoelomatidae
			Monstrilloida Sars, 1903	Monstrillidae

Subclass: Copepoda Milne Edwards, 1840

Infraclass: Neocopepoda Boxshall & Huys, 1991

Superorder: Podoplea Giesbrecht, 1882

Order: Cyclopoida Burmeister, 1834

Family: Lernaeidae Cobbold, 1879

Six genera of lernaeids are found parasitic on fish namely *Lamproglena* Nordmann, 1832, *Lernaea* Linnaeus, 1758, *Lernaeogiraffa* Zimmermann, 1922, *Dysphorus* Kurtz, 1924, *Afrolernaea* Fryer, 1956 and *Opistholernaea* Yin, 1960 (Paperna 1979b). The differentiation between lernaeid genera is based on the morphology of the parasitic females. In all genera, except *Lamproglena*, the head of the adult female is embedded in the tissue of the host. The head is armed with symmetrical protuberances, the head and "neck" is elongated and the swimming legs are degenerated.

The genus *Lamproglena* is specialised for attachment to the host's gills by means of spines on the maxillae and maxillipeds. Members of this genus retain a recognisable copepod appearance, as well as partial segmentation. The thoracic legs are rudimentary and the most posterior legs are absent (Paperna 1979b).

The Genus *Lamproglena* Nordmann, 1832

Generic Diagnosis

The body can be divided into three distinct regions, namely cephalothorax, leg-bearing thoracic segments and abdomen. Cephalothorax is partially separated from the first leg-bearing thoracic segment. First and second leg-bearing thoracic segments form a distinct neck. Third and fourth thoracic segments form an incipient trunk (Dippenaar, Luus-Powell & Roux 2001). Fifth thoracic segment separates genital complex from anterior thoracic segments by a waist-like constriction. Abdomen consists of three segments. Antennae with varying numbers of setae and maxillipeds are tipped with one to five claws. Thoracic legs may be distinctly or indistinctly segmented (Dippenaar *et al.* 2001). Caudal rami are longer than wide and each are tipped with spines (Yamaguti 1963b).

Species of *Lamproglena* Nordmann, 1832 known from Africa

Currently, there are 37 species of *Lamproglena* known worldwide, of which 13 have been reported from Africa. Two of these species were described from the Red Sea, namely *L. hemprechii* Nordmann, 1832 from *Myletes dentex* (Linnaeus, 1758), and *L. lichiae* Nordmann, 1832 from *Scomberoides lysan* (Forsskål, 1775) by Nordmann (1832).

Almost a century later Zimmerman (1923) described *L. werneri* Zimmermann, 1923 from *Bagrus bajad*, from the Nile River. Wilson (1928) described another species from the White Nile and the Red Sea, namely *L. angusta* Wilson, 1928 from the gills of the electric catfish, *Malapterurus electricus* (Gmelin, 1789). Capart (1944) described *L. monodi* Capart, 1944 from hosts of the genera *Hemichromis* Peters, 1858 and *Haplochromis* Hilgendorf, 1888. Fryer (1959), however, synonymised this species with *L. nyasea* Fryer, 1956 which was described from Lake Nyasa, Zimbabwe. Fryer (1956) described *L. clariae* Fryer, 1956 from Lake Nyasa, from the gills of *Clarias gariepinus*.

Capart also described two species in 1956 from Sudan i.e. *L. elongata* Capart, 1956 from *Citharinus citharus* (Geoffroy St. Hilaire, 1809), and *L. wilsoni* Capart, 1956 from *Clarotes laticeps* (Rüppell, 1829). In the same year Capart reported *L. monodi* also from Sudan, but from *Tilapia galilaea* (Linnaeus, 1758). In 1957, Humes (1957) described *L. cleopatra* Humes, 1957 from Egypt, from the gills of *Labeo forskalii*.

During 1960, Dollfus described *L. aubentonii* Dollfus, 1960 from *Hydrocynus brevis* (Günther, 1864), from Niger, but this species was synonymised with *L. hemprechii* by Fryer (1968). In 1961 Fryer described a species from *Barbus* *altianalis radcliffi* Boulenger, 1903 from Lake Victoria, namely *L. barbicola* Fryer, 1961 as well as two known species, namely *L. monodi* from species of *Haplochromis* and *Tilapia* and *L. clariae* from *Heterobranchis longifilis*.

In a publication of parasitic crustaceans of cichlid fishes of Africa from the Musée Royal de L'Afrique Centrale in Belgium, Fryer (1963) reported *L. monodi* from a wide range of *Tilapia* species.

The next year Fryer (1964) described *L. intercedens* Fryer, 1964 from the gills of *Citharines* species from Ghana. Fryer (1965) described another species, namely *L. cornuta* Fryer, 1964 from *Heterobranchus bidorsalis* Geoffroy Saint-Hilaire, 1809 and also reported *L. clariae* collected from the gills of *Clarias gariepinus*, both from the Nile River.

In 1967 Fryer published another report of parasitic copepods from cichlid fishes from the Musée Royal de L'Afrique Centrale. This report, however, mainly covered the genera *Haplochromis*, *Hemichromis* and *Pseudocrenilabrus*, which were infested with *L. monodi*.

In the mid seventies, Shotter (1977) reported five known species of *Lamproglena* from Nigeria, namely *L. clariae* from *Clarias anguillaris* (Linnaeus, 1758), *L. hemprechii* from the gills of *Alestes nurse* (Rüppell, 1832), *L. monodi* from *Tilapia galilaea*, *L. werneri* from *Auchenoglanis occidentalis* (Valenciennes, 1840) and *L. wilsoni* from *Chrysichthys nigrodigitatus* (Lacepède, 1803).

Douëllou & Erlanger (1994) reported two known species collected from Lake Kariba, namely *L. hemprechii* from *Hydrocynus vittatus* (Castelnau, 1861) and *L. monodi*, which were present on all the cichlid fishes examined.

During 2001, Dippenaar *et al.* described a species from two *Labeobarbus* hosts in South Africa, namely *Lamproglena hoi* Dippenaar, Luus-Powell & Roux, 2001 from *Labeobarbus marequensis* and *Labeobarbus polylepis* (Boulenger, 1907). According to Dippenaar *et al.* (2001), four other species of *Lamproglena* have been reported from southern Africa, namely *L. monodi*, *L. clariae*, *L. barbicola* and *L. cornuta*.

Piasecki (1993) stated that *L. hemprechii* and *L. lichiae* propably were described from fishes deposited the Berlin Museum. The hosts reported for *L. hemprechii*, are all freshwater *Hydrocynus* species and were probably collected from the Nile River. If the host reported for *L. lichiae* (*Lichia aculeata* = *Scomberoides lysan*) is indeed correct, this would mean that *L. lichiae* is a marine species and would be an exception amongst the other species of *Lamproglena*.

The African species of *Lamproglena*, the hosts and their distribution is summarised in Table 6.2. In Table 6.3 the distinguishing characters of the African species are summarised.

Table 6.2 Summary of the African species of *Lamproglena* Nordmann, 1832, the hosts and their distribution.

Species	Hosts	Distribution
Lamproglena angusta Wilson, 1928	*Malapterurus electricus* (Gmelin, 1789)	Nile River
L. barbicola Fryer, 1961	*Barbus altianalis radcliffi* Boulenger, 1903	Lake Victoria
L. clariae Fryer, 1956	*Clarias gariepinus* (Burchell, 1822)	Lake Nyasa, Lake Victoria, Malagarasi swamp and the White Nile
L. cleopatra Humes,1957	*Labeo forskalii* Rüppel, 1836	Egypt
L. cornuta Fryer, 1965	*Heterobranchus bidorsalis* Geoffroy Saint-Hilaire, 1809	Nile River, southern Africa
L. elongata Capart 1956	*Citharines citharus* (Geoffroy Saint-Hilaire, 1809)	Sudan
L. hemprechii Nordmann, 1832	*Alestes nurse* (Rüppell, 1832), *Hydrocynus vittatus* (Castelnau, 1861), *H. forskalii* (Cuvier, 1819), *Hepsetus odoe* (Bloch, 1794), *Myletes dentex* (Linnaeus, 1758)	Zimbabwe, Ghana, Niger and Red Sea
L. intercedens Fryer, 1964	*Citharinus* sp.	Ghana
L. lichiae Nordmann, 1832	*Scomberoides lysan* (Forsskål, 1775)	Red Sea
L. monodi Capart, 1944	*Serranochromis thumbergi* (Castelnau, 1861), *Pseudocrenilabrus philander* (Weber, 1897), *Tilapia* spp. *Haplochromis* spp	Lake Moero, Congo, Zimbabwe, Nigeria and Central Africa
L. werneri Zimmermann, 1923	*Auchenoglanis occdentalis* (Valenciennes, 1840), *Bagrus bajad* (Forsskål, 1775).	Galma and Nile River
L. wilsoni Capart, 1956	*Clarotes laticeps* (Rüppell, 1829), *Chrysichthys nigrodigitatus* (Lacepède, 1803)	Sudan
L. hoi Dippenaar, Luus-Powell & Roux, 2001	*Labeobarbus marequensis* (Smith, 1841), *Labeobarbus polylepis* (Boulenger, 1907)	South Africa

Table 6.3. African species of *Lamproglena* Nordmann, 1832 with a summary of the main distinguishing characters

Species	Characters	
Lamproglena angusta Wilson, 1928 (Figure 6.1A-G)	Total length:	6.5mm
	Antennule:	Fringe of spines on anterior margin near distal end. Terminal joint supplied with setae
	Antennae:	Four segmented with two setae on terminal segment
	Maxillae:	Swollen basal segment and terminal spine
	Maxilliped:	Armed with three terminal claws and accessory spine on inner margin
	Legs:	Pairs 1-4 biramous, each ramus consisting of two segments and terminating in two spines
L. barbicola Fryer, 1961 (Figure 6.1H-M)	Total length:	5mm
	Antennule:	Reduced to two distinct and one indistinct segment. Basal segment lacking anterior fringe of setae
	Antennae:	Four segmented, basal segment crowned with distal spinules
	Maxillae:	Long with single spine
	Maxilliped:	Armed with three recurved distal claws
	Legs:	Pairs 1-4 similar, allbiramous with reduced setation
L. clariae Fryer, 1956 (Figure 6.2A-F)	Total length:	9mm
	Antennule:	Two segmented, basal segment with margin of reduced setae on preaxial margin, terminal segment with four reduced setae and small preaxial seta
	Antennae:	Two segmented, distal segment with two small papillae and three reduced setae
	Maxillae:	Two distal chitinized spines
	Maxilliped:	Armed with three recurved chitinized claws
	Legs	Pairs 1-4 biramous with no sign of segmentation and reduced setation
L. cleopatra Humes,1957 (Figure 6.2G-K)	Total length:	2.6mm
	Antennule:	Swollen basal podomere and small distal podomere, both with naked setae
	Antennae:	Indistinctly four segmented, with five small setae on terminal segment
	Maxillae:	Terminal spine projecting through thin transparent covering layer
	Maxilliped:	Armed with three curved claws
	Legs:	Pairs 1-4 biramous with each ramus indistinctly two segmented. Endopodites of all legs terminating in blunt setae
L. cornuta Fryer, 1965 (Figure 6.3A-F)	Total length:	11mm
	Antennule:	Large and conspicuous, indistinct segmentation with few short setae on anterior margin and distal seta
	Antennae:	Two segmented, almost unarmed
	Maxillae:	Stout with single spine
	Maxilliped:	Armed with single claw and rounded fleshy lobe
	Legs:	Pairs 1-4 biramous with segmentation almost completely absent
L. elongata Capart 1956 (Figure 6.3G-J)	Total length:	4.5mm
	Antennule:	Two segmented with numerous setae on terminal segment
	Maxilliped:	Armed with five terminal claws

Table 6.3. Continued: African species of *Lamproglena* Nordmann, 1832 with a summary of the main distinguishing characters

Species	Characters	
L. hemprechii Nordmann, 1832 (Figure 6.4A-D)	Total length:	4.79mm
	Antennule:	Heavily sclerotized without setation
	Antennae:	Four segmented, basal segment with short blunt outgrowth, distal segment with at least three setae
	Maxillae:	Strongly inclined to basal part, with single sharp spine
	Maxilliped:	Armed with three terminal claws
L. hoi Dippenaar, Luus-Powell & Roux, 2001 (Figure 6.6D-H)	Total length:	3mm
	Antennule:	Indistinctly two segmented, with 22 setae on basal segment and nine setae on distal segment
	Antennae:	Indistinctly four segmented, second segment with 8-10 setae, terminal segment with four setae on inner margin, five setae on distal margin
	Maxillae:	Two segmented ending in single spine
	Maxilliped:	Two segmented, armed with three claws, one with spine-like extension
	Legs:	Pairs 1-4 biramous with three segmented exopod and two segmented endopod
L. intercedens Fryer, 1964 (Figure 6.4E-J)	Total length:	5mm
	Antennule:	Two segmented, reflexed dorsally with numerous setae
	Antennae:	Same as antennule
	Maxillae:	Stout with single spine
	Maxilliped:	Armed with five recurved claws
	Legs:	Pairs 1 & 2 large and conspicuous, directed outward and backward. Pairs 3 & 4 very small with reduced setation
L. lichiae Nordmann, 1832 (Figure 6.5A-C)	Total length:	3.9mm
	Antennule:	Delicate with two small terminal setae
	Antennae:	Three segmented with round-tip process on anterior margin of basal segment with five short spines
	Maxillae:	Single sharp spine
	Maxilliped	Armed with three terminal claws
L. monodi Capart, 1944 (Figure 6.4D-H)	Total length:	3.6mm
	Antennule:	Two segmented, basal segment with numerous setae on preaxial margin, distal segment with single preaxial seta and tuft of short terminal seta
	Antennae:	Two segmented
	Maxillae:	Long with two distal spines
	Maxilliped:	Armed with three claws
	Legs:	Pairs 1-4 biramous with indistinct segmentation, reduced setation
L. werneri Zimmerman, 1923	*No information available*	
L. wilsoni Capart, 1956 (Figure 6.6A-C)	Total length:	4.0mm
	Antennule:	Two segmented, terminal segment much reduced, external border with row of setae
	Maxilliped:	Armed with three claws

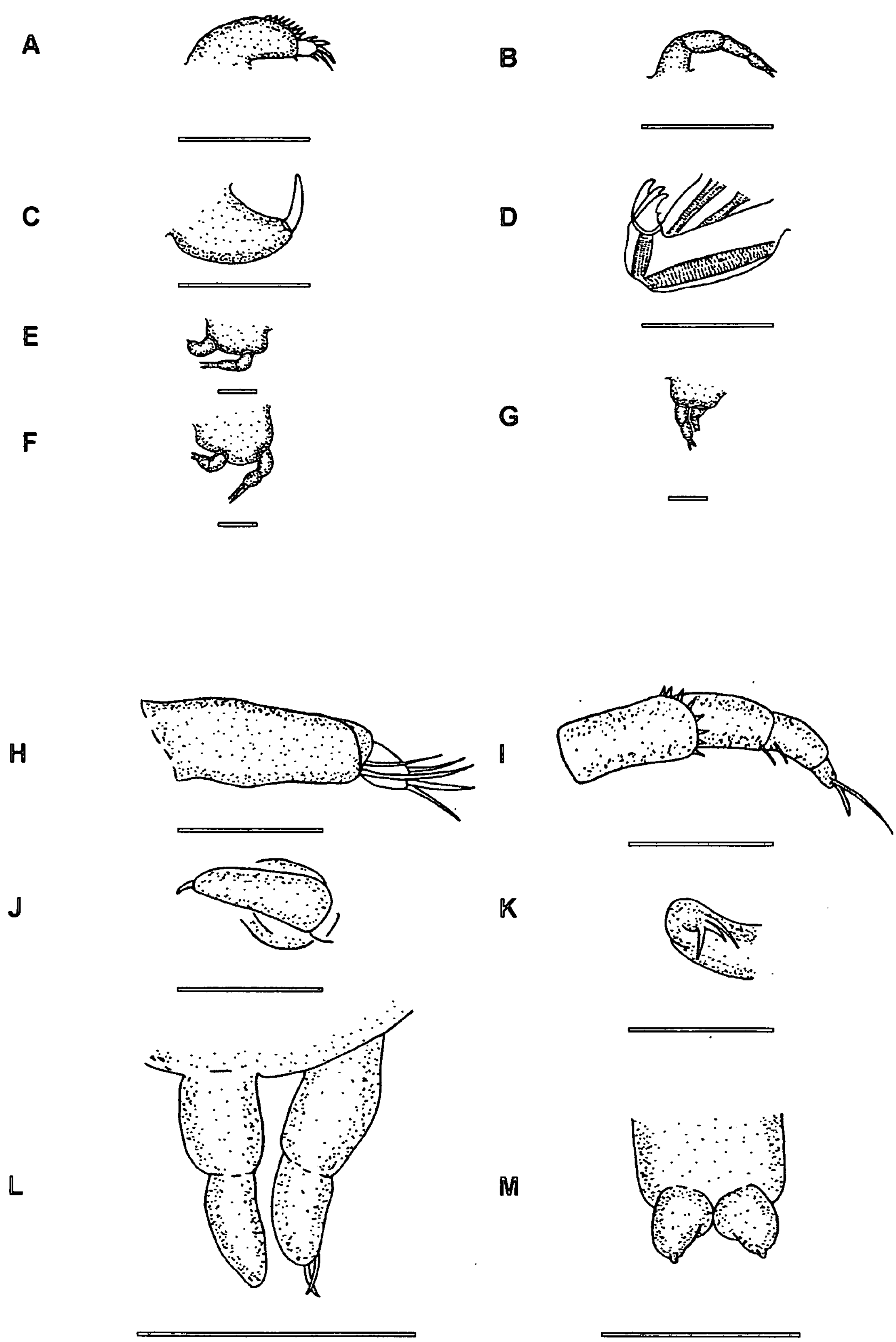


Figure 6.1. Diagrammatic drawings of *Lamproglena* Nordmann, 1832 species. **A-G** – *L. angusta* Wilson, 1928 (redrawn from Wilson 1928). **A** – antennule, **B** – antenna, **C** – maxillae, **D** – maxilliped, **E** – leg I, **F** – leg II, **G** – leg III. **H-M** – *L. barbicola* Fryer, 1961 (redrawn from Fryer 1961). **H** – antennule, **I** – antenna, **J** – maxillae, **K** – maxilliped, **L** – leg II, **M** – furcal rami. Scale bar: 300µm

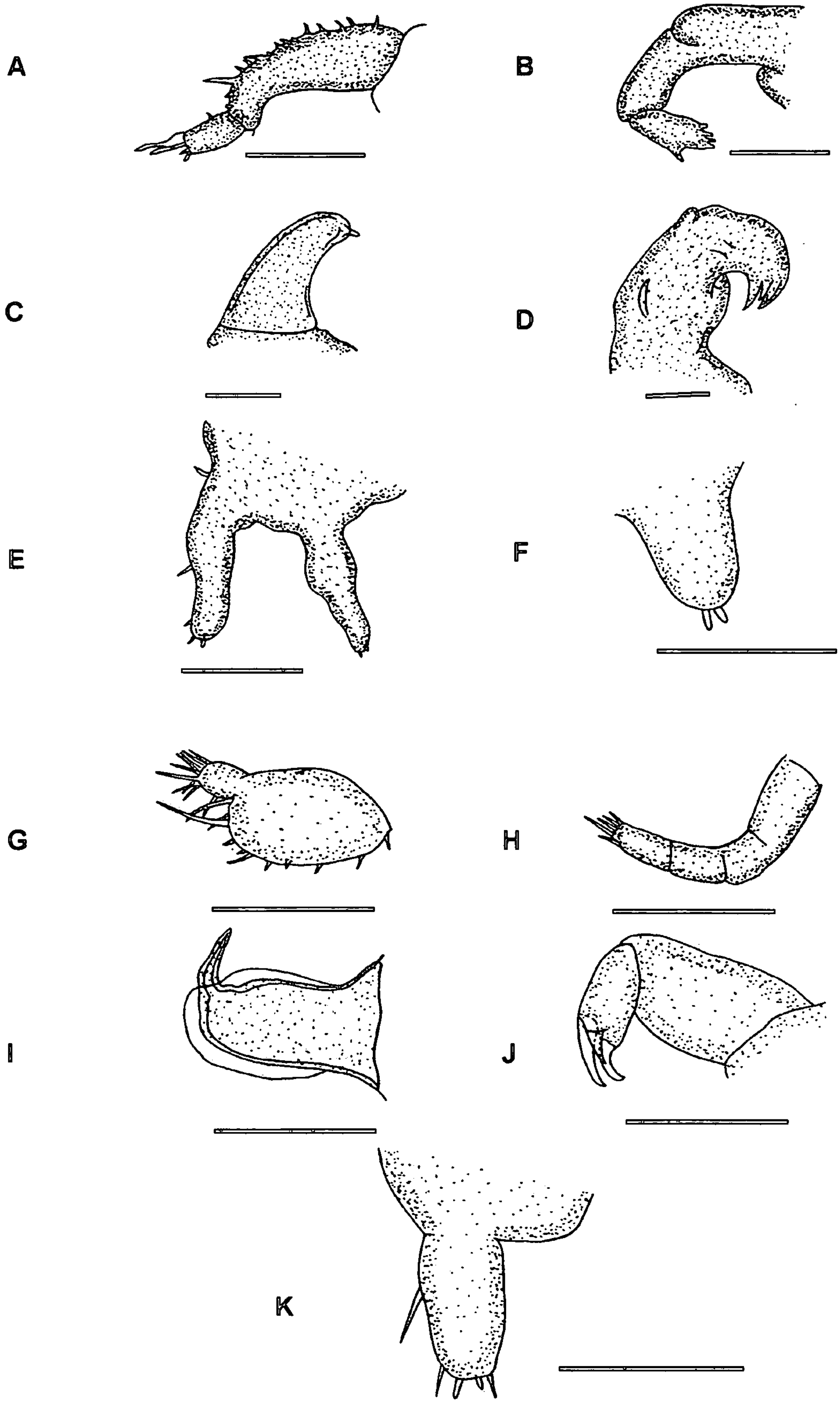


Figure 6.2. Diagrammatic drawings of *Lamproglena* Nordmann, 1832 species. **A-F** – *L. clariae* Fryer, 1956 (redrawn from Fryer 1956). **A** – antennule, **B** – antenna, **C** – maxillae, **D** – maxilliped, **E** – leg II, **F** – furcal ramus. **G-K** – *L. cleopatra* Humes, 1957 (redrawn from Humes 1957). **G** – antennule, **H** – antenna, **I** – maxillae, **J** – maxilliped, **K** – furcal ramus. Scale bar: 100µm

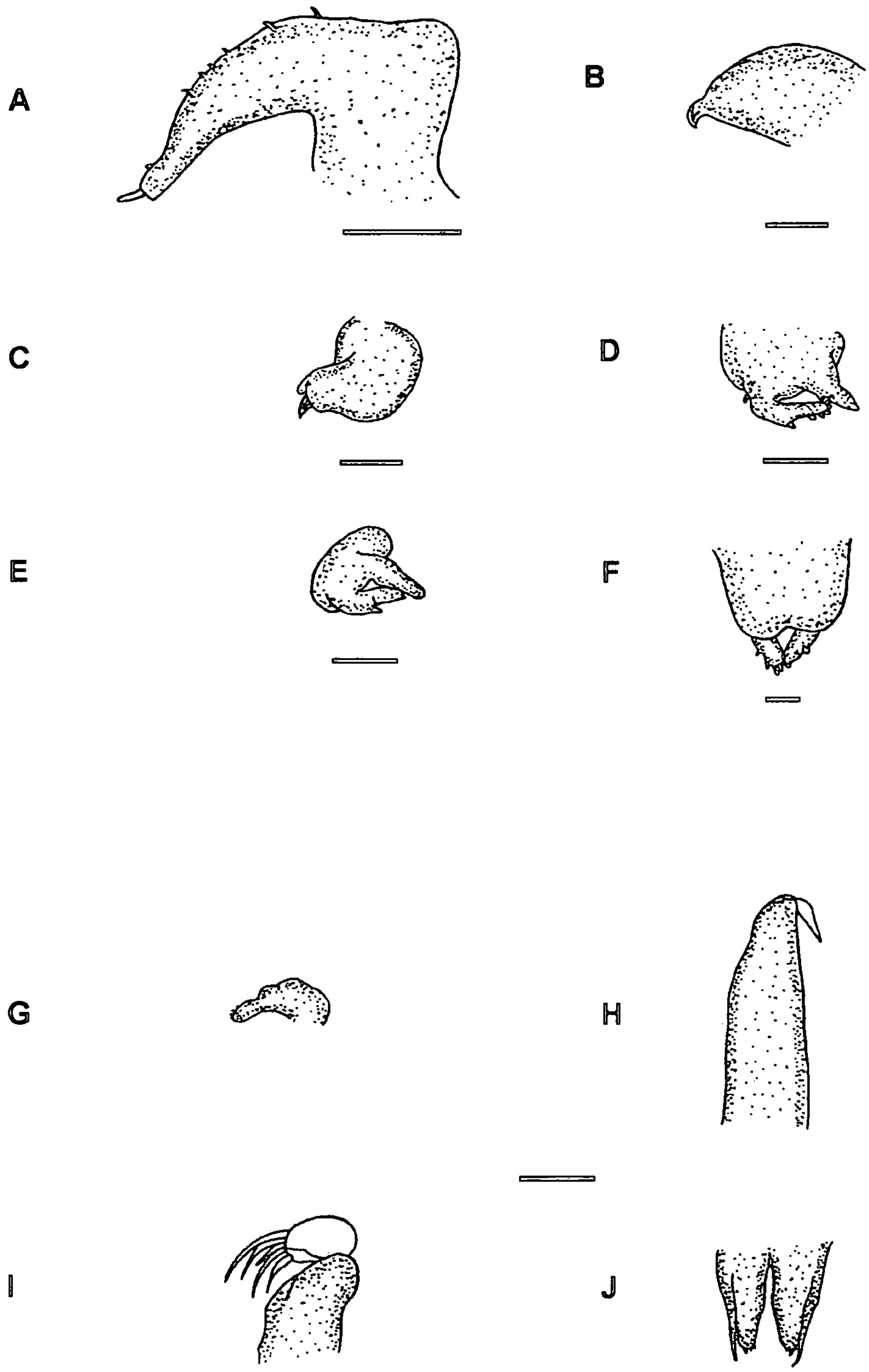


Figure 6.3. Diagrammatic drawings of *Lamproglena* Nordmann, 1832 species. **A-F** – *L. cornuta* Fryer, 1965 (redrawn from Fryer 1965). **A** – antennule, **B** – maxillae, **C** – maxilliped, **D** – legI, **E** – leg II. **F** – furcal rami. **G-J** – *L. elongata* Capart, 1956 (redrawn from Capart 1956). **G** – antenule, **H** – maxillae, **I** – maxilliped, **J** – furcal rami. Scale bar: 100µm

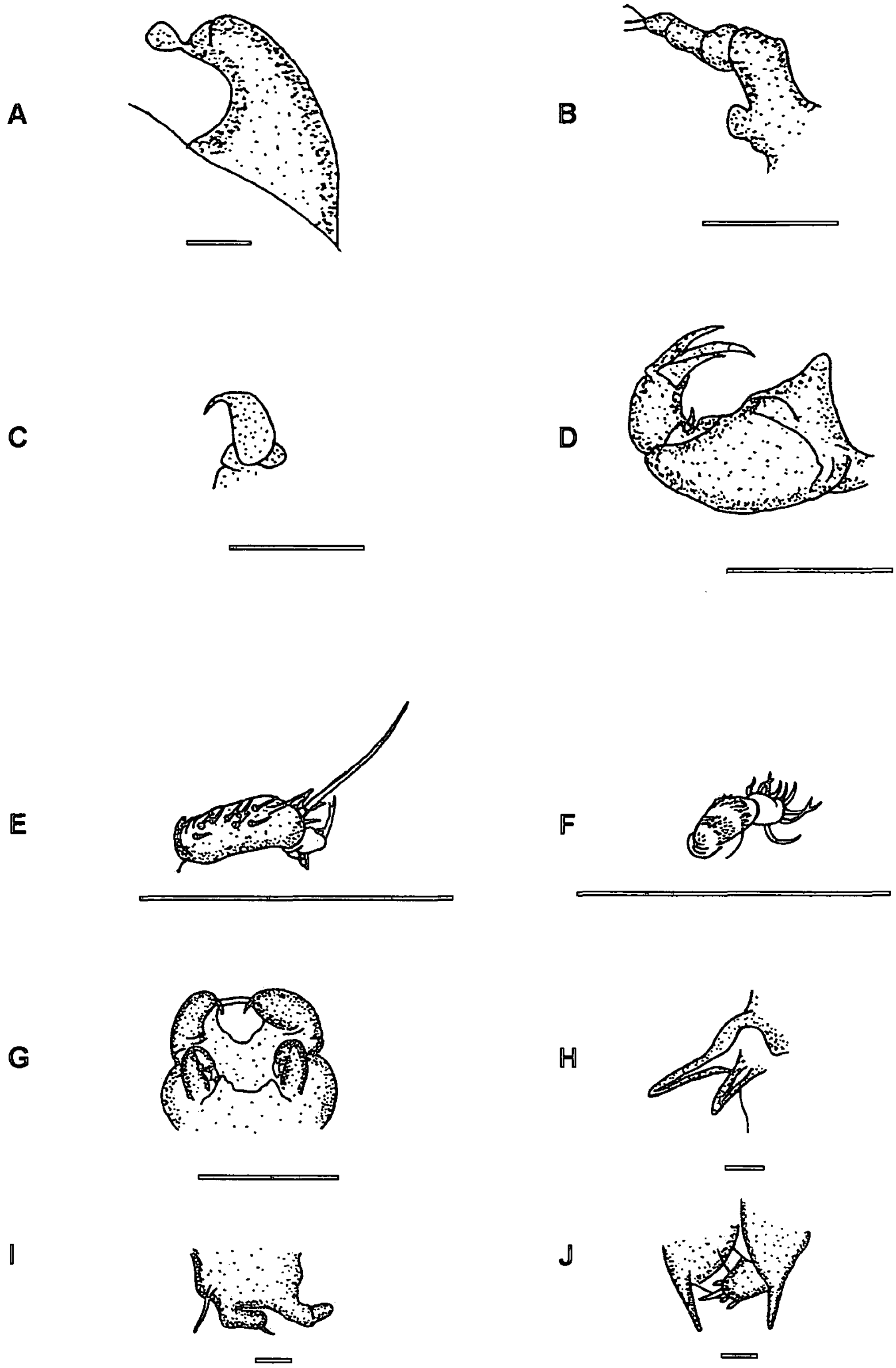


Figure 6.4. Diagrammatic drawings of *Lamproglena* Nordmann, 1832 species. **A-D** – *L. hemprechii* Nordmann, 1832 (redrawn from Piasecki 1993). **A** – antennule, **B** – antenna, **C** – maxillae, **D** – maxilliped. **E-J** – *L. intercedens* Fryer, 1964 (redrawn from Fryer 1964). **E** – antennule, **F** – antenna, **G** – maxillae and maxilliped, **H** – leg II, **I** – leg III, **J** – furcal rami. Scale bar A-D: 300µm, E,F: 300µm, G: 500µm, H: 50µm, I,J: 10µm

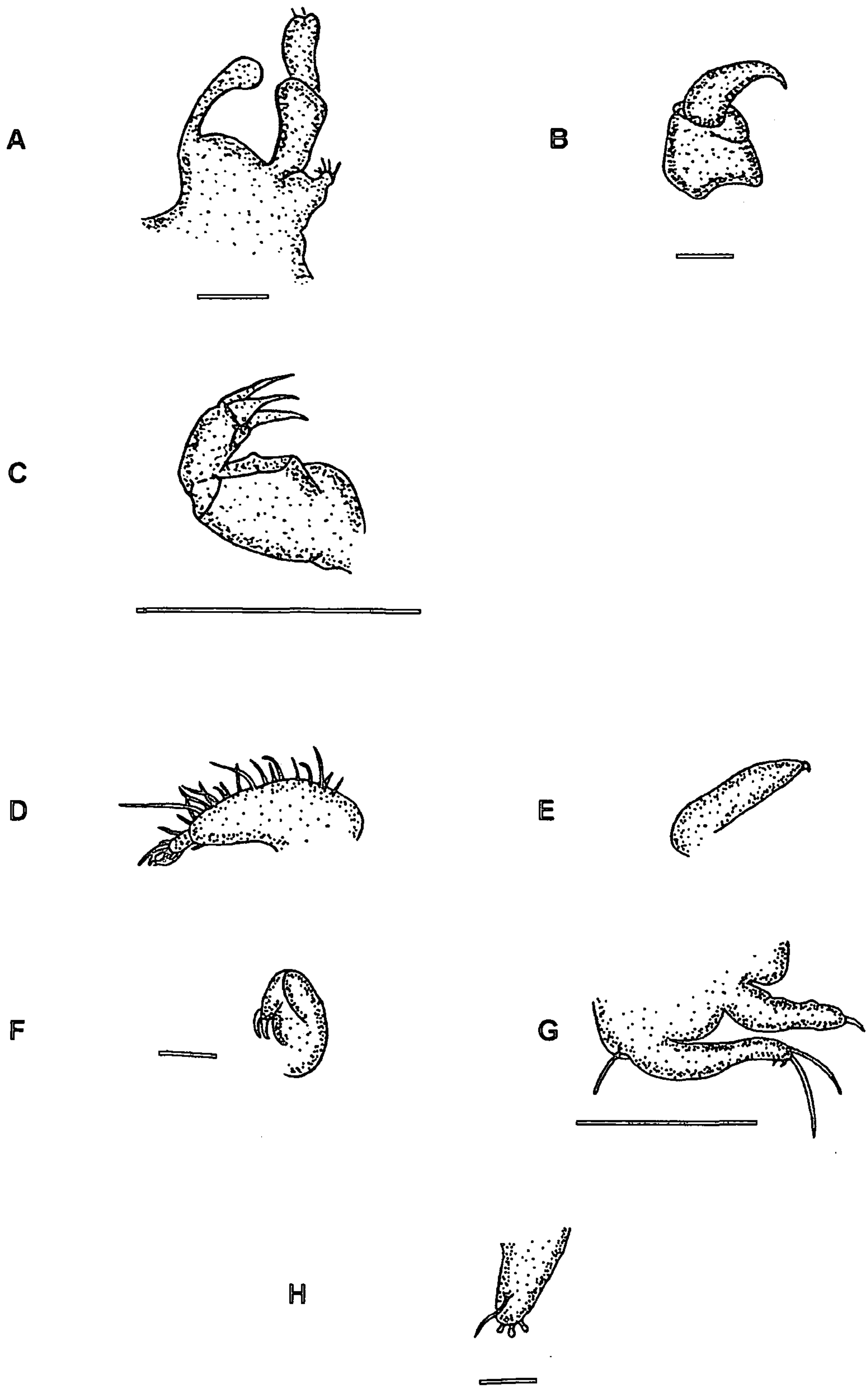


Figure 6.5. Diagrammatic drawings of *Lamproglena* Nordmann, 1832 species. **A-C** – *L. lichiae* Nordmann, 1832 (redrawn from Piasecki 1993). **A** – antennule and antenna, **B** – maxillae, **C** – maxilliped. **D-H** – *L. monodi* Capart, 1944 (redrawn from Fryer, 1956). **D** – antennule, **E** – maxillae, **F** – maxilliped, **G** – leg I, **H** – furcal ramus. Scale bar A-C: 300µm, D-H: 100µm

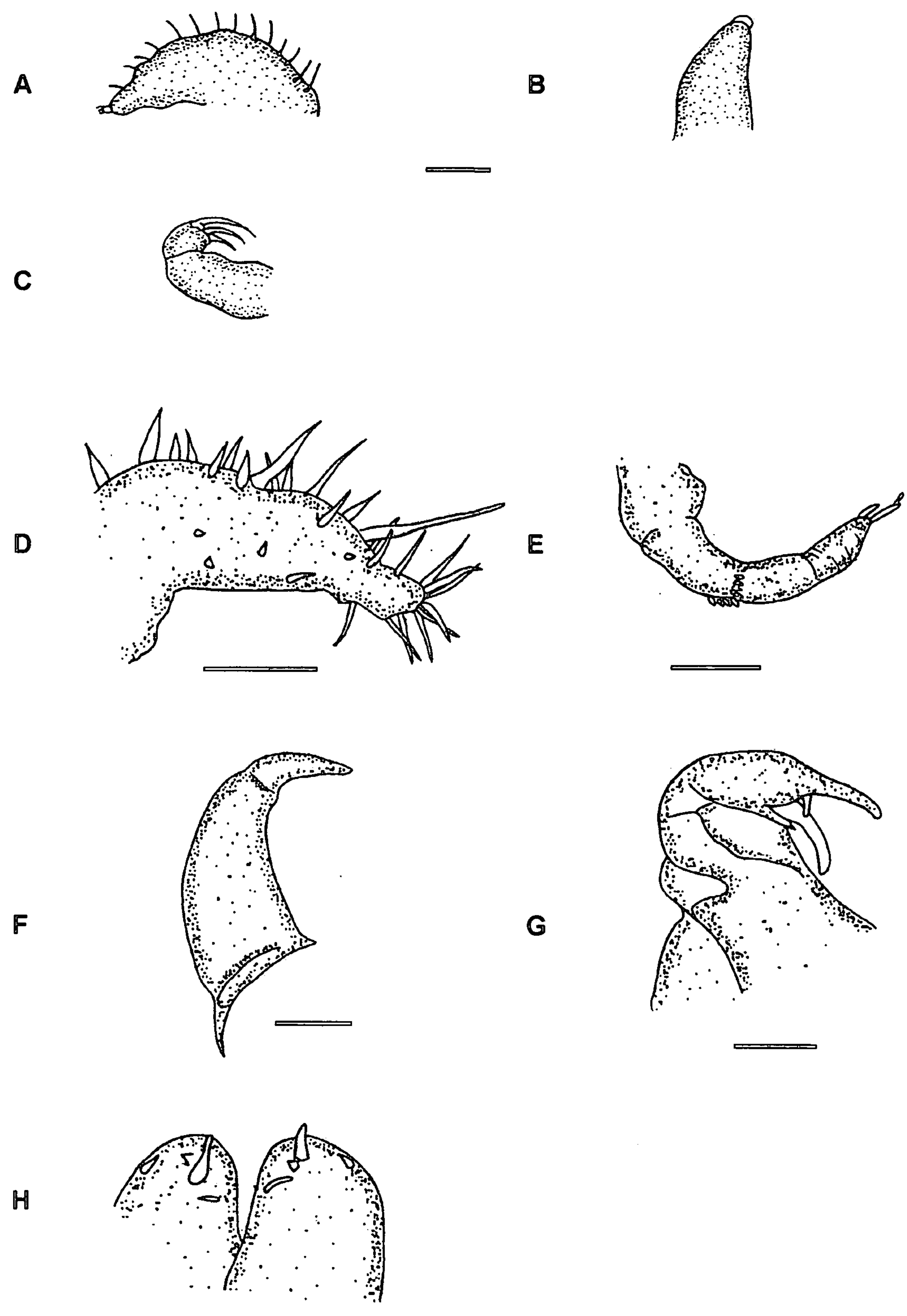


Figure 6.6. Diagrammatic drawings of *Lamproglena* Nordmann, 1832 species. **A-C** – *L. wilsoni* Capart, 1956 (redrawn from Capart 1956). **A** – antennule, **B** – maxillae, **C** – maxilliped. Scale bar: 100µm. **D-H** – *L. hoi* Dippenaar, Luus-Powell & Roux 2001 (redrawn from Dippenaar, Luus-Powell & Roux 2001). **D** – antennule, **E** – antenna, **F** – maxillae, **G** – maxilliped, **H** – furcal rami. Scale bar: 50µm

Parasitic Crustacea from Soetdoring Nature Reserve

Two species of parasitic crustaceans were collected from fishes of the Soetdoring Nature Reserve. These included representatives of the Branchiura as well as the Copepoda.

An *Argulus* sp. was collected from the skin of *Cyprinus carpio*, *Labeo capensis*, *L. umbratus*, and *Labeobarbus kimberleyensis* and a *Lamproglena* sp. was collected from the gills of *Clarias gariepinus*.

Argulus sp. A

Host and locality: *Cyprinus carpio*, *Labeo capensis*, *L. umbratus* and *Labeobarbus kimberleyensis* Soetdoring Nature Reserve, South Africa (28° 52' S, 26° 0' E)
Infestation Site: Skin
Specimens studied: Morphometric measurements made using light microscopy. Reference material (V2001/06/13-01, V2001/06/18-05, V2001/07/19-10, V2001/11/23-01) deposited in the collection of the Aquatic Parasitology Study group, University of the Free State.

Description:
Adult female: Body stout, 5.9mm long posterior margin of carapace extending posteriorly to cover fourth leg (Figure 6.7A, Figure 6.9A). Carapace comprising 78% of total length. Lateral lobes of carapace rounded, separated by a U-shaped sinus more than 1/3 length of carapace (36%). Paired respiratory area on ventral side of lateral lobes; small rounded area directly anterior to larger kidney shaped area. Thorax distinctly four segmented. Abdomen 1.3mm comprising 22% of total length; width 70% of length; posterior lobes ovoid separated by narrow sinus 1.6mm long, comprising 43% of total abdomen length. Paired spermathecae rounded, situated in fused part of abdomen. First segment of first antennae triangular with spinous medial projection. Second segment with

anterior and posterior directed projections, terminates in robust ventrally directed hook (Figure 6.7B, Figure 6.9B). Third and fourth segments slender with numerous terminal setae (Figure 6.7 B). Second antennae five-segmented, coxa heavily sclerotized with spinous process at posteromedial angle (Figure 6.7C, Figure 6.9B). Distal four segments less sclerotized with small number of terminal setae. First maxilla forms large suckers; rim with 40-48 supporting rods, comprising 5-7 overlapping sclerites (Figure 6.9C). Second maxilla five segmented (Figure 6.7D). Basal plate armed with numerous scales on ventral surface and three prominent pointed spines (Figure 6.9D); terminal segment with small claw and three short spines; ventral surface of all segments with patch of scales. First to fourth pair of legs (Figure 6.9E) biramous and nearly equal in size; flagellum present on legs one and two; pair of elongate projections on posterior margin of second leg; long plumose setae present on all legs.

Adult male: Body stout 5.1mm long; carapace comprising 78% of total length; carapace sinus comprising 31% of carapace length. Abdomen short 1.3mm, comprising 25% of body length; width 69% of length; posterior lobes rounded, separated by a narrow sinus 1.2mm long comprising 44% of abdomen length. Paired elongate testis situated in fused part of abdomen and extending posteriorly past sinus. Cephalic appendages and first two pairs of legs similar to those of female (Figure 6.8A, B). Accessory copulatory structures on third leg comprise a sac-like socket situated dorsally, with peg anteriorly on leg four (Figure 6.8C, D).

Remarks:

Based on the above description and morphometrical data as well as the key to species of *Argulus* provided by Rushton-Mellor (1994), *Argulus* sp. A can be identified as *A. japonicus* (Figure 6.7, Figure 6.8 & Figure 6.9).

This is an introduced species and does not seem to be host specific, as it was found to infest all cyprinid hosts collected.

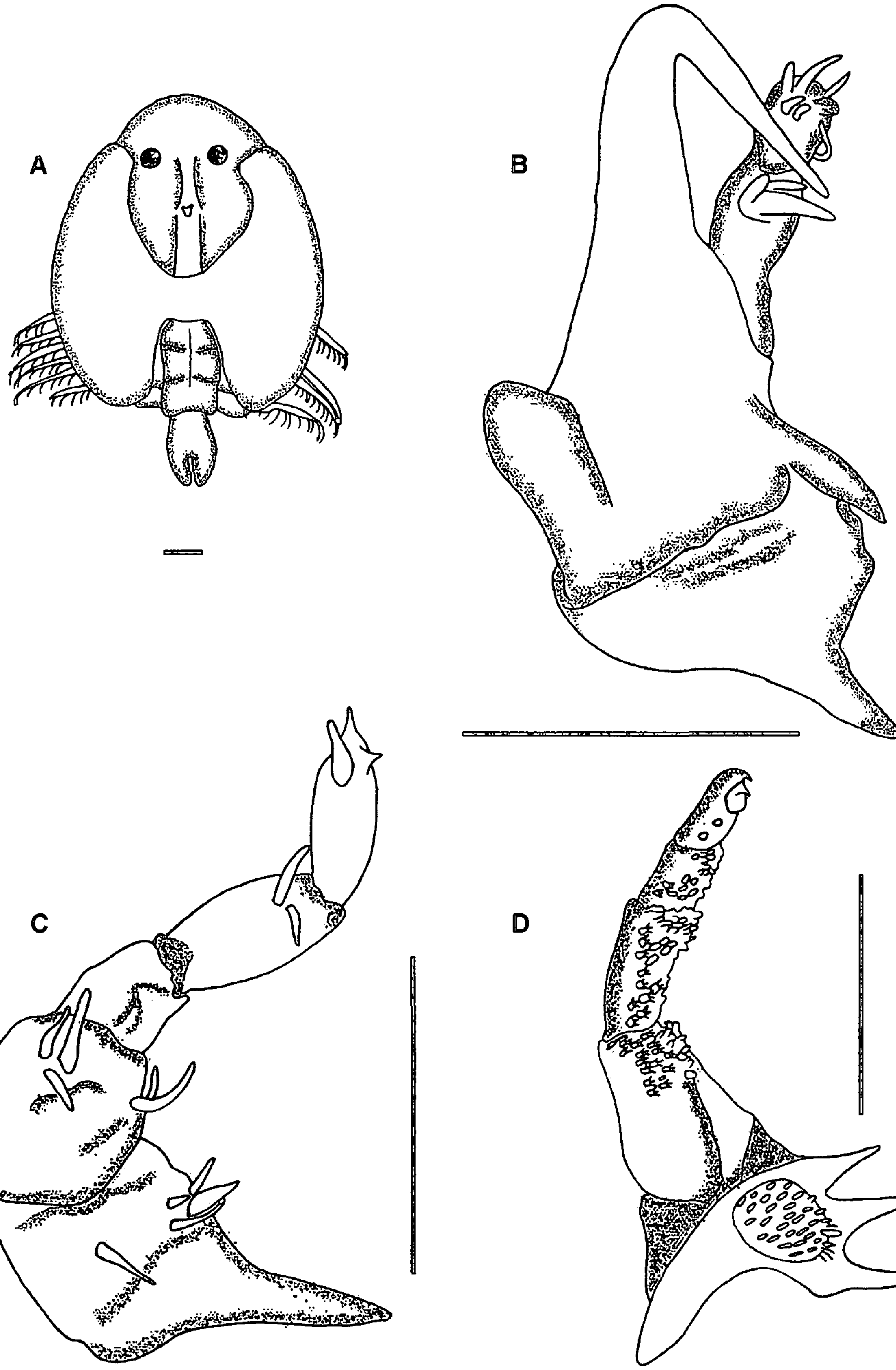


Figure 6.7. Microscope projection drawings of *Argulus japonicus* Thiele, 1900 collected from cyprinid fishes from the Soetdoring Nature Reserve. **A** – adult female (dorsal), scale bar: 0,5mm, **B** – first antenna, scale bar: 0.25mm, **C** – second antenna, scale bar: 0.5mm, **D** – second maxilla, scale bar: 0.5mm

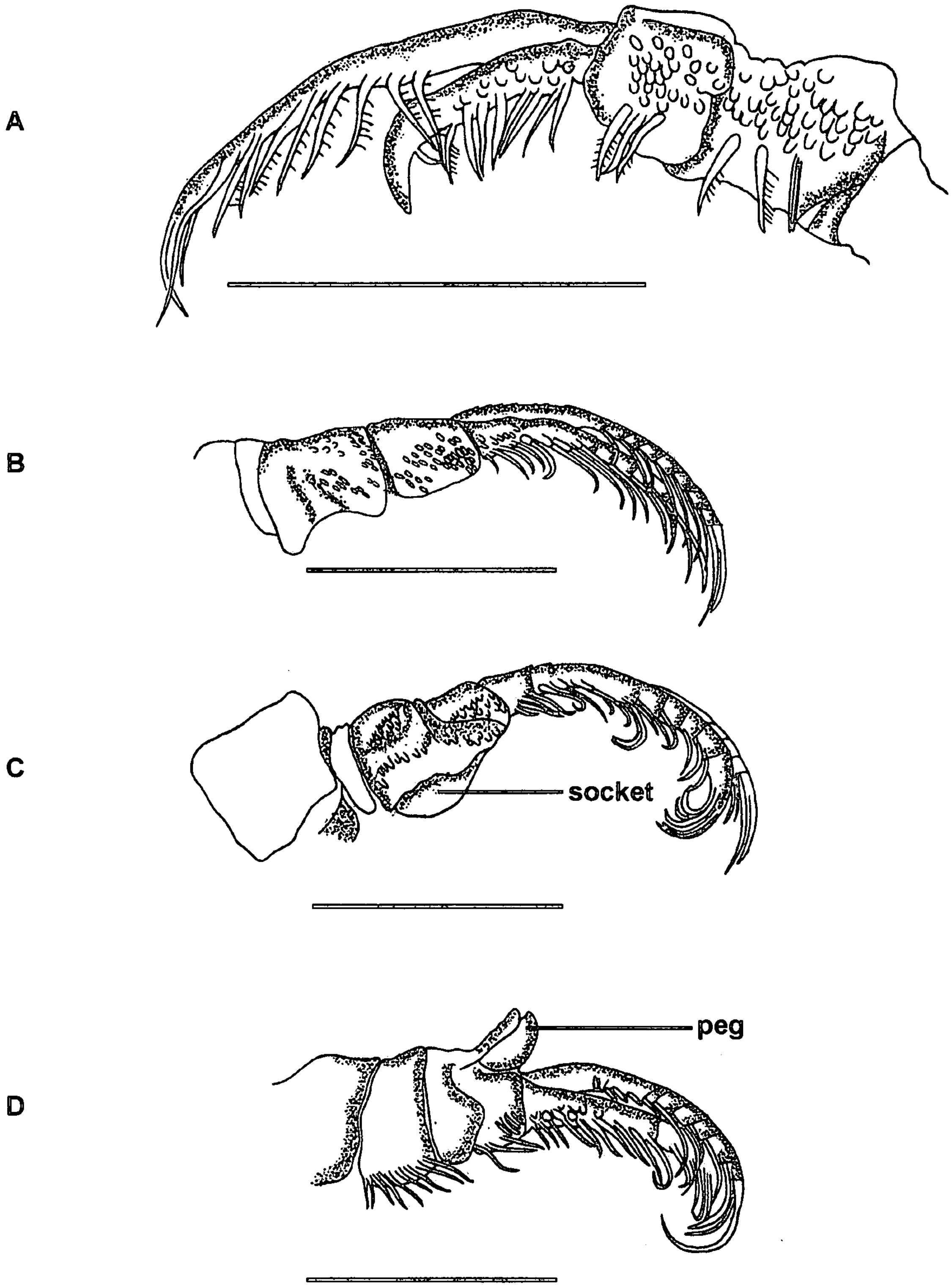


Figure 6.8. Microscope projection drawings of *Argulus japonicus* Thiele, 1900 collected from cyprinid fishes from the Soetdoring Nature Reserve. **A**, **B**, **C**, **D** – adult male (ventral). **A** – leg I, **B** – leg II, **C** – leg III, **D** – leg IV. Scale bar: 0.5mm

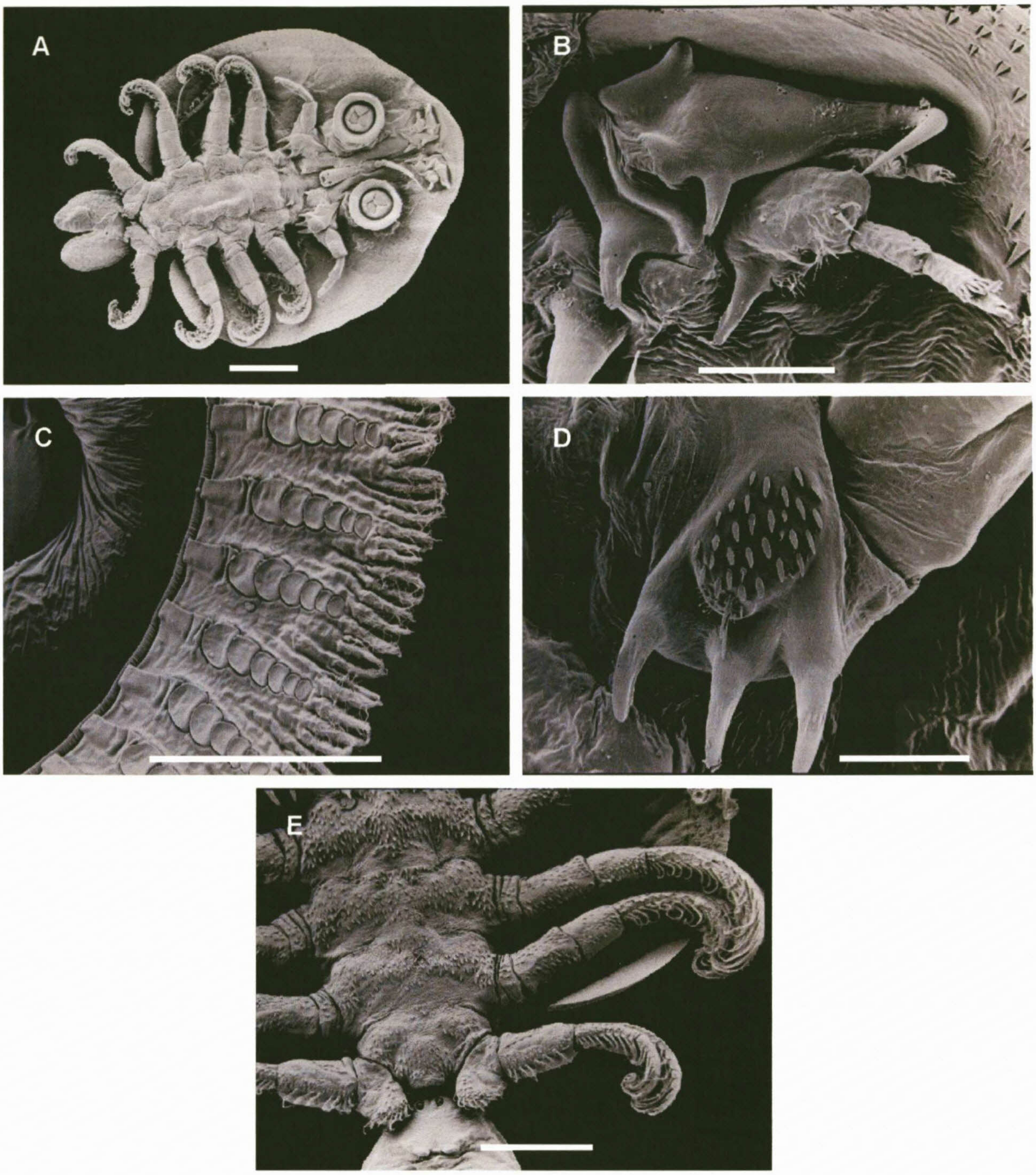


Figure. 6.9. Scanning electron micrographs of *Argulus japonicus* Thiele, 1900 collected from cyprinid fishes from the Soetdoring Nature Reserve. **A** – ventral view of female, **B** – first and second antennae, **C** – scerites of supporting rods of first maxilla, **D** – basal plate of second maxilla, **E** – legs of female (ventral). Scale bar A, E: 0.5mm, B, D : 0.25mm, C: 0.1mm

***Lamproglena* sp. A**

Host and locality: Clarias gariepinus, Soetdoring Nature reserve, South Africa (28° 52' S, 26° 0' E)

Infestation Site: Gills

Specimens studied: Morphometric measurements and drawings made using SEM micrographs. Reference material (V2001/06/19-04, V2001/09/25-10, V2001/05/01-01, V2001/11/28-05, V2001/09/20-08) deposited in the collection of the Aquatic Parasitology Study group, University of the Free State.

Description:

Adult female: Body elongated, 5.3mm long, indistinctly segmented (Figure 6.12A). Abdomen with three segments. Antennule (Figure 6.10C, Figure 6.12B) two segmented bearing a row of reduced setae along preaxial margin; terminal segment with four terminal setae and one preaxial. Antennae two segmented (Figure 6.10C, Figure 6.12B), terminal segment with two reduced papillae and three small setae. Maxillae short with wide base, bearing a single spine distally (Figure 6.10A, Figure 6.12C, D). Maxilliped short and robust, terminating in three chitinised claws (Figure 6.10B, Figure 6.12D, E). Legs I-IV much reduced; all biramous, indistinctly segmented. Exopod of leg I (Figure 6.11A) with single seta at basis, three setae along external margin, two terminal seta; coxa rudimentary with serrated edge. Exopod of leg II (Figure 6.11B) with single seta at basis, one seta on external margin, terminating in three setae; endopod with single seta at basis. Leg III (Figure 6.11C) with single seta at basis, two setae on external margin, one at midlength of leg, one near terminal end. Leg IV (Figure 6.11D) with seta at basis of endopod, single seta on external margin at midlength of leg, two terminal setae. Leg V much reduced with three posterior setae (Figure 6.11E). Caudal rami short, simple with four terminal papillae and one lateral papilla (Figure 6.11F, Figure 6.12F).

Remarks:

Based on the above description and morphometrical data *Lamproglena* sp. A can be identified as *L. clariae* (Figure 6.10, Figure 6.11 & Figure 6.12).

Lamproglena clariae is the only species known to infest *C. gariepinus*. There are, however, morphological variations between different populations of *L. clariae* (Fryer 1964). The population from the Soetdoring Nature Reserve show similarities to the population described from Lake Nyasa in some characters, such as the setae on the basis of the endopods. It also share similarities to the population from Lake Victoria, particularly in the papillae of the furcal rami.

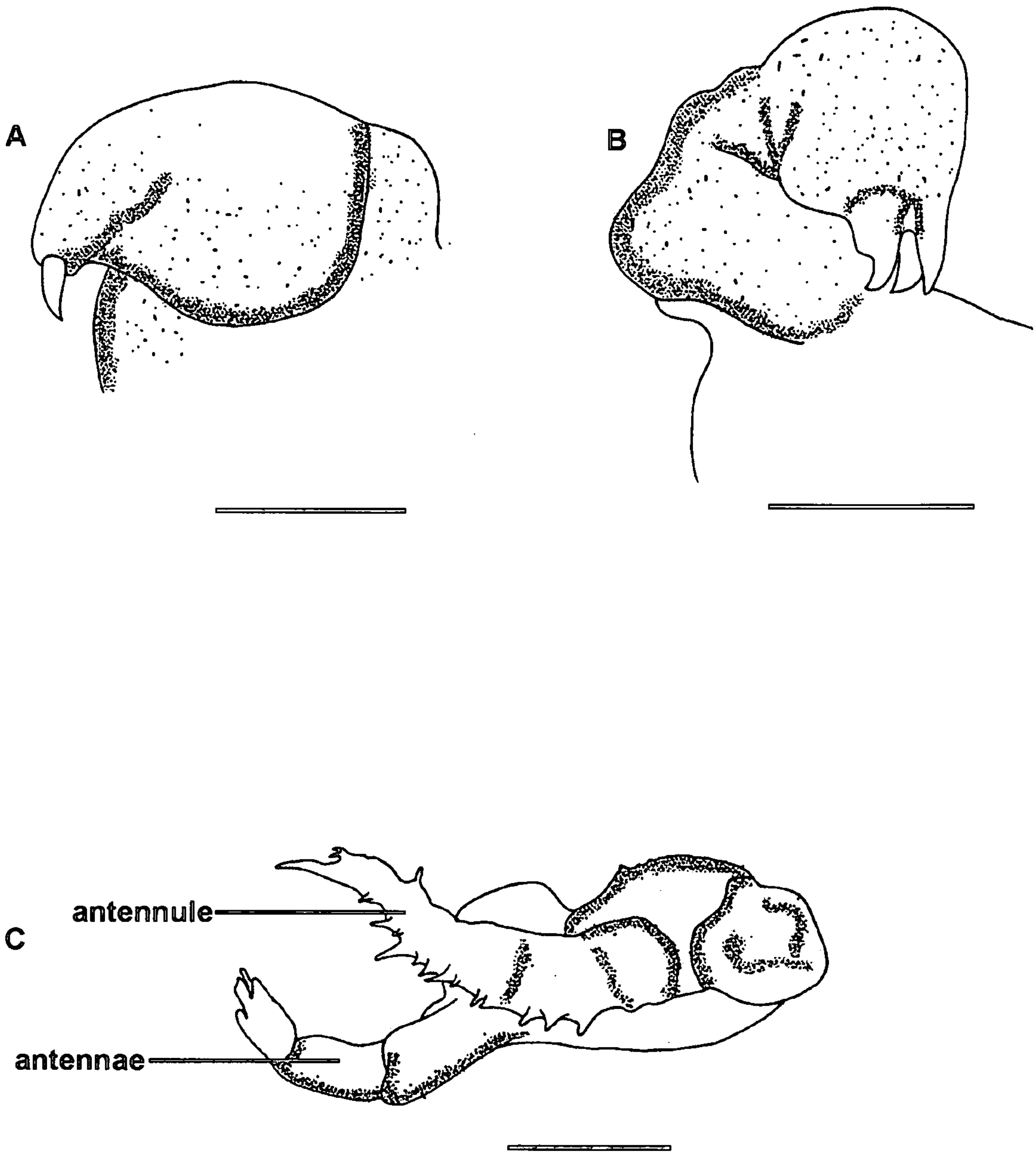


Figure 6.10. Microscope projection drawings of adult female *Lamproglena clariae* Fryer, 1956 from *Clarias gariepinus* (Burchell, 1822) collected from the Soetdoring Nature Reserve. **A** – maxillae, **B** – maxilliped, **C** – antennule and antennae. Scale bar: 100µm.

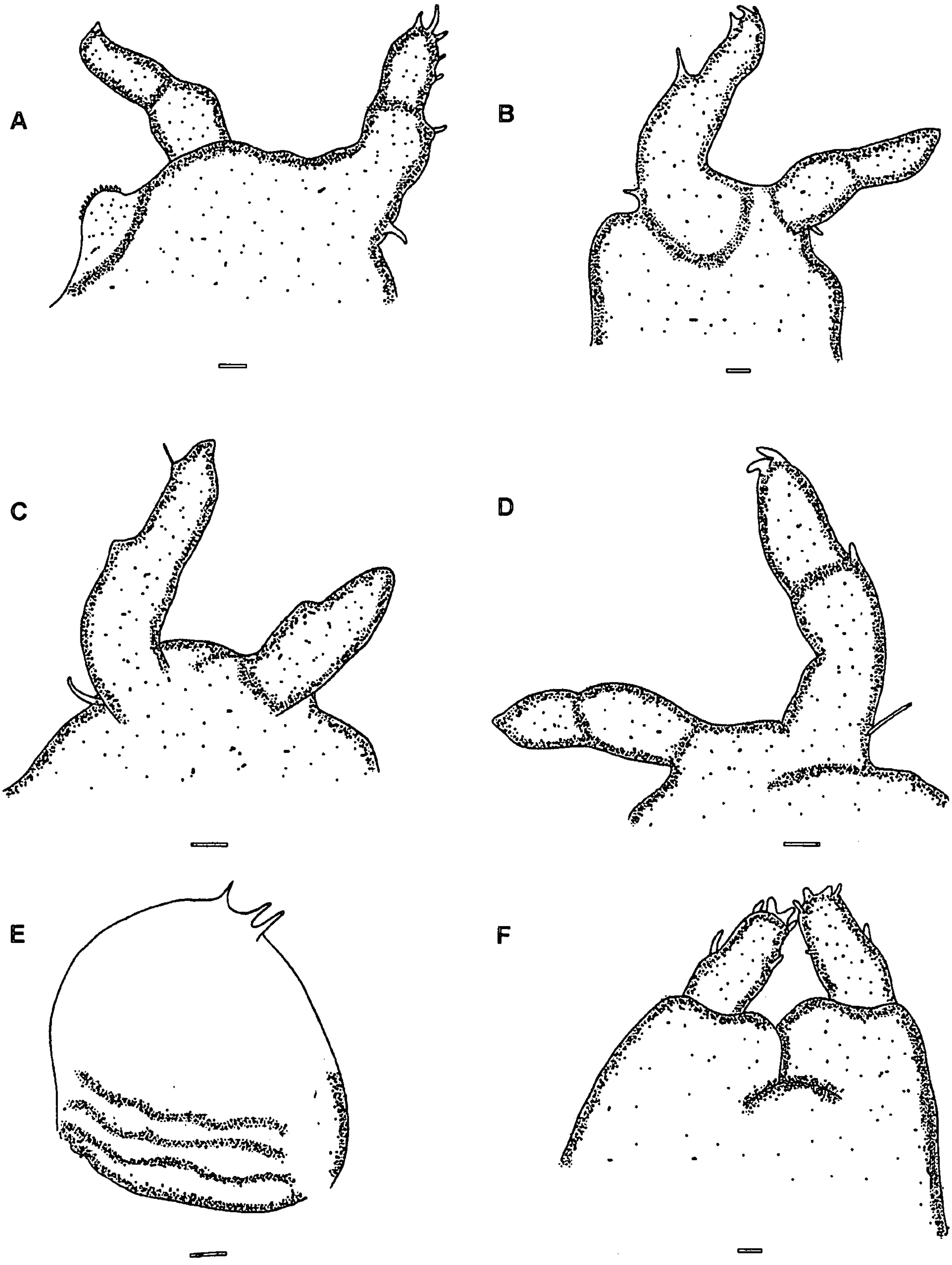


Figure 6.11. Microscope projection drawings of adult female *Lamproglena clariae* Fryer, 1956 from *Clarias gariepinus* (Burchell, 1822) collected from the Soetdoring Nature Reserve. **A** – leg I, **B** – leg II, **C** – leg III, **D** – leg IV, **E** – leg V, **F** – furcal rami. Scale bar: 10μm

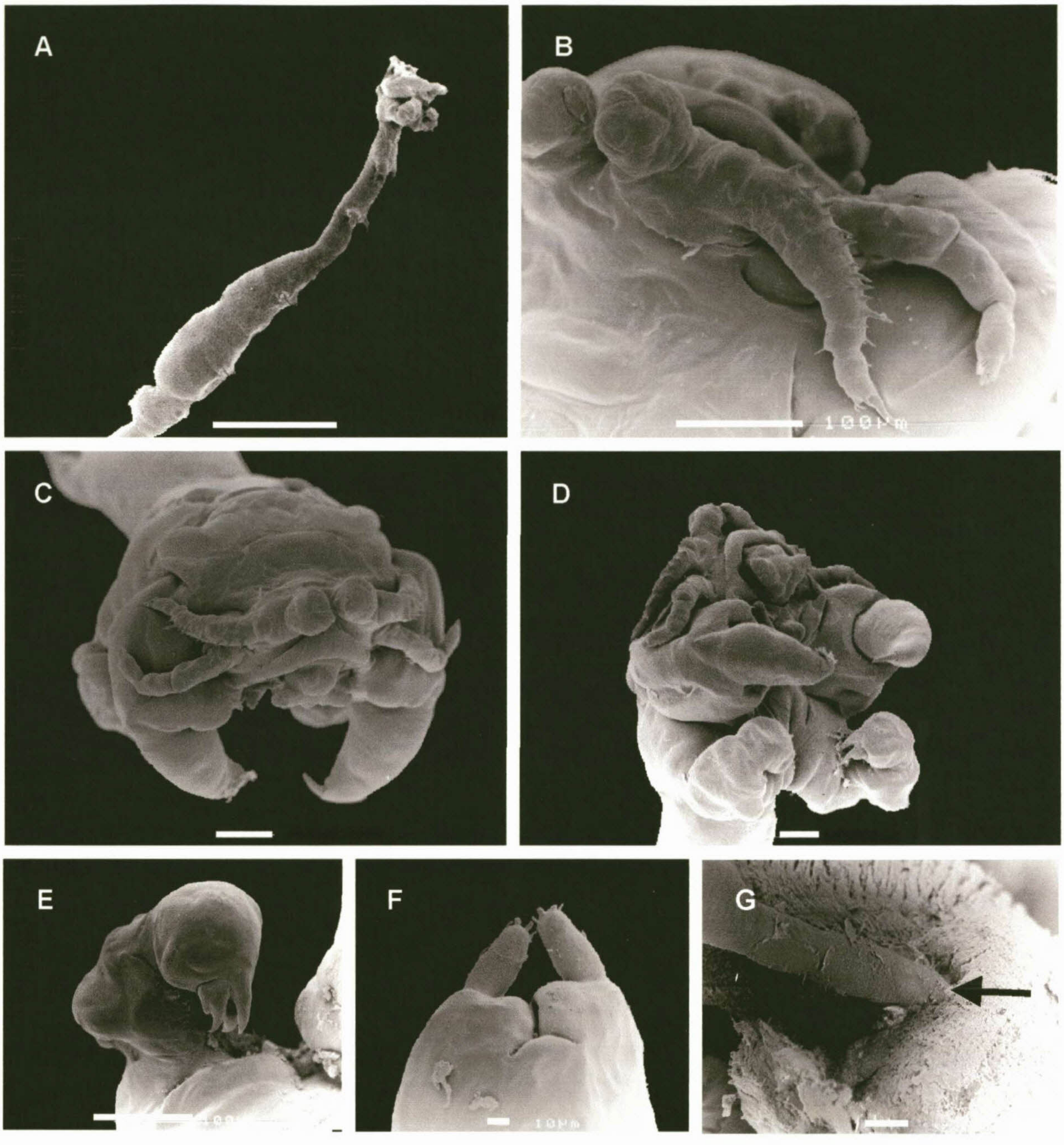
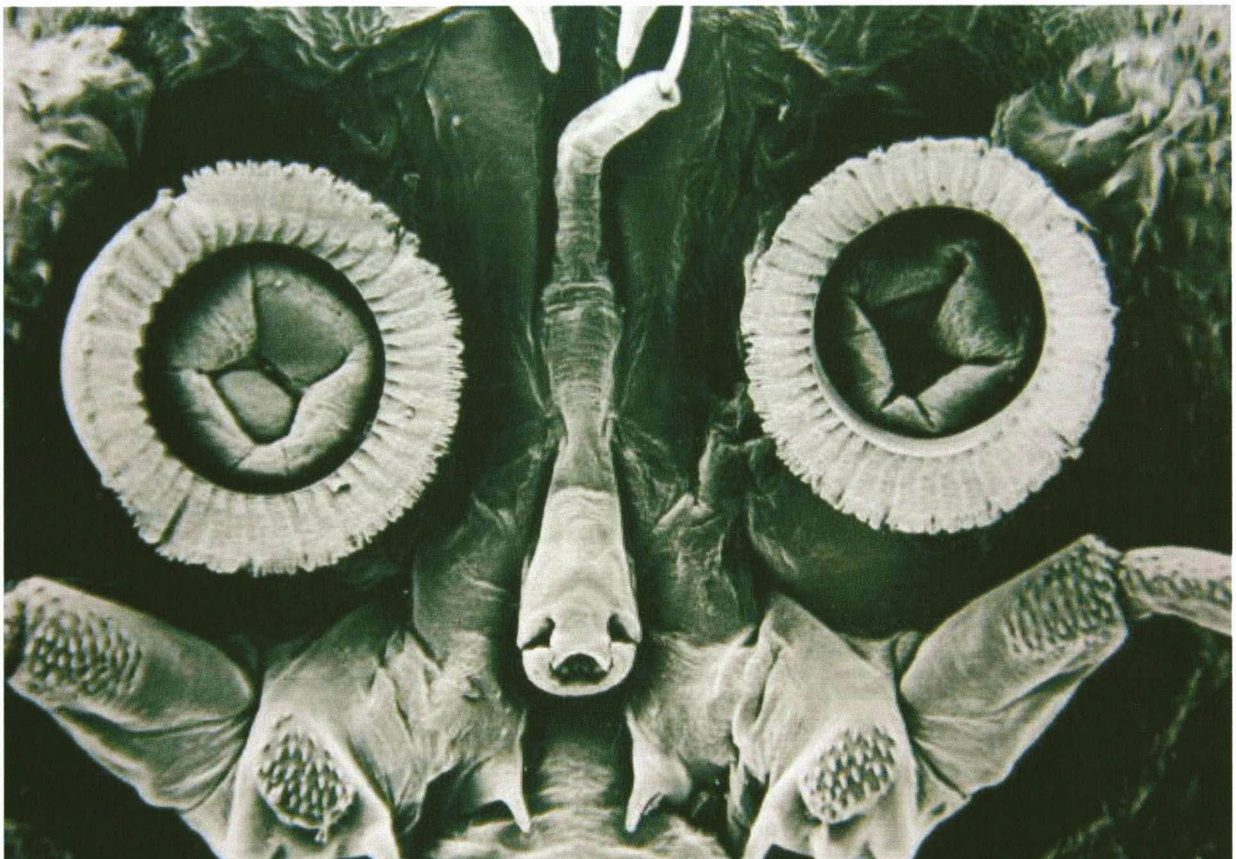


Figure 6.12. Scanning electron micrographs of *Lamproglena clariae* Fryer, 1956 collected from *Clarias gariepinus* (Burchell, 1822) from the Soetdoring Nature Reserve. **A** – anterior body part, **B** – antenna and antennule, **C** – anterior view of cephalothorax, **D** – lateral view of cephalothorax, **E** – maxilliped, **F** – furcal rami, **G** – female inbedded in gill filament. Scale bar A: 1mm, B, E, G: 100µm, C, D, F: 10µm



Chapter 7

Parasite Host Associations

In this chapter, information on the occurrence of ectoparasites on the fish of the Soetdoring Nature Reserve during the period of March 2001 to March 2002 is given. Infestation statistics of different parasite groups is also provided.

Results of fish hosts that were collected and infested with ectoparasites is presented in Table 7.1. Ciliophoran parasites collected included six trichodinid species as well as species of the genus *Apiosoma* (see Chapter 4). Monogenean parasites collected included gyrodactylid and dactylogyrid parasites, as well as *Paradiplozoon modderensis* (see Chapter 5). Although gyrodactylid representatives were collected, none of these could be described, either because infestation levels were to low, or not enough individuals could be successfully retrieved. Two species of parasitic crustaceans were collected, i.e. *Argulus japonicus* and *Lamproglena clariae* (see Chapter 6).

Of the twelve fish species that occur in the Modder River, only eight species were collected during the study period. This might be attributed to the high rainfall that occurred during the summer of 2001/2002. During the first survey in March 2001, the water level of the Krugersdrift Dam was estimated at 23%. Due to high rainfall in the following months and for the remainder of the study, the water level never dropped below 80%.

Except for *Gambusia affinis*, all other species of fish examined was found to be infested with one or more types of ectoparasite. Three specimens of *Labeobarbus kimberleyensis* were collected, of which only one specimen was infested with a single specimen of *Argulus japonicus*. The fish host most frequently encountered was *Labeo capensis*, of which 47 specimens were collected. Forty of these specimens were infested with ectoparasites. Eighteen specimens of *Labeo umbratus* were collected, of which 14 were infested. A total of twenty specimens of the introduced carp were collected. Only one of these specimens was not infested. A single specimen of *Tilapia sparrmanii* was collected. The skin of this specimen was infested with sessiline ciliophorans. A total of 32 specimens of the other cichlid fish occurring in the Modder River, namely *Pseudocrenilabrus philander* were collected. Thirty of these specimens were infested. Of the 18 specimens of *Clarias gariepinus* that were collected, 16 were infested with ectoparasites.

Table 7.1. Summary of the fish species collected from the Soetdoring Nature Reserve and numbers infested with ectoparasites. N-total number of fish collected, NHI-number of hosts infested, P-number of hosts infested expressed as a percentage of total number. SL-standard length and range

Fish host	SL	N	NHI	P
Cyprinidae				
Labeobarbus kimberleyensis (Gilchrist & Thompson, 1913)	360 (250-430)	3	1	33.3
Labeo capensis (Smith, 1841)	212.7 (60-420)	47	40	85.1
Labeo umbratus (Smith, 1841)	414.7 (200-485)	18	14	77.8
Cyprinus carpio Linnaeus, 1758	282.9 (70-680)	20	19	95
Cichlidae				
Tilapia sparrmanii Smith, 1840	85	1	1	100
Pseudocrenilabrus philander (Weber, 1897)	42.0 (20-55)	32	30	93.8
Clariidae				
Clarias gariepinus (Burchell, 1822)	685.6 (140-1000)	18	16	88.8
Poeciliidae				
Gambusia affinis (Baird & Girard, 1853)	25	1	0	0

The prevalence of the different groups of parasites infesting ***Labeo capensis*** is given in Figure 7.1. The prevalence of trichodinid parasites infesting the gills and skin of *L. capensis* was 12.8% and the prevalence of sessiline ciliophorans infesting the host was 2.1%. Gyrodactylid monogeneans were also found infesting the skin of *L. capensis* with a prevalence of 8.5%. The most prevalent ectoparasites for *L. capensis* were dactylogyrid monogeneans, which had a prevalence of 76.6%. These infestations were mainly *Dactylogyrus freistatensis* and *Dogielius capensis*. The diplozoid monogenean *Paradiplozoon modderensis* had a prevalence of 31.9%, with a mean intensity and abundance (Figure 7.2) of 3 and 0.89 respectively.

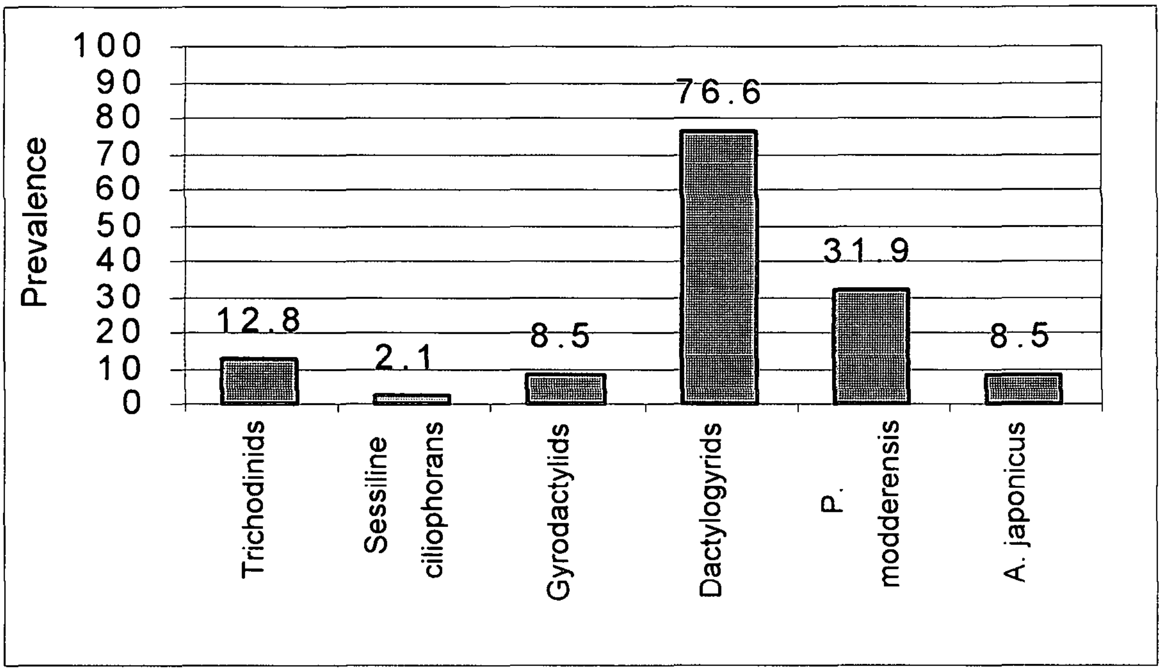


Figure 7.1. Histogram illustrating prevalence of the different ectoparasites infesting *Labeo capensis* (Smith, 1841). *P-Paradiplozoon*, A-*Argulus*

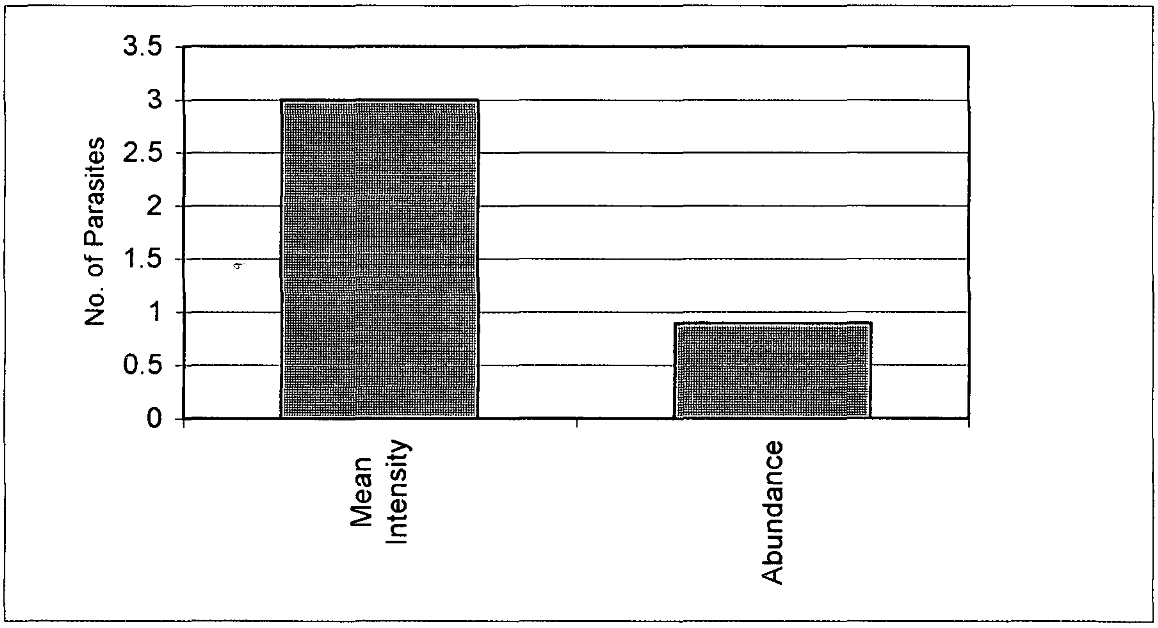


Figure 7.2. Histogram illustrating mean intensity and abundance for *Paradiplozoon modderensis* n. sp.

Mean intensity and abundance numbers refer to pairs of parasites and not individual specimens. Figure 7.3 shows the distribution of *P. modderensis* within the population of *L. capensis*. None of the fish were severely infested and the highest infestation recorded was six parasites. The numbers of parasites were not influenced by host size. The branchiuran *Argulus japonicus* had a prevalence of 8.5% for *L. capensis*.

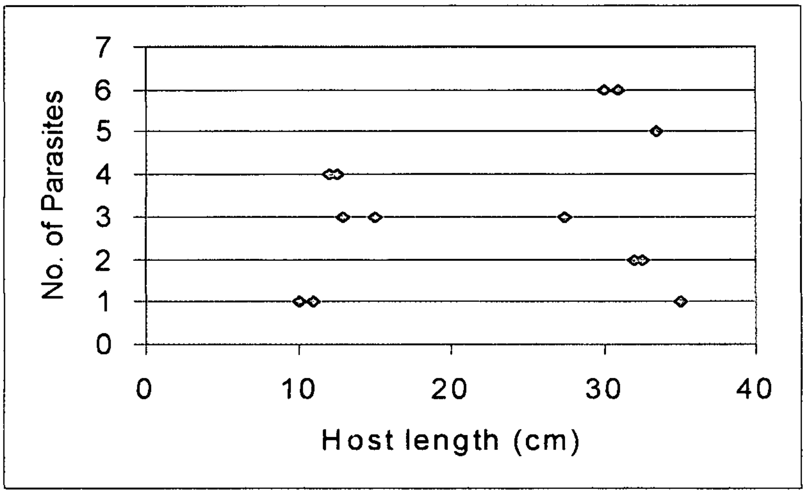


Figure 7.3. Scatter plot diagram illustrating the distribution of *Paradiplozoon modderensis* n. sp. on specimens of *Labeo capensis* (Smith, 1841).

Figure 7.4 represents the prevalence of ectoparasites collected from ***Labeo umbratus***. The prevalence for infestations by both trichodinid and sessiline ciliophorans was higher than for *L. capensis*, i.e. 33.3% and 5.6% respectively. Infestations by gyrodactylid monogeneans had prevalence in the same range as for *L. capensis*, i.e. 11.5%, but dactylogyrid prevalence was 55.6%, which is lower by almost 20%. *Argulus japonicus* had a prevalence of 22.2% for *L. umbratus*, which is almost three times higher than for *L. capensis*.

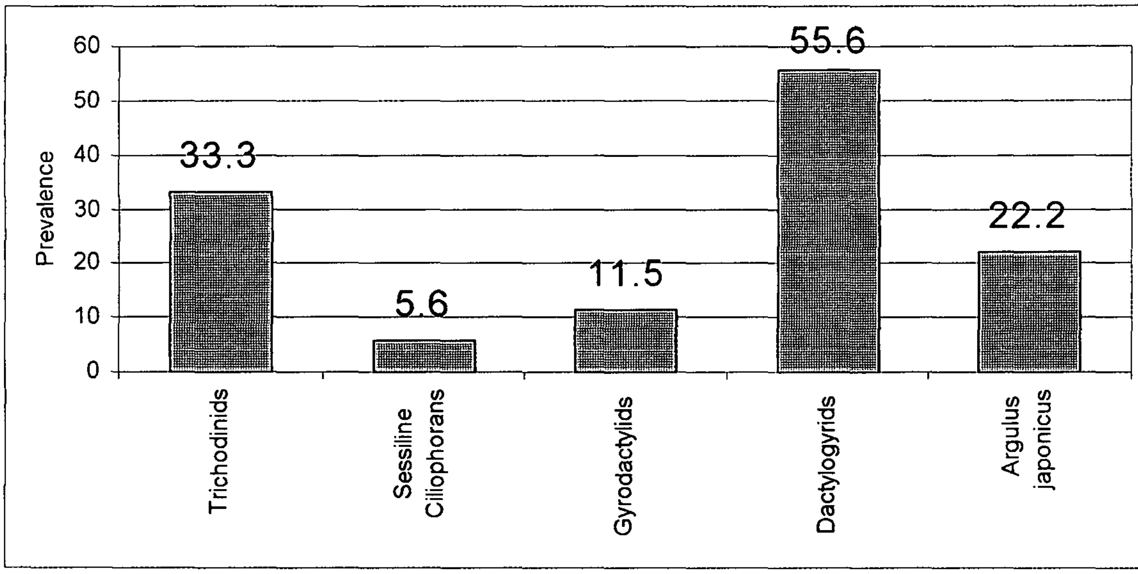


Figure 7.4. Histogram illustrating prevalence of the different ectoparasites infesting *Labeo umbratus* (Smith, 1841).

Figure 7.5 represents the prevalence of ectoparasites for ***Cyprinus carpio***. For the cyprinids, the carp showed the highest infestation of trichodinid as well as sessiline ciliophorans. The prevalence for trichodinids was 65.0%, which is almost double the prevalence for *L. umbratus* and five times higher than for *L. capensis*. Sessiline ciliophorans had a prevalence of 20.0%, which is almost four times higher than for *L. umbratus* and ten times higher than for *L. capensis*.

Infestations by gyrodactylid monogeneans had a prevalence of 55.0% for *C. carpio*, which is also higher than for both *L. capensis* and *L. umbratus*. The prevalence for dactylogyrid monogeneans (55.0%), however, was similar to that of *L. umbratus*, but lower than for *L. capensis*. In the case of *C. carpio*, however, these infestations were dominated by *Dactylogyrus extensus*, which were not collected from either *L. capensis* or *L. umbratus*. *Argulus japonicus* had a prevalence of 20.0%, which is similar to that of *L. umbratus*, but almost double that for *L. capensis*.

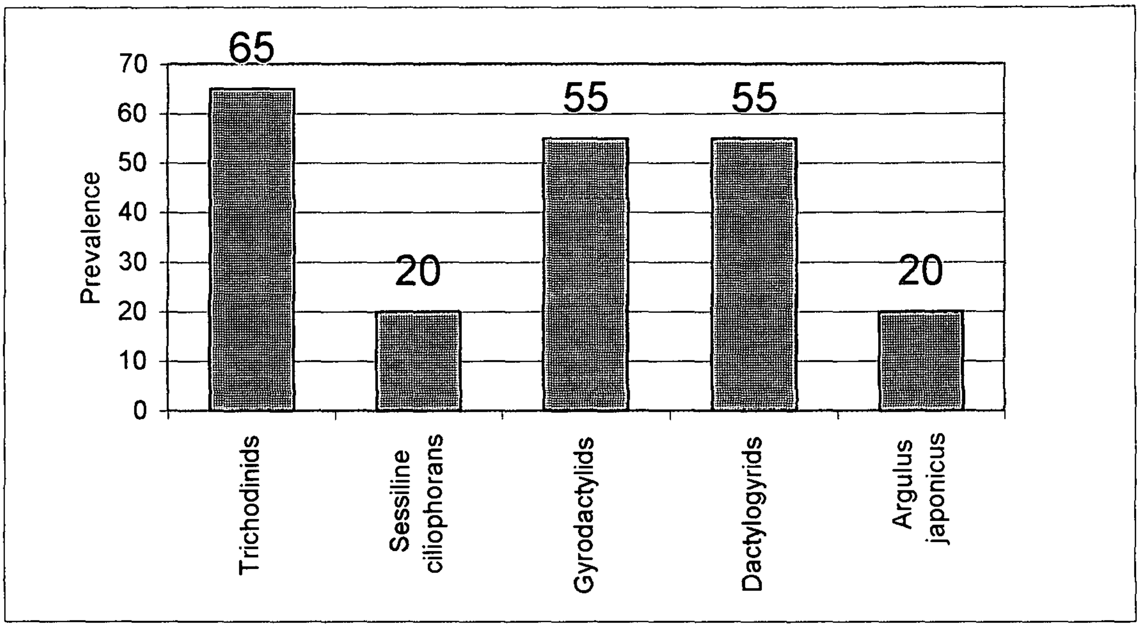


Figure 7.5. Histogram illustrating prevalence of the different ectoparasites infesting *Cyprinus carpio* Linnaeus, 1758.

The abundance and mean intensity of *A. japonicus* for the four cyprinid hosts collected is compared in Figure 7.6. Abundance of this branchiuran is almost the same for all four fish hosts. Highest mean intensity was 5.3 for *L. capensis* and varied between one to two for the other three cyprinid hosts.

Three groups of ectoparasites were found associated with ***Clarias gariepinus*** (Figure 7.7). The parasites with the highest prevalence were the dactylogyrid *Quadriacanthus aegypticus*. This parasite had a prevalence of 77.8%. Infestations by gyrodactylid monogeneans had a much lower prevalence of only 11.1%. The parasitic copepod *Lamproglena clariae* had a prevalence of 66.6%. Mean intensity and abundance of *L. clariae* is represented in Figure 7.8 and the distribution of the parasite within the host population in Figure 7.9. *Lamproglena clariae* had a mean intensity of 7.6 parasites and an abundance of 5.1. Distribution of this parasites do not seem to be affected by host length.

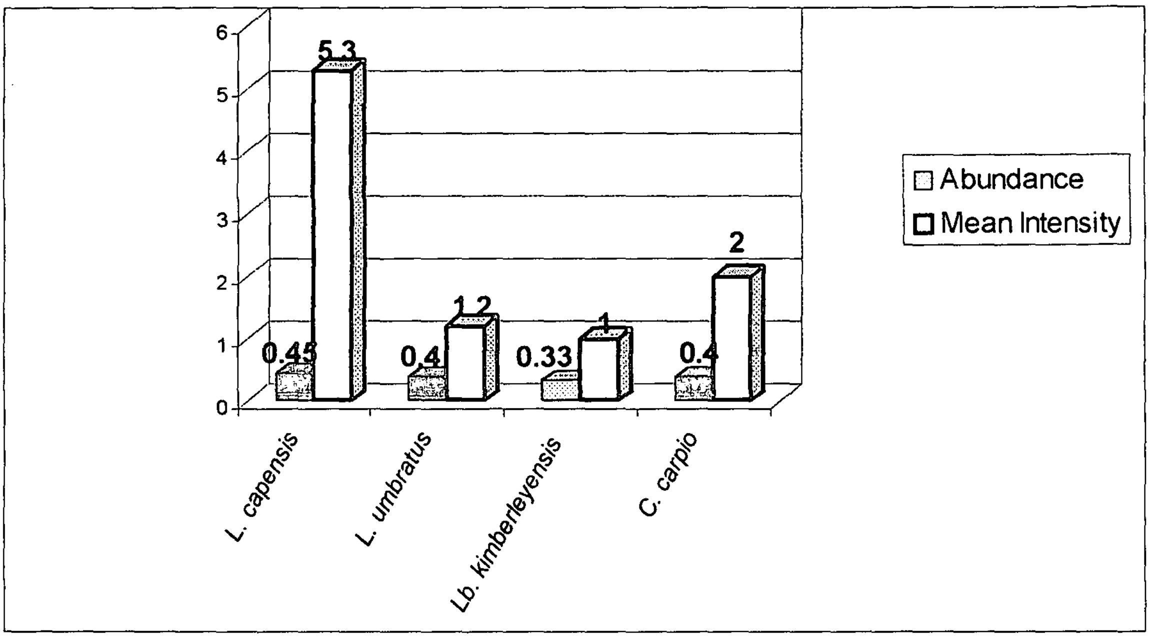


Figure 7.6. Histogram illustrating the abundance and mean intensity of *Argulus japonicus* Thiele, 1900 for the four cyprinid hosts collected. *C-Cyprinus. L-Labeo. Lb-Labeobarbus*

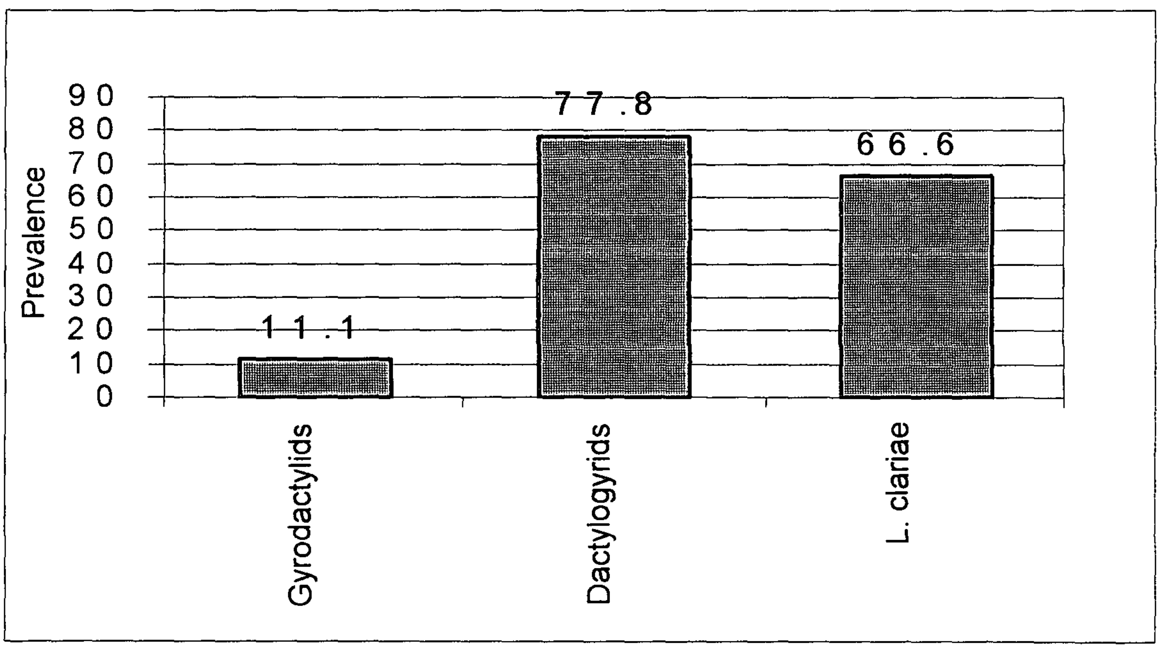


Figure 7.7. Histogram illustrating prevalence of the different ectoparasites infesting *Clarias gariepinus* (Burchell, 1822). *L-Lamproglena*

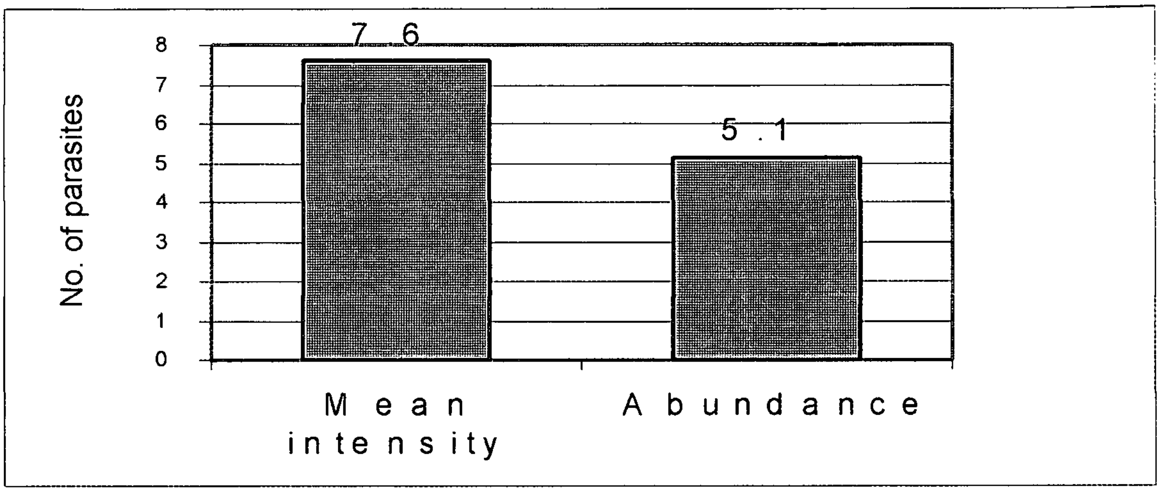


Figure 7.8. Mean intensity and abundance for *Lamproglena clariae* Fryer, 1956 collected from *Clarias gariepinus* (Burchell, 1822)

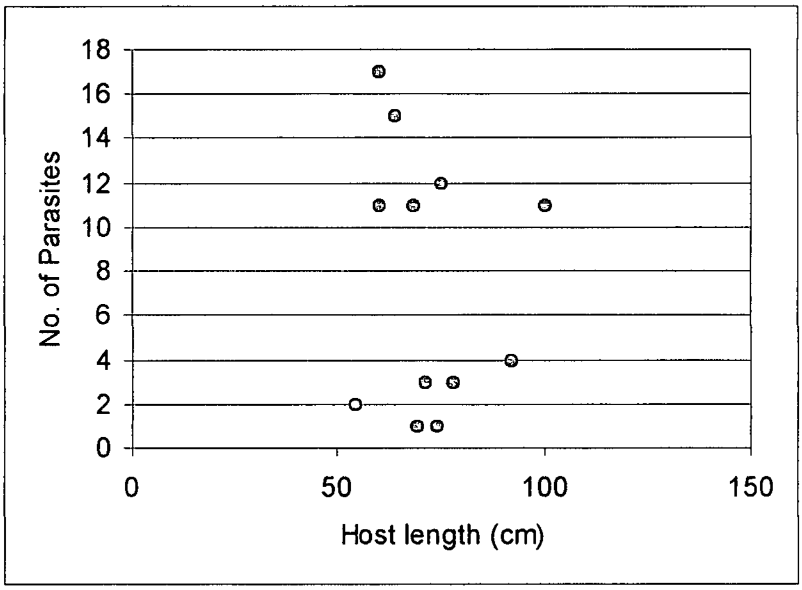


Figure 7.9. Scatter plot diagram illustrating the distribution of *Lamproglena clariae* Fryer, 1956 on specimens of *Clarias gariepinus* (Burchell, 1822)

The prevalence of ectoparasites for ***Pseudocrenilabrus philander*** is presented in Figure 7.10. Trichodinid infestations by *Trichodina centrostrigeata* showed the highest prevalence (84.4%) of all the parasites collected. The sessiline ciliophorans had a prevalence of 53.1%. Infestation by both gyrodactylid and dactylogyrid monogeneans showed low prevalence, i.e. 9.4% and 6.3% respectively.

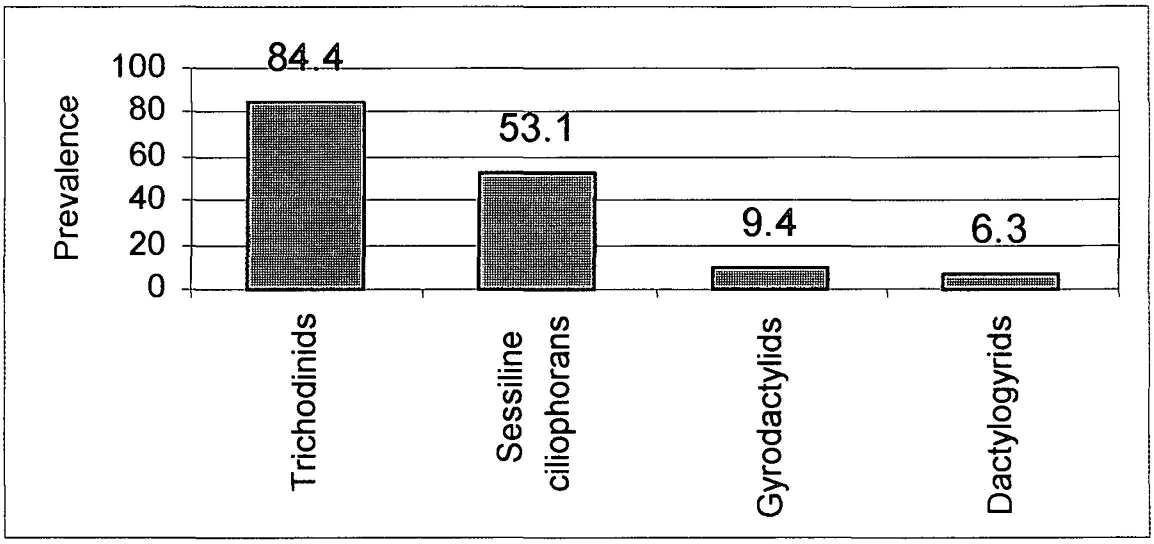


Figure 7.10. Histogram illustrating the prevalence of different ectoparasites infesting *Pseudocrenilabrus philander* (Weber, 1897).

The cyprinid hosts collected during the study seem to be more prone to monogenean infestations than to infestations by ciliophorans. This does not apply to *Cyprinus carpio*, for which prevalence of infestation by trichodinids were higher than monogenean prevalence. Prevalence of dactylogyrid monogeneans for both *Labeo capensis* and *L. umbratus* were higher than gyrodactylid prevalence. The prevalence of these two families of monogeneans was the same for *Cyprinus carpio*. The diplozoid monogenean, *Paradiplozoon modderensis*, was collected only from *L. capensis* and this monogenean appears to be host specific. *Argulus japonicus*, which was introduced to South Africa along with ornamental fish, does not seem to have preference for any of the cyprinid fish from which it was collected. It did, however, have the highest prevalence, mean intensity and abundance for *L. capensis*. The cichlid fishes, *Pseudocrenilabrus philander* and *Tilapia sparrmanii* were more frequently infested with ciliophorans than with monogeneans. Although only one specimen of *T. sparrmanii* was collected, this individual was infested with sessiline ciliophorans, but not with any monogeneans. Less than 10% of the specimens of *P. philander* were infested with dactylogyrid and gyrodactylid monogeneans.

Clarias gariepinus had the highest prevalence of gyrodactylid monogeneans and no ciliophorans were collected from this fish host. Species of *Quadriacanthus* are confined to siluriform hosts and *Q. aegypticus* was the only monogenean species collected from the gills of *C. gariepinus.* Except for *Heterobranchus longifilis*, *Clarias gariepinus* is the only other known host for the parasitic copepod, *Lamproglena clariae*, which was present on more than 66% of the specimens collected.

Chapter 8

General Discussion

Remarks on the parasite and host populations

The diversity of fishes present in the Modder River is very low in comparison to systems such as the Zambezi and even Limpopo and yet not even 70% of the species were collected from the Soetdoring Nature Reserve. During the pilot survey of March 2001, the water levels of the Krugersdrift Dam were very low, and collecting high numbers of fish was done with ease. Seaman *et al.* (2001a) recorded six fish species from the reserve in March 1999, while in March 2001, Seaman *et al.* (2001b) recorded only two species, namely *Labeo capensis* and *Labeobarbus aeneus*. The low numbers as well as the low diversity of fish collected both by Seaman *et al.* (2001b) and during the present study can be attributed to the high water levels.

The slow flowing, or stagnant water conditions at the different sampling localities could also have affected the low numbers of *Labeobarbus kimberleyensis*, and the absence of *L. aeneus* and *Austroglanis sclateri* as these species prefer fast flowing water. Two of the sampling localities (1 & 2) (Fig 2.2, Figure 2.4D & Figure 2.4E) were permanently dammed, and there was very little water flow. When the water level of the dam is low as it was during the pilot survey there is very little water at locality 3 (Figure 2.4F). After heavy rainfall, when the water level rises, locality 3 is turned into a fast flowing rapid and thereby gradually filling the dam, resulting in water pushing back into this site.

Considerable variation exists in the ectoparasitic fauna of the different fish species. The ectoparasitic fauna collected from the fishes is summarised in Figure 8.1-8.4. Cyprinid fishes were mainly parasitised by monogeneans, i.e. dactylogyrids and gyrodactylids and to a lesser extent by ciliophorans. Carp were the exception to this, being equally infested by monogeneans and ciliophorans.

The dactylogyrid monogeneans collected from *Labeo umbratus* resemble *Dactylogyrus freistatensis* and might well be the same species. Species of *Dactylogyrus* known from *Labeo* are frequently collected from more than one host species (see Table 5.2). However, in this study it could not be confirmed that *L. umbratus* and *L. capensis* are host to the same dactylogyrid species due to insufficient numbers of parasites collected from *L. umbratus*. The dactylogyrid collected from the gills of *C. carpio*, i.e. *D. extensus* was introduced along with carp, and not collected from the other cyprinids during this study.

The cichlid species had a much higher prevalence of ciliophorans than monogeneans, and it appears that ciliophorans are more abundant on smaller fish specimens.

The parasitic fauna from the gills of *Clarias gariepinus* is very unique and differs considerably from the parasites collected from the other fishes. *Quadriacanthus* species are only known from siluriform fishes and although a number of species of this genus are parasitic on *Clarias gariepinus*, it appears that these species are host specific (see Table 5.10). During this study, *C. gariepinus* was the only host from which parasitic copepods were collected. The parasitic copepod, *Lamproglena clariae* also appears to be specific to siluriform fishes, and has only been recorded from *Heterobranchus longifilis* and *C. gariepinus* (see Chapter 6).

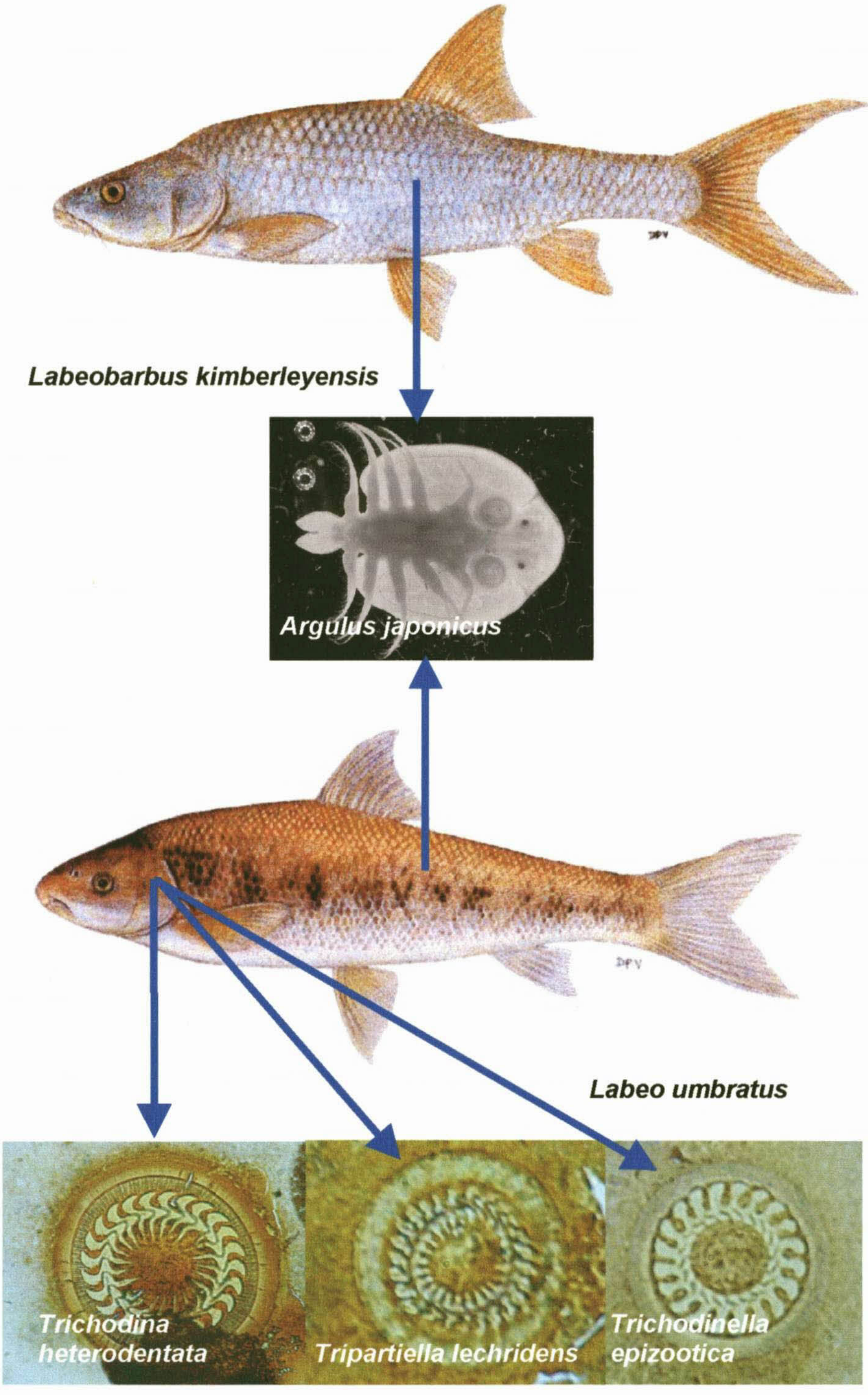


Figure 8.1. Simplified illustration of the ectoparasites collected from the gills and skin of cyprinid fishes from the Soetdoring Nature Reserve.

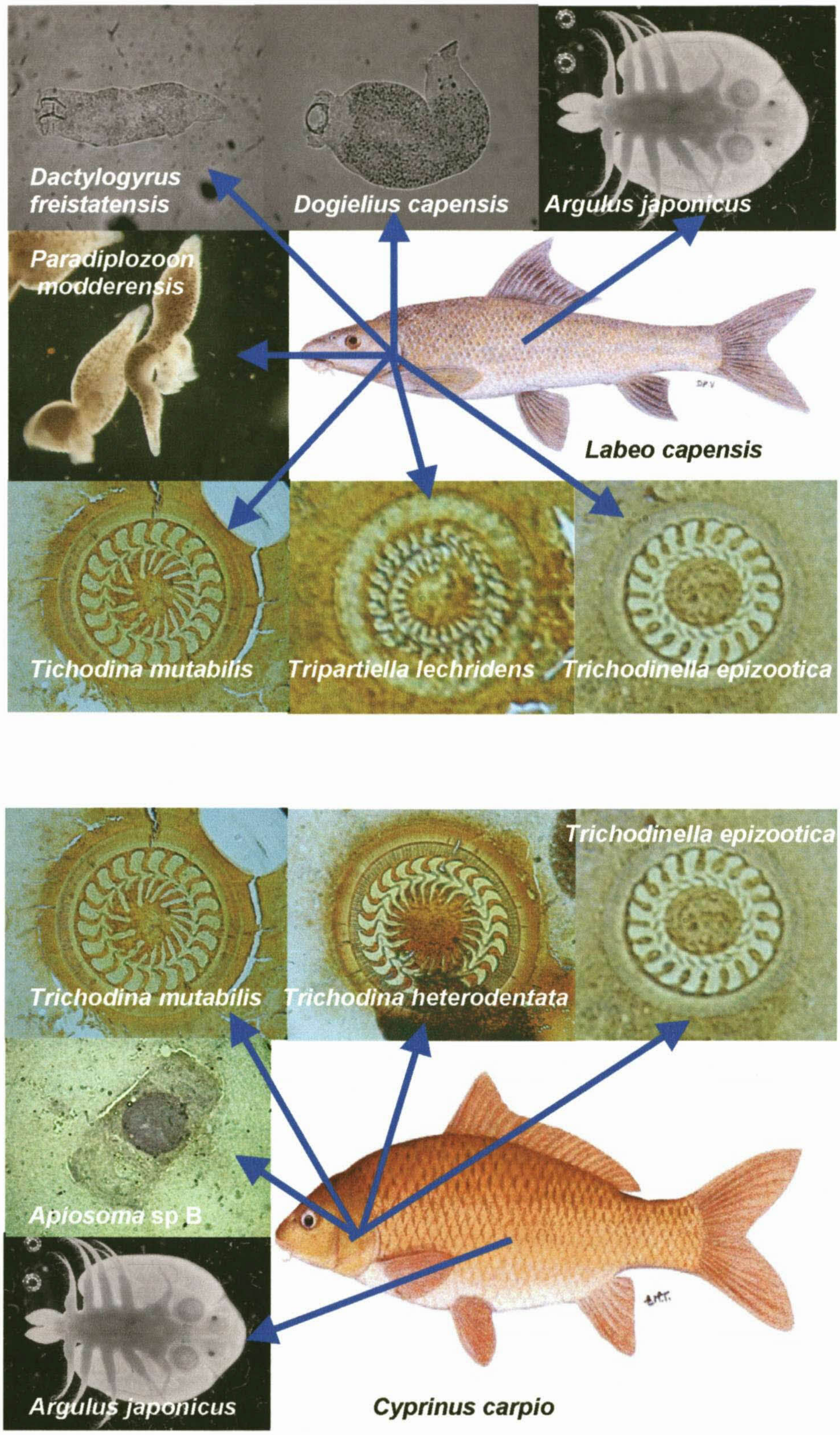


Figure 8.2. Simplified illustration of the ectoparasites collected from the gills and skin of cyprinid fishes from the Soetdoring Nature Reserve.

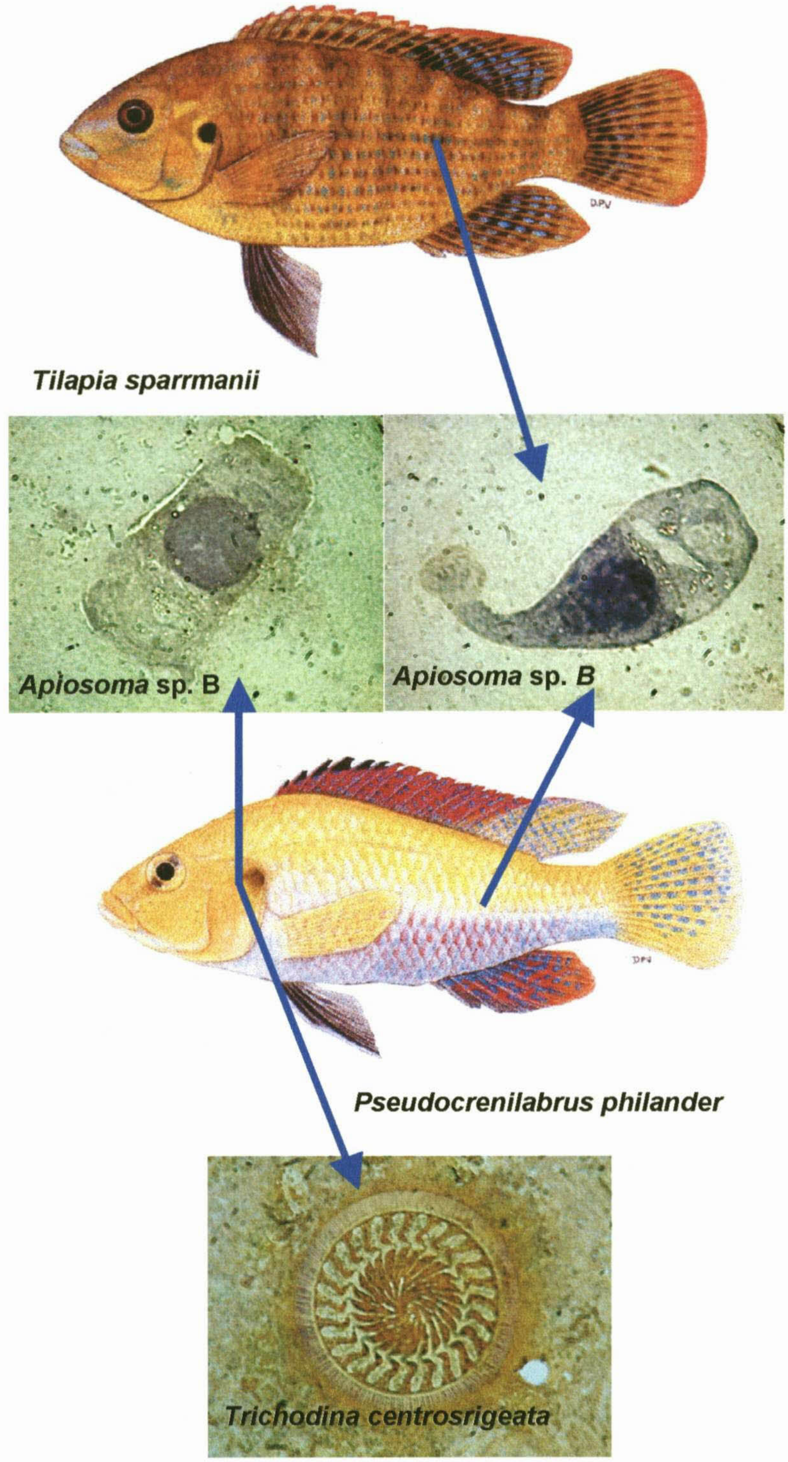


Figure 8.3. Simplified illustration of the ectoparasites collected from the gills and skin of cichlid fishes from the Soetdoring Nature Reserve.

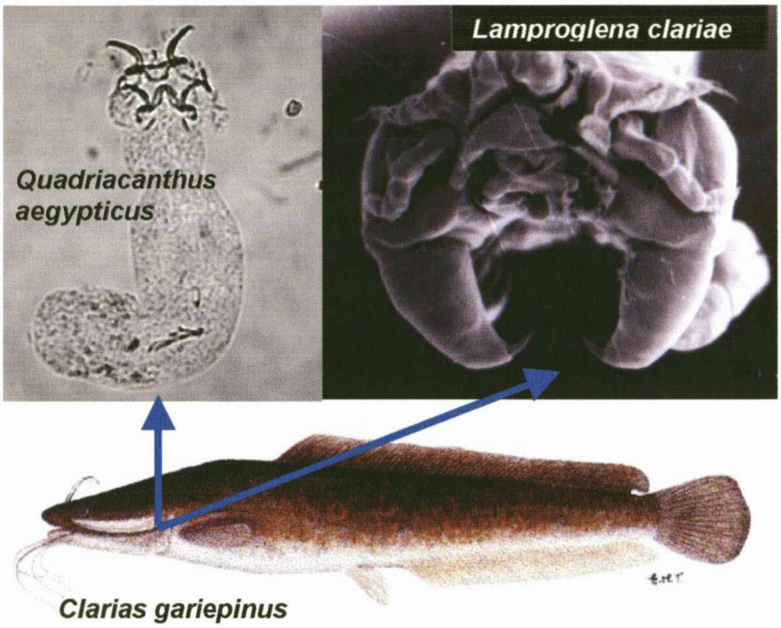


Figure 8.4. Simplified illustration of the ectoparasites collected from the gills of *Clarias gariepinus* (Burchell, 1822) from the Soetdoring Nature Reserve.

Pathogenicity

Ciliophorans

Trichodinid populations often occur in high densities on wild fish populations, but these infestations rarely cause mortalities (Lom & Dyková 1992). In populations confined to ponds, tanks or aquaria, trichodiniasis is a frequent problem. According to Schmidt & Roberts (1977), trichodinids may cause some damage to the gills of fish, although most have little pathogenic effect. Trichodinids are commonly accompanied by the presence of other parasites, and it is usually hard to determine the pathogenic effect that they have on the hosts (Davis 1947).

Several authors have reported on mortalities of fish as a cause of infestations by ciliophorans (Paperna 1979b; Van As, Basson & Theron 1984). These reports included mortalities of catfish, carp, and the Mozambique tilapia, *Oreochromis mossambicus*, as a result of infestations by *Trichodina* species.

The pathogenic action of ciliophorans varies from irritation of surface cells, as is the case with heavy infestations of ectocommensals, such as sessiline ciliophorans, to destruction of surface cells and penetration into deep tissue layers. Heavy infestations result in irritation of the skin integument and gill epithelium resulting in hyperplasia and later degeneration and necrosis. Sarig (1971) reported populations of trichodinids on the skin and gills so abundant that the normal structure of epithelium is not evident.

Sessiline ciliophorans of freshwater fish can cause mortalities due to high numbers of parasites on the gills of fish and hence cause the suffocation of the host (Davis 1947; Lom & Corliss 1968; Rogers 1969; Rogers 1971). Secondary infections by bacteria due to the attachment lesions of sessiline ciliophorans have also been implicated as another possible cause of fish mortalities.

Monogeneans

Unlike the oligonchoineans (which includes the family Diplozoidae), that have a less destructive manner of attaching and feeding on the host, the polyonchoineans (including the dactylogyrids) have a more disruptive manner of feeding and attaching on exposed integument, and cause significant tissue damage. Members of the Polyonchoinea have been known to cause significant pathology to their hosts in contrast to the Oligonchoinea, which are rarely associated with host mortalities (Cone 1995).

Most of the reported cases where dactylogyrids were implicated in mortalities or severe infestations are from *C. carpio* cultures. Paperna (1964a) recorded severe infections by *Dactylogyrus vastator* from carp stock. Another case of carp mortalities was reported by Eller (1975) where mortalities of carp in southern Russia were attributed to two species of *Dactylogyrus*, namely *D. vastator* and *D. extensus*. According to Van As & Basson (1988) dactylogyrid monogeneans (possibly of the genus *Quadriacanthus*) that occur on the gills of catfish, have caused severe mortalities to catfish fry.

Infested gills have been described to be grey-white in colour, having lost the natural red colour, were covered in mucous and had an irregular shape (Paperna 1964b). Gills also showed strong hyperplasia of the gill respiratory and lining epithelia, as well as the mucous goblets cells. This resulted in deformations of the gills filaments, especially near the apices. Research conducted by Buchmann, Slotved & Dana (1993) on the epidemiology of gill parasite infections of carp, showed that *D. extensus* embeds itself in the gill tissue and causes extensive cellular reaction.

Both *D. vastator* and *D. extensus* species cause epithelial hyperplasia and have been responsible for severe losses of both fry and adults (Eller 1975). *Dactylogyrus extensus* also causes epithelial cells to degenerate into secretory cells, resulting in the production of copious amounts of mucous. Excess excretion of mucous can also result from the method of attachment by dactylogyrids, where the anchors are inserted into the tissue of the host, as well as the movement of the monogeneans (Hwang & Yu 1987). The copious amounts of mucous that are produced are enough to impair respiratory functions of the gills (Bauer 1959).

The two species, *D. vastator* and *D. extensus* can occur on the same host and are involved in a unique symbiotic interaction. Paperna (1964b) reported that competitive exlusion exists between these two species. Gills infested with *D. vastator* undergo hyperplasia of the epithelial lining as well as the mucus goblet cells. These changes create conditions that are unsuitable for attachment by *D. extensus*. Pronounced hyperplasia, however, renders the gills unfavourable even for *D. vastator* and a decline, or even complete disappearance of these parasites is seen. After healing of the gills, infestation by *Dactylogyrus* species is again possible. An increase in the number of *D. vastator* and decline of the other species again takes places. Eventually, immunity against *D. vastator* is acquired and fish are again prone to infestations by other *Dactylogyrus* species.

Feeding by the monogeneans is also a potential cause of damage. According to Hwang & Yu (1987) feeding causes gills to bleed, which in turn cause haemorrhaging and oedema, resulting in respiratory blockage. Cone (1995) reported that monogeneans might well be mechanical vectors of viral and bacterial pathogens.

Parasitic crustaceans

The feeding activities of parasitic crustaceans often involve feeding on shredded host epidermis and branchial epithelium (Schmidt 1975). Parasites also move around as they feed, stimulating mucus production, epidermal proliferation and dilation of dermal capillaries. The feeding by species of *Argulus* involves the use of the pre-oral sting and legs to abrade the host epidermis. This causes an increase in the number of mucous cells, and the production of mucus around the wound. *Argulus japonicus* however, feeds on the blood of the host, and may also be responsible for the transmission of dracunculid nematodes (Moravec, Vidal-Martinez & Aguirre-Macedo 1999).

The damage by individual branchiurans is seldom reason for alarm, although heavy infestations by *Dolops* as well as *Argulus* have been implicated in fish mortalities (Fryer 1968; Kruger, Van As & Saayman 1983).

Species of *Lamproglena* cause variable degrees of damage (Fryer 1968). *Lamproglena monodi* causes little damage, with some proliferation of gill tissue. In the case of *Lamproglena clariae* however, the proliferation of gill tissue is immense and in some cases might well interfere with respiration. This proliferation can be seen in Figure 6.12G, where the specimen seems to be imbedded into the gills. According to Sproston, Yin & Hu (1950) this appearance is due to growth of the gill around the parasite and not by burrowing of the parasite into the gill.

Destruction of gill and skin tissue by ciliophorans, monogeneans and crustaceans is reflected in the incapacitated condition of the fish, which may lead to mortalities with an epizootic range. It is important to note however, that the reported mortalities are a result of fish kept in unnatural conditions, such as aquaria, fish ponds and other artificial impoundments. However, extremely high intensity of infestations by ectoparasites was not recorded from the fishes from Soetdoring Nature Reserve.

Alien Species

Part of the study was to determine if any introduced parasite species are present in the system. Apart from the two alien fishes that were collected, three introduced species of parasites were also collected. This includes two ciliophorans, *Trichodina mutabilis* and *Trichodinella epizootica* and the branchiuran, *Argulus japonicus*.

Common carp was introduced into southern Africa in the early 1700's. At least seven alien parasite species, most of which have been responsible for mortalities of indigenous species was introduced along with the carp (Bruton & Van As 1987). Apart from the parasites that were introduced with carp, this species also affects indigenous species by altering the habitat. The feeding habits of carp disturb the sediment, decreasing the water quality. Turbidity of the water is also increased, which may affect the success of predatory fish species.

Introduced fish species may also compete with indigenous species for food and space. They may also disrupt breeding patterns and parental care of offspring (Bruton & Van As 1987). This has already been reported to be the case for carp. Noble & Hemens (1978) reported that the population of carp in the Vaal River has reduced the numbers of *Labeo umbratus*. It could also be true of the mosquitofish, *Gambusia affinis*. Deacon, Hubbs & Zahuranec (1964) studied the effects of introduced fishes on the native fishes of southern Nevada, North America. They reported that in ponds where *G. affinis* were introduced, there has been a marked decline in the number of indigenous fish.

The species of *Apiosoma* (*Apiosoma* sp. A) collected from carp during the study resembles *A. piscicola*, which is one of the parasite species introduced with fish. This species was also collected from *Pseudocrenilabrus philander* and *Tilapia sparrmanii*. Although this species has not yet been implicated in the mortalities of any indigenous fish species the possibility can not be ruled out that this species could have a pathogenic effect on its hosts when occuring in high numbers. This has been reported for species of *Epistylis* Ehrenberg, 1930 that have been implicated in having extreme pathogenic effects on the hosts, such as large haemorrahagic lesions (red sore disease) with erosion of scales and sometimes bones (Rogers & Gaines 1975).

The dactylogyrid, *D. extensus*, which was collected from the gills of the carp is a well-known parasite of this fish. It appears that this parasite species is host specific. Many monogeneans, however, are known to display stenoxenic, occurring on closely related hosts, or euryxenic specificity, occurring on distantly related host species. The possibility therefore exists that under certain conditions, *D. extensus* could infest the other cyprinids of the Soetdoring Nature Reserve.

Two of the introduced parasite species collected were introduced with the gold fish, *Carassius auratus*. *Argulus japonicus* is a serious pathogen of indigenous fish when they occur in high numbers, which is often the case in impoundments. This branchiuran is wide spread throughout South Africa and has been responsible for mortalities of various indigenous fish (Kruger *et al.* 1983). *Trichodina mutabilis* is also a known pathogen of fishes introduced with gold fish. Not only is this the first record of this species from a natural fish population, but also the first record from an indigenous fish species (*Labeo capensis*).

Endoparasites

The initial objective of this project was to include endoparasites as part of the study. Due to the extent of the systematics and identification of the endoparasitic helminths, these parasites were not included in the present study. Fish collected during the study were however, examined for endoparasites. The fish that were infected with endoparasites are summarised in Table 8.1.

Table 8.1. Summary of the fish species collected from the Soetdoring Nature Reserve infested with endoparasites. **N**-total number of fish collected, **NHI**-number of hosts infested, **P**-number of hosts infested expressed as a percentage of total number

Fish Host	N	NHI	P	Endoparasites
Clarias gariepinus (Burchell, 1822)	18	8	44.4	Nematodes and Cestodes
Labeobarbus kimberleyensis (Gilchrist & Thomson, 1913)	3	2	66.6	Cestodes

The cestodes collected from *Labeobarbus kimberleyensis* were preliminary identified as *Bothriocephalus acheilognathi* Yamaguti, 1934. This species was introduced into South Africa along with grass carp, *Ctenopharyngodon idellus* Valenciennes, 1844, which occurs naturally in Japan and China. *Bothriocephalus acheilognathi* has spread throughout the subcontinent through intermediate host copepods (Bruton & Van As 1987). The cestode infects a wide range of cyprinids and has been responsible for the mortalities of *C. carpio* as well as *L. kimberleyensis* (Brandt, Van As, Schoonbee &

Hamilton-Attwell 1981; Van As, Schoonbee & Brandt 1981). The infected specimens of *L. kimberleyensis* collected during this study were severely parasitised with high numbers of cestodes removed from the intestine of the fish host. This parasite could be considered as another threat to the already vulnerable largemouth yellowfish. Positive identification of the nematodes from the intestine of *Clarias gariepinus* was not made. According to Paperna (1979b) there are two known species of adult nematodes from *C. gariepinus*, i.e. *Procamallanus laevionchus* (Wedl, 1862) and *Paracamallanus cyathopharynx* (Baylis, 1923). These nematodes firmly attach to the stomach mucosa by means of the buccal capsule. Neither of these species, however, have been reported to have a pathogenic effect.

Chapter 9

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Abstract

The Soetdoring Nature Reserve is situated on the banks of the Modder River northwest of Bloemfontein. The Krugersdrift Dam forms part of the reserve and supplies water to farmers in the lower reaches of the Modder River. Twelve fish species occur in the Modder River, of which two are introduced species. Specific objectives of the study was to determine the fish parasite diversity, and to establish if any introduced fish parasites are prevalent on the fishes from the Soetdoring Nature Reserve.

During monthly surveys to the Soetdoring Nature Reserve from March 2001 to March 2002 fish were collected from three different localities in the reserve. A total of eight fish species were collected, although in low numbers. The parasites collected included ciliophorans, monogeneans and parasitic crustaceans. Six known species of mobiline ciliophorans were collected from fishes, i.e. *Trichodina centrostrigeata* Basson, Van As & Paperna, 1983, *T. heterodentata* Duncan, 1977, *T. mutabilis* Kazubski & Migala, 1968, *Tripartiella lechridens* Basson & Van As, 1987, *T. leptospina* Basson & Van As, 1987 and *Trichodinella epizootica* (Raabe, 1950). Two species of sessiline ciliophorans were also collected, namely *Apiosoma* sp. A and *Apiosoma* sp. B. Representatives of the Monogenea collected included three new species, which were described as *Dactylogyrus freistatensis* n. sp., *Dogielius capensis* n. sp. and *Paradiplozoon modderensis* n. sp. as well as two known species, i.e. *Dactylogyrus extensus* (Mueller & Van Cleave, 1932) and *Quadriacanthus aegypticus* El-Naggar & Serag, 1986. The parasitic crustaceans included one branchiuran species, *Argulus japonicus* Muller, 1785, and one parasitic copepod, *Lamproglena clariae* Fryer, 1956.

This study was first to examine the whole spectrum of ectoparasites found associated with fish.

Keywords: Freshwater, fish parasites, Ciliophora, Monogenea, Branchiura, Copepoda, Soetdoring Nature Reserve.

Opsomming

Die Soetdoring Natuurreservaat is op die oewers van die Modderrivier noord-wes van Bloemfontein geleë. Die Krugersdriftdam vorm deel van die reservaat en voorsien water aan boere in die laer streke van die rivier. Twaalf visspesies kom in die Modderrivier voor, waarvan twee ingevoerde spesies is. Spesifieke doelstellings van die studie was om die diversiteit van visparasiete vas te stel, asook om te bepaal of ingevoerde vis parasiete enigsins op die visse van die Soetdoring Natuurreservaat voorkom.

Tydens maandelikse opnames is vis van drie verskillende lokaliteite by die Soetdoring Natuurreservaat vanaf Maart 2001 tot Maart 2002 versamel. Agt visspesies is versamel waarvan die getalle min was. Parasiete wat versamel is, sluit die volgende in: verteenwoordigers van die Ciliophora, Monogenea en parasietiese Crustacea. Ses bekende spesies van die mobiele siliofore is versamel, nl. *Trichodina centrostrigeata* Basson, Van As & Paperna, 1983, *T. heterodentata* Duncan, 1977, *T. mutabilis* Kazubski & Migala, 1968, *Tripartiella lechridens* Basson & Van As, 1987, *T. leptospina* Basson & Van As, 1987 en *Trichodinella epizootica* (Raabe, 1950). Twee spesies van sessiele siliofore is ook versamel, nl. *Apiosoma* sp. A en *Apiosoma* sp. B. Verteenwoordigers van die Monogenea sluit drie nuwe spesies in, nl. *Dactylogyrus freistatensis* n. sp., *Dogielius capensis* n. sp. en *Paradiplozoon modderensis* n. sp., asook twee bekende spesies, nl. *Dactylogyrus extensus* (Mueller & Van Cleave, 1932) en *Quadriacanthus aegypticus* El-Naggar & Serag, 1986. Verteenwoordigers van die parasietiese crustasieërs sluit die visluis, *Argulus japonicus* Muller, 1775 en 'n verteenwoordiger van die parasietiese Copepoda, *Lamproglena* clariae Fryer, 1956 in.

Die studie was die eerste om die voorkoms van die hele spektrum van ektoparasiete wat met visse geassosieer is te bestudeer.

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