A STUDY OF THE GASTROINTESTINAL HELMINTHS OF THE PHALACROCORACIDAE AND THE ANHINGIDAE IN THE NORTHERN PROVINCE, SOUTH AFRICA

(With 101 text figures)

by

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SUMMARY
OPSOMMING

SUMMARY

The present study was aimed at investigating the helminth parasitofauna of three of the most prevalent and widespread piscivorous birds frequenting aquatic ecosystems in the Northern Province of South Africa. These hosts are:

Phalacrocorax carbo
P. africanus
Anhinga melanogaster

The helminth parasites of the above avian species were studied on a seasonal basis with host material procured from selected collecting sites from the three most prominent drainage systems in the study area.

A total of 177 specimens of the three potential hosts were autopsied for gastrointestinal helminths. These hosts are parasitized by 24 helminths as listed below:

Trematoda

Strigea anhingae Ukoli, 1966
Schwartzitrema pandubi (Pande, 1939) Dubois & Pearson, 1965
* *Harvardia sandgroundi* Baer, 1932
* *Hysteromorpha triloba* Lutz, 1931
* *Diplostomum tregenna* Nazmi Gohar, 1932
* *D. ghanense* Ukoli, 1968
Petasiger exaeretus Dietz, 1909
* *Paryphostomum radiatum* (Dujardin, 1845), Dietz, 1909
* *Clinostomum complanatum* (Rudolphi, 1819)
* *Neutraclinostomum intermedialis* (Lamont, 1920)
* *Euclinostomum heterostomum* (Rudolphi, 1809)

* Denotes species that definitely utilize freshwater fish as intermediate hosts.

Cestoda

* *Ligula intestinalis* Linnaeus, 1758
* *Paradilepis scolecina* (Rudolphi, 1819)
* *P. delachauxi* (Fuhrmann, 1909)
* *Amirthalingamia macracantha* (Joyeaux & Baer, 1935) Bray, 1974
Echinorhynchotaenia tritesticulata Fuhrmann, 1909
Hymenolepis cormoranti Ortlepp, 1938

Nematoda

* *Contracaecum microcephalum* (Rudolphi, 1809)
* *C. rodhaini* Gedoelst, 1916
* *C. tricuspe* Gedoelst, 1916
* *C. carlislei* Ortlepp, 1938
* *C. lawrencei* Bisseru, 1955
* *C. rudolphii* Hatwich, 1964
* *C. jokli* Mokgalong, 1996

One of the primary objectives of the study was to establish possible fish-avian helminthological interrelationships. Nineteen of the 24 helminths procured from the three piscivorous avian hosts definitely utilize freshwater fish as a second intermediate host. Various surveys have been undertaken on the helminth parasites of indigenous fish populations in aquatic ecosystems of the present study area. This data bank was used to correlate the larval helminths parasitising fish species of the region with adult helminths procured from the three avian hosts studied.

This correlation was based on the following criteria:

- Morphological similarities;
- A wide range of ecological data;
- Numeric and distributional records of fish intermediate hosts and avian final hosts in the major aquatic ecosystems of the study area;
- A limited number of experimental infections of avian hosts with larval helminths from fish intermediate hosts.

By employing the preceding criteria it was possible to link, with almost definite certainty, 18 of the adult parasites of birds to larval forms infecting freshwater fishes of the area. In a planned follow-up study these preliminary linkages will be verified by introducing experimental infections to parasite free natural avian hosts. Adult material obtained via this route will be used for miracidial production to infect laboratory reared gastropods in order to research the molluscan phase of the trematodan life cycles in question. Life cycle studies will be concluded by subjecting artificially bred and laboratory reared fish to cercarial releasing snails.

One of the collecting sites (Middle Letaba Impoundment) also provided an opportunity to examine a limited number of 13 other aquatic/semi-aquatic avian species for infection with helminth parasites. Eleven of these 13 host species were found to be infected with 16 species of gastrointestinal helminths. Six of these species of helminths utilize fish as intermediate hosts, while five species also parasitise phalacrocoracid and/or anhingid hosts. The following list of helminth parasites were procured from these 13 avian hosts:

TREMATODA

* *Diplostomum tregenna*
* *Apharyngostrigea simplex*
Clinostomum complanatum
Neutraclinostomum intermedialis
Euclinostomum heterostomum
Nephrostomum ramosum
* *Eurycephalus aspinocollaris*
* *Cyclocoelum gendrei*
* *Uvulifer microcephallus*

CESTODA

* *Paradilepis urceus*
* *Hymenolepis ardeae*
* *Anomotaenia megascolecina*
* *Anomotaenia* sp.
* *Dendrouterina* sp.

NEMATODA

Contracaecum microcephalum
* *Microtetrameres spiralis*

* Represents first records for South African aquatic ecosystems.

It is felt that the results obtained from the present study focused attention on one of the most neglected areas of biological research in support of piscicultural enterprises. As such it also forms the basis for future research in this field of scientific endeavour. The study succeeded in identifying various future research projects. Amongst others, it came to light that very little published information exists on helminth parasites of South African marine piscivorous birds. This is surprising because the South African coastal regions and offshore islands host a great variety of piscivorous birds in large numbers (see also p.163). In addition the South African component of the Indian and Atlantic Oceans has a fish complement in excess of 2 200 different species. Researching fish-avian helminth interrelationships in the South African marine environment will indeed be a very worthwhile and challenging experience.

OPSOMMING

Die doel van die huidige ondersoek was om 'n uitgebreide studie van die wurmparasiete van die spysverteringskanaal van drie van die meer algemene en wydverspreide visvretende voëls by varswatersisteme van die Noordelike Provinsie van Suid Afrika te ondersoek. Die drie gasheerspesies wat vir hierdie ondersoek geïdentifiseer is, was:

Phalacrocorax carbo
P. africanus
Anhinga melanogaster

Die helminte van bogenoemde visvretende voëlsoorte is op 'n seisoensbasis ontleed aan die hand van besmettings van gashere afkomstig uit geselekteerde versamellokaliteite uit die drie hoofdreineringsisteme van die Provinsie.

'n Totaal van 177 gashere eweredig verspreid oor die drie voëlsoorte is vir spysverteringskanaalparasiete ontleed. Dit is bevind dat hierdie drie gasheersoorte deur 24 verskillende wurmparasiete geparasiteer word. Onderstaande lys verteenwoordig die verskillende wurmparasiete verdeel volgens taksonomiese hoofindelings:

TREMATODA

Strigea anhingae Ukoli, 1966
Schwartzitrema pandubi (Pande, 1939) Dubois & Pearson, 1965
* *Harvardia sandgroundi* Baer, 1932
* *Hysteromorpha triloba* Lutz, 1931
* *Diplostomum tregenna* Nazmi Gohar, 1932
* *D. ghanense* Ukoli, 1968
Petasiger exaeretus Dietz, 1909
* *Paryphostomum radiatum* (Dujardin, 1845), Dietz, 1909
* *Clinostomum complanatum* (Rudolphi, 1819)
* *Neutraclinostomum intermedialis* (Lamont, 1920)
* *Euclinostomum heterostomum* (Rudolphi, 1809)

* Dui parasiete aan wat van vistussengashere gebruik maak.

CESTODA

* *Ligula intestinalis* Linnaeus, 1758
* *Paradilepis scolecina* (Rudolphi, 1819)
* *P. delachauxi* (Fuhrmann, 1909)
* *Amirthalingamia macracantha* (Joyeaux & Baer, 1935) Bray, 1974
Echinorhynchotaenia tritesticulata Fuhrmann, 1909
Hymenolepis cormoranti Ortlepp, 1938

NEMATODA

* *Contracaecum microcephalum* (Rudolphi, 1809)
* *C. rodhaini* Gedoelst, 1916
* *C. tricuspe* Gedoelst, 1916
* *C. carlislei* Ortlepp, 1938
* *C. lawrencei* Bisseru, 1955
* *C. rudolphii* Hatwich, 1964
* *C. jokli* n. sp.

Een van die belangrikste doelstellings van die ondersoek was om moontlike vis-voël helmintologiese verwantskappe te bevestig. Twintig van die 24 wurmparasiete wat tydens die ondersoek geidentifiseer is, gebruik varswater vissoorte as tweede tussengasheer.

In die Noordelike Provinsie van Suid Afrika is alreeds verskeie ondersoeke uitgevoer op die wurmparasiete van die inheemse vissoorte (literatuurverwysings verskyn op bl.4). Gegewens en materiaal afkomstig uit hierdie visparasietopnames is gebruik in 'n poging om larwale wurmparasiete van vissoorte te koppel aan volwasse parasiete in die visvretende voëls wat ondersoek is. Die volgende gegewens is gebruik vir hierdie aaneenskakeling:

- Morfologiese ooreenkomste;
- 'n Verskeidenheid van ekologiese gegewens;
- Gegewens oor verspreiding en getalsterkte van vistussengashere en voëls wat as finale gashere optree in die akwatiese ekosisteme wat ondersoek is;
- 'n Aantal eksperimentele besmettings op voëlgashere met larwale helminte wat vanaf vistussengashere verkry is.

Deur bogenoemde kriteria met groot omsigtigheid en wetenskaplike oordeelsvermoë toe te pas kon daarin geslaag word om 18 van die volwasse helminte van die voëlgashere aan larwale vorme in visgashere te koppel. Dit moet egter duidelik uitgewys word dat sommige van hierdie verwantskappe slegs voorlopige koppelings verteenwoordig. Daar is reeds beplan aan 'n opvolgstudie om hierdie voorlopige koppelings te verifiëer.

In hierdie navorsing sal die volgende prosedures gevolg word:

- Eksperimentele infeksies sal op parasietvrye natuurlike voëlgashere uitgevoer word;
- Indien geslagtelik volwasse helminte volgens hierdie metode verkry word, sal die eiers uitgebroei word volgens standaard metodes;
- Mirasidiums sal aan laboratorium-uitgebroeide varswaterslakke blootgestel word om sodoende die lewensiklusstadia in gastropood slakke te ondersoek;
- Indien besmette slakke serkarieë produseer sal kunsmatig geteelde visse wat onder laboratoriumtoestande vry van helminte grootgemaak is, aan hierdie serkarieë blootgestel word.

Dit word beoog om met bogenoemde vier fases die totale lewensiklus van elkeen van die trematoodspesies wat gedurende die huidige studie gevind is, eksperimenteel na te gaan.

Een van die versamelokaliteite vir voëls wat vir die huidige ondersoek gebruik is, het die geleentheid gebied om 'n beperkte aantal van 13 ander waterliewende voëlsoorte vir wurmparasiete te ondersoek. Die spysverteringskanale van elf van hierdie 13 voëlsoorte was met helminte besmet. In totaal is 16 helmintsoorte uitgeken. Ses van hierdie helminte maak gebruik van varswatervis as 'n tweede tussengasheer, terwyl vyf van laasgenoemde wurms ook as parasiete in die kormorante en die slanghalsvoël voorkom. Onderstaande lys verteenwoordig die helminte wat die 13 voëlgashere parasiteer:

TREMATODA

* *Diplostomum tregenna*
* *Apharyngostrigea simplex*
Clinostomum complanatum
Neutraclinostomum intermedialis
Euclinostomum heterostomum
Nephrostomum ramosum
* *Eurycephalus aspinocollaris*
* *Cyclocoelum gendrei*
* *Uvulifer microcephallus*

CESTODA

* *Paradilepis urceus*
* *Hymenolepis ardeae*
* *Anomotaenia megascolecina*
* *Anomotaenia* sp.
* *Dendrouterina* sp.

NEMATODA
Contracaecum microcephalum
* *Microtetrameres spiralis*

* Spesies nie tevore in Suid-Afrika aangeteken nie.

Die huidige navorsing het aan die lig gebring dat daar groot leemtes is in ons kennis van die biologie en ekologie van die helminte van akwatiese omgewings. 'n Deeglike kennis van alle aspekte van visparasitologie is uiters noodsaaklik vir intensiewe visverbouing, asook vir die ekstensiewe benutting van bestaande visbevolkings op 'n wetenskaplik-verantwoordbare basis.

Die huidige ondersoek kon daarin slaag om verskeie toekomstige navorsingsprojekte op hierdie terrein te identifiseer. Onder andere, het dit opgeval dat betreklik min gepubliseerde kennis bestaan oor die wurmparasiete van Suid Afrikaanse marine visvretende voëls. Dit is verbasend, waneer daar besef word dat die Indiese en Atlantiese komponente van die Suid Afrikaanse kuslyn 'n groot verskeidenheid visvretende voëls in groot getalle huisves. Voeg hierby die feit dat die Suid Afrikaanse mariene visfauna uit meer as 2 200 visspesies bestaan, dan kan besef word wat 'n uitdagende en waardevolle studieveld hier gebied word. (Sien ook bladsy 163).

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Despite tremendous technological and scientific advances during the second half of the twentieth century, the provision of an adequate and balanced food supply for an ever increasing human population poses one of the most insoluble problems confronting man.

It is a well documented fact that almost two-thirds of the world's population are still not provided with a scientifically balanced meal for at least the greatest part of their lives (Arthur, 1969; Detwyler, 1971; Cox, 1974; Murdock, 1975; Simmons, 1986). This problem particularly emphasises itself in the least developing countries (LDC's) of the world where population growth still records annual figures between 3 - 4%. In 1970, 24 out of 97 LDC's had energy consumption deficits exceeding 10 per cent and a group of 45 LDC's were designated as the MSA (most seriously affected) nations. Of these, 26 are in Africa (Simmons, 1986).

It is thus clear that extension of agricultural areas and intensification of performance of existing agroecosystems is an obvious solution to resolve some of mankinds nutritional problems. However, most authorities are in agreement that nutritional deficiencies will still persist even if enhanced development of conventional agriculture were progressively sustained. Simmons (op cit) is of the opinion that a recommendable strategy to adopt is to: *work towards the improvement of yields of basic crops on the one hand and the development of supplementary [new] foods on the other. In the latter there is some emphasis on protein production because this has been preceived, not always correctly, as the main deficiency in areas of nutritional stress* (p. 190).

Aquaculture, and in particular, pisciculture, from brackish and freshwater systems is one particular category of developing [new] animal protein food sources in many LDC's. This is especially true in regions with pronounced seasonal rainfall patterns where man-made impoundments for storage of run-off water abound. Freshwater fish farming can, if planned correctly, and if wisely integrated with conventional irrigation farming, go a long way towards multipurpose usage of water. Fish farming uses water but does not necessarily have to consume it. (Saayman and Schoonbee, et. al., 1991).

Freshwater fish farming in Israel is an excellent example in this regard (Prinsloo, J.F., personal communication)

It is a well documented fact that mankind has, since his very early beginnings exploited wild fish stocks in order to meet his daily nutritional needs (F.A.O., 1954; Hickling, 1962; Holt, 1967; Bardack, Ryther and McLarney, 1972; Bowmaker, 1975; Gerking, 1977; Duncan-Brown, 1978 and Jackson, 1978).

In agricultural history the husbandry of fish also goes back to at least several thousand years. Hickling (1962) states that the ancient Asiatic civilisations are normally associated with the beginnings of developing a tradition of fish culture practices alongside methods of harvesting wild fish stocks. In Egypt there are archaeological evidence of intensive fish culture operations dating back to about 2500 B.C. (Hickling, 1962; Maar, *et al*, 1966).

It is ironical that Africa, and in particular Sub-Saharan Africa - registering the greatest proportion of MSA nations on any continent - has over the centuries lacked far behind other regions in freshwater fish husbandry. In recent times first attempts to cultivate cichlid species were made in Kenya (1924) followed by Zaïre in 1937. In Central East Africa attempts at pond culture started in Zambia (1942) and Zimbabwe in 1950 (Maar, *et al*, 1966). As recently as 1975 Nigeria was the only country on the African Continent with freshwater fish production figures in excess of 10,000 tons. This is in contrast to China which topped the list with 2.2 million tons (Fishing News International, August, 1977). The practice of fish culture in South Africa and its immediate neighbours even lacked further behind that of African Countries further to the North. (Bar-David, 1978; Brandt, 1980; Safriel and Bruton, 1984; Saayman and Schoonbee, *et al*, 1991).

It is difficult to understand why organized utilization of freshwater fish stocks in natural and man-made aquatic environments as well as intensive piscicultural practices have, as yet, not reached advanced levels and extensive yields in southern Africa in particular and Africa in general. Saayman and Schoonbee, et. al., (1991) are of the opinion that this situation may directly be attributed to a combination of the following reasons:

- In southern Africa with its long shoreline, rich marine fishing grounds and well-organized sea fisheries enterprises, marine fish has always formed a major source supplementing agriculturally produced animal protein sources;
- Until fairly recently the balance between production and availability of animal protein from terrestrial and marine sources and national demands was reasonably well structured. The need for the exploitation of additional animal protein sources ("New foods" of Simmons, 1986) was therefore not felt;
- The inland and rural communities of southern Africa have, to a large extent, not developed a tradition for fish as a nutrient source. This is perhaps due to the general availability as well as favourable price index of terrestrially produced animal protein. In South Africa, annual per capita consumption of fish averages 4.1 kg. compared to, for example, France (19.7 kg.), England (20.5 kg.). Spain (35.1 kg.) and Japan (49.9 kg.) (F.A.O. Agricultural Commodity Projection, 1970 - 1980).

The South African situation, however, as regards to the production and consumption of fish as an additional animal protein source, has changed drastically during the last two decades. This is mainly due to the following reasons as remarked upon by Saayman and Schoonbee, et. al., (1991):

- Declining tendencies in the marine fisheries output as reported by, amongst others, Stöhr, 1977; Anon, 1978; Grindley, 1978; Noble and Hemens, 1978; Cram, 1980; Butterworth, 1980; Lochner, 1980; Allanson and Jackson, 1983;

- The imbalance which developed between land protein resources on the one hand and population growth coupled with increased material standard of living (GDP) on the other. (= Ecological demand of the Blueprint for Survival - The Ecologist 2(1), 1972) as reported on for South Africa by the Presidents Council Report on Demographic Trends in South Africa (1983);

- Rising costs in refrigerated transportation of marine fish from coastal outlets to inland markets.

The overall end result of the foregoing synoptic scenario is a rapidly increasing South African interest in aquaculture and in particular freshwater fish production with regard to both intensive fish husbandry as well as extensive sustained yield cropping of wild fish stocks occurring in impounded water bodies. (Van der Waal, 1976; Roode, 1978; Bross, 1981; Hamman, 1981; Allanson and Jackson, 1983; Krause, 1984; Saayman, 1984; Safriel and Bruton, 1984, Van der Merwe, 1984; Bachelor, 1985; Hecht, 1985; Prinsloo and Schoonbee, 1986, Taylor and Van der Walt, 1985; Hecht, Uys and Britz, 1988).

This interest brought with it the realization that South Africa not only lags behind in technological expertise for intensive and extensive piscicultural enterprises, but also that basic and problem-oriented research in support of aquacultural ventures were grossly insufficient if not totally lacking in some critical areas. This stimulated various research organisations such as Universities, Government laboratories and Non-Governmental organizations to intensify and elaborate research efforts on South African aquatic ecosystems. Noble and Hemens (1978) reviewed the research needs on inland water ecosystems in South Africa and also listed the various institutions concerned with aquatic biological research and their respective fields of interest.

Safriel and Bruton (1984) sketched the aims and objectives for aquaculture supportive research in South Africa and stated inter alia that:

> *Research is aquired with the overall objective of providing the scientific information necessary for the practice of aquaculture by a diverse group of users including commercial fish farmers, agriculture authorities, farmers, the marine industry and agencies involved in economic planning and development.*

This broad objective was subdivided into five comprehensive programme objectives aimed at providing basic and problem-oriented research in support of aquaculture ventures.

Amongst the various research disciplines which contribute directly and indirectly to the success of piscicultural enterprises the very important role of basic and problem-oriented research on fish parasites cannot be overemphasised. Consequently, this aspect of scientific endeavour should be provided with a high priority rating. (Saayman, 1984; Saayman and Schoonbee et. al., 1991).

Fish ecological and/or limnological surveys on inland water ecosystems have, in the past, not paid particular attention to the parasitofauna of aquatic organisms. This is especially true with regards to their infra- and suprapopulation demographics, zoogeographical and host distribution, incidence, seasonal variation, life cycle details as well as pathological effects and the influence of zooparasites on the production of fish cultivated under controlled systems where fish is being stocked at high density levels. Up to as late as 1980 only 20 literature references on fish parasites of South African freshwater fish fauna appeared in the literature and the majority of these concentrates on taxonomic details/descriptions (Mashego, 1982; Britz, 1983; Saayman, 1984; Van As and Basson, 1984, 1988). An excellent example of the poor state of knowledge on parasites of South African indigenous freshwater fish species is the fact that Khalil (1971) in his check list of helminth parasites of African freshwater fishes lists only 10 helminth spp. from South African hosts, whereas the revised check list of the same author (in press) lists no less than 54 species. Similarly Khalil (1971) made no reference to any *Contracaecum* larvae being recorded from South African freshwater fish. Published, (Mashego and Saayman, 1981; Boomker, 1982; Saayman, Mashego and Mokgalong, 1986; Mokgalong and Saayman, 1986; Boomker, 1992, 1994 a and b) and unpublished surveys conducted since 1974 revealed no less than 43 South African indigenous fish species being infected with this widespread nematodan genus.

From the foregoing paragraphs it is evident that researchers have, within the limitations of time, scope and manpower, made substantial progress in researching the parasitofauna of South African indigenous fish species. This progress is further illustrated by the number of Magister and Ph.D. students that have completed their degrees in the field of fish parasitology as well as the number of fish parasitological research papers/posters presented annually at the congresses of the Parasitological Society of southern Africa.

Although progress is being evidenced regarding South African freshwater fish parasites the same cannot be said about the role played by piscivorous birds in the ecology of freshwater fish parasites. To date the only literature references on this topic are those of Ortlepp (1938); Bisseru (1955); Prudhoe and Hussey (1977) and Whitfield and Heeg (1977).

The present study on the helminth fauna of members of the Phalacrocoracidae and Anhingidae was specifically planned to address the shortfall mentioned in the preceding paragraph. The investigation was enhanced by the fact that it formed part of a multi-disciplinary Departmental research programme carried out over a period of seven seasons on the newly constructed Middle Letaba Impoundment in the North-eastern Transvaal Lowveld.

In this programme the following aspects of the general limnology of this impoundment, as it progressed through the first phase of Bowmaker's (1975*b*) developmental stages in the evolution of newly constructed man-made lakes, were investigated:

- The Middle Letaba Impoundment and its role in the socio-economic development of the Giyani District (Northern Province);
- Distribution and possible role of aquatic macrophytes in the Middle Letaba Impoundment;
- Physico-chemical conditions of the water;
- Plankton and Benthic macro-invertebrate fauna;
- Ecology of the larger fish species;
- Aspects of the ecology of the smaller fish species;
- Seasonality and abundance of waterbirds;
- Parasites of the fish population;
- Helminth parasites of selected examples of piscivorous and water-loving birds with particular reference to the gastrointestinal parasites of resident members of the Phalacrocoracidae and Anhingidae.

This investigation on the helminth parasites of piscivorous birds was planned with the following aims and objectives in mind:

- To meet the demand prompted by the dearth of information regarding the platyhelminth and aschelminth parasites of South African inland piscivorous birds;
- To discover probable fish-avian chain linkages which might exist through the numerically dominant piscivorous birds resident at the impoundment;
- To investigate the role played by members of the Phalacrocoracidae and Anhingidae in the completion of the life cycles and supra-population statistics of the following parasitic taxa:

  - Clinostomidae
  - Diplostomidae
  - Ligulid and paradilepid cestodes
  - *Contracaecum*;

- To establish the role played by piscivorous birds in the translocation of helminth parasites to newly constructed water bodies;

- To compare helminth incidence between Middle Letaba Phalacrocoracidae and Anhingidae and those resident at selected water bodies in the Northern Province that are already in Bowmakers (1975*b*) third phase of biological development.

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1

MATERIAL & METHODS

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MATERIAL AND METHODS

STUDY AREA:

The study area for the present investigation included the geographical region of the Northern Province of South Africa (Fig.1 p.13). This area is drained by two major riverine systems, namely, the Limpopo River Drainage System and the Olifants River Drainage System (Fig. 2, p.14). The area borders on three other southern African states, viz., Botswana to the west; Zimbabwe to the north and Mozambique to the east. The Limpopo River forms the boundary between the Northern Province of South Africa and Botswana and Zimbabwe to the west and north respectively (Fig.2 p.14).

The study area falls within the northern summer rainfall area of South Africa, which is characterized by extremely dry and mild winters. Most of the rain occurs in the form of convectional summer rainstorms. As a result of this very pronounced seasonal rainfall pattern a large number of man-made impoundments were constructed along the main Drainage Systems. During the present study avian final- as well as fish intermediate hosts were procured from selected aquatic ecosystems (See Fig. 2, p.14) and Table 1 below).

Table 1: Geographical location of sampling sites.

SAMPLING LOCALITY	DRAINAGE SYSTEM	LATITUDES (South)	LONGITUDES (East)
Piet Gouws Dam	Olifants	24°33'-24°35'	29°36'-29°38'
Olifants River	Olifants	24°45'-24°47'	29°25'-29°26'
Seshego Dam	Limpopo	23°51'-23°52'	29°22'-29°24'
Turfloop Dam	Limpopo	23°52'-23°54'	29°46'-29°48'
Nile River Swamps	Limpopo	24°06'-24°13'	28°54'-28°59'
Glen Alpine Dam	Limpopo	23°28'-23°30'	29°30'-29°33'
Luphephe Dam	Limpopo	22°37'-22°39'	30°23'-30°25'
Nwanedzi Dam	Limpopo	22°37'-22°38'	30°25'-30°26'
Hudson Ntsanwisi Dam	Letaba	23°16'-23°18'	30°45'-30°46'
Middle Letaba Impoundment	Letaba	23°17'-23°19'	30°24'-30°26'
Ebenhaezer Dam	Letaba	23°54'-23°56'	29°33'-29°56'
Tzaneen Dam	Letaba	23°45'-23°48'	30°10'-30°30'

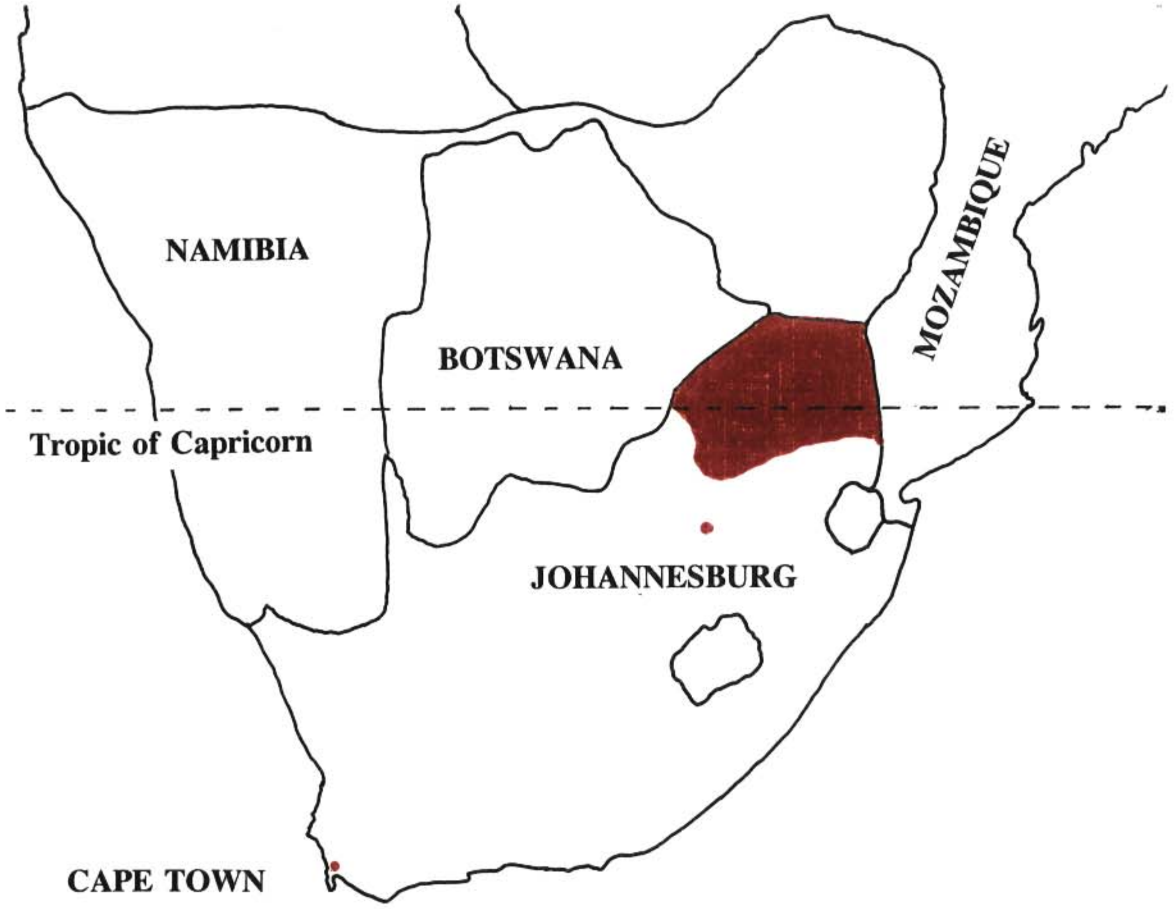


Fig. 1: The Northern Province of South Africa in relation to the rest of Southern Africa.

FIG. 2

MAP INDICATING COLLECTING SITES

Key:

1. - Loskop Dam

2. - Piet Gouws Dam

3. - Marble Hall

4. - Seshego Dam

5. - Turfloop Dam

6. - Ebenhaezer Dam

7. - Tzaneen Dam

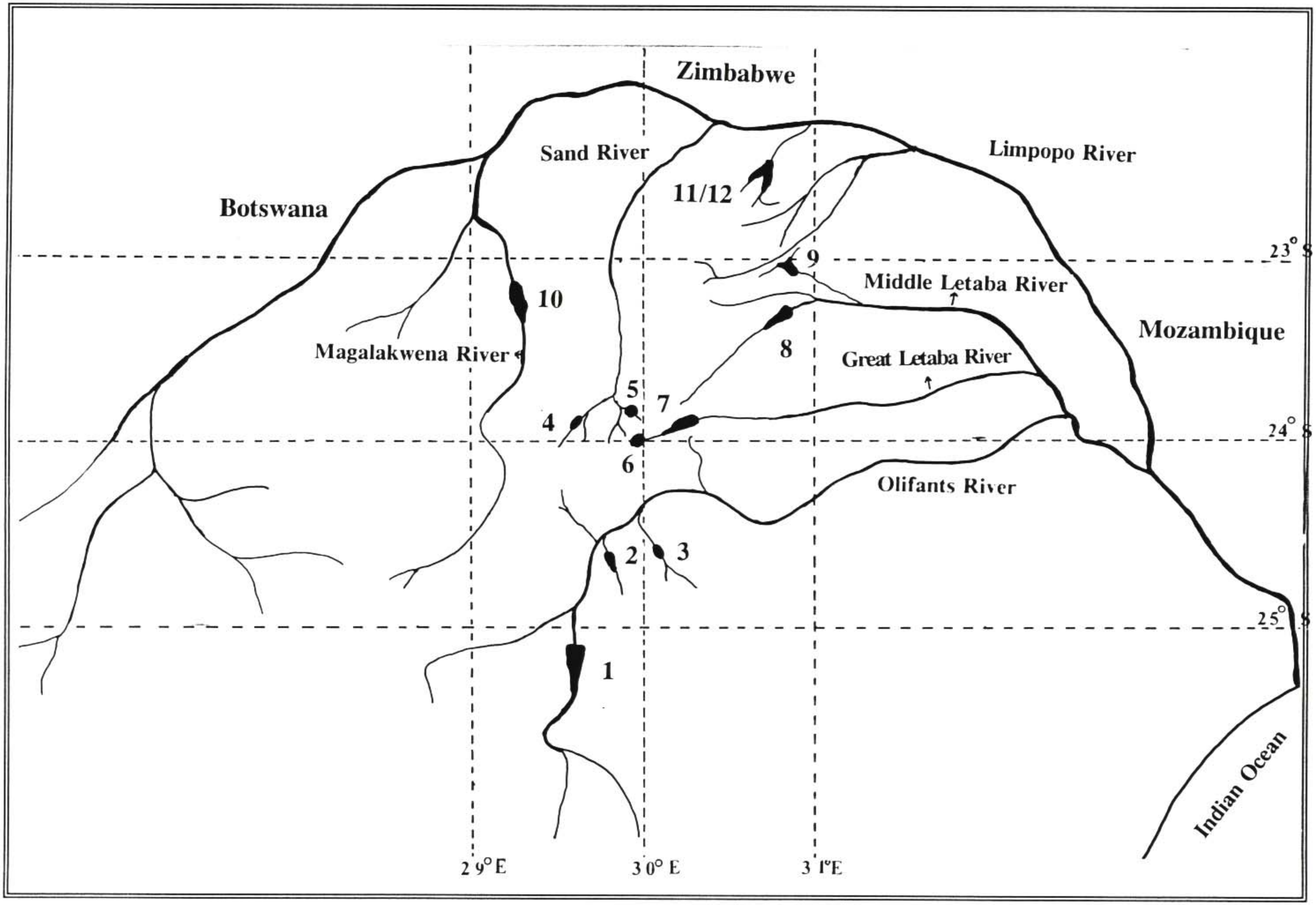
8. - Middle Letaba Dam

9. - Hudson Ntsanwisi Dam

10 - Glen Alpine Dam

11. - Nwanedzi Dam

12. - Luphephe Dam


Zimbabwe
Botswana
Sand River
Limpopo River
11/12
9
23° S
Middle Letaba River
10
Mozambique
Magalakwena River
8
Great Letaba River
5
7
4
6
24° S
Olifants River
2
3
25° S
1
Indian Ocean
29° E
30° E
31°E

PISCIVOROUS AVIAN HOSTS:

The present study aimed at an investigation of the helminth parasites of the avian families Phalacrocoracidae and Anhingidae. In the study area these families are represented by the following members:

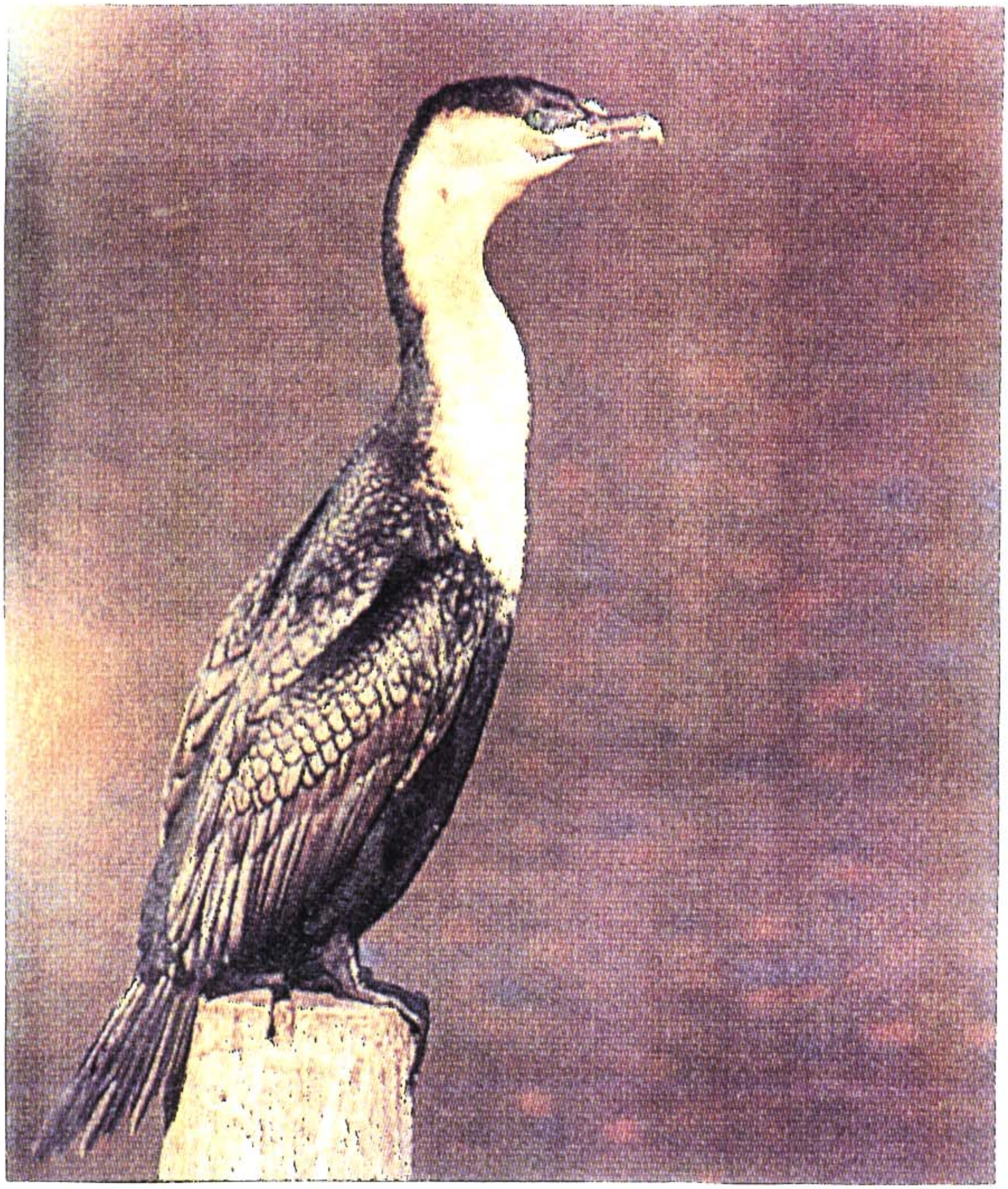
Phalacrocoracidae:	*Phalacrocorax carbo* Linnaeus, 1758 *P. africanus* Gmelin, 1789
Anhingidae :	*Anhinga melanogaster* Lacepede & Dauchin, 1802

The investigation also formed part of a multi-disciplinary Departmental study of the ecology of Middle Letaba Impoundment. This aquatic ecosystem (Fig.2 p.14) also provided the opportunity to examine other piscivorous birds which might play a role in the fish-avian parasitic linkage. These potential hosts were:

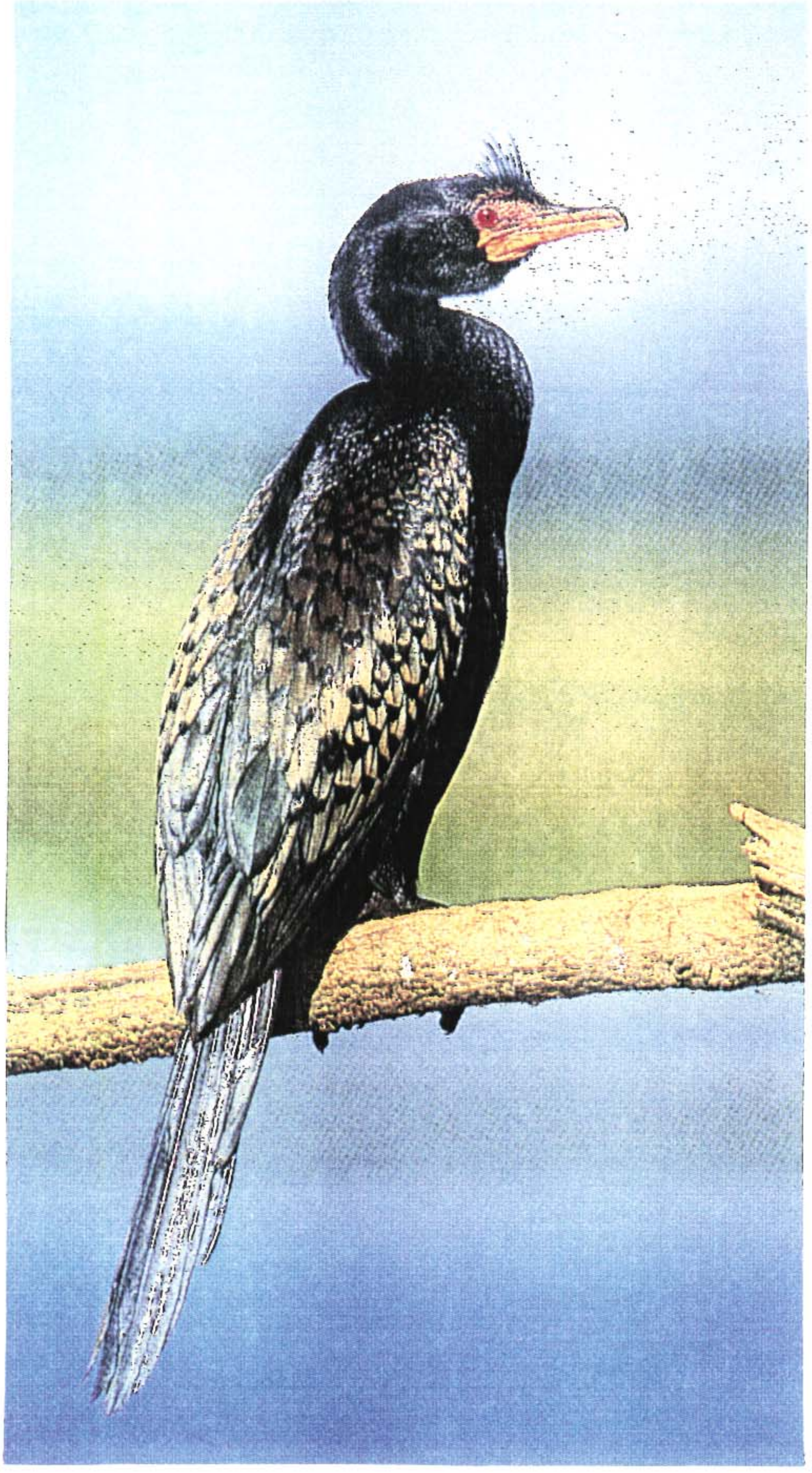
FAMILY	SPECIES
Ardeidae	*Ardea cinerea* *A. melanocephala* *A. purpurea* *Egretta garzetta* *Bubulcus ibis* *Butorides striatus* *Nycticorax nycticorax* *Ixobrychus minutus*
Plataleidae	*Platalea alba*
Jacanidae	*Actophilornis africanus*
Alcedinidae	*Ceryle rudis* *C. maxima* *Alcedo cristata*

All the bird species investigated were identified using the following field guides:

Robert's Birds of southern Africa,
edited by M.G.L. Maclean;
Field Guide to the Birds of southern Africa,
by Ian Sinclair;
Birds of southern Africa,
by K. Newman.



Phalacrocorax carbo **- Whitebreasted Cormorant**



Phalacrocorax africanus - **Reed Cormorant**

Anhinga melanogaster - **Darter**

PROCURING AND HANDLING OF AVIAN HOSTS:

Avian specimens were collected with the aid of a 12 - bore double barrel shotgun or a 0.22 calibre rifle.

After the birds were shot their beaks were sealed with elastic bands to avoid possible escape of clinotomatid and *Contracaecum* parasites lodged in their buccal cavities and oesophageal regions. Birds were transported to the field laboratory in sealed plastic bags and were immediately examined on arrival. If there was no time, they were refrigerated for a short time prior to examination. In all cases, however, the helminths were still found to be alive when the birds were autopsied.

The organs of the host examined included the buccal cavity, pharynx, oesophagus, stomach, duodenum, intestine and rectum. The procured helminths were washed in 0,9% saline solution before killing and subsequent fixation. Infections were recorded both qualitatively and quantitatively.

FIXATION AND PRESERVATION OF RECORDED PARASITES:

Trematodes were killed and fixed in hot Alcohol - Formal - Acetate (AFA), which consisted of:

500 ml	96% ethyl alcohol
60 ml	40% Formaldehyde
40 ml	Glacial Acetic Acid
400 ml	distilled water

Digenea were preserved in 80% Ethanol to which 5% glycerine was added.

More robust trematodes such as **clinostomes** were killed and fixed individually. Each specimen was transferred to a slide by means of a Pasteur pipette, covered with a coverslip and straightened before hot AFA was added. Slight pressure was applied to the coverslip until the worm was fixed in a flattened position. This procedure was deemed necessary to ensure that the material was suitable for subsequent microtechnical procedures.

After a period of about 30 minutes in the AFA the specimens were transferred to a labelled, screw top Petersen specimen bottle and preserved in 80% ethyl alcohol to which 5% glycerine was added.

Cestodes were relaxed by swirling in a petri dish with distilled water. The exact time for swirling depended on the size of the worms. The worms were fixed by adding hot AFA to the water in which they were being swirled. This was followed by preserving in 80% ethanol and 5% glycerine and stored in labelled specimen bottles.

Nematodes were killed and fixed in glacial acetic acid and preserved in 80% ethanol plus 5% glycerine.

In all instances care was taken not to apply excessive pressure to the parasites during collection, killing, fixation and preservation.

PROCEDURES FOR WHOLEMOUNT PREPARATIONS:

TREMATODA AND CESTODA

Specimens preserved in alcohol were brought down to water through descending grades of alcohol (80%, 70%, 50%, 30%) and finally washed in distilled water. Formalin preserved material were transferred directly to distilled water and washed in two or three changes.

Staining of worms took place in Aceto - Alum - Carmine solution:

Potassium Aluminium Sulphate
Carmine powder
Glacial Acetic Acid

Smaller specimens were stained for 15 - 20 minutes while larger specimens sometimes required periods up to twelve hours. For destaining purposes a 2% aqueous solution of HCL was used. Differentiation time varied according to the size of the specimen. A stereo microscope was employed to monitor colour loss, especially in the smaller worms. Rapid colour loss was arrested by transferring the specimens to an aqueous alkaline solution (1% KOH or NaOH).

After staining, dehydration in an ascending series of alcohol (30%, 50%, 70%, 90%, 96% and two changes of 100%), was carried out. Clearing was done in Clove oil before the specimens were permanently mounted in Canada Balsam.

Rostellar hooks were freed by cutting the rostellum and placing it on a slide to which two drops of Berlese Fluid were added in order to digest remaining tissues:

8 g.	Gum Arabic flakes
10 ml.	distilled water
74 g.	Chloral hydrate
3 ml.	Glacial Acetic acid

For permanent mounts, hooks were covered with a cover slide and sealed with transparent nail varnish.

NEMATODA

Nematodes were not stained but were directly cleared in Lactophenol or Beechwood Creosote. For permanent mounts, the parasites were placed on a slide in a few drops of the clearing agent, covered with a cover slip and the preparation sealed with Glyceel or transparent nail varnish.

En face preparations were made by removing the head of the nematode and manipulating it in molten glycerine jelly into an upright position on a cavity slide.

Whole mount drawings were made with the aid of a Leitz microprojector or a camera Lucida.

MICROTECHNICAL PREPARATIONS:

Standard microtechnical procedures were employed in preparing transverse serial sections of helminth parasites. Sections, five or eight millimicrons thick, were stained with Delafield's Haematoxylin and counterstained in Eosin. Xylene was used in clearing, while Synthetic Canada Balsam was used for permanent mounts.

GRAPHIC RECONSTRUCTION AND MEASUREMENTS:

Helminth parasites procured during this investigation were subjected to detailed anatomical study in order to elucidate their systematic position. Serial sections were drawn with the aid of a Leitz microprojector. The method of xylene piling and the enlargement formula described by Pusey (1939) were employed for graphic reconstructions.

Selected transverse sections were drawn or photographed for the illustration of important anatomical regions and organs. Serial transverse sections, graphic reconstructions, whole mount preparations and preserved specimens from the research of Mashego (1977; 1982); Saayman (1986) and Saayman and Schoonbee et. al.,(1991) were available for comparative analyses.

Unless otherwise stated, all measurements are given in millimeters (mm.).

SCANNING ELECTRON MICROSCOPY (SEM):

Specimens were dehydrated in an ascending series of alcohol where the material was kept for an hour in each concentration. After dehydration specimens were kept in 100% Amyl-Acetate before they were critically point dried with liquid CO_2. Helminths were finally sputter-coated with a gold layer and studied with the aid of a Hitachi 450 - and a Joel JSM 6100 scanning electron microscope.

EXPERIMENTAL LIFE CYCLE STUDIES:

A number of fish species from water bodies in the Northern Province, South Africa were found to harbour different clinostomatid metacercarial cysts (Mashego, 1977, 1982; Britz, 1983; Britz, Saayman and Van As, 1984; Britz, Van As and Saayman, 1984, 1985; Saayman, 1986 and Saayman and Schoonbee et. al., 1991). *Euclinostomum* cysts were found mostly in the muscles while those of *Clinostomum* were found encysted on the visceral peritonia. *Neutroclinostomum* were found encysted on the tissues of the branchial chamber.

In order to study the development from metacercariae to sexually mature forms, as well as to elucidate their systematic positions, it was decided to attempt raising these metacercariae to adulthood in experimental hosts. Four, five-day old domestic chicks (*Gallus domesticus*); four Grey heron (*Ardea cinerea*) nestlings and two Darter nestlings (*Anhinga melanogaster*) were used in the experiment.

Each experimental host was fed with five clinostomatid metacercarial cysts. The cysts were removed from their fish hosts with care being taken not to damage the cyst wall and fed immediately to the experimental hosts. The experimental infection was carried out such that the cysts were dropped as deeply into the gullet as possible. The beak of the host was kept closed so as to prevent regurgitation.

The domestic chicks died on the third post-infection day and yielded negative results on autopsy. *A. cinerea* and *Anhinga melanogaster* nestlings harboured clinostomatid parasites in the anterior part of the alimentary canal on examination after seven and eight days post-infection. The position of the parasites in the buccal cavity and oesophagus were noted. The parasites were collected, killed, fixed, preserved and stained following the procedures set out above.

In addition to these experimentally raised sexually mature clinostomids, material from similar experiments by Saayman was also made available for this study.

STATISTICAL EVALUATION OF DATA:

The infestation results obtained during this investigation were summarized by determining the prevalence, intensity and mean intensity of infection indexes as defined by the American Society of Parasitologists (Margolis, Esch, Holmes, Kuris and Schad, 1982).

Selected programmes of the **Statistical Analysis System (SAS, 1985)** were used to determine the possible significance of the results. The **Harvard Graphics Computer Programme** was used for the various graphical illustrations.

The material which was collected, processed and studied during the present investigation will be housed in the Parasitic Collection of the Department of Zoology, University of the North, Sovenga, South Africa.

In the general introduction (p. 4) it was mentioned that this study had access to material and data collected during previous (Mashego, 1977, 1982); Britz 1983 and Saayman, 1986) and concurrent (Saayman and Schoonbee et. al., 1991) surveys of fish parasites of the study area. Some larval helminths parasitising fish intermediate hosts, could, on morphological and ecological strength, be positively linked to adult forms in piscivorous birds. The following fish species were identified during this excercise following the taxonomic designations of Skelton (1993).

Family Mormyridae

Genus: *Marcusenius* Gill, 1862
M. macrolepidotus (Peters, 1852)

Family Cyprinidae

Genus: *Barbus* Cuvier and Cloquet, 1816
B. lineomaculatus Boulenger, 1903
B. neefi Greenwood, 1962
B. unitaeniatus Günther, 1866
B. bifrenatus Fowler, 1935
B. viviparus Weber, 1897
B. toppini Boulenger, 1916
B. radiatus Peters, 1852
B. trimaculatus Peters, 1852
B. eutaenia Boulenger, 1904
B. argenteus Günther, 1868
B. paludinosus Peters, 1852
B. mattozi Guimaraes, 1884
B. marequensis A. Smit, 1841

Family Schilbeidae

Genus: *Schilbe* Oken, 1817
S. intermedius Rüppel, 1832

Family Clariidae

Genus: *Clarias* Scopoli, 1777
C. gariepinus (Burchell, 1822)

Family Mochokidae

Genus: *Chiloglanis* Peters, 1868
C. pretoriae Van der Horst, 1931

Family Cichlidae

Genus: *Pseudocrenilabrus* Fowler, 1934
P. philander (Weber, 1897)

Genus: *Oreochromis* Günther, 1899
O. mossambicus (Peters, 1852)

For the taxonomy of the helminths recovered during the present study the following major works were consulted:

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The Trematoda - Ben Dawes (1956)
Systema Helminthum Vol. 1. - Yamaguti (1958)
Synopsis of Digenetic Trematodes of Vertebrates, Vol. 1 and 2 - Yamaguti (1971)

CESTODA:

Systema Helminthum Vol. 2 - Yamaguti (1959)
Keys to the Cestode Parasites of Vertebrates - Khalil, Jones and Bray, Editors (1994)

NEMATODA:

Systema Helminthum Vol. 3, Part 1 and 2 - Yamaguti (1961)
CIH Keys to the Nematode Parasites of Vertebrates, No.2.,
Keys to the Genera of the Ascaridoidea - Hartwich (1974)

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SECTION A

Helminth Parasites of *Phalacrocorax carbo*, *P. africanus* and *Anhinga melanogaster* involving a fish intermediate host in the life history.

A

INTRODUCTION

A

INTRODUCTION

The results obtained during the present investigation on the helminth parasites of the numerically dominant and most widespread members of the families Phalacrocoracidae and Anhingidae inhabiting South African inland water ecosystems, will be presented under two different sections, namely:

SECTION A: Helminth parasites of Phalacrocoracidae and Anhingidae involving a fish intermediate host in the life cycle,

and;

SECTION B: Helminth parasites not dependent on fish as intermediate hosts.

In total some 24 helminth parasites were recorded from *Phalacrocorax carbo, P. africanus* and *Anhinga melanogaster*. These species are classified under the following major taxa.

Species marked with an asterisk denote parasites which include fish as intermediate hosts and will therefore be discussed in Section A, chapters 2 - 4 while the rest will be presented in Section B, chapters 5 and 6.

Phylum **Platyhelminthes**
Class **Trematoda**
Family **Strigeidae** **Railliet, 1919**

Genus: *Strigea* Abildgaard, 1790
S. anhingae Ukoli, 1966

Genus: *Schwartzitrema* Pérez Vigueras, 1941
* *S. pandubi* (Pande, 1939) Dubois and Pearson, 1965

Family Diplostomidae Poirier, 1886 emend, Hughes, Higginbothom and Clary, 1942.

Genus: *Harvardia* Baer, 1932
* *H. sandgroundi* Baer, 1932
(= *H. duboisi* Gupta, 1963)
Genus: *Hysteromorpha* Lutz, 1931
* *H. triloba* (Rudolphi, 1819)

Genus: *Diplostomum* Von Nordmann, 1832
(= *Proalaria* LaRue, 1926)
* *D. tregenna* Nazmi Gohar, 1932
(= *D. mashonense* Beverley-Burton, 1962)
* *D. ghanense* Ukoli, 1968

Family Echinostomatidae Poche, 1926

Genus: *Petasiger* Dietz, 1909
P. exaeretus Dietz, 1909

Genus: *Paryphostomum* Dietz, 1909
* *P. radiatum* (Dujardin, 1845), Dietz, 1909
Various Synonyms: See p.58

Family Clinostomidae Lühe, 1901 emend Dollfus, 1932

Genus: *Clinostomum* Leidy, 1856
* *C. complanatum* (Rudolphi, 1819)
Various Synonyms: See p.72

Genus: *Neutraclinostomum* Feizullaev and Mirzoeva, 1983
* *N. intermedialis* (Lamont, 1920)
(= *C. phalocrocoracis* Dubois, 1930)

Genus: *Euclinostomum* Travassos, 1928
* *E. heterostomum* (Rudolphi, 1809).

Class Cestoda

Family Diphyllobothriidae Lühe, 1910
(= Dibothriocephalidae, Lühe, 1902)

Genus: *Ligula* Block, 1782
(= *Braunia* Leon, 1908)
* *L. intestinalis* Linnaeus, 1758

Family Dilepididae Railliet and Henry, 1909

Genus: *Paradilepis* Hsü, 1935
Various Synonyms: See p.135

* *P. scolecina* (Rudolphi, 1819)
Synonyms: See p.137

* *P. delachauxi* (Fuhrmann, 1909)
Various Synonyms: See p.140

Genus: *Amirthalingamia* Bray, 1974

* *A. macracantha* (Joyeaux and Baer, 1935)
Bray, 1974

Family Hymenolepididae Ariola, 1899

Genus: *Echinorhynchotaenia* Fuhrmann, 1909

E. tritesticulata Fuhrmann, 1909

Genus: *Hymenolepis* Weinland, 1858

H. cormoranti Ortlepp, 1938

Phylum Aschelminthes

Class Nematoda

Order Ascarididae Yamaguti, 1961
(= Ascaroidea Railliet and Henry, 1915)

Family Anisakidae (Railliet and Henry, 1912 Subfamily) Skrjabin and Karokhin, 1945
(= Heterocheilidae Railliet and Henry, 1915, in part;
= Stomachidae (Johnston and Mawson, 1945, Subfamily) Hartwick, 1957)

Subfamily Anisakinae
Railliet and Henry, 1912
(= Capsulariinae Johnston and Mawson, 1943;
= Filocapsulariinae Yamaguti, 1961, in part;
= Stomachinae Johnston and Mawson, 1945)

Genus: *Contracaecum* Railliet and Henry, 1912
(= *Kathleena* Luper and Atkinson, 1914;
= *Hysterothylacium* Ward and Magath, 1917;
= *Amphicaecum* Walton, 1927;
= *Cerascaris* Cobb, 1929;
= *Iheringascaris*, Pereira, 1935;
= *Contracaecum (Ornitocaecum)* Mozgovoi, 1951;
= *Contracaecum (Synthetonema)* Kreis, 1952)

* *C. microcephalum* (Rudolphi, 1809)
* *C. rodhaini* Gedoelst, 1916
* *C. tricuspe* Gedoelst, 1916
* *C. carlislei* Ortlepp, 1938
* *C. lawrencei* Bisseru, 1955

* *C. rudolphii* Hartwick, 1964
(= *C. spiculigerum* (Rudolphi, 1809)
Railliet and Henry, 1912

Contracaecum sp. of Bisseru, 1955; described
at present as *C. jokli* Mokgalong, 1996

2

Trematodan Parasites of *Phalacrocorax carbo*, *P. africanus* and *Anhinga melanogaster* involving a fish intermediate host in the life history.

2

During this study 177 host specimens of *Phalacrocorax* and *Anhinga* were investigated for helminth parasites. Subtotals for the different host species are as follows:

Phalacrocorax carbo	:	52
P. africanus	:	59
Anhinga melanogaster	:	66
	Total	177

All host specimens were collected from water bodies in the Northern Province of South Africa. All the water bodies from which avian hosts were procured, were also extensively researched for helmith fish parasites (Mashego, 1977; Mashego, 1981; Mashego and Saayman, 1981; Mashego, 1982 a and b; Britz, 1983; Mashego, 1983; Britz, Saayman and Van As, 1984, 1985; Saayman, 1986a; Mokgalong and Saayman, 1986; Saayman, Mashego and Mokgalong, 1986; Mashego, 1989 a and b; Mashego and Saayman, 1989; Saayman and Schoonbee et al, 1991).

The parasitological research team of the University of the North is in possession of an extensive data bank on the helminth parasites of indigenous fish populations of water bodies of the Northern Province of South Africa. It was therefore an added advantage for the present investigation to correlate the helminth parasites of the piscivorous birds investigated with the larval helminths occurring in/on indigenous fish species. It was found that *P. carbo, P. africanus* and *A. melanogaster* harbour 24 species of helminths 19 of which utilize indigenous freshwater fish as second intermediate hosts.

This chapter deals with the trematodan parasites of *P. carbo, P. africanus* and *A. melanogaster* which involve indigenous freshwater fish species as intermediate hosts.

Phylum Platyhelminthes

Class Trematoda

Order Digenea

Family Diplostomatidae Poirier, 1886 emend. Hughes, Higginbothom and Clary, 1942

Genus: *Harvardia* Baer, 1932
H. sandgroundi Baer, 1932

According to Yamaguti (1958,1971) the genus *Harvardia* contains only one species, viz., *H. sandgroundi* Baer, 1932. Literature searches for published literature up to 1995 revealed no further publications on this genus. It is therefore assumed that the only published records on this species are that of Baer, 1932 (cited from Yamaguti, 1958), who described the species for the first time from the intestine of *Phalacrocorax africanus* from a locality in Africa, and a reference in a publication by Ortlepp, 1938, who recorded it from the intestine of *Microcarbo africana africanoides* (= *Phalacrocorax africanus*) from the Pretoria District, South Africa. The publication of Baer, 1932 could, after various attempts, not be traced. Ortlepp, 1938, did not include an anatomical description in his publication neither did he furnish any details on infection statistics.

Material procured during the present study were positively identified as *H. sandgroundi* by scientists of the Parasitic Worms Division of the British Museum of Natural History.

In the light of the abovementioned lack of literature it was decided to cite the entire generic description given by Yamaguti, 1958 and to indicate by illustrations from stained wholemounts and scanning electron micrographs how closely the present material fits the generic description:

> *Diplostomidae, Diplostominae, Diplostomini: Body two-segmented. Forebody strongly concave, with its lateral and posterior borders recurved ventrally. Hindbody cylindrical, arising from dorsal side of forebody, reflexed, with its posterior extremity beneath anterior extremity of forebody. Oral sucker flanked on each side by very mobile, muscular, auricular lobe containing ducts of gland cells lying in anterior half of forebody. Tribocytic organ eversible, fungiform, covered all over with minute spines, with central cavity. Acetabulum large. Testes recurved in form of horse-shoe, convex dorsally. Ovary anteroventral to anterior testis. Laurer's canal opening at the angle formed by dorsal reflexion of hindbody. Vitellaria commencing immediately behind acetabulum. Bursa very deep, cylindrical, with strongly muscular wall. Uterus and ductus ejaculatorius joining at right angles at base of bursa. Parasitic in Steganopoda.* (p. 581)

During the present study *H. sandgroundi* were recorded from the middle third of the intestines of both *P. carbo* and *P. africanus* from five water bodies in the Northern Province of South Africa.

Prevalence, intensity and mean intensity values of infection were calculated. For reasons of clarity on the foregoing concepts the definitions as suggested by Margolis, Esch, Holmes, Kuris and Schad (1982) are given below:

● Prevalence:	Number of individuals of a host species infected with a particular parasite species ÷ number of hosts examined x 100.
● Intensity:	Number of individuals of a particular parasite species in each infected host. Usually expressed as a numerical range.
● Mean intensity:	Total number of individuals of a particular parasite species in a sample of host species ÷ number of infected individuals of the host species in the sample (= mean number of individuals of a parasite species per infected host in a sample.

Table 2: Prevalence, intensity and mean intensity values for infection of *Phalacrocorax carbo* and *P. africanus* with *Harvardia sandgroundi* in the Northern Province of South Africa.

HOST	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
P. carbo	2	Piet Gouws Dam	100	22 - 42	32
	39	Seshego Dam	36	4 - 16	9
	8	Middle Letaba Impoundment	100	11 - 18	15
P. africanus	44	Seshego Dam	68	3 - 28	9
	1	Turfloop Dam	100	9	9
	9	Middle Letaba Impoundment	33	4 - 18	10
	3	Hudson Ntsanwisi Dam	67	5 - 13	9

From the preceding table it is evident that both *P. carbo* and *P. africanus* play a major role in the maintenance of the life cycle of *H. sandgroundi* in the Northern Province of South Africa. Prevalence as well as mean intensity values would indicate that *P. carbo* perhaps play a slightly more pronounced role in this regard, but it should be remembered that *P. africanus* is the numerically dominant *Phalacrocorax* species amongst the resident cormorants at all the water bodies investigated during the present study. At Middle Letaba Impoundment, for example, Saayman and Schoonbee, et. al. (1991) reported an average of 17 *P. carbo* at the impoundment during bird counts over five successive seasons (Winter 1987 - Spring 1988). During the same period the seasonal average for *P. africanus* was 212. These data would then clearly indicate that *P. africanus* plays a much more significant role in the ecology and suprapopulation statistics of *H. sandgroundi* in water bodies of the Northern Province of South Africa.

The term suprapopulation is used here as defined by Esch, Gibbons and Bourque (1975) and supported by Margolis et. al. (1982). It denotes:

> *All individuals of a species of parasite in all stages of development within all hosts in an ecosystem.*

Yamaguti (1958) does not mention any research that has been carried out on the molluscan and fish intermediate hosts for *H. sandgroundi*. Extensive literature searches carried out for the present study also failed to locate any reference to these phases of the life cycle.

Surveys done on Diplostomatid parasites of freshwater fish of the Northern Province, South Africa (Mashego, 1977; Mashego 1982; Saayman, 1986a and Saayman and Schoonbee et. al. 1991) discovered at least four different Diplostomulae parasitising a wide variety of freshwater fish species in this region. Mashego (1982) recorded and described the morphology of three different diplostomulae from eleven Barbus species investigated. Saayman and Schoonbee et. al. (1991) recorded four different diplostomulae parasitising nine of the 12 fish species investigated at Middle Letaba Impoundment.

Judging from morphological details, (Fig.3, p.34 and Fig.4a-d, p.35) supplemented by the fact that *H. sandgroundi* must be able to successfully complete its life cycle in the Northern Province aquatic ecosystems, it is tempting to link one of the five Diplostomulum species to *H. sandgroundi*, viz., a Diplostomulum encysted between the integument and body musculature of the following fish hosts:

Barbus radiatus	Peters, 1853 - Mashego, (1982)
B. unitaeniatus	Günther, 1866 - Mashego (1982)
B. trimaculatus	Peters, 1852 - Mashego (1982)
B. paludinosus	Peters, 1852 - Mashego (1982)
Oreochromis mossambicus	(Peters, 1852) - Saayman and Schoonbee et. al. (1991)

This Diplostomulum is commonly known as Black grub (= Black spot disease). The black colour of the cyst is due to a dendritic pigmentation on the eliptical cyst wall that is of host origin. Dogiel, Petrushevski and Polyanski (1958) reported that cyprinid fish species are the principal intermediate host for this parasite which may cause mass mortalities during heavy infestations.

At Middle Letaba Impoundment where surveys for fish and avian strigeids were simultaneously carried out, Saayman and Schoonbee et. al. (1991) reported the following statistics for Black grub infections amongst the *O. mossambicus* population of the impoundment.

Table 3: Statistics for *H. sandgroundi* Diplostomulum infections amongst the *O. mossambicus* population of Middle Letaba Impoundment:

NO. OF HOSTS EXAMINED	PREVALENCE %	INTENSITY	MEAN INTENSITY
156	7.69	1 - 21	4.6

Mashego (1982) recovered Black grub metacercariae, anatomically similar to the ones infecting *O. mossambicus* from Middle Letaba Impoundment, from four Barbus spp., viz. *B. radiatus, B. unitaeniatus, B. trimaculatus* and *B. paludinosus* from one aquatic ecosystem in the Northern Province, whereas it was absent from 11 Barbus spp. from seven other sampling localities in the same region. Six Barbus spp. inhabit Middle Letaba Impoundment and Saayman and Schoonbee et. al. (1991) did not record Black grub cysts from these hosts. Prevalence figures, as given by Mashego (1982), range from 9% in *B. unitaeniatus* to 42% in *B. paludinosus*.

O. mossambicus is the most widespread and almost without exception also the numerically dominant fish species inhabiting water bodies in the Northern Province of South Africa. Black grub diplostomulae occur commonly in *O. mossambicus* populations throughout the region. (Saayman - Personal communication)

Judging from the preceding account it seems justifiable to consider Black grub diplostomulae to be the causative agents for *H. sandgroundi* infections in *P. carbo* and *P. africanus* in the subtropical northern regions of South Africa and that *O. mossambicus* is the primary fish intermediate host for this parasite. Barbus spp. act as supplementary intermediate hosts.

It is intended to verify the above assumptions by experimental life history studies. Should such be conclusive the above assumptions would be the first records of the second intermediate phases in the life cycle of *H. sandgroundi*.

FIG. 3.

HARVARDIA SANDGROUNDI

Detailed drawing illustrating the anatomy

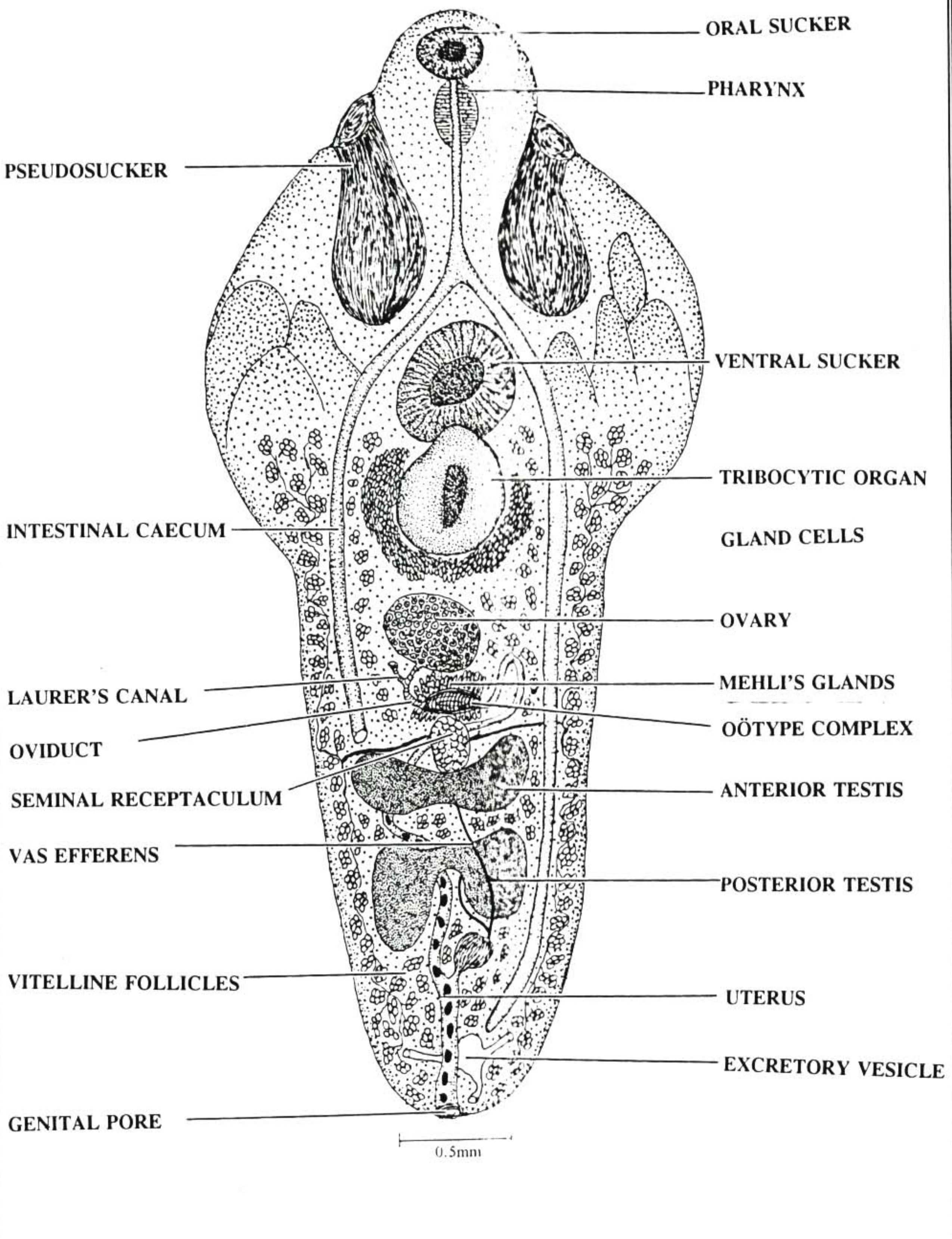

ORAL SUCKER
PHARYNX
PSEUDOSUCKER
VENTRAL SUCKER
TRIBOCYTIC ORGAN
GLAND CELLS
INTESTINAL CAECUM
OVARY
MEHLI'S GLANDS
LAURER'S CANAL
OÖTYPE COMPLEX
OVIDUCT
SEMINAL RECEPTACULUM
ANTERIOR TESTIS
VAS EFFERENS
POSTERIOR TESTIS
VITELLINE FOLLICLES
UTERUS
EXCRETORY VESICLE
GENITAL PORE
0.5mm

FIG. 4.

HARVARDIA SANDGROUNDI
(Scanning Electron Microscopy)

A. *Entire worm*

B. *Posterior end of hindbody*

C. *Anterior end of forebody*

D. *Spines covering tribocytic organ*

Key:

a. - ventral sucker

ep. - excretory pore

fb. - forebody

gp. - gonopore

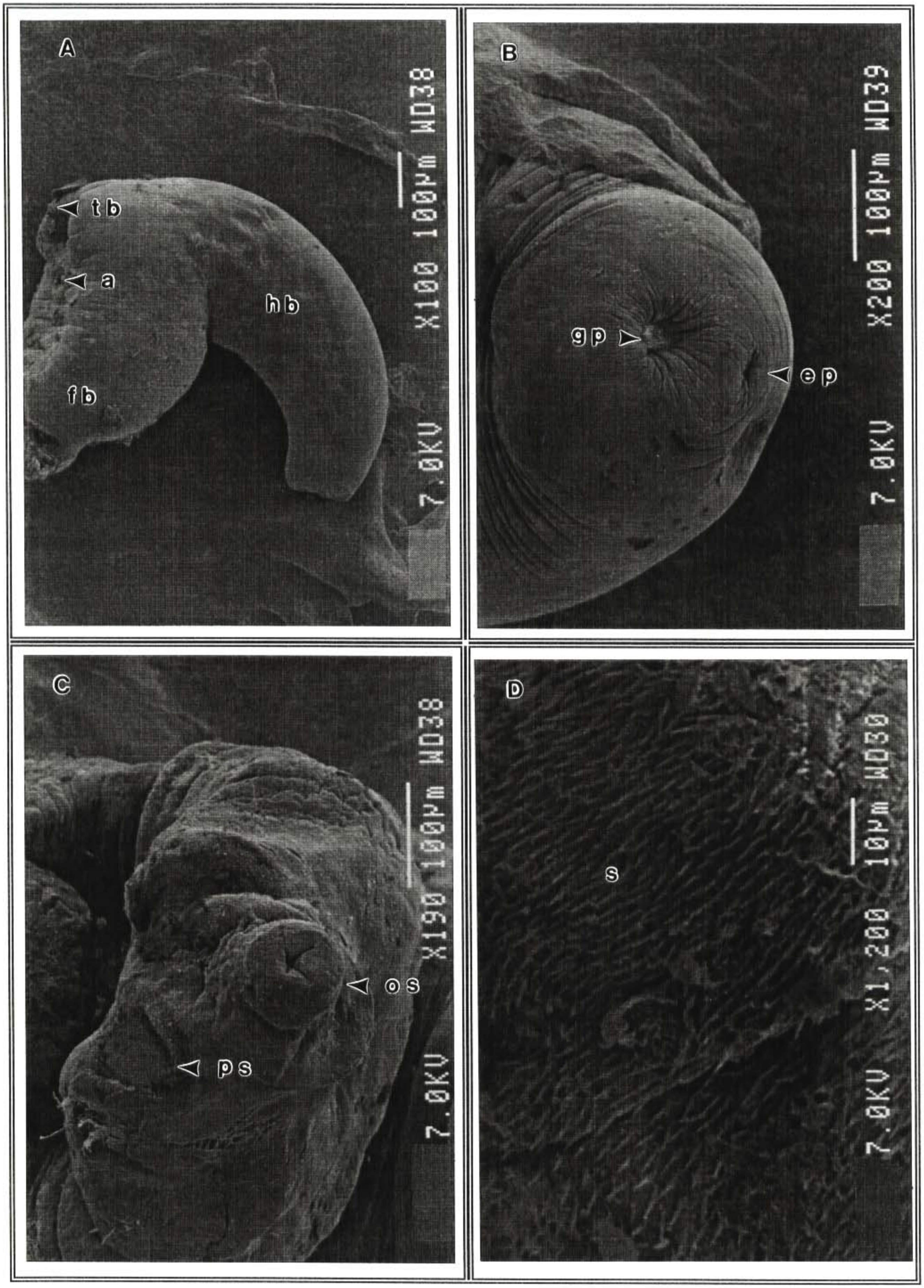
hb. - hindbody

os. - oral sucker

ps. - pseudosucker

s. - spines

tb. - tribocytic organ


A
tb
a
hb
fb
7.0KV X100 100µm WD38
B
gp
ep
7.0KV X200 100µm WD39
C
os
ps
7.0KV X190 100µm WD38
D
s
7.0KV X1,200 10µm WD30

Genus : *Hysteromorpha* Lutz, 1931.

H. triloba (Rudolphi, 1819)
(= *Distoma trilobum* Rudolphi, 1819;
= *Hemistomum trilobum* Diesing, 1850;
= *Hemistoma trilobum* Lühe, 1909; Krause, 1914;
Wedl, 1858;
= *Proalaria triloba* LaRue, 1926; Ciurea, 1933;
= *Diplostomum trilobum* Hughes, 1929; Ciurea, 1930;
= *Hysteromorpha triloba* Lutz, 1931; Dubois, 1938;
Yamaguti, 1939, 1958;
= *Diplostomum granulosum* Goss, 1940)

Genotype: *H. triloba* described by Rudolphi (1819) as *Distoma trilobum* after examination of four specimens from the intestine of the European cormorant, *Phalacrocorax carbo* (L) [= *Pelecani carbonis*), from Austria.

The above synonymy indicates that the exact taxonomic placing of this parasite was extremely uncertain for more than a century. Huggins (1954), in his paper on the life history of *H. triloba*, elaborated rather extensively on the taxonomic history. This historical account can be summarised in the following chronological sequence:-

- Described by Rudolphi (1819) as *Distoma trilobum* parasitising *P. carbo* (= *Pelecani carbonis*) from Austria;

- Diesing (1850) created a new genus *Hemistomum* and included *D. trilobum* as *Hemistomum trilobum*. The host was given as *Haliaeus carbo*;

- Brandes (1891) also listed *Hemistomum trilobum* with the host given as *Pelecanus crispus* from Austria;

- Lühe (1909) also listed this parasite as *Hemistomum trilobum* and remarked that, in addition to *P. carbo*, it was also found in *Pelecanus onocrotalus*, both hosts being from Austria. Because the material from *P. onocrotalus* was substantially larger than those from *P. carbo* Lühe (1909) expressed the opinion that the *P. onocrotalus* material might possibly belong to a different species;

- Stossich (1897) reported *Hemistomum trilobum* from *Botaurus stellaris* in Italy, but gave no other information besides listing the parasite. Dubois (1938) is of the opinion that the fluke listed by Stossich (1897) from *B. stellaris* might possibly be the same species as listed by Brandes (1891) from *Pelecanus onocrotalus*. This latter fluke was described by Krause (1914) as a new species, *Hemistomum confuscum*;

- LaRue (1926) created a new genus, *Proalaria*, and included *Histomum trilobum* as *Proalaria triloba*. This name was retained by Ciurea (1930) who studied large numbers from *P. carbo* and *P. pygmeus* and metacercaria procured from cyprinid fish. Both fish and avian hosts were from Roumania and Ciurea (1930) was the first person to associate his metacercarial material as well as a metacercarium described by Hughes (1929) with the adult flukes obtained from cormorants;

- Lutz (1931) published his research on the life cycle of this parasite and changed the name to *Hysteromorpha triloba*. Sexually mature parasites were obtained from *P. brasiliensis* (= *P. olivaceus*) in Brazil whereas the cercariae were obtained from *Planorbis immurus*. *Leptodatylus ocellatus* and *Poecilia vivipara* were successfully used as experimental fish hosts;

- The generic and specific designation of Lutz (1931) was followed by amongst others Dubois (1938, 1970); Yamaguti (1939, 1958); Chandler and Johnston (1942); Rausch (1948); Hugghins, 1953, 1954 a and b) and Moravec, Nasincova and Scholz, (1988);

- Goss (1940) described *Diplosomum granulosum* from *P. ater* taken in Australia, but these worms were later proved to be *Hysteromorpha triloba* by Johnston (1942).

A study of the literature revealed the following definitive hosts and geographical distribution of *H. triloba*. Data are presented in chronological sequence:

- *Phalacrocorax carbo* (= *Pelecani carbonis*) from Austria (Rudolphi, 1819);

- *P. carbo* and *P. pygmeus* from Roumania (Ciurea, 1930);

- *P. brasiliensis* (= *P. olivaceus*) from Brazil (Lutz, 1931);

- *P. auritus* from Minnesota, USA (Hawkins, 1932);

- *P. carbo hanadae* from Kurodo, Japan (Yamaguti, 1939);

- *P. ater* (= *P. sulcirostris)* from Perth, Australia (Goss, 1940);

- *P. carbo novae-hollandiae, P. melanoleucus* and *P. fuscescens* (= *P. leucogaster*) from Australia (Johnston, 1942);

- *P. a. auritus* from Wisconsin and Manitoba, USA (Chandler and Rausch, 1948);

- *P. a. auritus* from Illinois, USA (Hugghins, 1953);

- *P. carbo novea-hollandiae* from Tailem Bend, South Australia and Bathurst, New South Wales, Australia; *P. melanoleucus* from Tailem Bend and Gleneg River, Victoria, Australia; *P. sulcirostris* (= *P. ater*) and *P. fuscescens* (= *P. leucogaster*) from Tailem Bend (Johnston, 1942);

- *P. a. auritus* from Wisconsin and Manitoba, USA (Chandler and Rausch, 1948);

- *P. carbo* from Trebon, Czechoslovakia (Moravec, Nasincova and Scholz, 1988).

The foregoing host- and geographical list totally agrees with the statement of Yamaguti (1958) that *H. triloba* is a host specific parasite to species of the genus *Phalacrocorax*. All records, as indicated by Yamaguti (op. cit.) are from Europe, North and Central America, Australia and Japan. It is surprising that no records of the occurrence of this parasite in India or Africa could be traced from post 1958 publications. The present material from *Phalacrocorax* spp. in the Northern Province therefore appears to be the first record of this parasite in the Afro-Tropical Region.

Yamaguti (1958) mentions that *Herodias egretta, Nyctanassa violacea, Egretta garzetta, Ardea* spp., *Nycticorax* sp. and *Pelecanus* sp. were all successfully used as experimental hosts in life history studies. Lutz (1931), in his experimental studies on the life cycle of *H. triloba*, succeeded to employ *Nycticorax violaceus* [= *Nyctanassa violacea* (L)] and *Ardea leuce* (= *Herodias egretta*) as experimental hosts.

From the foregoing summary the question arises whether members of the family Anhingidae - closely related to the Phalacrocoracidae - or members of the families Ardeidae and Pelecanidae could act as natural or reservoir hosts for *H. triloba*?

During the present study *H. triloba* was frequently recorded from the intestines of *P. carbo* and *P. africanus* (Table 4, p.39), but never turned up to be parasitic in the 66 examined host specimens of *Anhinga melanogaster*. As part of the study various resident species of the family Ardeidae such as *Ardea cinerea, A. melanocephala, A. purpurea, Egretta garzetta, Bubulcus ibis, Butorides striatus, Nycticorax nycticorax* and *Ixobrychus minutus* were also investigated for the presence of intestinal helminths. *H. triloba* was never recorded as parasitising the above herons, although the parasite occurs in the resident members of the Phalacrocoracidae at Middle Letaba Impoundment (30° 24' 15" E., 23° 16' 20" S.) from which water body these birds were also procured. This study therefore undoubtedly confirms that *H. triloba* is species specific to members of the genus *Phalacrocorax*.

Table 4: Prevalence, intensity and mean intensity values for infection of *Phalacrocorax carbo* and *P. africanus* with *Hysteromorpha triloba* in the Northern Province of South Africa.

HOST	N.	WATER BODY	PREVALENCE	INTENSITY	MEAN INTENSITY
P. carbo	39	Seshego Dam	23	5 - 18	9
	2	Piet Gouws Dam	100	15 - 17	16
	8	Middle Letaba Impoundment	50	7 - 12	9
	2	Glen Alpine Dam	100	4 - 7	6
	1	Ebenhaezer Dam	-	-	-
P. africanus	44	Seshego Dam	48	2 - 18	8
	9	Middle Letaba Impoundment	-	-	-
	1	Turfloop Dam	-	-	-
	3	Hudson Ntsanwisi Dam	67	2 - 8	5

The preceding table clearly indicates that both *P. carbo* and *P. africanus* act as final hosts for *H. triloba*.

From infection statistics alone it is rather difficult to establish which of the two host species play the most important role in the life history of the parasite. From a numerical dominance point of view (refer p.32) it is tempting to suggest that *P. africanus* might very well occupy a more important role in this regard within the present study area.

The total absence of *H. triloba* in the resident population of *P. africanus* of Middle Letaba Impoundment is difficult to explain apart from reasoning that *P. africanus* is more dependent on cyprinid than on cichlid fish in satisfying their dietary requirements.

Although no experimental life history studies were attempted during the course of the present investigation, it is nevertheless tempting to link one particular *Diplostomulum* recovered from freshwater fish in the study area to adults of *H. triloba*. This attempt is justified purely on anatomical comparison between the metacercariae procured by Mashego (1982) and Saayman and Schoonbee et. al. (1991). On strength of this comparison (Fig.5, p.41) a strigeid *Diplostomulum* found unencysted in the body musculature of the following fish hosts is provisionally regarded as the metacercarium for *H. triloba*:

B. radiatus	Peters, 1853 - Mashego (1982)
B. trimaculatus	Peters, 1852 - Mashego (1982)
B. paludinosus	Peters, 1852 - Mashego (1982)
B. unitaeniatus	Günther, 1866 - Mashego (1982)
Oreochromis mossambicus	(Peters, 1852) - Saayman, 1866; Saayman and Schoonbee et. al. (1991)

Freshwater fish infection statistics for the suspected metacercarium of *H. triloba* in water bodies of the Northern Province of South Africa are summarized in Table 5 below.

The validity of assuming the *Diplostomulum* below to be the metacercarium of *H. triloba* will be tested by envisaged experimental life cycle studies. For the time being this assumption must be regarded as the first metacercarial linkage to adult *H. triloba* in phalacrocoracid hosts in the Afro-Tropical region.

Table 5: Infection statistics of freshwater fish hosts with the possible metacercarium of *H. triloba* in the Northern Province, South Africa.

FISH HOST	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
Barbus radiatus	-	Luphephe and Nwanedzi Dams	36	-	-
B. trimaculatus	-	Luphephe and Nwanedzi Dams	1	-	-
B. paludinosus	-	Luphephe and Nwanedzi Dams	15	-	-
B. unitaeniatus	-	Luphephe and Nwanedzi Dams	4	-	-
B. lineomaculatus	-	Luphephe and Nwanedzi Dams	6	-	-
Oreochromis mossambicus	53	Piet Gouws Dam	13.2	1 - 5	3.7
O. mossambicus	156	Middle Letaba Impoundment	4.48	1 - 12	3.1

Genus : *Diplostomum* von Nordmann, 1832

(= Proalaria LaRue, 1926)

FIG. 5

HYSTEROMORPHA TRILOBA
(Scanning Electron Microscopy)

A. *Entire worm*

B. *Position of tribocytic organ relative to ventral sucker*

C. *Posterior end of hindbody*

D. *Anterior end of forebody*

Key:

a. - ventral sucker

fb. - forebody

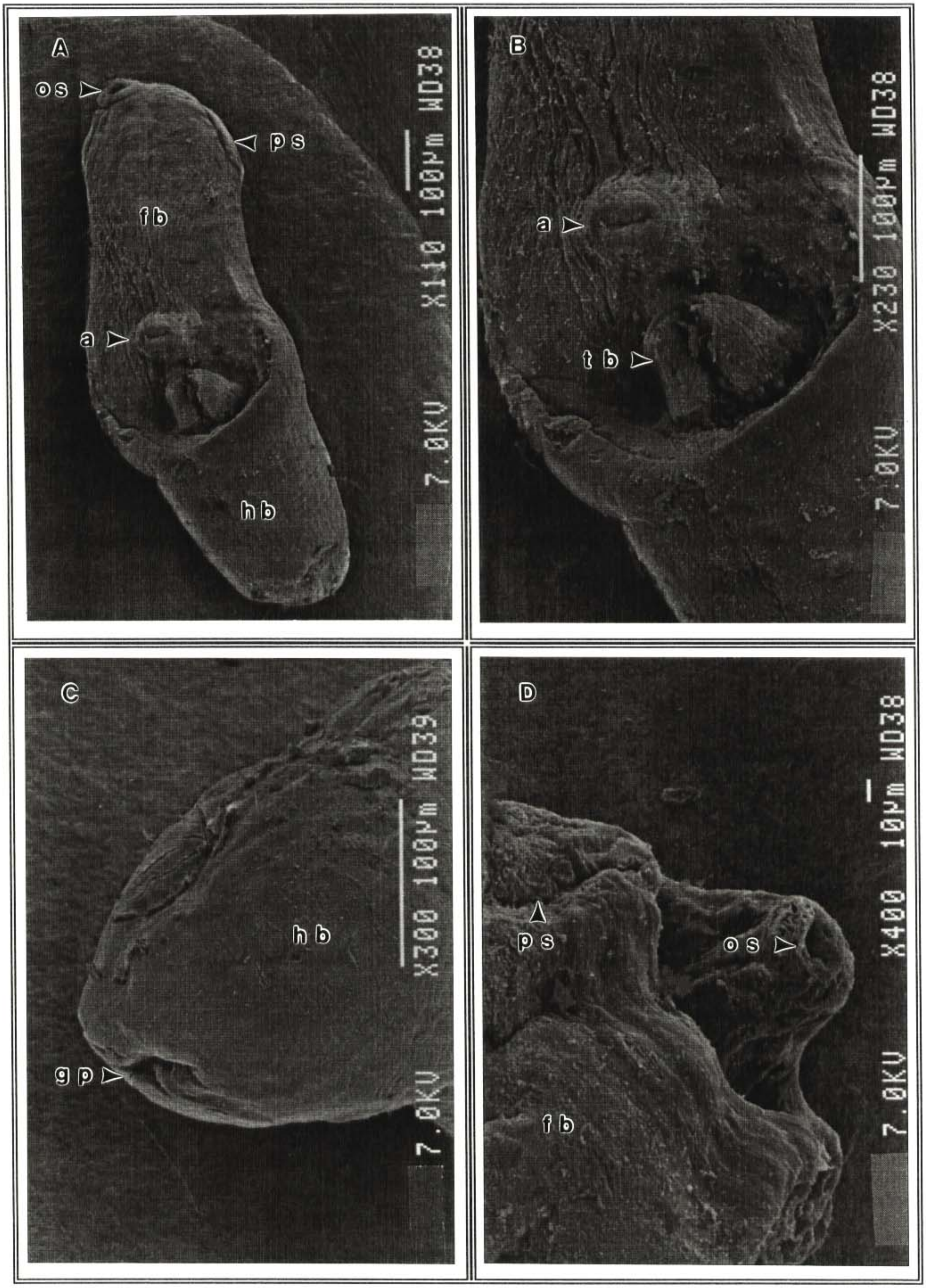
gp. - gonopore

hb. - hindbody

os. - oral sucker

ps. - pseudosucker

tb. - tribocytic organ


A
os
ps
fb
a
hb
7.0KV X110 100µm WD38
B
a
tb
7.0KV X230 100µm WD38
C
hb
gp
7.0KV X300 100µm WD39
D
ps
os
fb
7.0KV X400 10µm WD38

D. tregenna Nazmi Gohar, 1932
(= *D. mashonense* Beverley-Burton, 1963)

Genotype: *D. spathaceum* (Rudolphi, 1819)
(= *D. volvens* Von Nordmann, 1832
Hemistomum pileatum Brandes, 1888)

Diplostomum is a very large and cosmopolitan genus, which, according to Yamaguti (1958), contains no less than 26 species parasitising mainly piscivorous birds. Since 1958 various new species have been added such as:

D. sterni Gupta, 1958
D. sobolevi Schigin, 1959
D. paracaudum (Iles, 1959)
D. sudarikovi Schigin, 1960
D. ardeiformium Odening, 1962
D. ghanense Ukoli, 1968
D. petromyzi-fluviatilis Sweeting, 1975
D. pseudospathaceum Niewiadomska, 1984

The life history of *Diplostomum* spp. (Fig.11, p.57) involves a freshwater gastropod (mostly *Lynnea* spp.) and metacercariae in various freshwater fishes. Metacercariae in freshwater fishes are commonly referred to as the *diplostomulum* stage. It has become common practice to use the generic name *Diplostomulum* Brandes, 1892 for diplostomatoid metacercariae whose adult forms are unknown. It must, however, be pointed out that there is no general adherence to this practice to be observed in the published literature.

The African representatives of the genus *Diplostomum*, whether as parasites of fish intermediate hosts or adult forms in homoithermic animals, are still rather incompletely known. Khalil (1963), could not find records of any *Diplostomulum* larvae from African fish in the published literature. He probably missed the publication on *Monocera heterobranchi* Wedl, 1861 (= *Diplostomulum heterobranchi* (Wedl, 1861) from *Clarias lazera* in Egypt. This parasite was later included in the Check List of Helminth Parasites of African Freshwater Fishes (Khalil, 1971). The same author mentions *D. tregenna* Nazmi Gohar, 1932 from the Egyptian Kite, *Milvus migrans*, as the only adult *Diplostomum* known from the African continent.

Beverley-Burton (1963) described *D. mashonense* from the cranial cavity of *Clarias mossambicus (Clarias gariepinus)* (Zimbabwe) and *C. mellandi* (Zambia) with adult forms from *Ardea cinerea*. Dubois (1970) synonymised this species with *D. tregenna* Nazmi Gohar, 1932. Ukoli (1968) described *D. ghanense* from *Anhinga rufa rufa (= A. melanogaster)* from Ghana.

Since the above remarks of Khalil (1963) various diplostomulae have been recorded from African freshwater fishes. Khalil (1971) lists the following diplostomulae belonging to the larval collective group *Diplostomulum* Brandes, 1892:

1. *Diplostomulum heterobranchi* (Wedl, 1861)
   = *Monocerca heterobranchi* Wedl, 1861.
   Host: *Clarias lazera* (= *C. gariepinus*) Egypt.

2. *Diplostomulum* of *Diplostomum leonensis*
   Hosts: *Epiplatys sengalensis* Williams and Chaytor, 1966, Sierra Leone
   Epiplatys sexfasciatus Williams and Chaytor 1967, Sierra Leone.

3. *Diplostomulum* of *Diplostomum mashonense* Beverley-Burton, 1963
   Hosts: *Clarias mellandi* Beverley-Burton, 1963, Zambia
   Clarias mossambicus (= C. gariepinus) Beverley-Burton, 1963, Zimbabwe.

4. *Diplostomulum* of *Diplostomum tregenna* Nazmi Gohar, 1932
   Hosts: *Clarias lazera (= C. gariepinus)* Khalil (1963 and 1969), Sudan.

Number two above has since been transferred to the genus *Posthodiplostomatoides* Williams, 1969; while number three has been synonymised with *D. tregenna* Nazmi Gohar, 1932 by Dubois (1970).

In the revised **Check List of Helminth Parasites of African Freshwater Fishes** (Khalil, in press) various fish species infected with diplostomulae have been added. These are:

***Diplostomulum* sp.**

Barbus sp. Lombard (1968), South Africa
Micropterus sp. Lombard (1968), South Africa
Tilapia sp. Lombard (1968), South Africa
Barbus argenteus Prudhoe and Hussey (1977), South Africa
Clarias gariepinus Prudhoe and Hussey (1977), South Africa
Barbus lineomaculatus Mashego (1982), South Africa
B. marequensis Mashego (1982), South Africa
B. mattozi Mashego (1982), South Africa
B. neefi Mashego (1982), South Africa
B. paludinosus Mashego (1982), South Africa
B. trimaculatus Mashego (1982), South Africa
B. unitaeniatus Mashego (1982), South Africa

The present study recorded two species of *Diplostomum*, namely, *D. tregenna* Nazmi Gohar, 1932 from *P. carbo, P. africanus, Anhinga melanogaster* and *Ardea melanocephala* and *D. ghanense* Ukoli, 1968 species specific to *A. melanogaster*.

Morphologically these species do not differ in any detail from the descriptions of Nazmi Gohar (1932) [*D. tregenna*] and Ukoli (1968) [*D. ghanense*]. Fig.8, p.52 and Fig.10, p.56 clearly substantiate this statement. *D. tregenna* and *D. ghanense* from South African piscivorous hosts must therefore be regarded as new host and/or geographical records. As was the case with other helminths the present study carefully recorded infection rates. These will be presented in Table 6, p.46 (*D. tregenna*) and Table 8, p.55 (*D. ghanense*). It was also possible to link *Diplostomulum* infections in a number of freshwater fish species to the relevant *Diplostomum* species parasitising the piscivorous birds investigated for this study.

Genus: *Diplostomum* Von Nordmann, 1832

(= *Proalaria*) La Rue, 1926

D. tregenna Nazmi Gohar, 1932
(= *D. mashonense*) Beverley-Burton, 1963.

Diplostomulum mashonense was desribed by Beverley-Burton (1963) from the cranial cavity of *Clarias mossambicus* [= *C. gariepinus* (Burchell, 1822)] from Zimbabwe and *C. mellandi* from Zambia. The adult was developed experimentally in domestic chickens (*Gallus domesticus*), and was afterwards found naturally in *Ardea cinerea*.

Mashego (1977) conducted a seasonal investigation of the helminth parasites of *C. gariepinus* in the Northern Province of South Africa and described the morphology of *Diplostomulum mashonense* in great detail at the hand of graphic reconstructions from serial sections according to the method of Pusey (1939). Prudhoe and Hussey (1977) recorded *Diplostomulum* metacercariae from the cranial cavity of *C. gariepinus* from the Transvaal, South Africa. These authors noted a very close resemblance between their material and the material described by Beverley-Burton (1963), except that the Transvaal material had a much more pronounced constriction between the forebody and hindbody. Prudhoe and Hussey (1977) also remarked that their material bears a close resemblance to metacercariae which Khalil (1963) described from *C. lazera* (=*C. gariepinus*) from the Sudan. Khalil (1963) in feeding experiments, using four day old domestic chickens, obtained adult forms and assigned these to *Diplostomum tregenna* Nazmi Gohar, 1932. *D. mashonense* Beverley-Burton, 1963 was synonymised with *D. tregenna* Nazmi Gohar, 1932 by Dubois (1970). Concurrent with the present study *Diplostomulum* metacercariae were also recovered from the cranial cavity of *C. gariepinus* and the cranial cavities and eyes of the following fish hosts:

HOST		SITE OF INFECTION
Barbus unitaeniatus	Günther, 1866	Cranial cavity and eyes
B. bifrenatus	Fowler, 1935	Cranial cavity and eyes
B. toppini	Boulenger, 1916	Eyes
B. trimaculatus	Peters, 1852	Cranial cavity and eyes
B. paludinosis	Peters, 1852	Cranial cavity and eyes
B. marequensis	Smit, 1841	Eyes
Oreochromis mossambicus	Peters, 1852	Cranial cavity and eyes
Pseudocrenilabris philander	Weber, 1897	Cranial cavity and eyes

In addition to the host specimens mentioned in the preceding table Mashego (1982) recorded diplostomulae from the eyes of nine *Barbus* spp. from other water bodies in the Northern Province of South Africa. These metacercareae are morphologically similar to the diplostomulae recorded from the host species (Table 7, p.48) from Middle Letaba Impoundment. The host species of Mashego (1982) include, besides *B. unitaeniatus, B. trimaculatus, B. paludinosus* and *B. marequensis*, also *B. lineomaculatus* Boulenger, 1903; *B. neefi* Greenwood, 1962; *B. radiatus* Peters, 1853; *B. argenteus* Günther, 1868 and *B. mattozi* Guimareas, 1884.

Microscopic examination of the metacercariae from the aforementioned hosts from Middle Letaba Impondment, together with morphological comparison between the diplostomulae from *C. gariepinus* (Beverley-Burton, 1963; Mashego, 1977; Prudhoe and Hussey, 1977), the metacercariae from *C. gariepinus* (Khalil, 1963) and the metacercariae from *Barbus* hosts (Mashego, 1982), tend to indicate that all these forms could possibly be regarded as morphospecies. Minor morphological differences, particularly differences indicated by morphologic indexes, which occur between these metacercariae are considered to be the result of one or a combination of the following factors:

- Different host species;
- Host species from different aquatic ecosystems;
- Different infection sites eg. cranial cavity or vitreous humor of the eyes;
- Different stages of metacercarial development;
- Different methods of preservation and/or microtechnical procedures.

A great many researchers in this field, amongst others, Johnston (1942); Hugghins (1954b); Khalil (1963) and Britz (1983) have remarked that the above factors may, in one way or another, cause minor intraspecific differences.

It is intended to verify the preceding assumption with future experimental infections using domestic chickens and nestlings of *P. carbo, P. africanus, Anhinga melanogaster, Ardea melanocephala* and *A. cinerea*. Nestlings of natural hosts will be treated with antihelminthics such as tetrachlorethylene (Hugghins, 1953, 1954b and 1956) to ensure absence of previous naturally aquired infection.

Table 6: Infection statistics of *Phalacrocorax carbo, P. africanus, Anhinga melanogaster* and *Ardea melanocephala* in the Northern Province, South Africa, with adults of *Diplostomum tregenna* Nazmi Gohar, 1932.

AVIAN HOST	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
P. carbo	39	Seshego Dam	59	5 - 41	15
	8	Middle Letaba Impoundment	63	8 - 22	14
	2	Piet Gouws Dam	100	73 - 168	121
	2	Glen Alpine Dam	-	-	-
	1	Ebenhaezer Dam	-	-	-
P. africanus	44	Seshego Dam	36	4 - 23	11
	9	Middle Letaba Impoundment	22	4 - 11	8
	3	Hudson Ntsanwisi Dam	33	2	2
A. melanogaster	24	Seshego Dam	54	5 - 21	11
	12	Middle Letaba Impoundment	75	7 - 37	16
	11	Hudson Ntsanwisi Dam	55	12 - 43	24
	2	Luphephe Dam	50	10	10
	6	Piet Gouws Dam	83	5 - 23	18
	4	Glen Alpine Dam	50	5 - 7	6
	1	Tzaneen Dam	-	-	-
	4	Olifants River	-	-	-
Ardea melanocephala	5	Middle Letaba Impoundment	20	4	4

Table 6 indicates that four piscivorous birds were recorded as final hosts for *Diplostomum tregenna* in the study area, namely, *P. carbo, P. africanus, Anhinga melanogaster* and *Ardea melanocephala*. In neighbouring Zimbabwe, Beverley-Burton (1963) found *Ardea cinerea* to be a natural host for *D. tregenna*. During the present study four *A. cinerea* hosts from Middle Letaba Impoundment were examined for infection with this parasite, but a zero prevalence figure was obtained.

The present study recorded prevalence figures between zero and 100% for the various hosts from the nine aquatic ecosystems from which hosts have been procured. Mean values ranged between 1 - 168. These figures indicate that *D. tregenna* is ecologically well established in the area with indications of very high infra- as well as suprapopulation values. The parasite also has a wide geographical distribution within the study area. From the data contained in Table 6, p.46, it would appear that the Phalacrocoracidae and Anhingidae are the principal hosts for this parasite, while members of the Ardeidae, particularly *Ardea melanocephala*, might act as reservoir hosts. On strength of population statistics of the phalacrocoracid and anhingid birds resident and resident/breeding at water bodies in the region. (personal observations and Saayman and Schoonbee et. al. (1991), it would be safe to conclude that both *P. africanus* and *A. melanogaster* are major role players in maintaining the suprapopulations of this parasite in aquatic ecosystems in the Northern Province of South Africa.

Infrapopulation statistics (Table 6, p.46) for *D. tregenna* in piscivorous birds in the study area indicate the presence of a good supply of the Diplostomulae of this parasite in the dietary budget of the final hosts. It was thus tempting to review the results of helminthological research surveys on fish hosts that have already been undertaken in the Northern Province. This excercise yielded the following results:-

- The fish intermediate host positively identified as carrier of *D. tregenna* diplostomulae in the Sudan (Khalil, 1963) and Zimbabwe (Beverley-Burton, 1963) namely *C. gariepinus*, is a common and widespread inhabitant of freshwater ecosystems in the study area. Mashego (1977) completed an investigation on the helminth parasites of this host in the area under discussion and found it to be heavily infected with *Diplostomulum* metacercariae morphologically similar to those described by Khalil (1963) and Beverley-Burton (1963). Prudhoe and Hussey (1977) also recorded a *Diplostomulum* from the cranial cavities of *C. gariepinus* hosts from the central and southern Transvaal regions. The latter material, although differing in minor detail from the material of Khalil (1963), Beverley-Burton (1963) and Mashego (1977), could be designated diplostomulae of *D. tregenna* (See also pp.42 and 44).;

- Mashego (1982) recorded unencysted diplostomulae in the vitreous humor of the eyes of nine *Barbus* spp. inhabiting water bodies of the Northern Province of South Africa. The morphology of these forms was described in very precise detail;

- Saayman and Schoonbee et. al. (1991), in an unpublished report, recorded metacercariae from the cranial cavities of *C. gariepinus* similar to those recorded by Khalil (1963), Beverley-Burton (1963), Mashego (1977) and Prudhoe and Hussey (1977) from the same host species. Saayman and Schoonbee (op cit) also provide infection statistics for diplostomulae from the brain cavities and eyes of a number of *Barbus* and cichlid species inhabiting the freshwater ecosystem (Middle Letaba Impoundment) investigated by them.

- As indicated on p.45 the present investigation examined the *Barbus* related metacercariae of Mashego (1982) and the diplostomulae reported on by Saayman and Schoonbee et. al. (1991). On account of very close morphological similarities, substantiated by ecological realities, it was decided to include these diplostomulae, together with the *Diplostomulum* metacercariae of *C. gariepinus*, as potential second intermediate life history candidates for *D. tregenna*. This assumption needs to be tested by envisaged experimental life history studies (Refer p.33).

The rate of infestation of Northern Province *Clarias, Barbus* and cichlid hosts with proven and potential *D. tregenna* diplostomulae is presented in Table 7.

Table 7: Selected infection statistics for Northern Province *Clarias, Barbus* and cichlid hosts with *D. tregenna* metacercariae. Fish hosts from water bodies from which avian hosts have also been procured were selected for compiling this table. References: 1 = Mashego (1977), 2 = Mashego (1982) and 3 = Saayman and Schoonbee et. al. (1991)

FISH HOST AND REFERENCE	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
Clarias Gariepinus 1	71	Seshego Dam	100	-	up to 2391 both localities
C. gariepinus 1	40	Piet Gouws Dam	100	-	
C. gariepinus 3	24	Middle Letaba Impoundment	83	2 - 205	68
Barbus paludinosus 2 *B. trimaculatus* 2 *B. marequensis* 2 *B. mattozi* 2 *B. lineomaculatus* 2 *B. neefi* 2 *B. radiatus* 2 *B. unitaeniatus* 2 *B. argenteus* 2	**597 host specimens of these nine species were examined**	Various water bodies, including Seshego and Piet Gouws Dams	30 Average for nine host species	1 - 200 Statistics for nine host species	26 For nine host species investigated

Table 7: **continued**

FISH HOST AND REFERENCE	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
B. paludinosus 2	33	Middle Letaba Impoundment	73 E 10 B	1 - 55 E 1 - 4 B	11E 3 B
B. trimaculatus 3	92 E 89 B	Middle Letaba Impoundment	13 E 3 B	1 - 6 E 0 - 1 B	2.67 E 1.0 B
B. marequensis 3	13 E 12 B	Middle Letaba Impoundment	30.76 E - B	1 - 7 E - B	3.75 E - B
B. unitaeniatus 3	90 E 74 B	Middle Letaba Impoundment	75.56 E 1.35 B	1 - 34 E 0 - 36 B	7.0 E 36.0 B
B. bifrenatus 3	7 E 7 B	Middle Letaba Impoundment	57.14 E 14.29 B	1 - 3 E 0 - 4 B	2.50 E 4.0 B
B. toppini 3	98 E 92 B	Middle Letaba Impoundment	42.86 E - B	1 - 18 E - B	2.74 E - B
Oreochromis mossambicus 3	137 E 125 B	Middle Letaba Impoundment	2.06 E 7.20 B	1 - 4 E 1 - 7 B	1.75 E 3.0 B
Pseudocrenilabris philander 3	47 E 45 B	Middle Letaba Impoundment	4.26 E 4.44 B	1 - 1 E 2 - 3 B	1.0 E 2.6 B

N = number examined; E = infection of eyes; B = infection of cranial cavity

If the assumptions concerning the causative diplostomulae for *D. tregenna* infections in piscivorous avian hosts in the Northern Province are correct (See p.45), Table 7 indicates that no less than 14 species of freshwater fish can act as intermediate hosts for this parasite.

Diplostomulae parasitising the cranial cavity of *C. gariepinus* have been positively identified as *Diplostomulum tregenna* (Khalil, 1963; Beverley-Burton, 1963; Prudhoe and Hussey, 1977 and Mashego, 1977). On the strength of this, supplemented by the extremely high infection levels of *C. gariepinus* with *D. tregenna* diplostomulae [Prevalance of 93% and a mean intensity in excess of 2000 - Mashego (1977)], it seems reasonable to assume that *Clarias* hosts act as the principal fish intermediate host for *D. tregenna* infections in the Northern Province of South Africa. *Barbus* and cichlid hosts infected with *D. tregenna* metacercariae would, on infection statistics alone, be labelled as reservoir hosts.

Speculating on the previous assumption, and taking biophysical factors into consideration, one is confronted with the following realities:

- The studies of Mashego (1977) indicate that *C. gariepinus* harbours an extremely high rate of infection with diplostomulae of *D. tregenna* realising prevalence levels of 93% and with mean intensity figures in excess of 2000 parasites per infected host. This must surely be the result of a gradual build-up in infection levels over an extended period of time with older fish having substantially higher mean intensity levels of infection;

FIG. 6

DIPLOSTOMULUM TREGENNA

Graphic reconstruction to illustrate the alimentary and nervous systems (After Mashego, 1977).

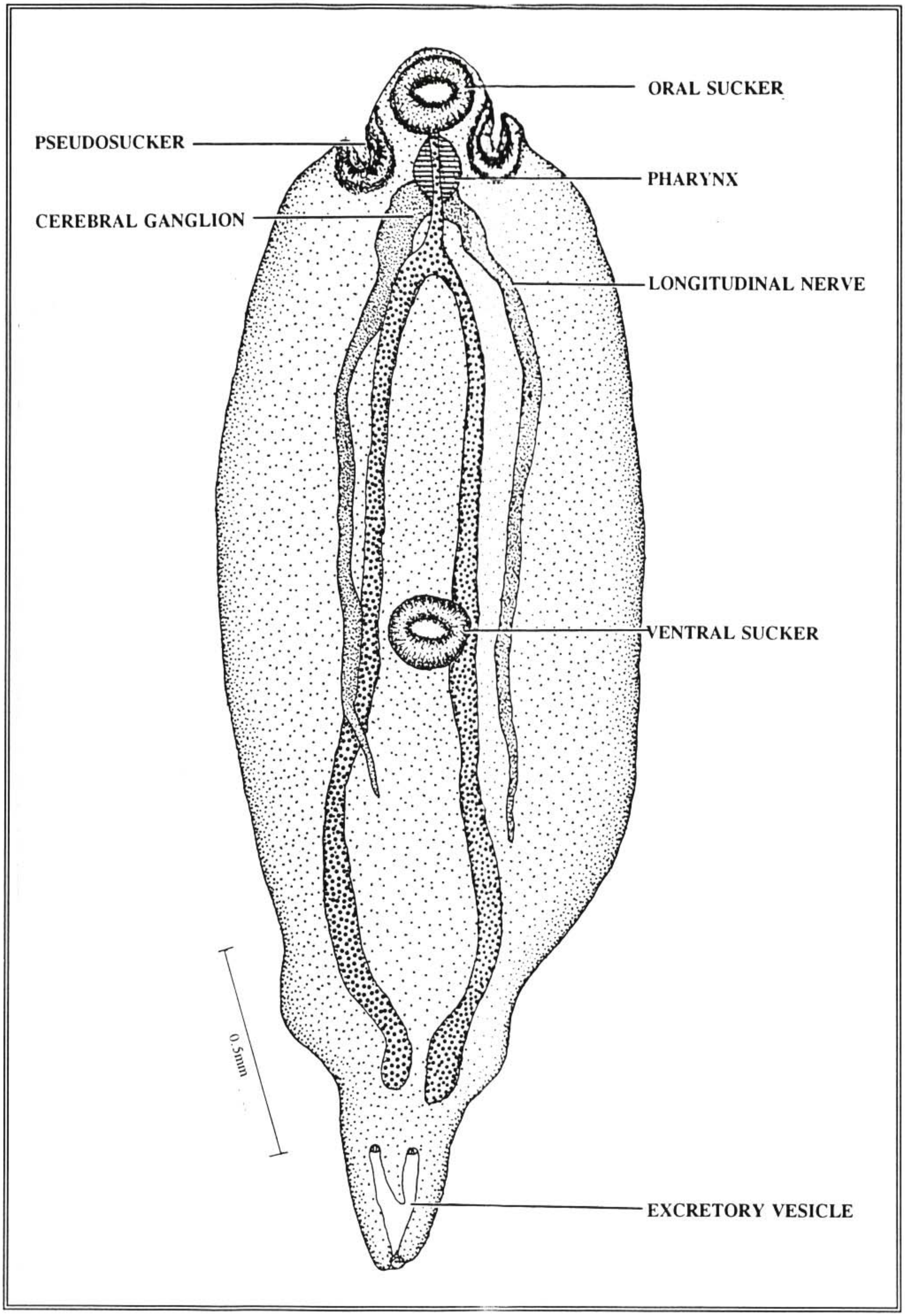

ORAL SUCKER
PSEUDOSUCKER
PHARYNX
CEREBRAL GANGLION
LONGITUDINAL NERVE
VENTRAL SUCKER
0.5mm
EXCRETORY VESICLE

FIG. 7

DIPLOSTOMULUM TREGENNA

Graphic reconstruction to illustrate the tribocytic organ and reproductive primordia (After Mashego, 1977).

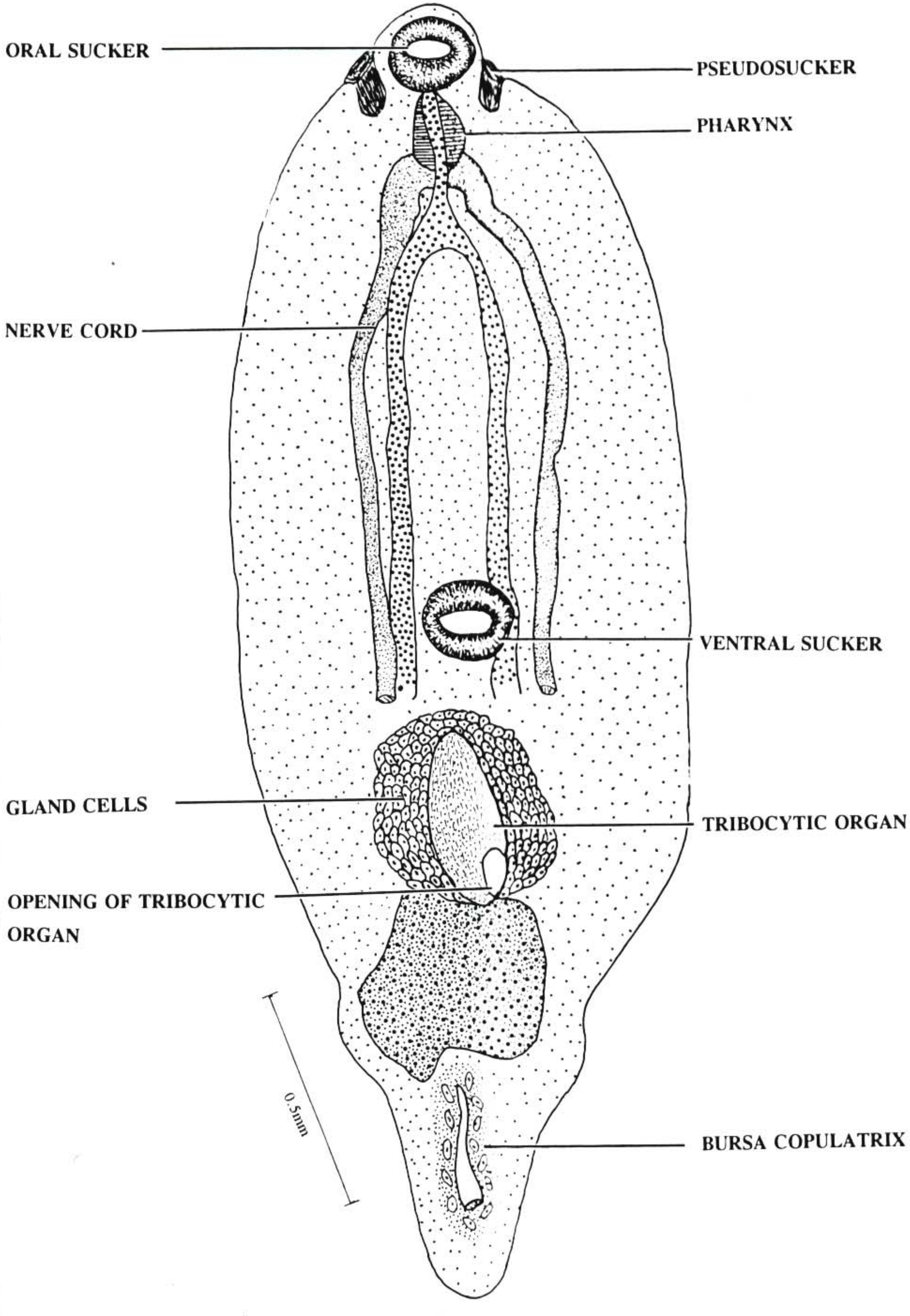

ORAL SUCKER
PSEUDOSUCKER
PHARYNX
NERVE CORD
VENTRAL SUCKER
GLAND CELLS
TRIBOCYTIC ORGAN
OPENING OF TRIBOCYTIC ORGAN
0.5mm
BURSA COPULATRIX

FIG. 8

DIPLOSTOMUM TREGENNA x 200

Morphology
(After Nazmi-Gohar, 1932)

Key:

a. - ventral sucker

at. - anterior testis

gp. - genital opening

ho. - adhesive organ

os. - oral sucker

ov. - ovary

ps. - pseudosucker

pt. - posterior testis

sr. - seminal receptaculum

ut. - uterus

vf. - vitelline follicles

vr. - vitelline reservoir

vs. - seminal vesicle

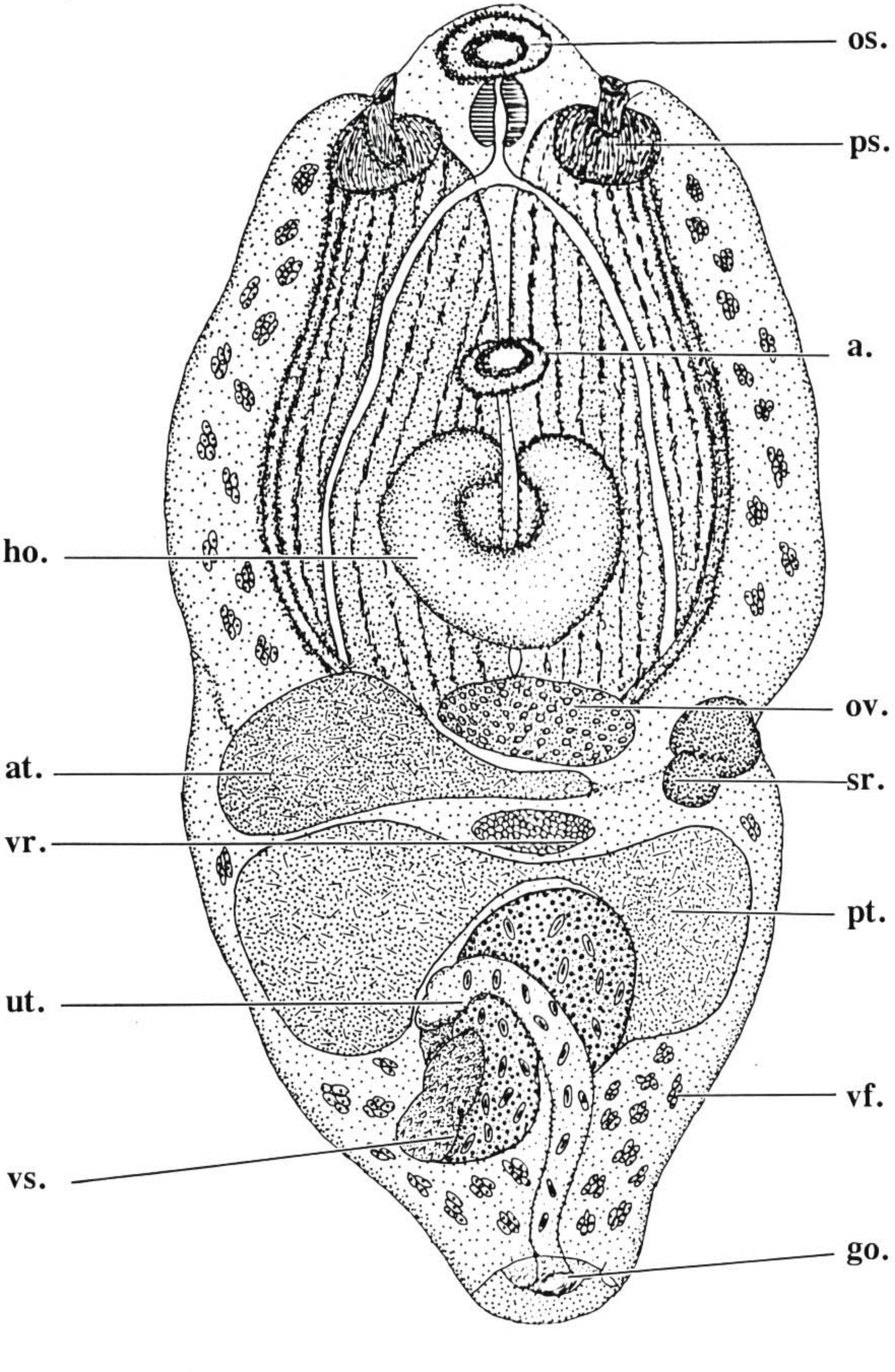

os.
ps.
a.
ho.
ov.
at.
sr.
vr.
pt.
ut.
vf.
vs.
go.

FIG. 9

DIPLOSTOMUM TREGENNA
(Scanning Electron Microscopy)

A. ***Entire worm***

B/ ***Spines covering forebody***

C. ***Anterior end of forebody***

D. ***Posterior end of hindbody***

Key:

a. - ventral sucker

ep. - excretory pore

fb. - forebody

gp. - genital opening

hb. - hindbody

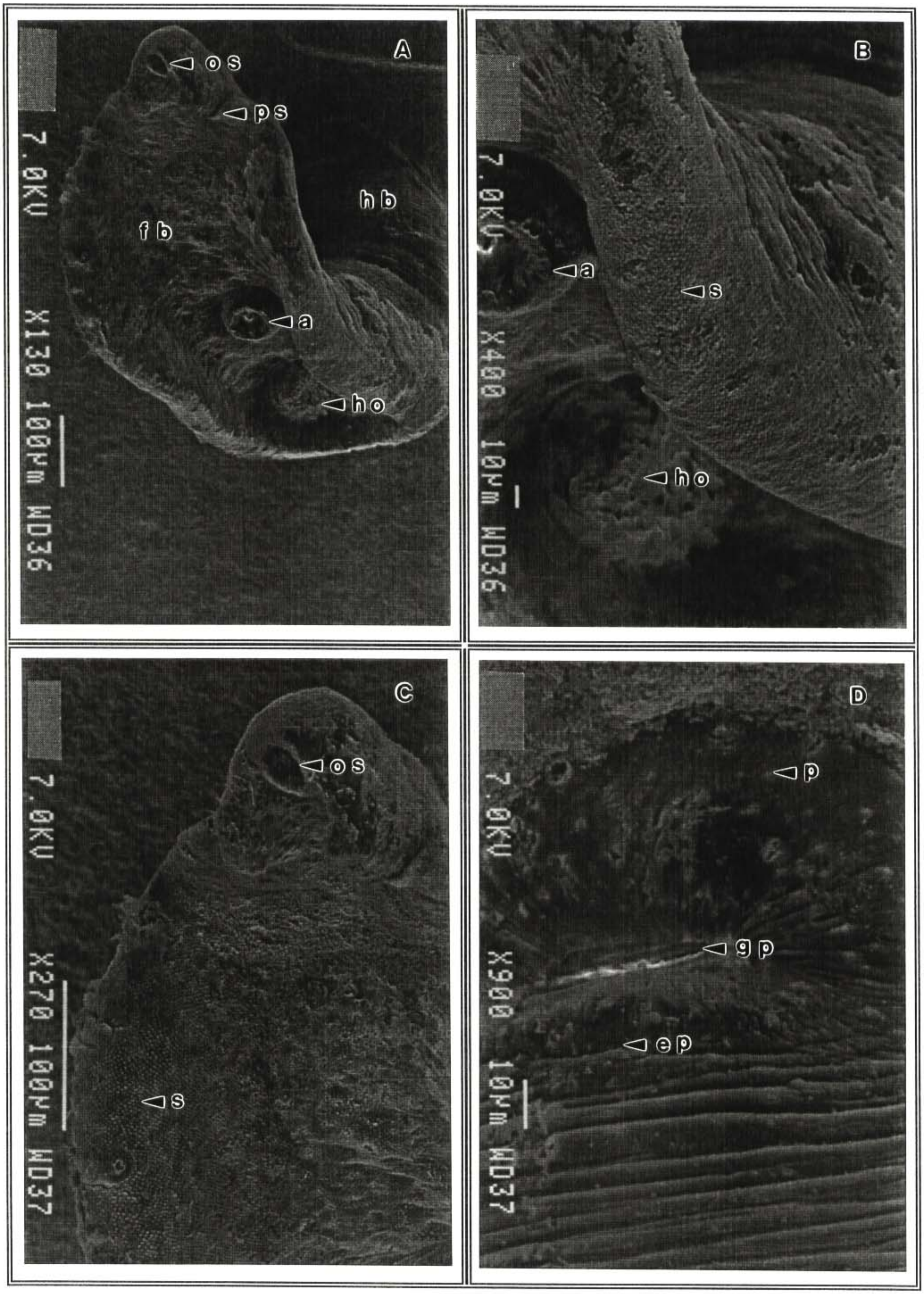
ho. - holdfast organ

os. - oral sucker

p. - papillae

ps. - pseudosucker

s. - spines


A
os
ps
hb
fb
a
ho
7.0KV X130 100µm WD36
B
a
s
ho
7.0KV X400 10µm WD36
C
os
s
7.0KV X270 100µm WD37
D
p
gp
ep
7.0KV X900 10µm WD37

- *Clarias* has an excessively hard bony capsule surrounding the brain. How, it may be argued, does a piscivorous bird with a relatively weak, pointed bill not designed for crushing and tearing, succeed in aquiring metacercariae lodged around the brain tissues of *Clarias* hosts older than a few months? This question is not at all easy to answer;

- A logical conclusion to the question posed in the previous paragraph is that diplostomulae lodged in the cranial cavity of at least sexually matured *Clarias* hosts would be fairly, if not completely, inaccessible to phalacrocoracid, anhingid and ardean final hosts of *D. tregenna*. Under such circumstances the parasite would then literally be trapped in a life history **cul de sac**;

- Following this argument to its logical conclusion, it seems reasonable to assume that very young *Clarias*, together with cyprinid and cichlid fish, act as the principal intermediate hosts in the successful completion of the life cycle of *D. tregenna* in the Northern Province of South Africa and possibly in the rest of Africa as well.

Apart from Cormorants, Darters and Herons other possible final hosts for *D. tregenna* in South Africa may be pelicans (*Pelecanus onocrotalus* and *P. rufescens*) as well as the African Fish Eagle, *Haliaeetus vocifer*, and the Yellowbilled Kite, *Milvus migrans parasitus*. During the duration of the study Pelicans and Yellowbilled kites were observed as visitors to Middle Letaba Impoundment while a pair of African Fish Eagles were recorded as resident/breeding (Saayman and Schoonbee, et. al. (1991).

Genus: *Diplostomum* Von Nordmann, 1832
(= *Proalaria* LaRue)
D. ghanense Ukoli, 1968

During the present study *D. ghanense* was recorded from the intestines of *Anhinga melanogaster* procured from seven aquatic ecosystems in the Northern Province. It is a parasite that is apparently very host specific to *A. melanogaster* as it was never recorded from any of the other piscivorous/semi-piscivorous birds examined during the study.

D. ghanense was first described by Ukoli (1964, 1968) from *A. rufa rufa* (= *A. melanogaster*) collected at Nungua Lake near Accra, Ghana. The present material agrees most closely with the original description (Ukoli, 1968) [Figs. 4 and 5] and it was therefore decided to label it as *D. ghanense* and extend its geographical distribution.

In his studies Ukoli (1968) did not attempt to link his material to possible fish intermediate hosts. Helminthological surveys of indigenous freshwater fish from water bodies in the Northern Province (Saayman, unpublished data and Saayman and Schoonbee, et. al., 1991) procured strigeid metacercariae that are sufficiently different from the diplostomulae of

D. tregenna, but morphologically closely similar to *D. ghanense* [Fig.10, p.56]. These metacercariae are from the same localities from which avian hosts were collected for the present study. On the strength of morphological as well as ecological grounds it was decided to consider these diplostomulae as the *Diplostomulum* of *D. ghanense*. As was previously pointed out (p.33) this assumption needs to be verified by experimental infections using both types of diplostomulae. However, for purposes of this investigation the infection rates for the metacercaria mentioned in the preceding paragraphs, will be considered as part of the suprapopulation statistics of *D. ghanense* in the Northern Province.

Table 8: Prevalence, intensity and mean intensity statistics for *D. ghanense* infection in *A. melanogaster* in the Northern Province of South Africa.

WATER BODY	N.	PREVALENCE %	INTENSITY	MEAN INTENSITY
Seshego Dam	24	58	7 - 21	12
Piet Gouws Dam	6	100	5 - 61	32
Luphephe Dam	2	50	6	6
Hudson Ntsanwisi Dam	11	45	3 - 31	13
Middle Letaba Impoundment	12	67	12 - 58	24
Tzaneen Dam	1	100	15	15
Olifants River	4	50	7 - 12	10
Glen Alpine Dam	4	-	-	-

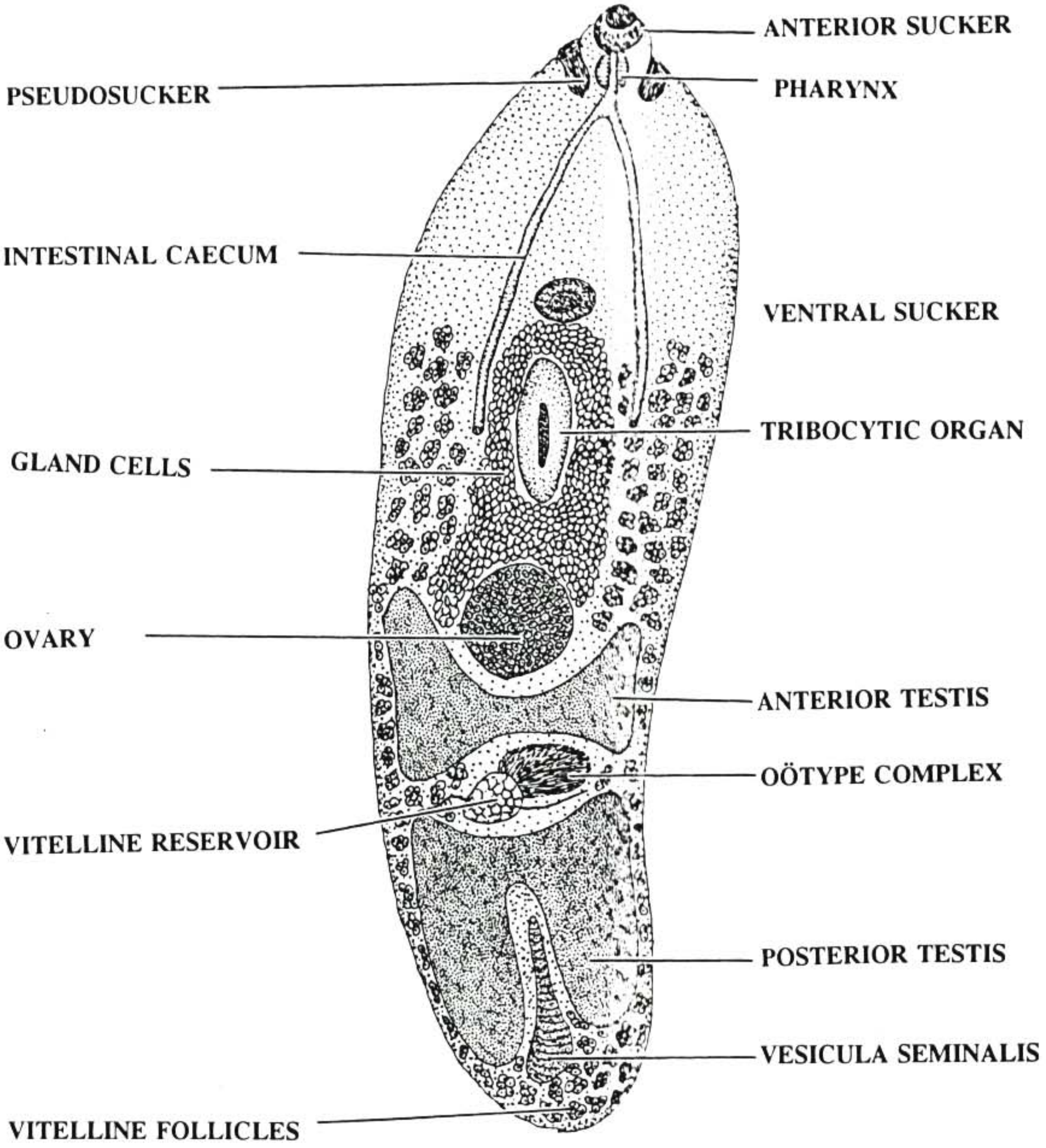
Table 9: Prevalence, intensity and mean intensity figures for infection of fish hosts with metacercariae of *D. ghanense*. All hosts are from Middle Letaba Impoundment.

FISH HOST	INFECTION OF EYES				INFECTION OF CRANIAL CAVITY			
	N.	P.%	I	MI	N.	P.%	I	MI
Barbus trimaculatus	76	9.21	1 - 11	7.0	72	4.17	1 - 1	1.0
B. unitaeniatus	90	77.44	1 - 104	12.72	74	6.76	1 - 8	3.6
B. toppini	98	2.04	1 - 2	1.50	92	-	-	-
B. marequensis	13	53.85	2 - 53	35.43	12	-	-	-
Oreochromis mossambicus	137	2.19	1 - 1	1.00	125	60.00	1 - 38	6.43
Pseudocrenilabrus philander	47	2.12	1 - 1	1.00	45	11.11	1 - 4	2.40

FIG. 10.

DIPLOSTOMULUM GHANENSE x 80

Diagram illustrating the morphology.
(From present material and Ukoli, 1968)


ANTERIOR SUCKER
PSEUDOSUCKER
PHARYNX
INTESTINAL CAECUM
VENTRAL SUCKER
TRIBOCYTIC ORGAN
GLAND CELLS
OVARY
ANTERIOR TESTIS
OÖTYPE COMPLEX
VITELLINE RESERVOIR
POSTERIOR TESTIS
VESICULA SEMINALIS
VITELLINE FOLLICLES

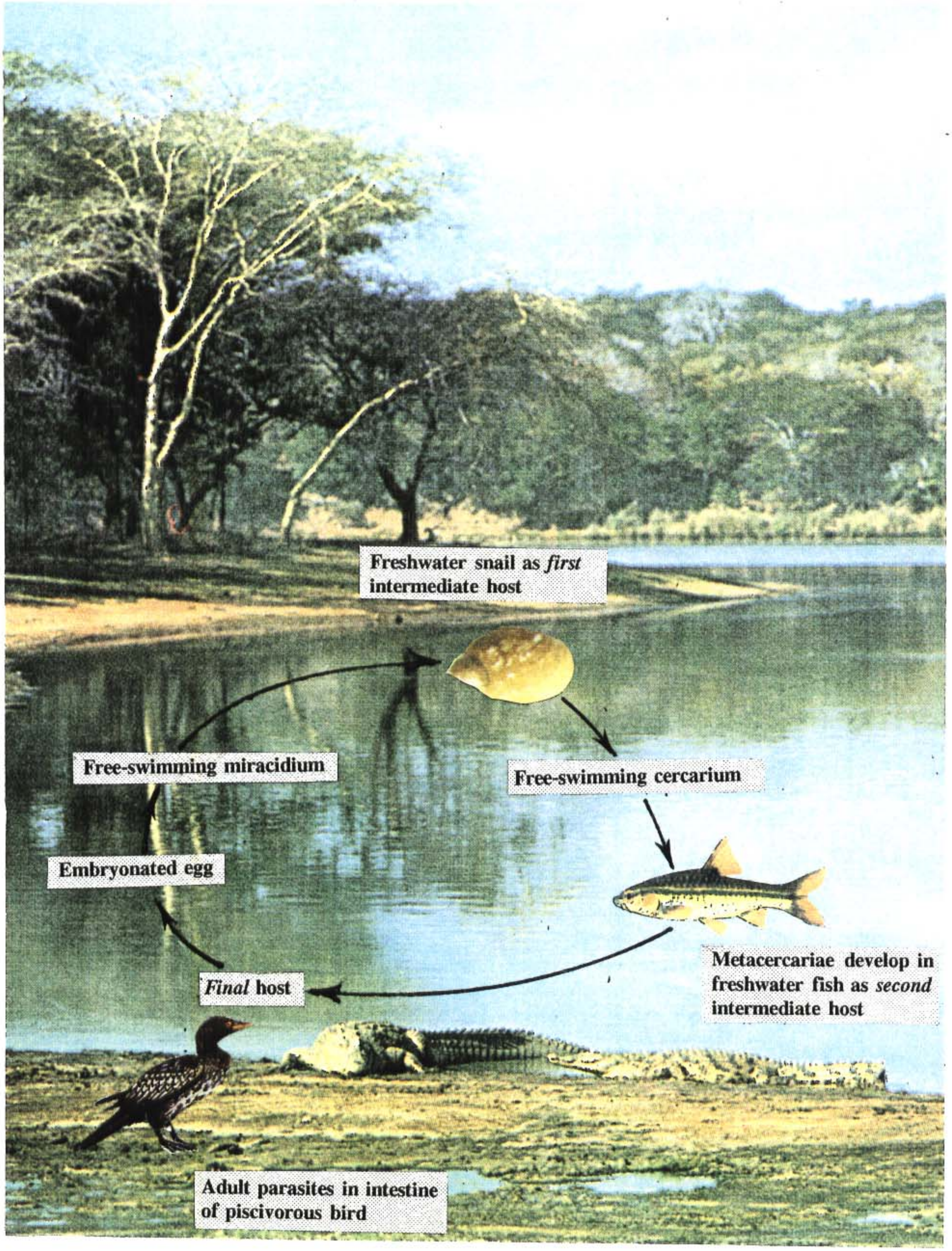


Fig. 11 - Life cycle of diplostomatid parasites

Table 9: from Saayman and Schoonbee, et. al., 1991

N = Number of hosts examined
P% = Prevalence percentage
I = Intensity
MI = Mean intensity

From the data contained in Tables 8 and 9 the following deductions may be arrived at:

- *D. ghanense* is species specific to *A. melanogaster*, at least so in the Northern Province of South Africa. A related diplostome species, *D. tregenna*, was found to parasitise three additional avian hosts in this region. The majority of fish hosts from which *A. melanogaster* gets infected with the potential or suspected metacercarium of *D. ghanense* also carry the *Diplostomulum* of *D. tregenna* yet *D. ghanense* was not recorded from any of the phalacrocoracid and ardean hosts investigated for the present study;

- *D. ghanense* is a common and widespread parasite of resident/breeding colonies of *A. melanogaster* in the Northern Province recording prevalence levels of up to 100 per cent for some aquatic ecosystems;

- Judging from infection statistics (Table 9, p.55) of fish with the suspected diplostomulae of *D. ghanense*, the parasite is firmly established in at least six fish intermediate hosts. Of these hosts *B. toppini* and *P. philander* seem to play a less significant role in the completion of the life history of the parasite.

Family : Echinostomatidae Poche, 1926

Genus : ***Pharyphostomum* Dietz, 1909.**
P. radiatum (Dujardin, 1845) Dietz 1909
(= *Distomum radiatum* Dujardin, 1845;
D. echinatum Wedl, 1857;
Echinoschasmus ternuicollis Johnston, 1917;
P. testitrifolium Gogate, 1934
P. tenuicollis Johnston & Angel, 1942
Paryphostomum phalacrocoracis Goss, 1940.

The genus *Paryphostomum* was erected by Dietz in 1909 with *P. radiatum* from *Phalacrocorax carbo* from Central Europe as type species. The species *radiatum* (= *D. radiatum*) was established by Dujardin in 1845 from two parasites from the intestines of *P. carbo* in the collection of the Paris Museum.

P. radiatum is a species that is host specific to members of the Phalacrocoracidae and Anhingidae having been procured from the following regions and hosts:

Phalacrocorax carbo	Central Europe -	Dietz, 1909
P. melanoleucus	Australia -	S.J. Johnston, 1917
P. melanoleucus	Australia -	T.H.Johnston, 1918
Cormorants ?	Whales, U.K. -	Edwards, 1927
Dendrocygna javanica	Rangoon -	Gogate, 1934
P. africanus	South Africa -	Ortlepp, 1938
P. carbo hanedae	Japan -	Yamaguti, 1938
P. carbo hanedae *P. capillatus*	Japan -	Yamaguti, 1939
P. ater (= P. sulcirostris) *P. melanoleucus*	Australia -	Goss, 1940
P. carbo *P. melanoleucus* *P. fuscescens* *P. sulcirostris*	Australia -	T.H. Johnston, 1942
Anhinga rufa levaillantii *(= A. melanogaster)*	Zambia -	Bisseru, 1957
P. carbo	Taiwan -	Fischthal and Kuntz, 1976
Phalacrocorax sp.	India -	Gupta, 1979
P. carbo	Czechoslovakia -	Nasincova, Scholtz & Moravec, 1993
P. carbo *P. africanus* *Anhinga melanogaster*	South Africa -	Present study, 1996.

In the above list one host species other than Phalacrocoracidae and Anhingidae are reflected as hosts for *P. radiatum*. This is:

> *Dendrocygna javanica* (Anseriformes) in which Gogate 1934 found *P. testitrifolium*, which was synonymised with *P. radiatum* by Johnston 1942. If this synonymy was based on very strict morphological comparison, then the occurrence of *P. radiatum* in *D. javanica* must be labelled as the first and only record of this parasite in a host other than a member of the Phalacrocoracidae or Anhingidae.

Bisseru (1957), recorded a single, sexually mature specimen from *A. melanogaster* in Zambia. This specimen was very small, measuring 1mm. long by 0,45mm. broad across the posterior testes. The normal size range of *P. radiatum* is between 3 - 6+ mm. (Dietz, 1909; Edwards, 1927; Johnston, 1942; Nasincová et. al. 1993 and present study). If the identification of Bisseru was correct his material must rank as the smallest sexually mature specimen ever recorded for *P. radiatum.*

Detailed anatomical descriptions (supplemented by morphometric data) for *P. radiatum* were published by Edwards, 1927; Goss, 1940; Johnston, 1942 and Nasincová et. al. (1993). These descriptions are supplemented by anatomical data provided by Gogate (1934) and Bisseru (1957). The morphology of *P. radiatum* specimens obtained during the present study was analysed with the aid of stained whole mount preparations and S.E.M. studies. Figs.11- -15, pp.62-66 provide a comparative account of the morphology of this parasite.

The life cycle of *P. radiatum* was studied by Johnston and Angel (1943); Kiseliene (1969, 1970); Arystanov (1980)* and Nasincová (1992). The life history of the parasite passes through three hosts, viz., a freshwater snail as FIRST INTERMEDIATE HOST; amphibians and fish as SECOND INTERMEDIATE HOSTS and water loving birds as FINAL HOSTS.

Johnston and Angel (1943) studied the molluscan phase of the life cycle in *Amerianna pyramidata, A. pectorosa* and *A. tenuistriata* (= genera *Physa, Bulinus* and *Isodora*) of South Australia. Nasincová et. al. (1993) found the snails *Gyraulus albus, Segmentina nitida* and *Radix auricularia* as natural intermediate hosts for *P. radiatum* in Czechoslovakia, while the authors succeeded in experimentally infecting *Bathyomphalus contortus* and *Anisus leucostomus*.

Metacercariae were obtained experimentally by Johnston and Angel (1943) in five species of aquarium fish (names not mentioned) and the tadpole of *Pseudophryne libroni*. Natural infections were obtained from three species of Australian freshwater fish, namely, *Carassius auratus, Pseudaphritis urville* and *Tandanus tandanus*. Nasincová et. al. (1993) succeeded in experimentally infecting the following fish species:

> *Scardinius erythropthalmus, Tinca tinca, Gobio gobio, Alburnoides bipunctatus, Blicca bjoerkna, Cyprinus carpio* and *Noemacheilus varbatulus*. In these hosts metacercariae were localized in the nasal cavities, in the orbital cavities around the eyes, on the gills and in the skin of the cranial region.

Final hosts recorded for *P. radiatum* are summarized on p.59.

Metacercariae of *P. radiatum* have not been recorded by fish parasitological investigations in the Northern Province of South Africa (Mashego, 1977, 1982; Britz, 1983; Saayman, 1986 and Saayman and Schoonbee et. al. 1991). These parasites must surely utilise some of the freshwater fish species of the northern regions of South Africa as intermediate hosts if the infection statistics provided in Table 10 below are taken into consideration.

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* paper not seen in the original

It is intended to search for these metacercariae in freshwater fish of the Olifants- and Limpopo Drainage Systems in a follow-up study to the present investigation. Most of the anatomical sites of infection as provided by Nasincová et. al. (1993) are areas that are normally not subjected to careful scrutiny in general fish parasitological surveys.

Table 10: Prevalence, intensity and mean intensity values for infection of *Phalacrocorax carbo, P. africanus* and *Anhinga melanogaster* with *Paryphostomum radiatum* in the Northern Province of South Africa.

AVIAN HOST	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
P. carbo	39	Seshego Dam	87	3 - 150	42
	8	Middle Letaba Impoundment	88	1 - 47	29
	2	Piet Gouws Dam	100	12 - 14	13
	2	Glen Alpine Dam	100	86 - 98	92
	1	Ebenhaezer Dam	100	14	14
P. africanus	44	Seshego Dam	64	6 - 262	56
	9	Middle Letaba Impoundment	33	4 - 30	14
	3	Hudson Ntsanwisi Dam	33	8	8
	1	Turfloop Dam	-	-	-
	2	Olifants River	50	17	17
A. melanogaster	24	Seshego Dam	29	6 - 71	26
	12	Middle Letaba Impoundment	25	8 - 27	18
	11	Hudson Ntsanwisi Dam	9	14	14
	2	Luphephe Dam	50	22	22
	6	Piet Gouws Dam	67	4 - 24	13
	4	Glen Alpine Dam	100	7 - 41	26
	1	Tzaneen Dam	-	-	-
	4	Olifants River	25	13	13
					4

Analysis of the infection statistics presented in Table 10 above, clearly indicates that:-

- *P. radiatum* is well established in the aquatic ecosystems of the Olifants- and Limpopo River Drainage Systems of the northern regions of South Africa;
- The parasite utilises at least three final hosts, namely *P. carbo, P. africanus* and *Anhinga melanogaster*. All these three hosts have a continuous distribution within the study area and are numerically well represented at all aquatic ecosystems within the study area;

FIG. 12.

PARYPHOSTOMUM RADIATUM

(Illustration of general morphology.
(After Edwards, 1927).
Refer also Figs. 15 and 16

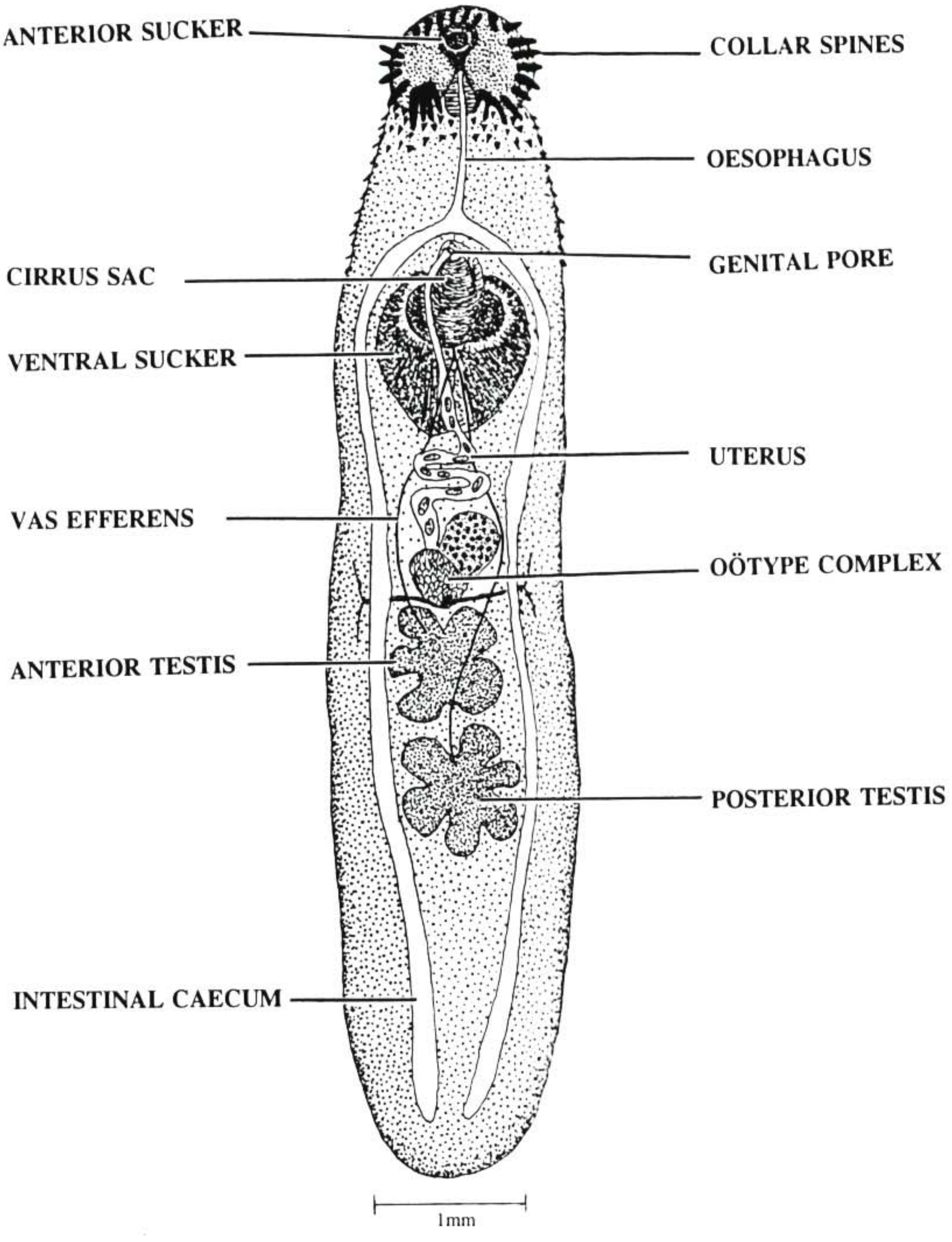

ANTERIOR SUCKER
COLLAR SPINES
OESOPHAGUS
GENITAL PORE
CIRRUS SAC
VENTRAL SUCKER
UTERUS
VAS EFFERENS
OÖTYPE COMPLEX
ANTERIOR TESTIS
POSTERIOR TESTIS
INTESTINAL CAECUM
1mm

FIG. 13

PARYPHOSTOMUM RADIATUM

Drawing indicating extent of vitelline follicles.
(After Edwards, 1927).
Refer also Fig. 15

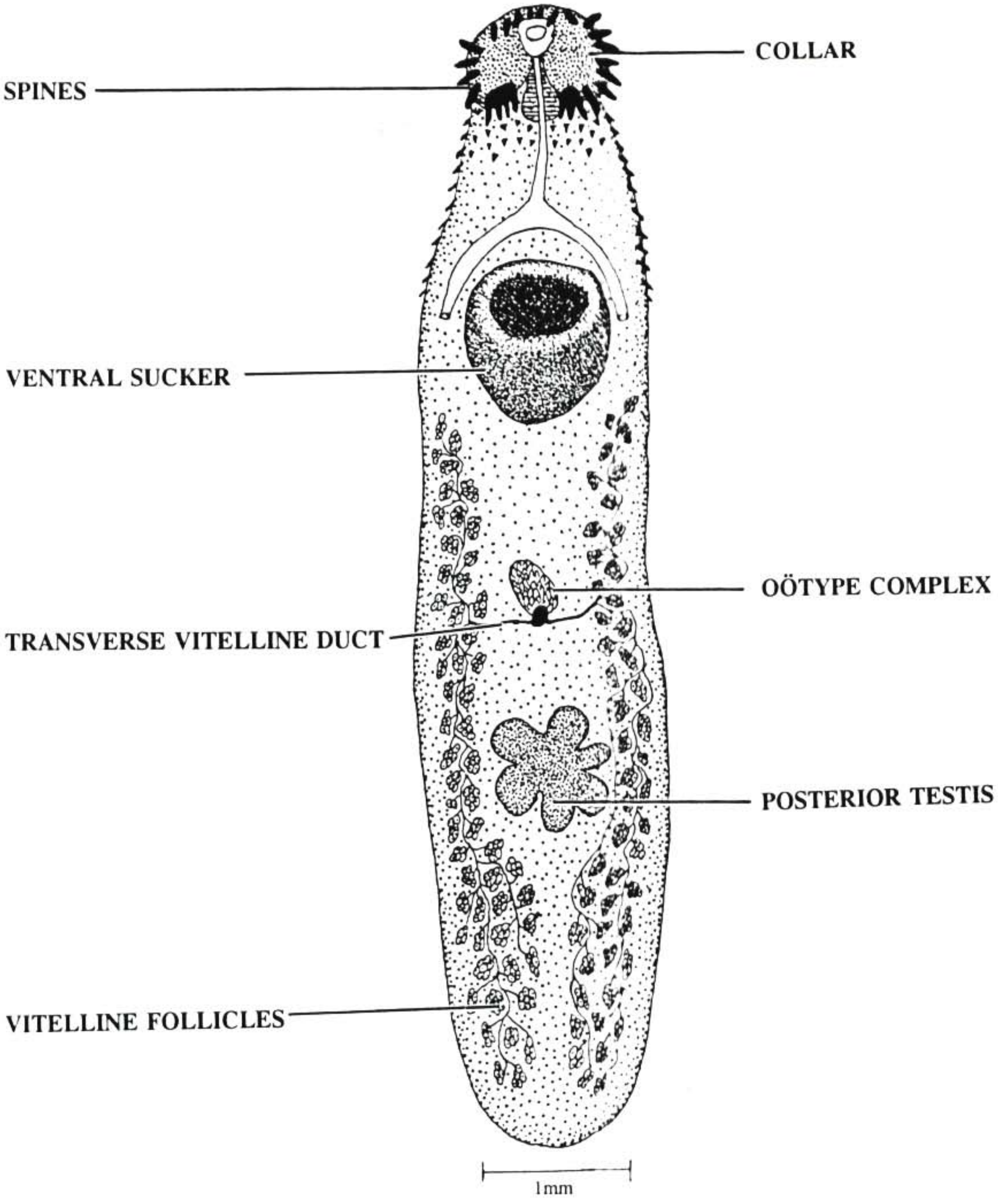

COLLAR
SPINES
VENTRAL SUCKER
OÖTYPE COMPLEX
TRANSVERSE VITELLINE DUCT
POSTERIOR TESTIS
VITELLINE FOLLICLES
1mm

FIG. 14

PARYPHOSTOMUM RADIATUM

Diagramatic representation of the topography of the oötype complex. (After Edwards, 1927).

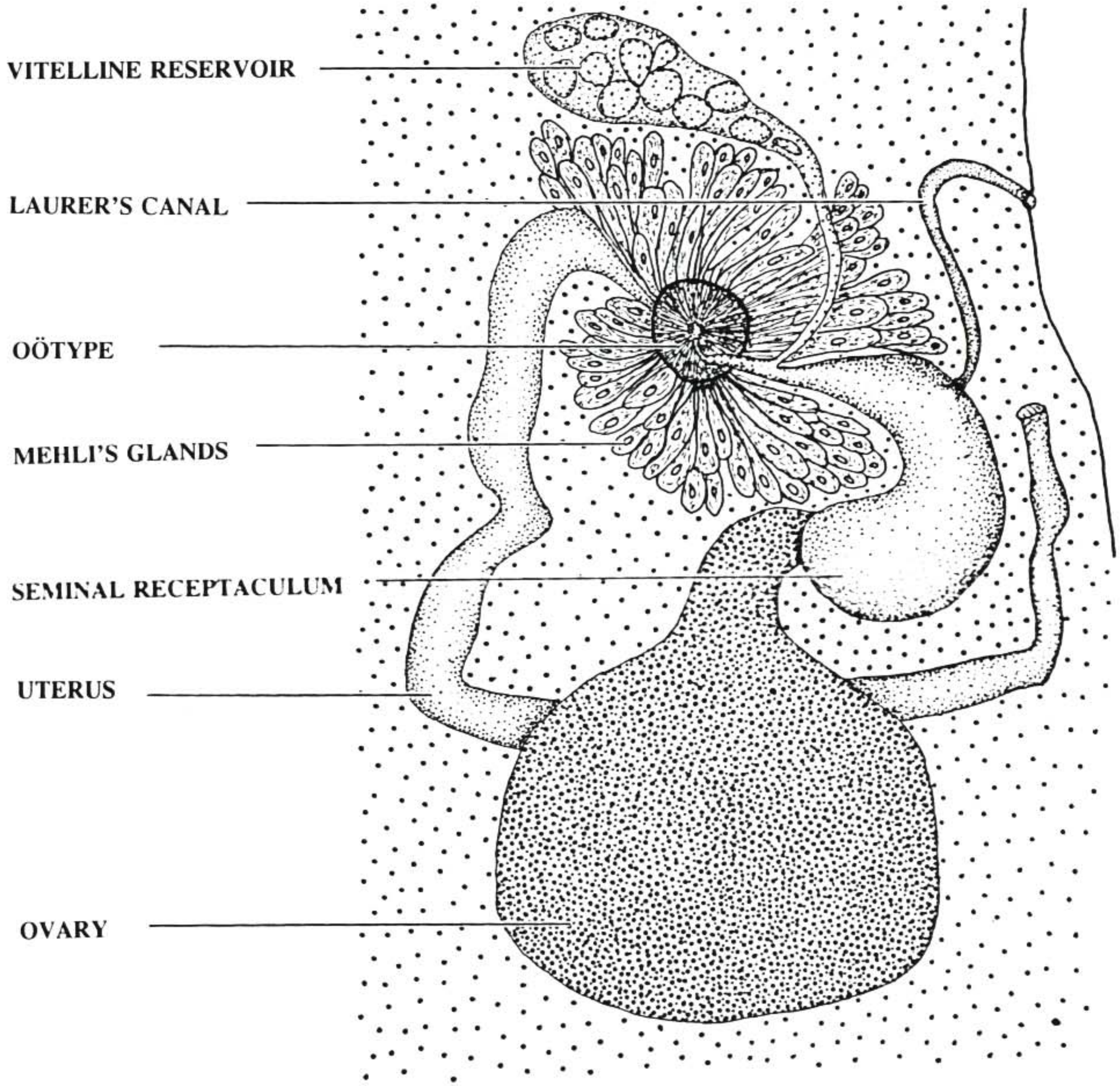

VITELLINE RESERVOIR
LAURER'S CANAL
OÖTYPE
MEHLI'S GLANDS
SEMINAL RECEPTACULUM
UTERUS
OVARY

FIG. 15

DIPLOSTOMUM GHANESE AND PARYPHOSTOMUM RADIATUM
(Light Microscopy)

A. *D. ghanense - entire worm x 50*

B. *D. ghanense - hindbody x 125*

C. *P. radiatum - collar with spines x 50*

D. *P. radiatum - entire worm x 12*

Key:

a. - ventral sucker

at. - anterior testis

c. - collar

e. - egg

ho. - holdfast organ

os. - oral sucker

ps. - pseudosucker

pt. - posterior testis

vf. - vitelline follicles

vs. - vesicula seminalis

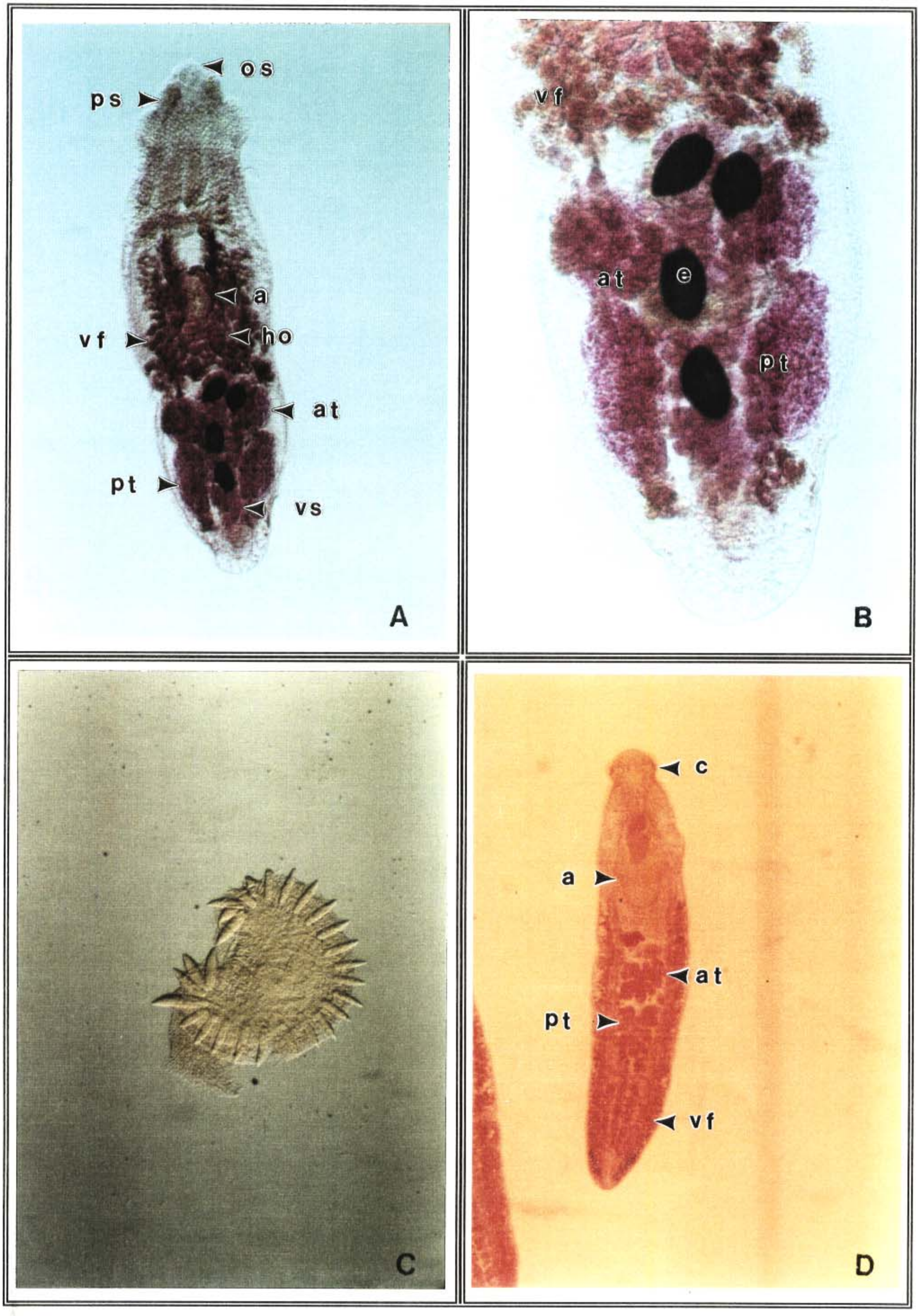

os
ps
a
vf
ho
at
pt
vs
A
vf
at
e
pt
B
C
c
a
at
pt
vf
D

FIG. 16.

DIPLOSTOMUM GHANENSE AND PARYPHOSTOMUM RADIATUM
(Scanning Electron Microscopy)

A. D. ghanense - anterior end of forebody

B. D. ghanense - posterior end of hindbody

C. P. radiatum - collar

D. P. radiatum - anterior part of body

Key:

a. - ventral sucker

c. - collar

cr. - cirrus

ep. - excretory pore

fb. - forebody

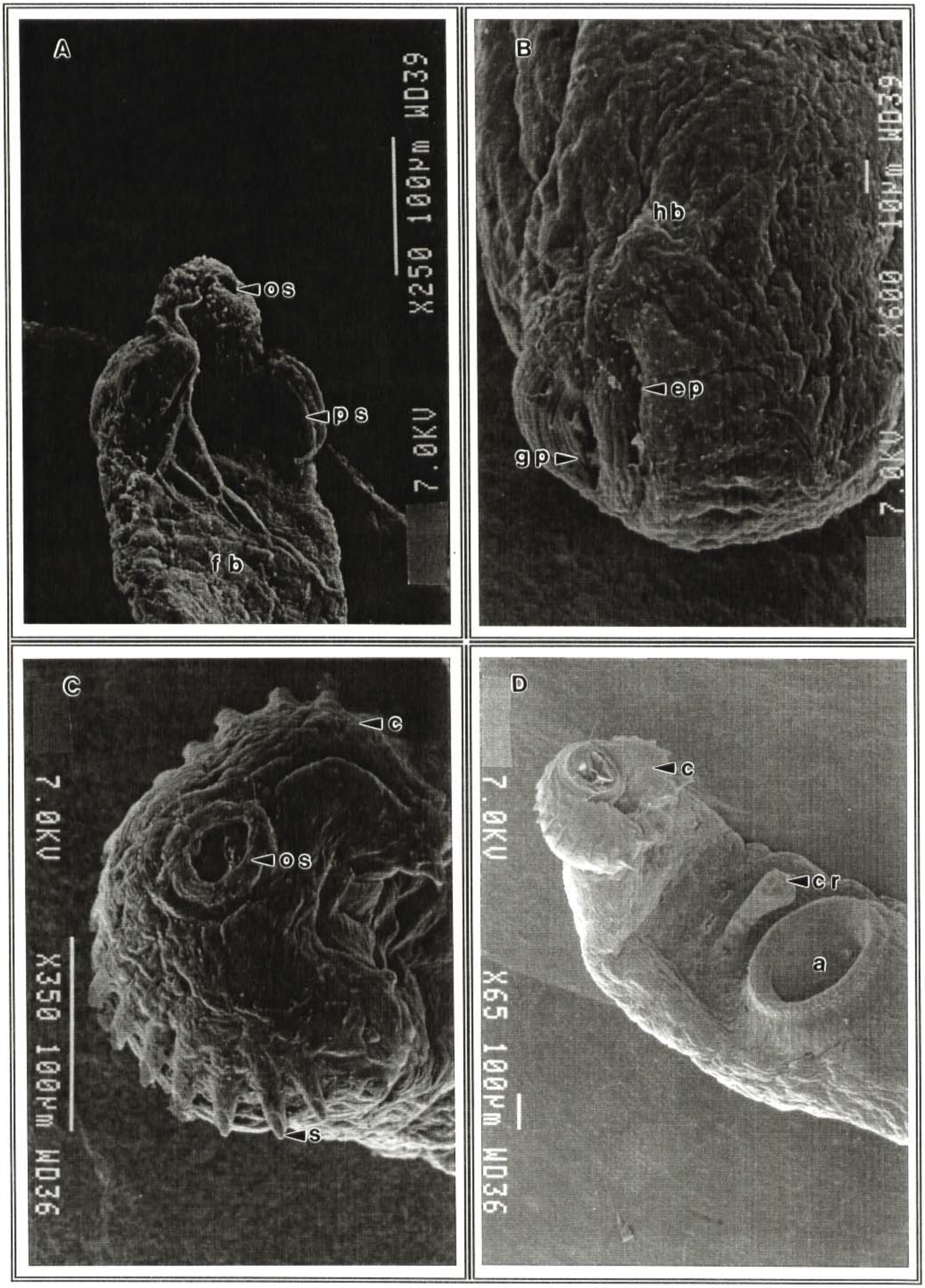
gp. - gonopore

hb. - hindbody

os. - oral sucker

ps. - pseudosucker

s. - spine


A
os
ps
fb
X250 100µm WD39
7.0KV
B
hb
ep
gp
X600 10µm WD39
7.0KV
C
c
os
s
7.0KV X350 100µm WD36
D
c
cr
a
7.0KV X65 100µm WD36

- Infection statistics with *P. radiatum* are reasonably high for all three final hosts. Intensity figures and mean intensity figures reach as high as 262 and 56 respectively;

- It must be more than a reasonable certainty that this parasite utilizes one or more of the fish species of this area as an intermediate host. The three final hosts are exclusively piscivorous, utilising smaller fish species and/or juveniles of the larger fish species in their dietary budget.

Family: Clinostomatidae, Lühe, 1901

Subfamily: Clinostominae, Pratt, 1902

Genus: *Clinostomum*, Leidy, 1856
C. complanatum (Rudolphi, 1819)
Braun, 1899

Genus: *Neutraclinostomum* Feizullaev and Mirzoeva, 1983
N. intermedialis (Lamont, 1920)

Genotype: According to Yamaguti (1958) the type species is *C. gracile* Leidy 1856. Loss (1899) designated *C. heterostomum* (Rudolphi, 1809) as the type. A survey of the literature reveals that the taxonomic designations of these forms changed with time. However, recent authors such as; Ukoli (1966), Singh (1968), Grabda-Kazubska (1974), Dowsett and Lubinsky (1980), Lo, Huber, Kou & Lo (1981), Feizullaev & Mirzoeva (1983) and Aohagi, Shibahara & Kagota (1995) are inclined to consider *C. complanatum* (Rudolphi, 1819), Braun, 1899 as the genotype.

The geographical distribution of members of the family Clinostomatidae is very wide and, according to Grabda-Kazubska (1974), occupies the entire zone of the world within the annual isotherm of 10°C, with a clearly defined preference for the warmer tropical and subtropical regions. Britz (1983) summarised distributional areas to be Africa, Southern Asia and North America.

The life cycle of Clinostomatid parasites (Fig.30, p.109) typically involves three hosts. Adult parasites are found in the buccal cavity and oesophageal region of piscivorous birds, while the relatively large metacercariae (5 - 15mm) encyst on the branchial tissues and visceral organs as well as in the muscles of fish intermediate hosts. Freshwater gastropods particularly *Lynnaea* spp. and *Bulinus* spp., serve as first intermediate hosts.

SYNOPSIS OF THE TAXONOMY OF THE FAMILY CLINOSTOMATIDAE LÜHE, 1901

A review of the relevant literature reveals that the taxonomic designations of the subtaxa of the family Clinostomatidae Lühe, 1901 have, in the past, been in a somewhat chaotic disarray. The same remark can be made in respect of the number and synonymy of described species and their inclusion amongst the genera of the various subfamilies.

The above situation is to be expected for a taxonomic entity where some species are recorded and described only from larvae (cercariae and metacercariae) parasitising intermediate hosts, whereas others are described from sexually mature parasites in final hosts. This, in turn, results in a situation where metacercariae are either not linked to adult forms or sometimes incorrectly linked. This remark is well substantiated by the fact that Agarwal (1959) in his revision of the genus *Clinostomum* lists 14 species described from adult parasites and 12 species described from metacercariae. Of these only three metacercarial species could be linked to adult species.

Another factor which has certainly contributed to the confusing lower order taxonomy of this group is the fact that insufficiently well studied characters are often used in the taxonomy of the Clinostomatidae (Baer, 1933; Price, 1938; Ukoli, 1955a; Feizullaev and Mirzoeva, 1983).

The following synoptic and chronological account on the systematic disposition of the family Clinostomatidae substantiates the ensuing statements:

- Lühe (1901) created the family Clinostomatidae with type genus *Clinostomum* Leidy, 1856. The family was designated as parasites of Reptiles, Birds and Mammals (Yamaguti, 1958);

- Braun (1901) listed nine valid species of the genus *Clinostomum* known at that stage. All nine species were described from adult parasites in final hosts;

- Baer (1933) described the adult of *C. lophophallum* and drew up a key to distinguish the various known adult and metacercarial forms. The following characteristics were considered in constructing this key:

    - Extension and arrangement of vitelline follicles;
    - position of ventral suckers;
    - relative size of oral sucker;
    - uterine sac with or without lateral extensions;
    - position of gonads;
    - presence or absence of vitelline reservoir.

Eleven species from sexually mature and three species from metacercariae were included in this classification;

- In 1938 Price modified the above key proposed by Baer (1933) by using, in addition, characteristics such as:

    - position of gonads in relation to postacetabular region of body;
    - position of genital pore;
    - position of uterus and its opening into the uterine sac.

    All the adult species of Baer (1933) were recognised except *C. lambitans* Nicol, 1914. Added to Baer's list were *C. australiense* Johnston, 1916 and *C. vanderhorsti* Ortlepp, 1935. Price (1938) recognised the three metacercarial species of Baer (1933), namely, *C. dictyotum* Monticelli, 1893, *C. piscidium* Southwell and Prashed, 1918, *C. chrysicthys* Dubois, 1930, and added two additional species, *C. delagi* and *C. pseudoheterostomum* described by Tabangui in 1933;

- Dollfus (1950) proposed five genera to be included in the family Clinostomatidae:

    Clinostomum Leidy, 1856
    Euclinostomum Travassos, 1929
    Ithyoclinostomum Witenberg, 1925
    Clinostomoides Dollfus, 1950
    Clinostomatopsis Dollfus, 1932

- Agarwal (1959) using similar morphological characteristics, also reviewed the genus *Clinostomum* and included or synonymised all the species described since 1901 in his keys for the identification of adults and metacercariae of the genus. This author recognised 14 adult *Clinostomum* species and 12 species of metacercariae.

    As was mentioned earlier, only three of the 12 metacercarial species could be linked positively to adult species. These are *C. marginatum* (= *C. complanatum*) Rudolphi, 1819, *C. australiense* Johnston, 1916 and *C. giganticum* Agarwal, 1959.

- Yamaguti (1958) elevated the genera *Ithyoclinostomum* Witenberg, 1925; *Euclinostomum* Travassos, 1929 and *Clinostomum* Leidy, 1856 to subfamily rank and simultaneously excluded the genus *Clinostomatoides* Dollfus, 1950, but retained *Clinostomatopsis* Dollfus, 1932. The following taxonomic hierarchy for the family Clinostomatidae was proposed by Yamaguti (1958):

Family Clinostomatidae Lühe, 1901
Subfamily Ithyoclinostominae Yamaguti, 1958
Genus: *Ithyoclinostomum* Witenberg, 1926

Subfamily Clinostominae Pratt, 1902
Genus: *Clinostomum* Leidy, 1856
Genus: *Clinostomatopsis* Dollfus, 1932

Subfamily Euclinostominae Yamaguti, 1958
Genus: *Euclinostomum* Travassos, 1928;

- Ukoli (1966a) studied the life history and development of *C. tilapiae* Ukoli, 1966, and also reviewed the genus *Clinostomum* from descriptions, measurements and illustrations of most of the described species. He (Ukoli, 1966a) came to the conclusion that most of the diagnostic characters used by previous workers (Baer, 1933; Price, 1938; Wesley, 1944 and Agarwal, 1959) vary considerably within the species. These variations were ascribed to external influences such as methods of fixation, the state of contraction or expansion of the parasite or the developmental stage of the worm at the time of examination. Ukoli (1966) considered the characters most suitable for differentiating species of the genus *Clinostomum* to be:

  - Anterior extent of the vitellaria;
  - Presence of lateral extensions in the uterine sac;
  - Region of the body in which the gonads are located;
  - Shape of testes;
  - Position of genital pore relative to gonads, particularly the anterior testes;
  - Position of cirrus pouch.

- Employing the above features Ukoli (1966) reduced the 39 species of *Clinostomum* described from sexually mature parasites to a mere 12. In this scheme of classification no less than 20 species were synonymised with *C. complanatum* (Rudolphi, 1819). Amongst others, the species described from South Africa, *C. vanderhorsti* Ortlepp, 1935 was, in agreement with Dollfus (1950), synonymised with *C. complanatum*;

- Yamaguti (1971) in his **Synopsis of Digenetic Trematodes of Vertebrates** proposed yet another scheme of classification for the family Clinostomatidae. The main essentials of this scheme are:

- The recognition of three subfamilies for the Clinostominae from birds, namely, Ithyoclinostominae Yamaguti, 1958; Euclinostominae Yamaguti, 1958 and Clinostominae Pratt, 1902;

- The addition of one more genus to the subfamily Clinostominae, namely, Clinostomoides Dollfus, 1950 emend Yamaguti 1971;

- Feizullaev and Mirzoeva (1983) studied 1 386 specimens of clinostomes known in the literature as *Clinostomum complanatum* Rudolphi, 1819; *C. hornum* Nicol, 1914; *C. foliiforme* Braun, 1899; *C. kassimovi* Grandjean, 1960; *C. heluans* Braun, 1899; *C. attenuatum* Cort, 1913; *C. intermedialis* Lamont, 1920; *Clinostomoides brieni* Dollfus, 1950 and *Euclinostomum heterostomum* Rudolphi, 1809.

  This study identified stable and unstable taxonomic characteristics as well as the variability amplitude of each character. It also indicated the possibility of using variable characters after the amplitude of variations had been demonstrated for the systematics of the family Clinostomatidae. It was further concluded that:

  many characters used in the systematics of Clinostomidae were not suitable. Their taxonomic value had not been demonstrated and the variability amplitude had not been studied. Such were the meristic characters (width of spines on the body surface, sizes of body and organs and their relationships) and also the various variations in the position and shape of organs noted when comparing material with the type species. Also the extent of the uterus, the place of junction of the uterine duct with the uterus (uteroductus) and whether the uterine duct forms loops or not, in the presence or absence of uterine processes, in the radial or otherwise position of the vitelline follicles, the posterior extension of vitellaria and the shape of the gonads. It became clear that variability of these characters was conditioned by individual, age and ecophenotypic variations.

  *To the demonstrated taxonomically viable characters belong: the shape and position of the uterus; the point of junction of the uterine duct with the uterus; the presence or absence of an oral sucker and the pharynx; the shape of the intestine, the structure and position of the intestinal crura; the shape of the vitellaria and their position; the position of the gonads in relation to body length; the shape of the anterior testis (for **Euclinostomum** and **Tumaclinostomum**) and the position of the genital pore.*
  [Literally translated from Russian text]

  On the strength of their research findings Feizullaev and Mirzoeva (1983) proposed the following scheme of classification for Clinostomatid parasites:

Superfamily Clinostomoidea Lühe, 1901
(= Clinostomiformes Travassos, Freita and Kohn, 1969)

Family Clinostomidae Lühe, 1901

Subfamily Clinostominae Lühe, 1901

Genus: *Clinostomum* Leidy, 1856

With only one species, *C. complanatum* (Rudolphi, 1819), Braun, 1899.

SYNONYMS:

C. marginatum (Rudolphi, 1819), Braun, 1899; *C. gracile* Leidy, 1856; *C. dubium* Leidy, 1856; *C reticulatum* Looss, 1885; *C. lambitans* Braun, 1899; *C. foliiforme* Braun, 1899; *C. attenuatum* Cort, 1913; *C. hornum* Nicol, 1914; *C. australiense* Johnston, 1917; *C. piscidum* Southwell and Prashad, 1918; *C. pusillum* Lutz, 1928; *C. chrysichthys* Dubois, 1929; *C. lophophallum* Baer, 1933; *C. delagi* Tubangui, 1933; *C. vanderhorsti* Ortlepp, 1935; *C. abdoni* Tubangui and Garcia, 1939; *C. prashadi* Bhalerao, 1942; *C. dasi* Bhalerao, 1942; *C. gideoni* Bhalerao, 1942; *C anusi* Wesley, 1944; *C kalapphahi* Bhalerao, 1947; *C. shizothoraxi* Kaw, 1950; *C. pyriforme* Prudhoe, 1957; *C. deccanum* Jaiswal, 1957; *C. demiegrettae* Jaiswal, 1957; *C. hyderabadensis* Jaiswal, 1957; *C. macrostomum* Jaiswal, 1957; *C. mastacembeli* Jaiswal, 1957; *C. progonium* Jaiswal, 1957; *C. singhi* Jaiswal, 1957; *C kassimovi* Vaidova and Feizullaev, 1957; *C. giganticum* Agarwal, 1959; *C. chabaudi* Vercammen Grandjean 1960; *C. cutaneum* Paperna, 1964, *C. tilapiae* Ukoli, 1966; *C. golvani* Hassi and Bayssade-Dufour, 1980

Genus: *Ithyoclinostomum* Witenberg, 1926
I. dimorphum Diesing, 1850

Genus: *Clinostomatopsis* Dollfus, 1932
C. sorbens (Braun, 1899)

Genus: *Clinostomoides* Dollfus, 1950
C. brieni Dollfus, 1950
(= *Clinostomum ophiocephali* Tabangui, 1944)

Genus: *Neutraclinostomum* Feizullaev & Mirzoeva, 1983
N. intermedialis (Lamont, 1920)
(= *C. phalacrocoracis* Dubois, 1930)

Genus: *Tumaclinostomum* Van der Kuyp, 1953
T. multicaecum (Tubangui and Masilungan, 1935)
(= *E. multicaecum* Tubangui and Masilungan, 1935
Clinostomum philipinense Velasquez, 1960

Euclinostomum srivastavai Pandy and Baugh, 1960)

Genus: *Euclinostomum* Travassos, 1928
(= *Metaclinostomum* Pandey and Baugh, 1970)
E. heterostomum (Rudolphi, 1809) Travassos, 1928

SYNONYMS:

Clinostomum africanum Galli-Valerio, 1906; *Euclinostomum clarias* Dubois, 1929; *E. indicum* Bhalerao, 1942; *E. skrjabini* Kuraschwili, 1948; *E. channai* Jaiswal, 1957; *E. bhagavantami* Jaiswal, 1957; *E. heptacaecum* Jaiswal, 1957; *E. vanderkuypi* Fischthal and Kuntz, 1963; *E. dollfusi* Fischthal and Kuntz, 1963; *Metaclinostomum srivastavai* Pandey and Baugh, 1971.

Subfamily Opisthophallinae Travassos, 1928

Genus: *Opisthophallus* Baer, 1923
(= *Neprocephalus* Odhner, 1901)
O. lagri-incapsulatus Wedl, 1861
Parasites of reptiles

FAMILY Odhneriotremidae Travassos, Freitas and Kohn, 1969

Genus: *Odhneriotrema* Travassos, 1928
(= *Homoscaphis* Caravan, 1933)
O. microcephala (Travassos, 1922) Travassos, 1928
O. incommodum (Leidy, 1856) McIntosh, 1935
Parasites of crocodiles

From the above scheme for the classification of clinostome parasites the following is evident:

- Feizullaev and Mirzoeva (1983) do recognise two families, viz., family Clinostomidae Lühe, 1901 and family Odhneriotremidae Travassos, Freitas and Kohn, 1969, under the superfamily Clinostomoidea Lühe, 1901.

- The family Odhneriotremidae contains only one genus *Odhneriotrema* (Travassos, 1922), Travassos, 1928, while the family Clinostomidae contains no less than seven genera. All the clinostome parasites of fish and birds are included in the latter subfamily.

- The seven genera of the subfamily Clinostominae were included under three seperate subfamilies by Yamaguti (1971).

The foregoing account on the systematics of clinostomatid parasites of fishes, reptiles and birds clearly indicates substantial disagreement amongst the different workers in this field of parasitological research. (refer also remark p.68). For purposes of this investigation it was decided to follow the scheme of classification proposed by Feizullaev and Mirzoeva (1983). Two reasons prompted this decision:

a. It is the latest resumé on the taxonomy of the group that could be traced in the literature, and,

b. These researchers were the first to apply modern taxonomic principles, eg., variability amplitudes (cf.p.71) to test for stable and unstable anatomical characteristics in the classificatory designations of clinostomatid parasites.

Following the scheme of classification of Feizullaev and Mirzoeva (1983) the present study identified three clinostomatid parasites of piscivorous birds in the Northern Province of South Africa. These are:

Genus: *Clinostomum* Leidy, 1856
C. complanatum (Rudolphi, 1819)
Braun, 1899

Genus: *Neutraclinostomum* Feizullaev & Mirzoeva, 1983
N. intermedialis (Lamont, 1920)

Genus: *Euclinostomum* Travassos, 1928
E. heterostomum (Rudolphi, 1809)
Travassos, 1928

For the identification of the above three species morphologically viable taxonomic characteristics (Ukoli, 1966; Feizullaev and Mirzoeva, 1983), supplemented by ecological and life history details, were used. These criteria will be elaborated on in the following pages.

Genus *Clinostomum* Leidy, 1856

C. complanatum (Rudolphi, 1819)
Braun, 1899

Synonymy: see page 72

Numerous adult and metacercarial forms have been described under the genus *Clinostomum* (cf. pp.68-69). Ukoli (1966a) reduced the number of species from 39 to 12 (cf.p.70), while Feizullaev and Mirzoeva (1983) synonymised all described forms with *C. complanatum* (cf.p.72). This followed on the transfer of some forms alien to the genus by Travassos (1928); Dollfus (1932); Van der Kuyp (1953) and Feizullaev and Mirzoeva (1983) to other genera.

MORPHOLOGY OF *Clinostomum complanatum*:

Numerous anatomical descriptions and morphometric measurements of *Clinostomum* spp. appear in the literature, e.g., Braun (1901); Johnston (1912); Cort (1913); Ortlepp (1935); Bhalerao (1942, 1947); Jaiswal (1957); Singh (1959); Agarwal (1959); Pandey (1965); Ukoli (1966a); Mashego (1982); Britz (1983); Britz, Saayman and Van As (1984) and Chu-Fang Lo (1984).

Most of these descriptions resulted from the study of mounted specimens with the result that finer micromorphological and cytological detail are often lacking. The descriptions of Ortlepp (1935); Mashego (1982); Britz (1983) and Britz et. al. (1984) are the most detailed because these researchers also used serial sections in addition to wholemounts.

The majority of descriptions on the morphology of *Clinostomum* spp. were intended to separate or distinguish different species, which have since been drastically synonymised. So, for example, Ukoli (1966a) reduced the number of species in the genus *Clinostomum* from 39 recognized species to a mere 12 (cf.p.70). Feizullaev and Mirzoeva (1983) synonymised all described species of *Clinostomum* and recognised only one species, namely, *C. complanatum*.

For reasons enumerated on in the preceding paragraphs, and for purposes of this study - which follows the systematics suggested by Feizullaev and Mirzoeva (1983) - it was considered practical to refer to the following morphological descriptions:

C. complanatum	-	Ortlepp (1935);
N. intermedialis	-	Ukoli (1966a); Britz (1983);
E. heterostomum	-	Mashego (1977); Britz (1983).

Anatomical data provided by the preceding authors, were augmented by anatomical details observed during the present study. (Figs. 17-23, 25, 27 and 28, pp. 80 - 95.

Table 11: Infection statistics of *Phalacrocorax carbo, P. africanus, Anhinga melanogaster* and *Ardea cinerea* in the Northern Province of South Africa with adults of *Clinostomum complanatum* (Rudolphi, 1819), Braun, 1899

AVIAN HOST	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
P. carbo	39	Seshego Dam	74	1 - 24	9
	8	Middle Letaba Impoundment	63	1 - 37	11
	2	Piet Gouws Dam	100	23 - 28	26
	2	Glen Alpine Dam	100	6 _ 11	9
	1	Ebenhaezer Dam	-	-	-
P. africanus	44	Seshego Dam	56	1 - 6	3
	9	Middle Letaba Impoundment	33	1 - 5	3
	3	Hudson Ntsanwisi Dam	100	1 - 2	1
	1	Turfloop Dam	-	-	-
	2	Marble Hall	100	6 - 8	7
A. melanogaster	24	Seshego Dam	92	1 - 19	8
	12	Middle Letaba Impoundment	83	3 - 190	48
	11	Hudson Ntsanwisi Dam	100	3 - 53	14
	2	Luphephe Dam	-	-	-
	6	Piet Gouws Dam	100	10 - 59	28
	4	Glen Alpine Dam	100	1 - 5	3
	1	Tzaneen Dam	100	7	7
	4	Olifants River	100	12 - 33	20
	2	Marble Hall	-	-	-
A. cinerea	3	Middle Letaba Impoundment	66	1 - 3	2

Table 11 indicates that four piscivorous birds do regularly act as final hosts for *Clinostomum complanatum* in the study area. From the infection statistics it would appear that *A. melanogaster* and *P. carbo* act as the predominant hosts, while *P. africanus* and *A. cinerea* play subsidiary roles in this respect.

It is interesting to note that only one out of the eight members of the family Ardeidae that were investigated at Middle Letaba Impoundment harboured this parasite. A brief scrutiny of the literature revealed that members of the family Ardeidae serve as natural hosts for *C. complanatum* in many parts of the world. Many researchers have also used members of the Ardeidae in experimental infections with this parasite. In this regard the following references may be cited:

- Braun (1900) reported *Ardea* spp. as natural hosts for clinostome parasites in various localities in Europe. Amongst others, he listed the following:

C. heterostomum	in *Ardea purpurea*
C. foliiforme	in *A. purpurea*
C. dimorphum	in *A. cocoi*
C. marginatum	in *Ardea* sp.
C. complanatum	in *A. cinerea*
C. lambitans	in *Ardea* sp.;

- Cort (1913) list *A. herodias, A. cocoi* and *Ardea* sp. together with *Nycticorax nycticorax* as natural hosts of *C. marginatum* in Brazil;

- Nicoll (1914) reported on *N. caledonicus* and *Botaurus poeciloptilus* as natural hosts for *C. complanatum* in Queensland, Australia;

- Ortlepp (1935) raised *C. vanderhorsti* to adulthood in *A. melanocephala* as an experimental host;

- Jaiswal (1957) listed *A. cinerea* as natural host for *C. deccanum* and *C. complanatum* in Hyderabad, India, while *Demiegretta asha* acted as host for *C. demiegretta* in the same Province;

- Singh (1959) reported *Egretta garzetta, A grayii, Bubulcus ibis* and *N. nycticorax* as natural and experimental hosts for *C. piscidium* in Raipur, India;

- Pandey (1965, 1973) in his research on *C. piscidium*, in Lucknow, India, found *A. grayii* and *B. ibis* to be naturally infected with this clinostome species;

- Ukoli (1966a) found *N. nycticorax* and *Anhinga melanogaster* to be the natural hosts for *C. tilapiae* in Ghana, while the same author successfully used *Ardea melanocephala* and *B. ibis* as experimental hosts.

- Chu-Fang Lo, Frans Huber, Guang-Hsuing Kou and Ching-Jen Lo (1981) successfully used *E. garzetta* and *N. nycticorax* as experimental hosts for *C. complanatum* in Taiwan, R.O.C.;

- Aohagi, Shibahara, Machida, Kagota and Hayashi (1992) reported on *A. cinerea, E. garzetta, E. intermedia* and *N. nycticorax* as natural hosts for *C. complanatum* in Japan.

N.B. All Clinostome spp. referred to in the above summary have been synonymised with *C. complanatum* (Ukoli, 1966a, Feizullaev and Mirzoeva, 1983).

From the above summary it is clear that a wide range of ardeiform birds are ecologically as well as physiologically susceptible to infections with *Clinostomum* parasites.

Apart from *A. cinerea* the followng herons resident at Middle Letaba Impoundment were examined for infections with *C. complanatum*:

Ardea melanocephala
A. purpurea
Egretta garzetta
Bubulcus ibis
Nycticorax nycticorax
Butorides striatus
Ixobrychus minutus

The absence of infection with *C. complanatum* of the above seven Ardeidae at Middle Letaba Impoundment can only be explained by assuming that they do not feed on the fish intermediate hosts of this parasite in the impoundment. (cf.Table 11 p.76). Examination of these hosts at other water bodies in South Africa will have to be undertaken before a final pronouncement on their role in the maintenance of the life history of *C. complanatum* in South Africa can be made.

Anhinga melanogaster, because of their numerical dominance at water bodies in the Northern Province of South Africa, must be regarded as the avian host which plays the most important role in the suprapopulation statistics of *C. complanatum* in this region.

Table 11, p.76 also shows that some of the identified hosts realised 100% prevalence figures at five water bodies in the study area, namely, Piet Gouws Dam, Glen Alpine Dam, Hudson Ntsanwisi Dam, Tzaneen Dam and the Olifants River. In all these water bodies, except Piet Gouws Dam, two fish species that are heavily infected with metacercariae of *C. complanatum*, namely, *Marcusenius macrolepidotus* (Peters, 1852) and *Schilbe intermedius* (Rüppell, 1832) abound. (Refer also Table 12, p.79). These fish hosts do not occur at the other sampling localities from which avian hosts were procured.

Table 12: Infection statistics of fish intermediate hosts with metacercariae of *Clinostomum complanatum* in the Northern Province of South Africa. Data compiled after Mashego (1982), Saayman (1986a) and Saayman and Schoonbee et. al. (1991).

FISH HOST	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
Marcusenius macrolepidotus (Peters, 1852)	524	Various water bodies in the Limpopo and Olifants River Drainage Systems	54.7	1 - 122	6.70
Schilbe intermedius (Rüppel, 1832)	399	Various water bodies in the Limpopo and Olifants River Drainage Systems	28.7	1 - 21	3.38
Chiloglanis pretoriae (Van der Horst, 1932)	115	Various water bodies in the Limpopo and Olifants River Drainage Systems	5.2	1 - 4	2.17
B. trimaculatus (Peters, 1852) *B. paludinosus* (Peters, 1852) *B. radiatus* (Peters, 1853) *B. unitaeniatus* (Günther, 1866) *Barbus mattozi* (Guimaraes, 1884) *B. eutaenia* (Boulenger, 1904)	247 for 6 hosts	Various water bodies in the Limpopo and Olifants River Drainage Systems	13	1 - 11	
B. marequensis (Smith, 1841)	13	Middle Letaba Impoundment	7.7	1	1
B. trimaculatus (Peters, 1852)	89	Middle Letaba Impoundment	2.44	-	1
B. unitaeniatus (Günther, 1866)	82	Middle Letaba Impoundment	1.1	2	2
Pseudocrenilabris philander (Weber, 1897)	47	Middle Letaba Impoundment	6.4	-	1

FIG. 17

CLINOSTOMUM COMPLANATUM

Graphic reconstruction illustrating the topography of the internal organs

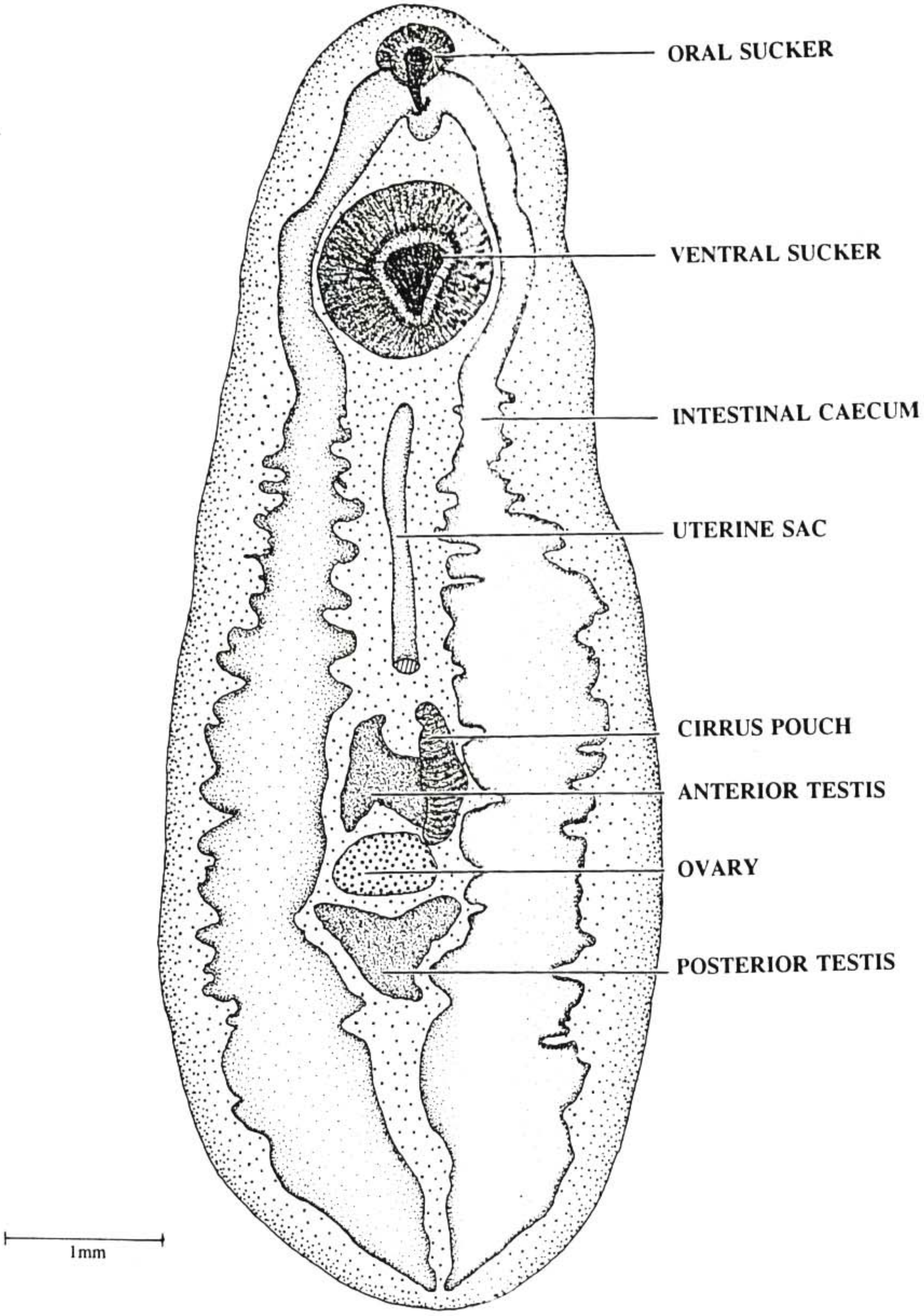

ORAL SUCKER
VENTRAL SUCKER
INTESTINAL CAECUM
UTERINE SAC
CIRRUS POUCH
ANTERIOR TESTIS
OVARY
POSTERIOR TESTIS
1mm

FIG. 18

CLINOSTOMUM COMPLANATUM

Graphic reconstruction illustrating the reproductive system of a sexually mature specimen

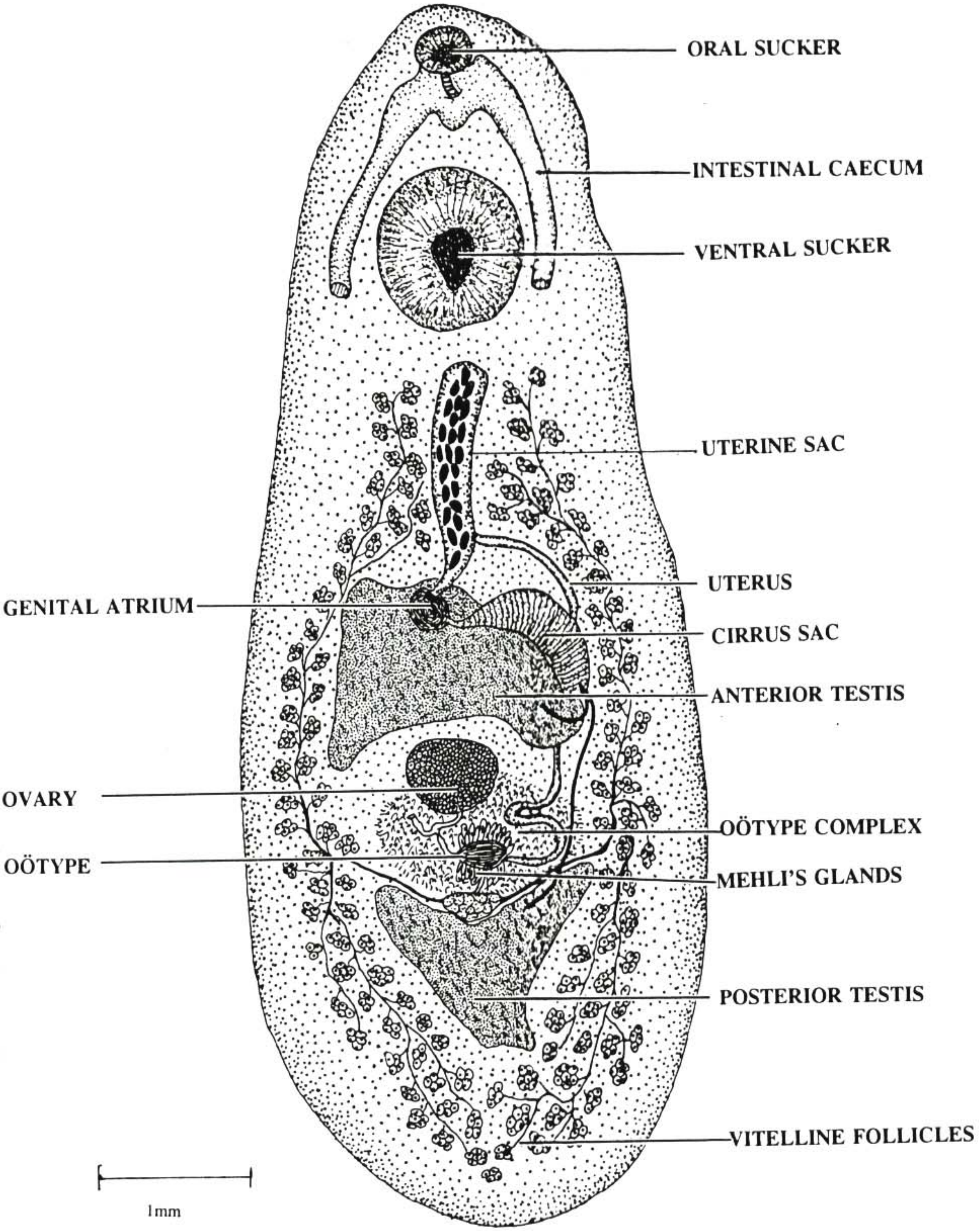

ORAL SUCKER
INTESTINAL CAECUM
VENTRAL SUCKER
UTERINE SAC
UTERUS
GENITAL ATRIUM
CIRRUS SAC
ANTERIOR TESTIS
OVARY
OÖTYPE COMPLEX
OÖTYPE
MEHLI'S GLANDS
POSTERIOR TESTIS
VITELLINE FOLLICLES
1mm

FIG. 19

CLINOSTOMUM COMPLANATUM
(Scanning Electron Microscopy)

A. *Entire worm - ventral view*

B. *Anterior end of body*

C. *Dorsal surface - posterior half*

D. *Ventral surface showing papillae*

Key:

a. - ventral sucker

cr. - cirrus

ep. - excretory pore

gp. - gonopore

lc. - Laurer's canal

os. - oral sucker

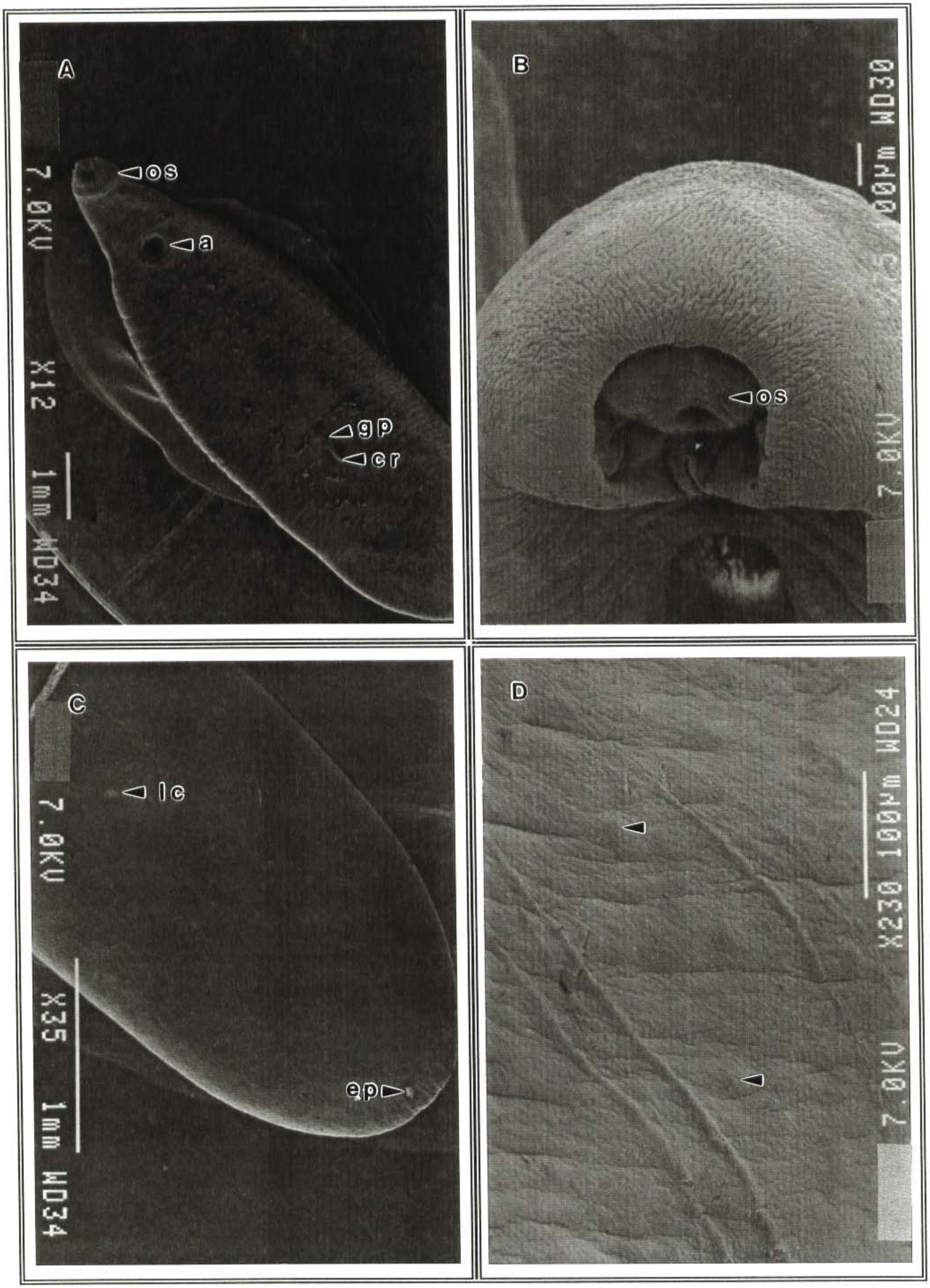

A
os
a
gp
cr
7.0KV X12 1mm WD34
B
os
7.0KV X25 00µm WD30
C
lc
ep
7.0KV X35 1mm WD34
D
7.0KV X230 100µm WD24

FIG. 20.

CLINOSTOMUM COMPLANATUM AND NEUTRACLINOSTOMUM INTERMEDIALIS
(Light Microscopy)

A. Clinostomum complanatum - showing extent of vitellaria relative to ventral sucker x 25

B. Neutraclinostomum intermedialis - showing extent of vitellaria relative to ventral sucker x 12

C. Clinostomum complanatum - showing shape of testes x 12

D. Neutraclinostomum intermedialis - showing shape of testes x 6

Key:

a. - ventral sucker

pt. - posterior testis

vf. - vitelline follicles

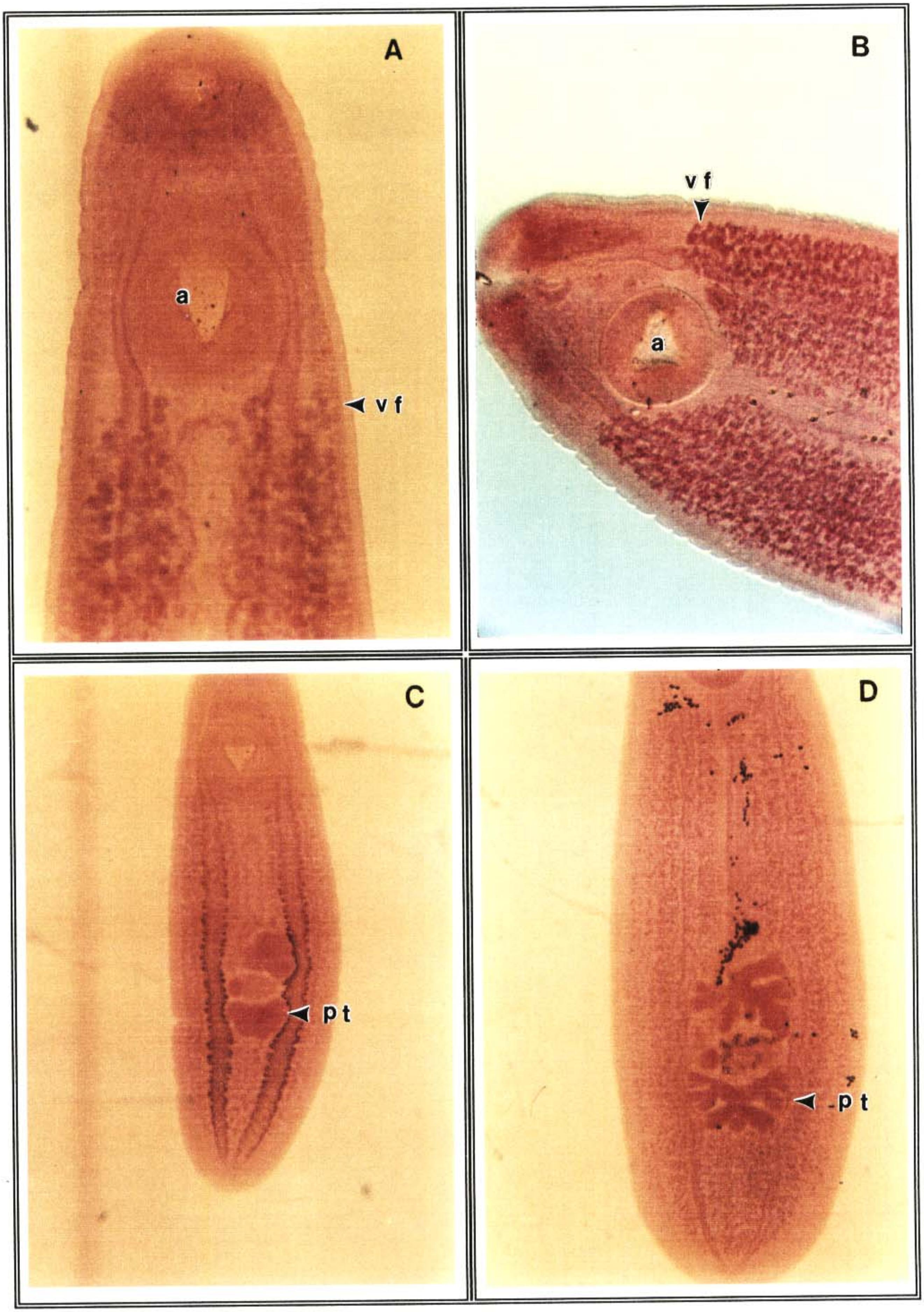

A
a
vf
B
vf
a
C
pt
D
pt

Table 12, p.79, reveals that no less than 11 freshwater fish hosts inhabiting the water bodies of the Northern Province, South Africa, have been positively identified as carriers of metacercariae of *C. complanatum*. These metacercariae (Fig.17) occur encysted on the swimbladder and on the visceral peritonia of their respective hosts. (Saayman, 1986a, Mashego, 1982 and Saayman and Schoonbee et. al., 1991).

M. macrolepidotus and *S. intermedius* together with *C. pretoriae* are, according to infection statistics, the principal intermediate hosts for *C. complanatum* in the study area. Of these three hosts *M. macrolepidotus* is the most susceptible to infections with metacercariae of *C. complanatum*. This host not only recorded the highest prevalence of infection (54.7%), but also carries very heavy worm burdens with intensity and mean intensity values of 1 - 122 and 6.70 respectively. *M. macrolepidotus*, together with *S. intermedius* do have a discontinuous distribution in the water bodies of the Northern Province. In water bodies where these two fish hosts do not occur *P. philander* and *Barbus* spp. act as the principal fish intermediate hosts for *C. complanatum*. *Barbus* spp. and *P. philander* are very widespread in water bodies in the Northern Province (Gaigher, 1969; Hecht and Saayman, 1981; Hecht and Mashego, 1981; Hecht, Polling and Mokgalong, 1981; Hecht and Scholtz, 1983; Kleynhans, 1984 ; Saayman, 1986*a* and Schoonbee, Hecht, Saayman and Polling, 1995).

Metacercariae procured from the peritoneum of the swimbladder of *M. macrolepidotus* were successfully raised to sexually mature parasites in nestlings of *B. ibis*. Worms were removed from the buccal capsules of the experimental hosts at 24 hour intervals up to 160 hours after infection (Saayman - Personal Communication). On morphological examination these trematodes compare in every anatomical detail with adult *C. complanatum* obtained from natural infections in *P. carbo, P. africanus, Anhinga melanogaster* and *Ardea cinerea*. Further experimental infections involving parasite free natural hosts as well as other ardean hosts (refer p.33) are envisaged.

Genus *Neutraclinostomum* Feizullaev and Mirzoeva, 1983

N. intermedialis (Lamont, 1920)
(= *C. phalacrocoracis* Dubois, 1930)

In assigning the present material obtained from *A. melanogaster* to *Neutraclinostomum intermedialis* (Lamont, 1920), the classificatory scheme proposed by Feizullaev and Mirzoeva (1983) was followed.

Lamont (1920) described a new species of *Clinostomum*, namely, *C. intermedialis* from *Phalacrocorax vigua* Vieillot, in Venezuela. She distinguished this species from other described species of the genus on the following discernible morphological characteristics:

- Cirrus sac and genital pore between the testes and not anterior to them;

- Testes distinctly lobulated and situated in the posterior third of the body;
- Vitelline glands begin at the level of ventral sucker and extend to the extreme posterior end of the body;
- The great extent of the uterus - occupying almost the entire area between the anterior testes and the ventral sucker.

From the rather unimpressive illustration provided by Lamont (1920) it is apparent that she did not distinguish between the uterus, uterine sac and the metraterm, but considered all these structures to constitute the uterus.

Dubois (1930) described a new species, *C. phalacrocoracis* from *Phalacrocorax levaillanti* in Angola. In this species the cirrus sac is also situated in the intertesticular space with the genital opening ventral to the posterior half of the anterior testis. Baer (1933) pointed out that if Lamont (1920) figured the junction of the uterus to the uterine sac correctly, then *C. intermedialis* should be placed into an independent genus. He (Baer, op. cit.) based his argument on the (for the genus) unusual junction of the uterus with the proximal part of the uterine sac. In all the species of the genus *Clinostomum* the uterus joins the uterine sac somewhere anterior to its proximal part.

Price (1938) gave a redescription of *C. intermedialis* Lamont, 1920. Price (op. cit.) clearly distinguished between the anatomical entities - uterus, uterine sac and metraterm and remarks as follows:

> *A restudy of the type specimen shows that instead of the uterus making 'two longitudinal loops' as stated by Lamont, the nature of this structure is similar to other species of the genus. The ascending limb of the uterus, however, is quite long and joins the stem of the uterus far anteriad as in* ***Clinostomum chrysichthys*** *Dubois, 1930.* ***C. intermedialis*** *may be distinguished from the latter species in having a cirrus pouch almost entirely posterior to the anterior testis instead of in the zone of that organ as in* ***C. chrysichthys****. The only other species with which* ***C. intermedialis*** *may be confused is* ***C. phalacrocoracis*** *Dubois, 1930, but in the latter species the ascending limb of the uterus joins the uterine stem near its base instead of far anterior as in the former.*

The last remark of Price (1938) as quoted above, is quite significant in the correct systematic designation of *C. intermedialis* and *C. phalacrocoracis*. This aspect will be enumerated on in the ensuing discussion.

Ukoli (1966a) recorded *C. phalacrocoracis* from the buccal cavity of *Anhinga rufa rufa* (= *A. melanogaster*) from Accra, Ghana. This author noted the following relevant morphological characteristics:

- Uterus opening into the uterine sac near its base in front of the anterior testis;

- Cirrus sac and genital pore occupying the intertesticular space rather than being anterior to the anterior testis.

Feizullaev and Mirzoeva (1983), in their revision of the systematics of the family Clinostomidae, followed the suggestion of Baer (1933) and placed *C. intermedialis* Lamont, 1920 in an independent genus, namely, *Neutraclinostomum* with the following justification for the generic separation:

- The morphological features of *C. intermedialis* are typical of the genus *Clinostomum* except for the point of junction of the uterus with the uterine sac and the position of the cirrus and genital pore in the intertesticular space;
- The foregoing two characteristics are typical of the genera *Euclinostomum* and *Tumaclinostomum*;
- *C. intermedialis*, however, does not fit into either of the latter genera because of the shape of the alimentary canal which is typical of *Clinostomum* and very atypical of the highly diverticulated intestinal caecae of *Tumaclinostomum* and *Euclinostomum*.

In their taxonomic revision Feizullaev and Mirzoeva (1983) synonymised *C. phalacrocoracis* with *N. intermedialis*. Their genus *Neutraclinostomum*, therefore, contains only one species, namely, *N. intermedialis* (Lamont, 1920) new combination.

Synonym:	*C. phalacrocoracis* Dubois, 1930
Host :	*Anhinga melanogaster*

During the present study on the helminth parasites of piscivorous birds in the Northern Province of South Africa, a second clinostomatid species was recovered from the buccal cavity and oesophagus of *A. melanogaster*. This parasite was, on superficial examination, considered different from *C. complanatum* recovered from the same host as well as from *P. carbo, P. africanus* and *A. cinerea*. During autopsy at the field laboratory the two species were temporarily separated on macromorphological detail only.

Subsequent microtechnical analysis revealed that *A. melanogaster* does indeed play host to two different clinostomatid species. The one species was positively identified as *C. complanatum* (Rudolphi, 1819) Braun, 1899 (see pp.75-84), while the second species was assigned to *Neutraclinostomum intermedialis* (Lamont, 1920).

Britz (1983) and Britz, Saayman and Van As (1984a) recovered metacercariae from the gill chambers of *Oreochromis mossambicus* (Peters, 1852) from various water bodies in the Northern Province and assigned these parasites to *C. tilapiae* (Ukoli, 1966a). Britz (1983) also recovered two distinct species of clinostomes from the oesophagus and buccal cavity of a single specimen of *A. melanogaster* from the Luphephe/Nwanedzi Impoundments, Northern Province, which she identified as *C. complanatum* (= *C. vanderhorsti*) and *C. tilapiae*. The same author also used experimentally raised adults from *Ardea cinerea* which were also designated as *C. tilapiae*. In this experimental infection which was performed by Saayman (Personal Communication), metacercariae from the gill chambers of *O. mossambicus* were used.

The present study re-examined material used by Britz (1983) and Britz et. al. (1984a) and came to the conclusion that what these authors described as *C. tilapiae* is in fact *N. intermedialis* (Lamont, 1920). Four, and possibly five, reasons prompted this:

- The location and the shape of the testes;
- The position of the cirrus sac and the genital pore in the intertesticular space;
- The extent of the vitellaria;
- The junction of the uterus with the uterine sac at its proximal end;
- The relative size of the metacercariae and adults compared to *C. complanatum*.

The material used by Britz (1983) and Britz et. al. (1984a) could therefore not belong to the genus *Clinostomum* if the diagnostic characteristics as proposed by Feizullaev and Mirzoeva (1983) are employed.

The *C. tilapiae* parasites described by Ukoli (1966a) from the gill chambers of *Tilapia zilli, T. heudeloti* and *T. galilaea* intermediate hosts and *B. ibis* (experimental), *N. nycticorax* and *A. melanogaster* (natural infections), have since been synonymised with *C. complanatum* by Feizullaev and Mirzoeva (1983).

In discussing Table 13, p.88 it should be noted that *A. melanogaster* registers prevalence statistics for *N. intermedialis* of 50 - 100% for almost all the water bodies from which hosts have been procured. For two aquatic ecosystems, namely, Piet Gouws Dam and Middle Letaba Impoundment, the intensity and mean intensity figures for infection were also relatively high.

Table 13: Prevalence, intensity and mean intensity values for infection of *Anhinga melanogaster* with *Neutraclinostomum intermedialis* in the Northern Province of South Africa.

WATER BODY	N.	PREVALENCE %	INTENSITY	MEAN INTENSITY
Seshego Dam	24	88	1 - 11	6
Piet Gouws Dam	6	100	10 - 35	19
Luphephe Dam	2	50	2	2
Hudson Ntsanwisi Dam	11	100	1 - 31	8
Middle Letaba Impoundment	12	75	7 - 72	35
Tzaneen Dam	1	-	-	-
Olifants River	4	100	8 - 15	11
Glen Alpine Dam	4	75	2 - 5	4

The above high infection values for *N. intermedialis* must be read together with the infection statistics of this host with *C. complanatum* (Table 11, p.76). In comparing the two tables the following becomes evident:

- *A. melanogaster* hosts resident at aquatic ecosystems in the Northern Province carry a very high burden of clinostomatid parasites. The worm burden of this host becomes even more aggravated if it is considered that it also carries very heavy loads of *Contracaecum* parasites (Tables 40 and 41, p.185). In the light of these statistics, and considering also that *A. melanogaster* is the numerical dominant piscivorous avian species at water bodies in the Northern Province, the role of this bird in the transmission of the numerically dominant parasites of freshwater fish in the region cannot be overemphasised. Clinostome and *Contracaecum* parasites of freshwater fish, due to their relatively large size and obvious locations, are the major fish parasites that could, and do, cause market resistance to freshwater fish marketing enterprises. *A. melanogaster*, therefore, must surely be regarded as a major ecological factor in the economy of piscicultural enterprises in the subtropical regions of South Africa in particular, and Africa in general. Unabated conservation policies for these birds on public waterways and major aquatic ecosystems would not be ecologically founded if their role in the transmission of major freshwater fish parasites did not form part of the overall scenario.

The reason why the Piet Gouws Dam and Middle Letaba populations of *A. melanogaster* register higher infection values with *N. intermedialis* can be explained by taking the following into account:

- The predominant intermediate fish host for *N. intermedialis* in the Northern Province of South Africa is *Oreochromis mossambicus* (Table 14 below);
- At Piet Gouws Dam a fish population study clearly showed *O. mossambicus* to be the numericlly dominant fish species in the impoundment comprising 83.6% numerically and 69.0% of the total estimated fish biomass (Schoonbee et. al., 1995);
- At Middle Letaba Impoundment the studies of Van Senus (1989) also indicated *O. mossambicus* to be the numerically dominant fish species in the impoundment.

In conclusion it can be said that the life history requirements of *N. intermedialis* are very well established in the Northern Province of South Africa where two of the major role players occupy numerical dominant positions in their respective ecological niches.

Table 14: Comparison of Prevalence, Intensity and Mean intensity values for *Neutraclinostomum intermedialis* infections of *Oreochromis mossambicus* in major water bodies in the Northern Province of South Africa. After Saayman and Schoonbee et. al., 1991.

WATER BODY	N.	PREVALENCE %	INTENSITY	MEAN INTENSITY
Seshego Dam	35	38.0	1 - 5	3.0
Turfloop Dam	23	-	-	-
Piet Gouws Dam	59	35.6	1 - 14	2.84
Tompi Seleka Fish Station	25	64.0	1 - 2	1.50
Nile Flood Pans	58	62.1	1 - 13	3.46
Glen Alpine Dam	89	14.6	1 - 6	2.0
Luphephe/Nwanedzi Impoundments	114	28.9	1 - 6	2.11
Nzhelele Dam	15	7.0	1 -	1.0
Middle Letaba Impoundment	177	48.0	1 - 21	4.40

FIG. 21

NEUTRACLINOSTOMUM INTERMEDIALIS

Graphic reconstruction of the alimentary canal

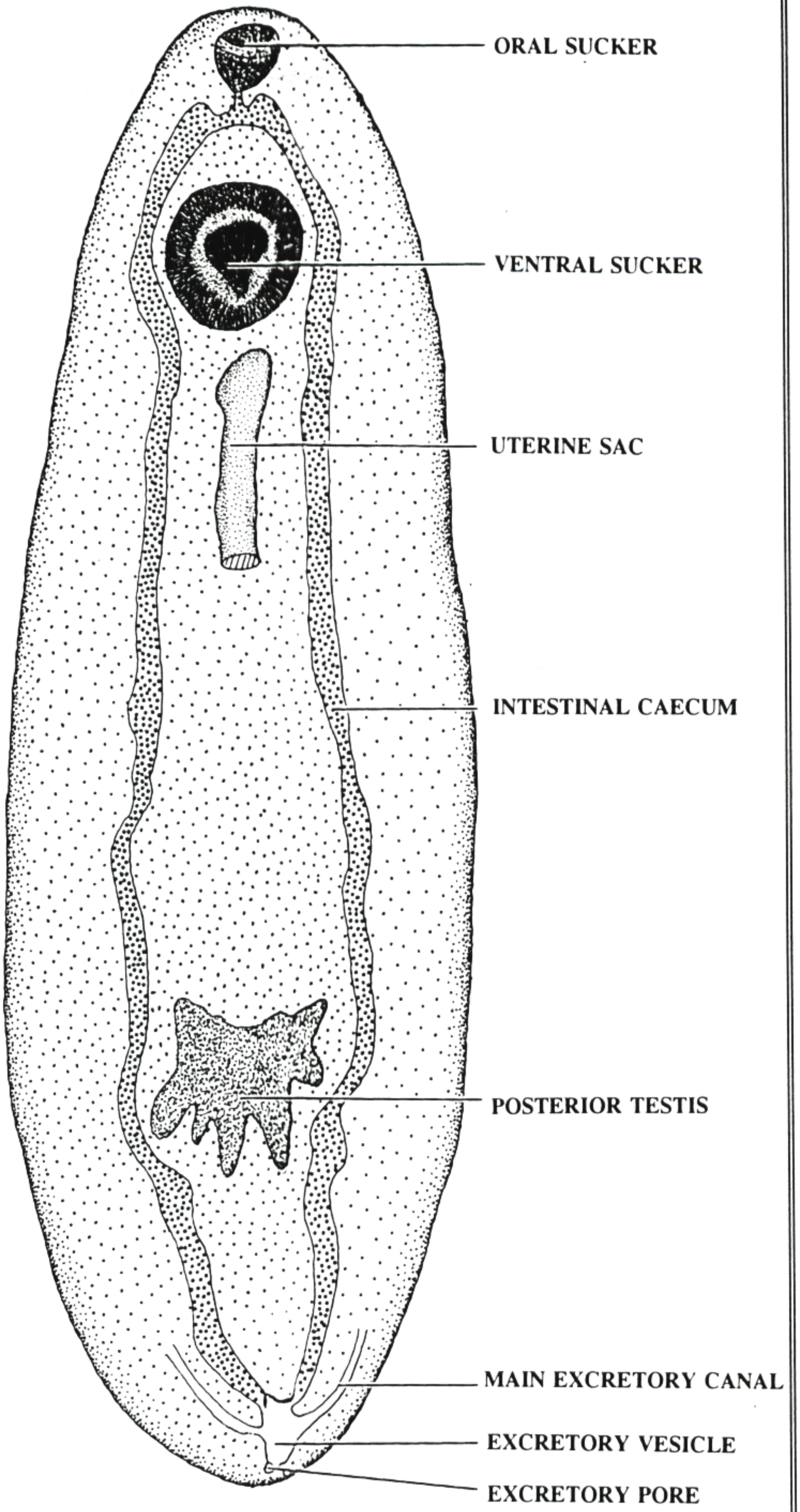

ORAL SUCKER
VENTRAL SUCKER
UTERINE SAC
INTESTINAL CAECUM
POSTERIOR TESTIS
MAIN EXCRETORY CANAL
EXCRETORY VESICLE
EXCRETORY PORE

FIG. 22

NEUTRACLINOSTOMUM INTERMEDIALIS

Graphic reconstruction illustrating topography of reproductive organs and extent of vitellaria
Refer also Fig. 20

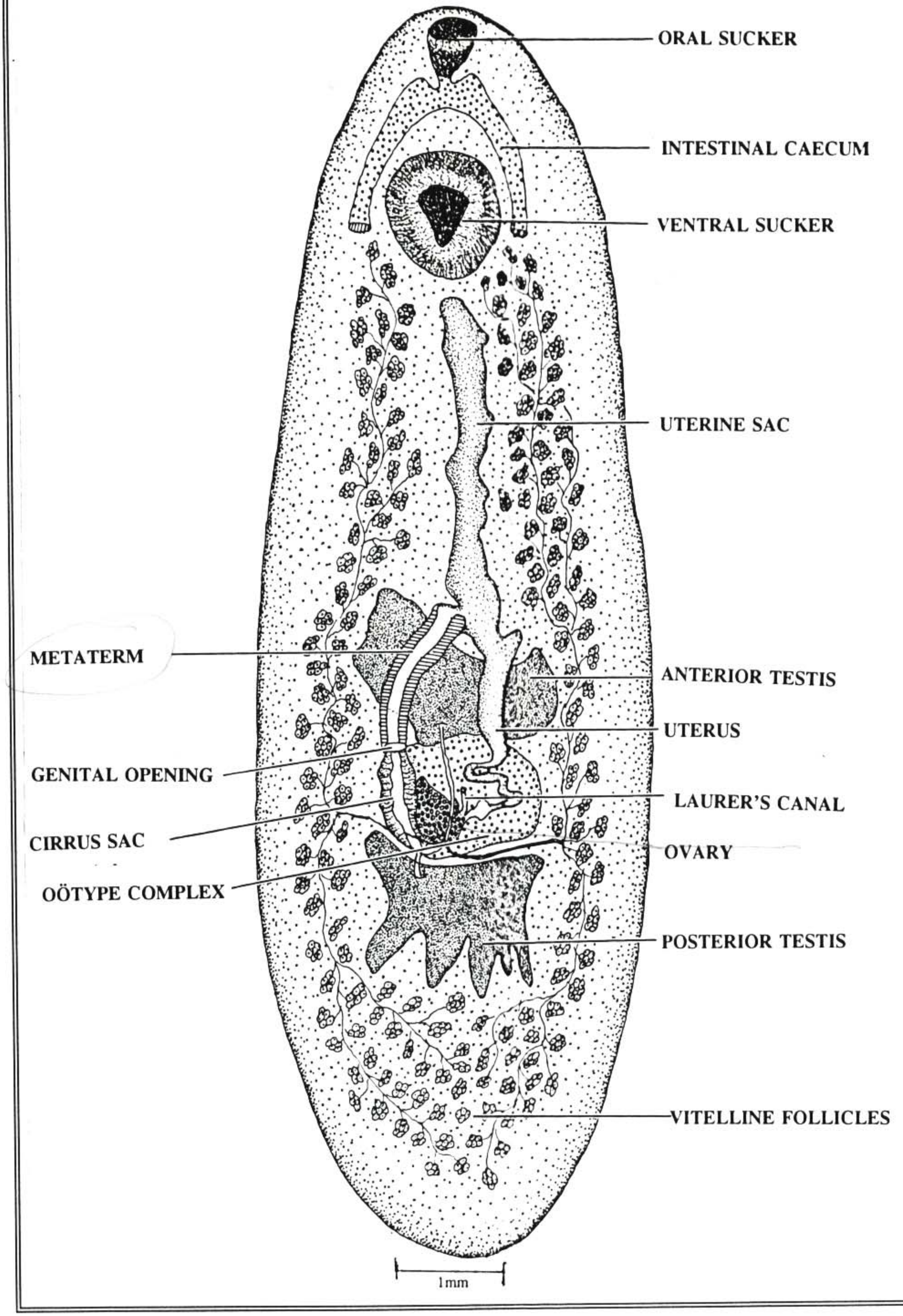

ORAL SUCKER
INTESTINAL CAECUM
VENTRAL SUCKER
UTERINE SAC
METATERM
ANTERIOR TESTIS
UTERUS
GENITAL OPENING
LAURER'S CANAL
CIRRUS SAC
OVARY
OÖTYPE COMPLEX
POSTERIOR TESTIS
VITELLINE FOLLICLES
1mm

FIG. 23

NEUTRACLINOSTOMUM INTERMEDIALIS

Diagrammatic representation of the reproductive system

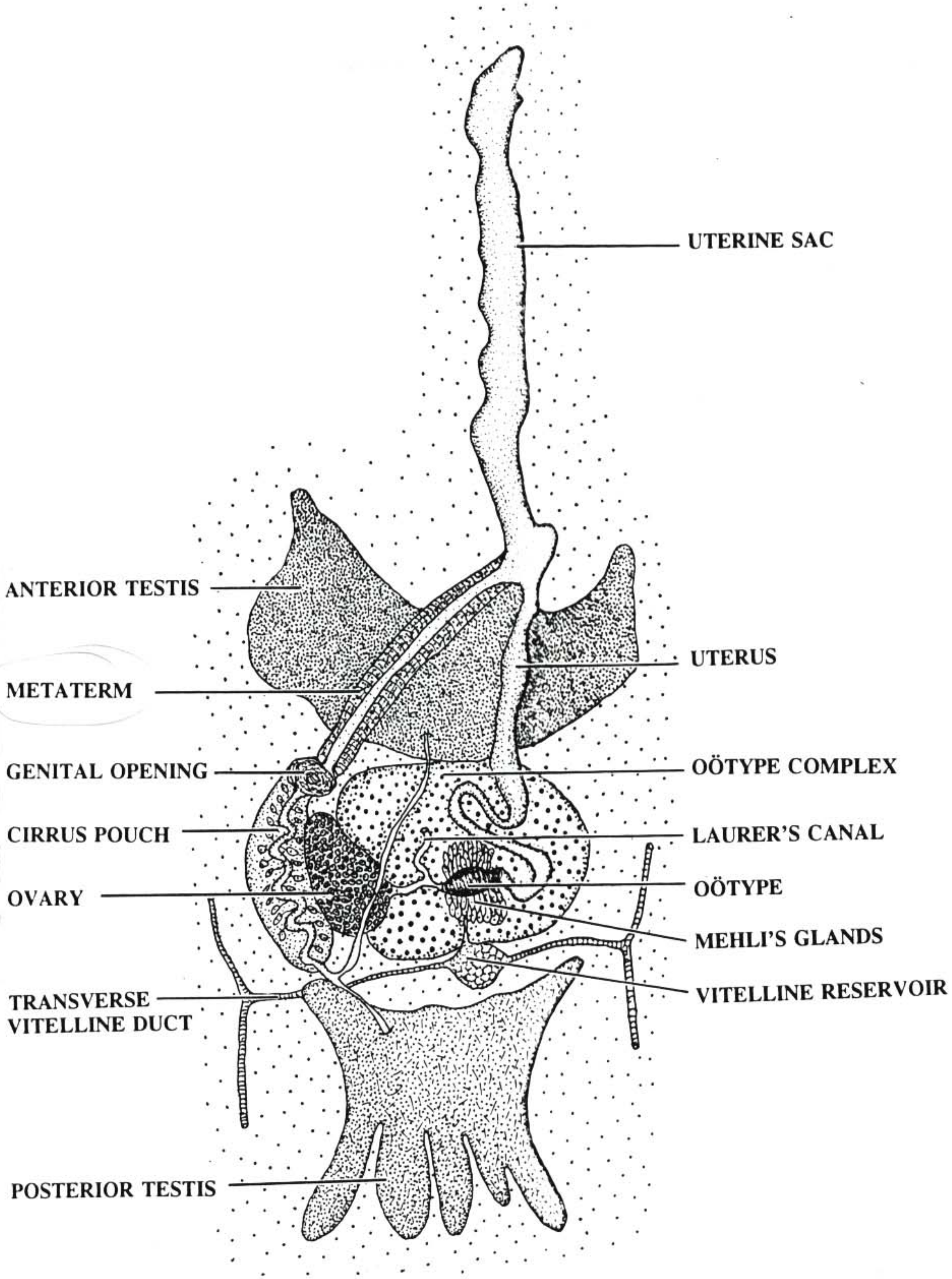

UTERINE SAC
ANTERIOR TESTIS
UTERUS
METATERM
GENITAL OPENING
OÖTYPE COMPLEX
CIRRUS POUCH
LAURER'S CANAL
OVARY
OÖTYPE
MEHLI'S GLANDS
VITELLINE RESERVOIR
TRANSVERSE VITELLINE DUCT
POSTERIOR TESTIS

FIG. 24

NEUTRACLINOSTOMUM INTERMEDIALIS
(Light Microscopy)

A. *Egg laying adult raised experimentally in Ardea cinerea x 12*

B. *Uterus full of eggs occupying entire space between ventral sucker and anterior testis x 12*

C. *Metacercaria showing extent of digitation of posterior testis x 12*

Key:

e. - eggs

pt. - posterior testis

ut. - uterus

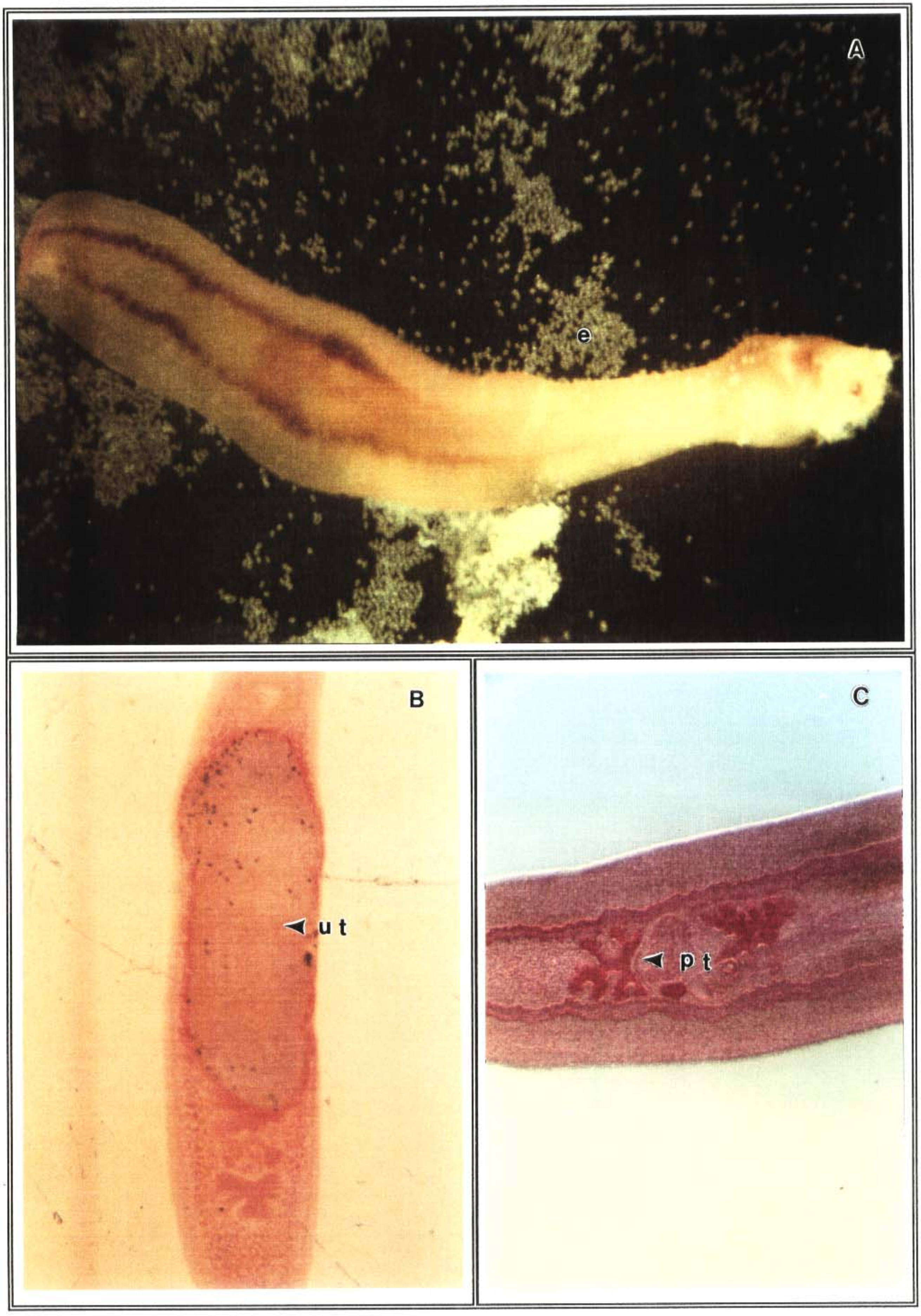

A
e
B
ut
C
pt

FIG. 25.

NEUTRACLINOSTOMUM INTERMEDIALIS
(Scanning Electron Microscopy)

A. *Anterior end of the body showing ventral sucker and anterior sucker*

B. *Papillae on the ventral surface of the body*

C. *Dorsal surface showing Laurer's canal and excretory pore*

D. *Dorsal surface without papillae*

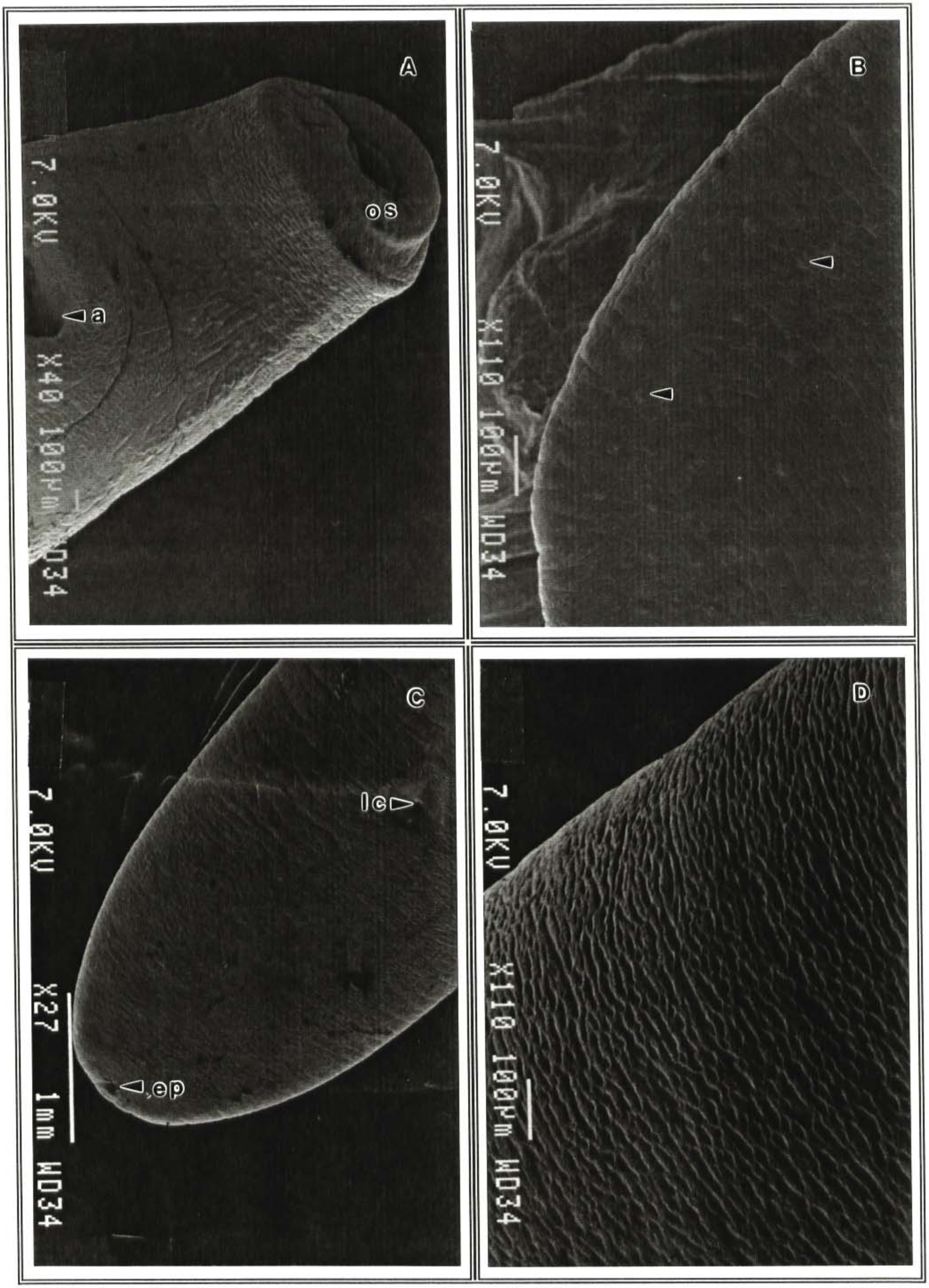
Key:

a. - ventral sucker

ep. - excretory pore

lc. - Laurer's canal

os. - oral sucker


A
os
a
7.0KV X40 100µm WD34
B
7.0KV X110 100µm WD34
C
lc
ep
7.0KV X27 1mm WD34
D
7.0KV X110 100µm WD34

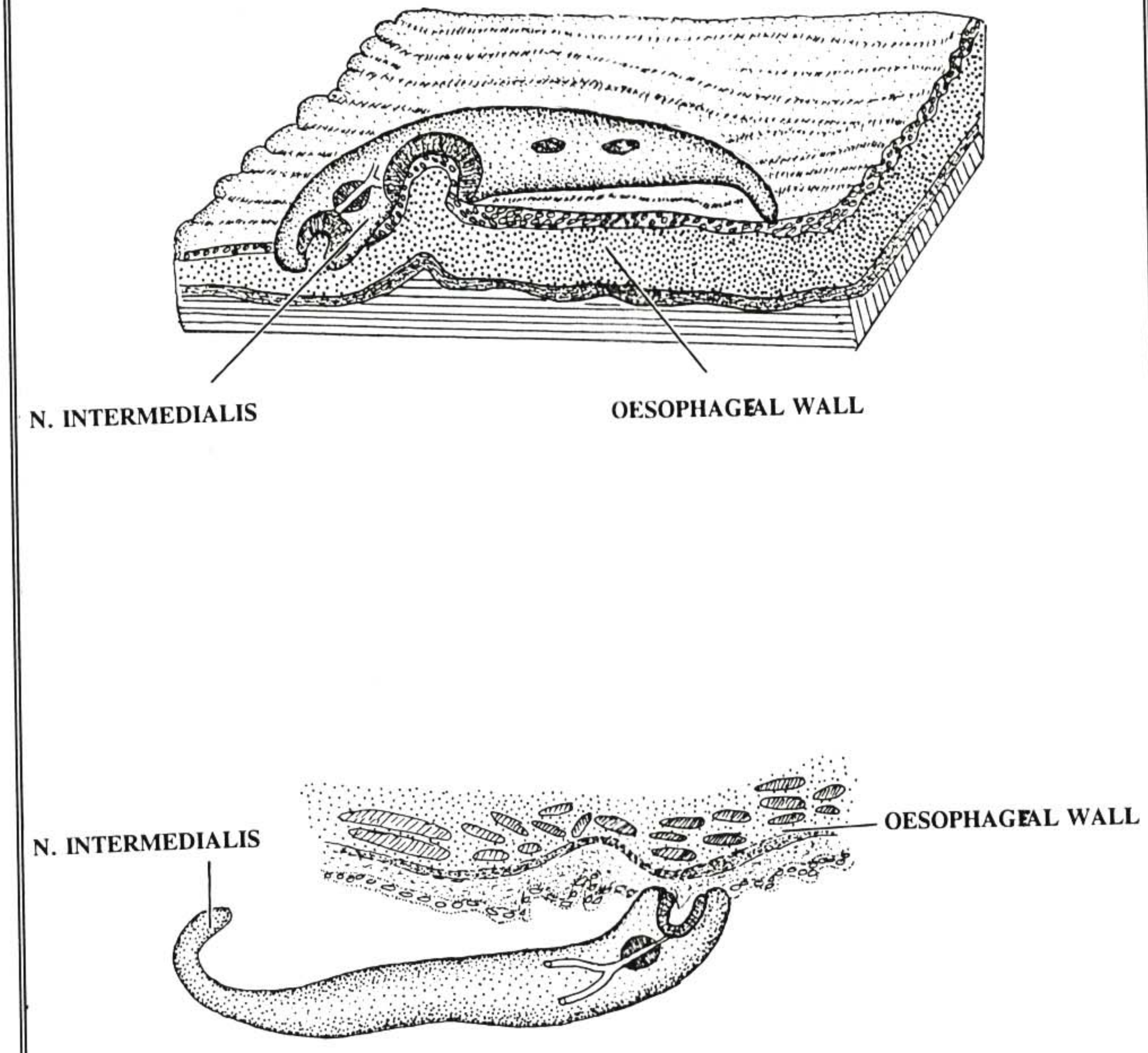


FIG. 26

NEUTRACLINOSTOMUM INTERMEDIALIS

Diagrammatic representation of the method of attachment
(After Ukoli, 1970)

The results of the present investigation indicate that *N. intermedialis* appears to be very host specific in its occurrence in the northern regions of South Africa. In its adult stage it only parasitises *A. melanogaster*, whereas the identified metacercarium is by and large restricted to *O. mossambicus*. In Ghana, Ukoli, (1966a) also found *A. melanogaster* infected, while Dubois, (1930) described his material from *Phalacrocorax levaillanti* from Angola. Lamont (1920), who described this species for the first time, used specimens obtained from *P. virgua* Vieillot from Lake Valencia, Venezuela.

Host specificity, especially if it includes both the second intermediate as well as final host, may on a comparative basis, be regarded as somewhat of a limiting factor. Judging from the infrapopulation status of *N. intermedialis* in the study area this is not necessarily the case for the Northern Province of South Africa. *O. mossambicus*, as well as *A. melanogaster*, are widespread in the region and both occupy numerically dominant positions in their respective ecological niches. In addition, the prevalence and mean intensity levels of infection for both the metacercarial and the adult stages of the parasite are relatively high for the majority of the aquatic ecosystems investigated (Table 13, p.88 and Table 14, p.89).

In comparing Table 13, p.88 and Table 14, p.89 it becomes clear that the intensity and mean intensity figures of infection for Middle Letaba Impoundment are significantly higher than those obtained for fish and avian hosts at the other aquatic ecosystems investigated. *O. mossambicus* occupies the numerically dominant position in this impoundment, whereas *A. melanogaster* is by far the numerically dominant piscivorous bird at Middle Letaba Impoundment. These facts tend to indicate that the *O. mossambicus* population of the latter impoundment would still be under severe pressure of infection with *N. intermedialis* at least so for the foreseeable future.

Genus: *Euclinostomum* Travassos, 1928
E. heterostomum (Rudolphi, 1809)

This parasite was first described by Rudolphi in 1809 as *Distoma heterostomum* with *Ardea purpurea* from Genoa, Italy as host. Travassos (1928) created the genus *Euclinostomum* to distinguish it from the genus *Clinostomum* on account of the highly diverticulated intestinal caecal (Fig.26, p.106).

Yamaguti (1958) established the subfamily Euclinostominae for the reception of *Euclinostomum* as its genus. In their taxonomic revision of the family Clinostomidae Lühe, 1901, Feizullaev and Mirzoeva (1983) did not recognise the subfamily Euclinostominae Yamaguti, 1958, but included *Euclinostomum* under the subfamily Clinostominae Lühe, 1901.

Keys for the identification of known metacercariae and adults of *Euclinostomum* have been designed by Jaiswal (1957); Agarwal (1958); Fischthal and Kuntz (1963) and Gupta and Jehan (1977).

During the second half of this century various authors discussed the validity and/or synonymy of described forms of the genus (Van de Kuyp, 1953; Singh, 1959; Ukoli, 1966c; Pandey and Baugh, 1970; Rai, 1970; Dennis and Sharp, 1973; Dönges, 1974; Gupta and Jehan, 1977; Feizullaev and Mirzoeva, 1983). Ukoli (1966c), for example proposed that only two species be recognised for the genus *Euclinostomum*, namely:

1. *E. heterostomum* (Rudolphi, 1809)
   (= *E. clarias* Dubois, 1930; *E. indicum* Bhalerao, 1942;
   E. bhagavantami Jaiswal, 1957; *E. channai* Jaiswal, 1957;
   E. heptacaecum Jaiswal, 1957);

2. *E. multicaecum* Tabangui and Masilungan, 1935.

Feizullaev and Mirzoeva (1983) in their revision of the Clinostomatidae synonymised all the described forms of *Euclinostomum* with *E. heterostomum* (Rudolphi, 1809), except for *E. multicaecum* for which the genus *Tumaclinostomum* Van der Kuyp, 1953 is retained.

The list of synonyms of *E. heterostomum* (Rudolphi, 1809) as proposed by Feizullaev and Mirzoeva (1983) is as follows:

Clinostomum africanum Galli-Valerio, 1906;
E. indicum Bhalerao, 1942;
E. skryabini Kuraschwili, 1948;
E. channai Jaiswal, 1957;
E. heptacaecum Jaiswal, 1957;
E. vanderkuypi Fischthal and Kuntz, 1963;
E. dolfusi Fischthal and Kuntz, 1963.

The genus *Euclinostomum* has a very wide geographical distribution. Britz (1983) summarised the existing literature and listed the following countries:

> Canada, Italy, Poland, Russia, Africa (various countries - see Table 15 below), Israel, Turkestan, India, Indo-China, Celebes, Philippines.

Noteworthy is that no records are available for the regions of the United States of America, South America and Australasia where *Clinostomum* spp. have been recorded.

Table 15: Geographical- and host distribution of *Euclinostomum heterostomum* (Rudolphi, 1809) in Africa, as summarised from existing literature.

COUNTRY	FISH HOST	AVIAN HOST	LITERATURE REFERENCE
South Africa (Orange Free State)	Unidentified	-	Mönnig (1926)
South Africa (Transvaal)	*O. mossambicus*	-	Lombard (1968)
	T. rendalli	-	Lombard (1968)
	C. gariepinus	-	Mashego (1977)
	C. gariepinus	*A. cinerea*	Prudhoe and Hussey (1977)
	O. mossambicus	*A. cinerea*	Prudhoe and Hussey (1977)
	O. mossambicus	*A. cinerea*	Britz (1983)
	O. mossambicus	-	Britz, Saayman and Van As (1985)
	O. mossambicus	-	Saayman & Schoonbee et. al. (1991)
Zimbabwe	-	*Scopus umbretta*	Prudhoe and Hussey (1977)
Malawi	*O. mossambicus*	-	Paperna (1980)
Angola	*C. angolensis* (= *C. gariepinus*)	-	Dubois (1930)
Congo	-	*A. goliath*	Dolfus (1950)
Ghana	*T. zilli and T heudeloti*	*Anhinga melanogaster and P. africanus*	Ukoli (1966c)
	T. zilli and T. heudeloti	-	Fischthal and Thomas (1970
Uganda	*Macropleurodus bicolor and Haplochromis* sp.	-	Khalil and Thurston (1973)
Algeria	-	*Ardeola valloides*	Dolfus (1932)
Gabon	*Clarias* sp.	-	Manter & Pritchard (1969)
Liberia	-	*Bubulcus ibis*	Dennis and Sharp (1973)
Egypt	*Clarias* sp. and *T. zilli*	-	Fischthal and Kuntz (1963)
Egypt	-	*A. goliath*	El-Naffar, Khalifa and Sakla (1980)

From the preceding distributional records it is clear that *E. heterostomum* is a trematode species that is remarkable for its wide geographical distribution throughout the old world where both metacercariae and adults were found. In the Northern Hemipshere countries, adult specimens were mostly recorded with the exception of Poland where both adult and metacercarial forms were recorded (Grabda and Grabda, 1954; Grabda-Kazubska, 1974). It should be noted that the latter records were from an aquatic ecosystem which received heated water runoff from a large power station.

Since Ardeiformes, which can serve as final hosts, are birds with a long migratory range, *E. heterostomum* adults can easily be carried from southern countries to the Northern Hemisphere regions. The occasional find of an adult *E. heterostomum* in Northern or Eastern Europe and Canada need not prove that the whole life history can be completed in these regions (Dönges, 1974). In conclusion, it would appear that the genus *Euclinostomum*, like *Clinostomum* (p.67) shows clear affinities for the warmer tropical and subtropical zones.

Members of the family Ardeidae seem to be the preferred final hosts for this genus (Rudolphi, 1809; Von Linstow, 1866; MacCullum, 1899; Dollfus, 1932, 1950; Kurashvili, 1948; Srivastava, 1950; Van der Kuyp, 1953; Shigin, 1954; Jaiswal, 1957; Agarwal, 1959; Dennis and Sharp, 1973; El-Naffar, et. al., 1980 and Britz, et. al., 1985). Other piscivorous birds may also act as final hosts (Ukoli, 1966c; Prudhoe and Hussey, 1977 and the present study).

The morphology of *E. heterostomum* was described in rather complete detail by Van der Kuyp (1953); Agarwal (1958); Mashego (1977); Britz (1983) and Britz, Van As and Saayman (1984b). Less detailed morphological descriptions were also provided by Tabangui and Masilungan (1935); Bhalerao (1942); Grabda-Kazubska (1974); Gupta and Jehan (1977); El-Naffar, et. al., (1980) and Mashego and Saayman (1989).

NOTES ON THE MORPHOLOGY OF *E. heterostomum*

Over the last century various authors contributed to our knowledge of the morphology of *E. heterostomum* (see above for literature references). The most complete and detailed descriptions are those of Mashego (1977); Britz, 1983 and Britz et. al., 1984b. Metacercarial and sexually matured adults obtained during the present study agree very closely with the descriptions mentioned earlier. It was therefore deemed unnecessary to provide a full morphological description of the present material.

The authors mentioned above do however disagree on certain anatomical aspects eg.:

- Position of excretory pore;
- Anatomical designations for the precaecal part of the alimentary canal;
- Presence or absence of a distinct pharynx;
- Exact location of junction of vasa efferentia to form vas deferens;
- The topography of the structures contained within the oötype complex.

All of these aspects will be discussed below and illustrated with graphic reconstructions, photos and electron micrographs.

Position of excretory pore:

Most authors seem to agree that the excretory vesicle is Y or V shaped and that the excretory pore opens middorsally and at the very posterior end of the body (Van der Kuyp, 1953; Dennis and Sharp, 1973; Mashego, 1977; Britz, 1983 and Britz et. al., 1984b). Ukoli (1966c) described the excretory pore as being posterior and subterminal and illustrate it on the ventral surface. Specimens from the present study clearly indicate the position of the excretory pore to be terminal and in the mid-dorsal line.

Argawal (1958); Ukoli (1966c) and Dönges (1974) did not describe the excretory system in any great detail. The best descriptions of this system are from Mashego (1977); Britz (1983) and Britz et. al., (1984b). In the present material the excretory system with its network of collecting, recurrent and communicating vessels conforms to the description of the latter authors.

Anatomical designations for the precaecal part of the alimentary canal:

The presence or absence of a typical muscular pharynx in the genus *Euclinostomum* appears to be a matter of controversy. Various authors have given different names to the histologically distinguishable sections of the precaecal portion of the alimentary canal. These names have not always followed the rules of anatomical nomenclature and have therefore given rise to even greater confusion. Van der Kuyp (1953) and Ukoli (1966c) described a rudimentary pharynx which is followed by an oesophagus opening into the intestinal caeca. Argarwal (1958), on the other hand, describes a prepharynx followed by *thickly muscular and conspicuous pharynx* which opens directly into the intestinal caeca. According to this author an oesophagus seems to be absent. Similarly Dubois (1930) noted a typical trematodan pharynx in his metacercarial material, an observation shared by authors such as Bhalerao (1942); Dollfus (1950) and Fischthal and Kuntz (1963). Jaiswal (1957); Mashego (1977), Britz (1983) and Brits, et. al., (1984b) described their material to be apharyngeal and considered the entire precaecal tube to constitute an oesophagus. Grabda-Kazubska (1974) described a short oesophagus following the oral sucker *with thick muscular wall forming a bulb-like structure at its base.*

Dönges (1974) examined histological sections in order to elucidate the structure of this part of the alimentary canal and found *little histological similarity to the pharynx structure of other trematodan families*. Dönges (op. cit.) proposed that this part of the alimentary canal of *Euclinostomum* be called a pharyngeal organ whose function is probably *that of a valve to retain the parasite's caecal contents.*

Examination of serial sections from *Euclinostomum heterostomum* from southern Africa reveals a definite absence of pronounced muscular layers in the wall of any part of the precaecal portion of the alimentary canal. This is in agreement with the descriptions of Jaiswal (1957); Mashego (1977); Britz (1983) and Britz et. al. (1984b). The proposal of Dönges (1974) to call the anterior portion of the alimentary canal of *Euclinostomum* a pharyngeal organ is accepted for the present study.

The location of junction of vasa efferentia to form the vas deferens:

Mashego (1977); Britz (1983) and Britz et. al. (1984b) found the junction of the vasa efferentia to form the vas deferens to be located immediately on the inside of the cirrus sac, i.e., after entering the cirrus sac as separate tubes. Dennis and Sharp (1973) located the junction of the vasa efferentia to be on the outside of the cirrus sac whereas authors like Van der Kuyp (1953); Jaiswal (1957); Agarwal (1958); Grabda-Kazubska (1974) and Gupta and Jehan (1977) do not mention the vasa efferentia. Material from the present study agrees with the descriptions of Mashego (1977); Britz (1983) and Britz et. al. (1984b).

Topography of structures contained within oötype complex:

Mashego (1977) described the oötype complex as distinctly separated from the parenchyma by a membraneous connective tissue capsule. This capsule surrounds the oviduct, seminal receptacle, yolk receptacle, oötype, Mehli's glands and the proximal portion of the uterus as well as the distal part of Laurer's canal. (Fig.28, p.107). Britz (1983) and Britz et. al. (1984b) in their studies on *Euclinostomum* material agree with the description of Mashego (1977). Other authors such as Van der Kuyp (1953); Jaiswal (1957); Agarwal (1958); Ukoli (1966c); Dennis and Sharp (1973); Dönges (1974) and Grabda-Kazubska (1974) do not discuss the topography of the oötype complex, neither do they provide detailed anatomical descriptions of the structures contained within the oötype complex.

Material from the present study agree in every detail with the anatomical descriptions of the oötype complex provided by Mashego (1977); Britz (1983) and Britz et. al. (1984b).

The material procured from avian hosts during the present study as well as material from concurrent surveys on *Euclinostomum* infections of freshwater fish species in the Northern Province (Saayman and Schoonbee et. al., 1991) are assigned to *E. heterostomum* (Rudolphi, 1809).

The present investigation found six piscivorous bird species to act as hosts for *E. heterostomum* in the Northern Province of South Africa. These hosts are:

Phalacrocorax carbo
P. africanus
Anhinga melanogaster
Ardea cinerea
A. melanocephala
A. purpurea

Table 16: Infection statistics of piscivorous avian hosts with sexually mature *Euclinostomum heterostomum* in the Northern Province of South Africa

AVIAN HOST	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
Phalacrocorax carbo	39	Seshego Dam	64	1 - 8	3
	8	Middle Letaba Impoundment	88	1 - 21	7
	2	Piet Gouws Dam	100	8 - 11	10
	2	Glen Alpine Dam	100	2 - 6	4
	1	Ebenhaezer Dam	100	2	2
P. africanus	44	Seshego Dam	14	1 - 5	2
	9	Middle Letaba Impoundment	22	1 - 10	6
	3	Hudson Ntsanwisi Dam	67	1	1
	1	Turfloop Dam	-	-	-
	2	Olifants River	-	-	-
Anhinga melanogaster	24	Seshego Dam	25	1 - 4	2
	12	Middle Letaba Impoundment	42	1 - 11	4
	11	Hudson Ntsanwisi Dam	27	1 - 3	2
	2	Luphephe Dam	50	3	3
	6	Piet Gouws Dam	17	2	2
	4	Glen Alpine Dam	-	-	-
	1	Tzaneen Dam	-	-	-
	4	Olifants River	25	3	3
Ardea cinerea	3	Middle Letaba Impoundment	100	4 - 6	5
A. melanocephala	5	Middle Letaba Impoundment	100	1 - 8	5
A. purpurea	2	Middle Letaba Impoundment	50	1	1
--------------------	--------	------------------------	--------------------	-----------------	-----------------
Egretta garzetta	2	Middle Letaba Impoundment	-	-	-
Bubulcus ibis	7	" "	-	-	-
Nycticorax nycticorax	3	" "	-	-	-
Butorides striatus	2	" "	-	-	-
Ixobrychus minutus	1	" "	-	-	-

From infection statistics obtained it is difficult to label any of these hosts as the predominant carrier of this parasite. The statistics contained in Table 16, p.102, do however indicate that *E. heterostomum* is widespread within the study area and that the ecological requirements for its life history must occur at most, if not all, of the major aquatic ecosystems within the region. This statement is substantiated by the work of Britz (1983), Britz et. al. (1985), Table 16, p.102 and Table 17 below.

During a multidisciplinary ecological study of Middle Letaba Impoundment, over seven successive seasons, Saayman and Schoonbee et. al. (1991) recorded two fish intermediate hosts for *E. heterostomum*, namely, *O. mossambicus* and *C. gariepinus*. Infection statistics for *E. heterostomum* parasites of these fish hosts are provided in Tables 17 below and 18, p.104.

Table 17: Infection statistics of *O. mossambicus* and *C. gariepinus* with metacercariae of *E. heterostomum* at Middle Letaba Impoundment, Northern Province, South Africa: After Saayman and Schoonbee et. al. (1991)

FISH HOST	N	PREVALENCE %	INTENSITY	MEAN INTENSITY
O. mossambicus	177	24.86	1 - 9	2.2
C. gariepinus	21	4.76	Only one host with four parasites	specimen infected with four metacercariae

From the preceding table it is evident that *O. mossambicus* acts as the principal intermediate host for *E. heterostomum* in Middle Letaba Impoundment. The same is also true for other aquatic ecosystems within the study area such as Glen Alpine Dam, Piet Gouws Dam, Seshego Dam, Nzhelele Dam, Luphephe and Nwanedzi Twin Impoundments, Nile River Swamps and Lepellane Dam (Britz et. al., 1985).

Mashego (1977) examined in excess of 10 000 specimens of *C. gariepinus* for *E. heterostomum* infections and found only two individuals to be infected with one parasite each. Britz et. al. (op. cit.) investigated 21 species of freshwater fish in the Northern regions of South Africa and found only *O. mossambicus* to be infected with metacercariae of *E. heterostomum*, while Saayman and Schoonbee et. al. (1991) reported on a single *E. heterostomum* in *Mesobola brevianalis* (Boulenger, 1908) from the present study area.

In the light of the above it must be concluded that *O. mossambicus* is the principal intermediate host for *E. heterostomum* in the subtropical regions of South Africa, and, that other freshwater fish hosts may, on occasion, act as reservoir hosts. This statement may be relevant also for the rest of Africa judging from the publications of Fischthal and Kuntz, 1963; Ukoli, 1966c; Lombard, 1968; Khalil and Thurston, 1973; Dönges, 1974; Prudhoe and Hussey, 1977; El-Nafar and Khalifa, 1981.

The piscivorous birds that act as final hosts for *E. heterostomum* (Table 16, p.102) are fish hunters and not scavengers and will normally not take large-sized prey fish. Britz (1983, p.227) found *small fish and fingerlings of O. mossambicus not to carry any clinostomatid infections*. This author drafted a hypothesis for such an occurrence on the following three possibilities:

- It may be possible that some small fish may become infected, but die as a result of the infection; a case of selective mortality of heavily infected smaller fish. This reason was also suggested by Paperna (1980) for the absence of clinostomatid infections in juvenile *Tilapia* spp. in Lake Victoria, Africa;
- In the likelihood that cercariae are carried in the circulatory system to the anatomical sites of infection, Britz (op. cit.) postulated that the blood vessels of smaller *O. mossambicus* may be too narrow to accommodate the body of the cercaria comfortably and, therefore, the absence of infection in fish of less than 5 cm total length;
- If small fish should carry clinostomatid metacercarial infections, piscivorous birds would carry an extremely high *parasitic load* as they eat mainly smaller fish and *piscivorous birds normally do not carry more than ten adult trematodes in the oesophagus* (p.228).

The above views of Britz (1983) and Paperna (1980) are not supported by the results obtained during the present study (Table 16, p.102 and Table 17, p.103) neither by the infection statistics of the *O. mossambicus* population of Middle Letaba Impoundment as provided by Saayman and Schoonbee et. al. (1991) - see Table 18 below:

Table 18: Analysis of *Euclinostomum heterostomum* infections of *Oreochromis mossambicus*: Middle Letaba Impoundment, Northern Province, South Africa: After Saayman and Schoonbee et. al., (1991).

PARAMETER	LENGTH GROUP OF *O. mossambicus* (cm)			
	<10	10 - 20	21 - 30	>30
Number examined	70	52	54	1
Number infected	7	14	22	1
Prevalence (%)	10	26.9	43.2	100
Intensity	1	1 - 9	1 - 8	1
Mean Intensity	1	2.6	2.2	1

From the above table it is evident that all the major length groups of *O. mossambicus* may become infected with *E. heterostomum*.

Although the highest levels for intensity and mean intensity were recorded for the 10 - 30 cm length groups, it should be remembered that the smaller length groups are numerically dominant in any normal fish population pyramid. In a fish population study on Piet Gouws Dam (Northern Province) Schoonbee et. al. (1995) found the 6 - 15 cm size group to constitute no less than 64% of the *O. mossambicus* population. If the 1 - 5 cm length classes could have been included in the above study the 1 - 15 cm size classes would probably have constituted in excess of 75% of the total population. It is this size class (1 - 15 cm) that is normally preyed upon by the identified piscivorous bird carriers of *N. intermedialis* and *E. heterostomum* parasites. For Ghana, Ukoli (1966b), also found species of *Tilapia* within the above size range to be infected with metacercariae of both *Neutraclinostomum* and *Euclinostomum*.

The foregoing factual information therefore suggests that the infrapopulation statistics in the size groups of prey fish normally consumed by avian carriers of *E. heterostomum* is ecologically well established in the study area.

The life cycle of clinostomatid parasites:

The life cycle of clinostomatid parasites (Fig.30) normally involves three different hosts:

A freshwater gastropod as first intermediate host
Metacercariae in fish intermediate hosts
A piscivorous bird as final host

A literature study reveals that the snail intermediate hosts for members of the genera *Clinostomum* and *Neutraclinostomum* have not been identified with any certainty in any territory in Africa. A similar situation exists for *Euclinostomum*, with the exception of a report by Dönges (1974) who, after carrying out various infection and rearing experiments, revealed that the snail intermediate host for *E. heterostomum* in West Nigeria, is *Bulinus (Physopsis) globosus*. Britz (1983) speculates that for South African aquatic ecosystems *Lymnaea natalensis* may act as the snail intermediate host for *C. complanatum* and *N. interme-dialis*, while *Melanoides tuberculata* occupies this position for *E. heterostomum*. On ecological grounds the role of *Bulinus B. tropicus* may however not be disregarded in this respect.

In Africa clinostomatid metacercariae have been reported from many fish families notably Mormyridae, Cyprinidae, Schilbeidae, Amphiliidae, Clariidae, Mochokidae and Cichlidae. Recorded final hosts for clinostomatid trematodes are herons (various species), cormorants, darters and pelicans (Paperna, 1980).

FIG. 27

EUCLINOSTOMUM HETEROSTOMUM

Graphic reconstruction illustrating the alimentary canal
(After Britz, 1983)

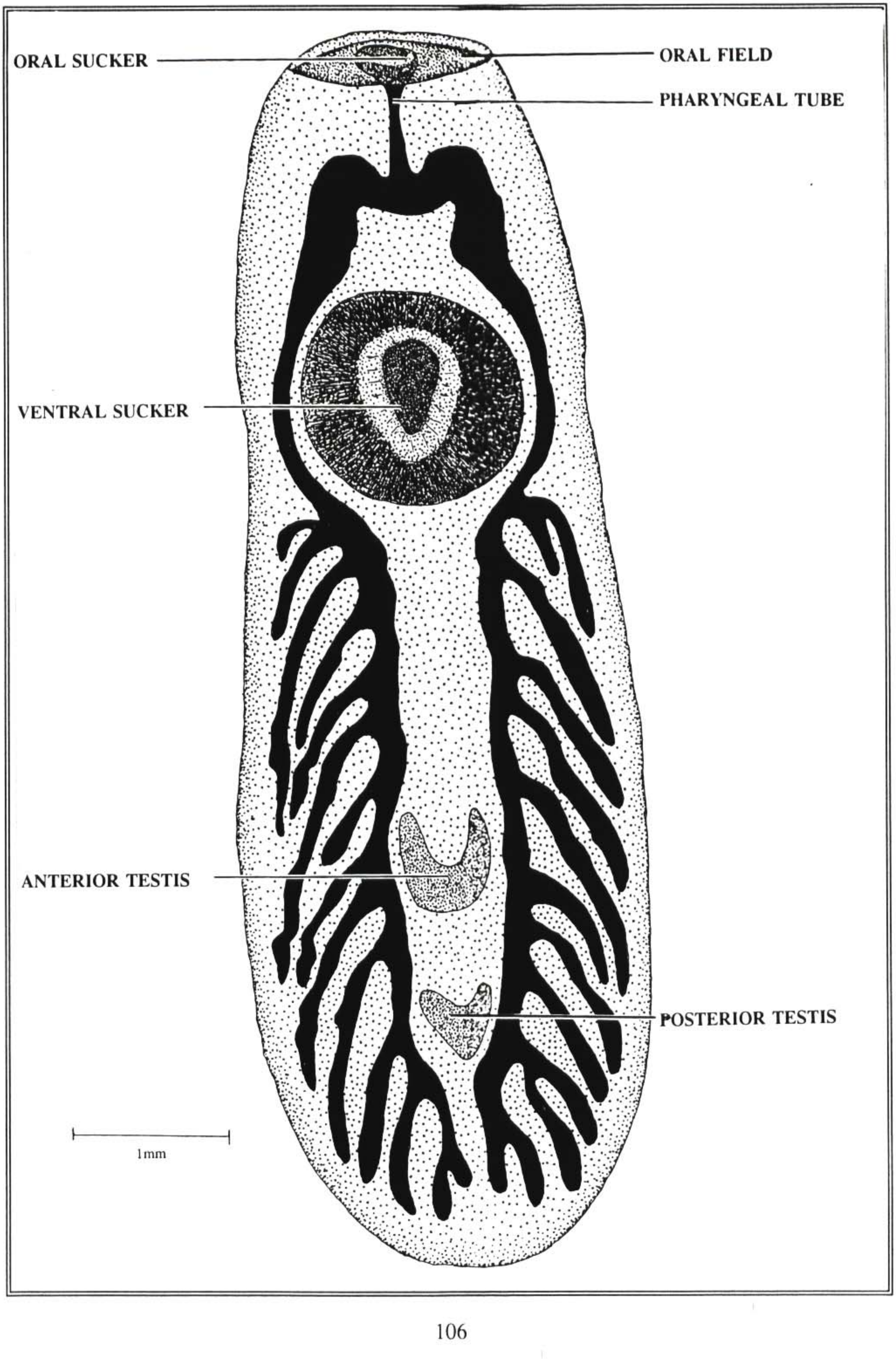

ORAL SUCKER
ORAL FIELD
PHARYNGEAL TUBE
VENTRAL SUCKER
ANTERIOR TESTIS
POSTERIOR TESTIS
1mm

FIG. 28

EUCLINOSTOMUM HETEROSTOMUM

Graphic reconstruction of the topography of the reproductive system

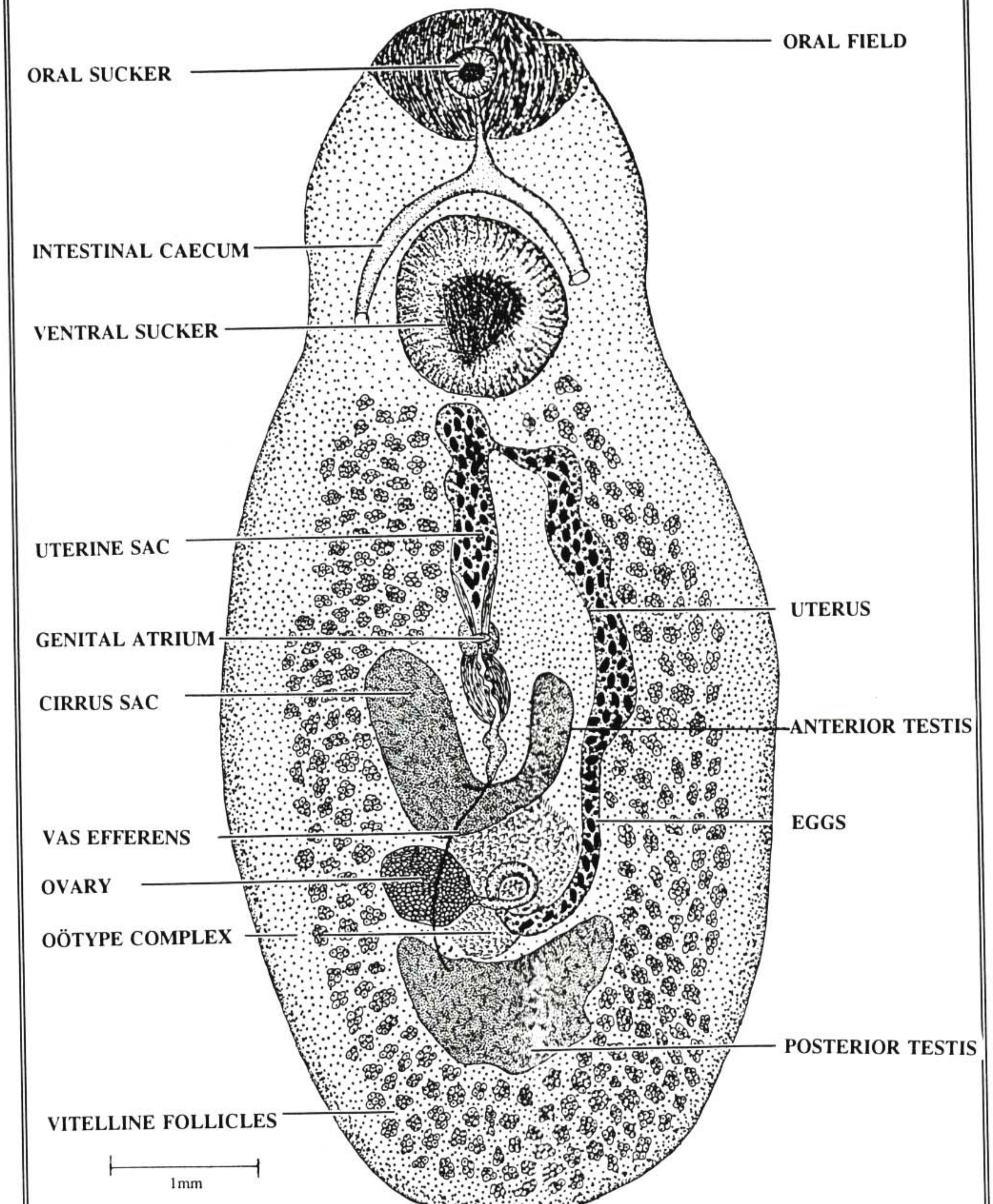
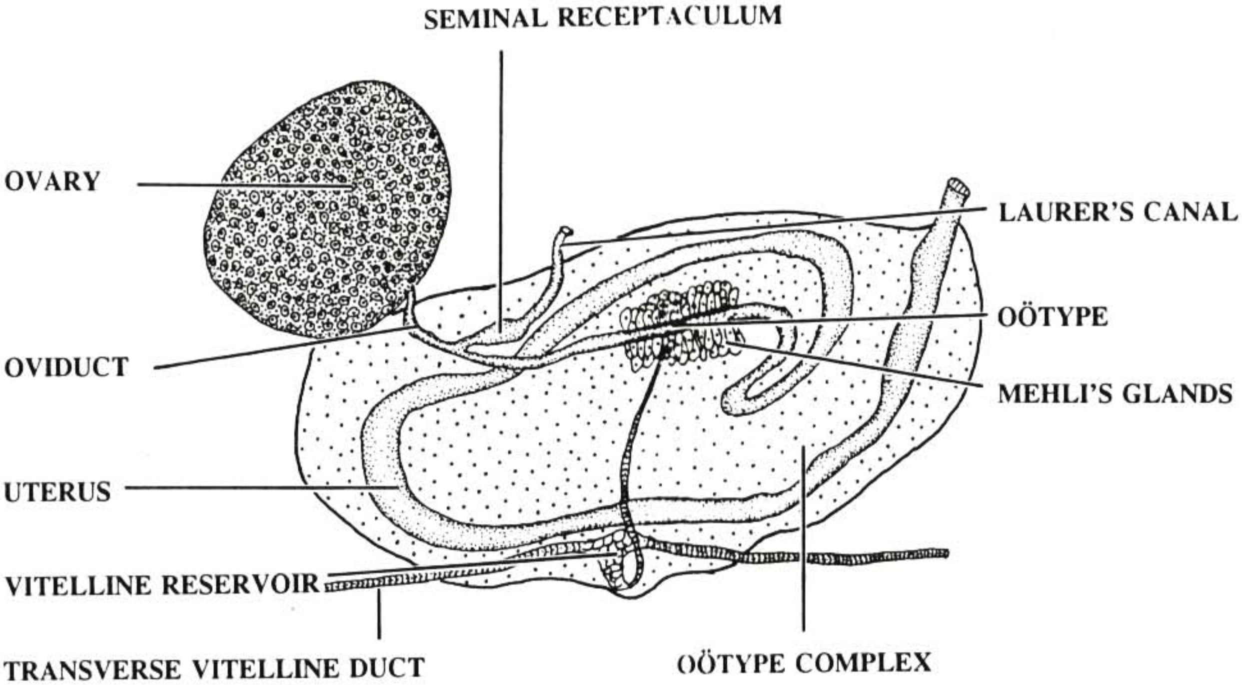

ORAL FIELD
ORAL SUCKER
INTESTINAL CAECUM
VENTRAL SUCKER
UTERINE SAC
UTERUS
GENITAL ATRIUM
CIRRUS SAC
ANTERIOR TESTIS
EGGS
VAS EFFERENS
OVARY
OÖTYPE COMPLEX
POSTERIOR TESTIS
VITELLINE FOLLICLES
1mm

FIG. 29

EUCLINOSTOMUM HETEROSTOMUM

Diagrammatic representation of the topography of the oötype complex
(After Britz, 1983)


SEMINAL RECEPTACULUM
OVARY
LAURER'S CANAL
OÖTYPE
OVIDUCT
MEHLI'S GLANDS
UTERUS
VITELLINE RESERVOIR
TRANSVERSE VITELLINE DUCT
OÖTYPE COMPLEX

PATHOLOGY, ECOLOGICAL, ECONOMIC AND PUBLIC HEALTH IMPORTANCE OF TREMATODES OF THE FAMILIES DIPLOSTOMIDAE POIRIER, 1886 AND CLINOSTOMIDAE LÜHE 1901.

Trematodan metacercariae encysting in the dermis, subdermal layers, muscles, branchial chambers and coelomic cavities of freshwater fish hosts were reported from many parts of the world. The same holds for unencysted metacercaria that occur in the cranial cavities and eyes (vitreous humor and lenses) of their fish hosts.

Trematodes of the above nature recorded during the present study from fish intermediate and avian final hosts belong to the genera *Harvardia* Baer, 1932; *Hysteromorpha* Lutz, 1931; *Diplostomum* Van Nordmann, 1832; *Clinostomum* Leidy, 1856; *Neutraclinostomum* Feizullaev and Mirzoeva, 1983 and *Euclinostomum* (Rudolphi, 1809).

Although metacercarial cysts of the genera *Clinostomum, Neutraclinostomum* and *Euclinostomum* attain relatively large sizes (3 - 18mm), and despite the fact that gill and visceral infections in fish may register relatively high mean intensity values (Table 14, p.89, Table 17, p.103, Table 18, p.104, Table 19, p.109 and Tables 20-21, p. 110), it does not appear as if these parasites cause morbid effects to semi-adult and adult specimens of the larger fish species. This observation is also supported by Paperna (1980). In fingerlings and the smaller fish species severe infections with clinostomatid metacercariae are likely to be detrimental. Paperna (1980) reported mortalities amongst 40 - 60mm long *Oreochromis mossambicus* infected with metacercariae encysted on the visceral peritonia and mesenteria. Intensities were as low as 3 - 5 worms but the worms nevertheless exerted severe pressure on the visceral organs, mainly the liver and intestine. Infected fish assumed a dropsied appearance. During a survey at Middle Letaba Impoundment (Fig.2, p.14) Saayman and Schoonbee et. al. (1991) found a number of juvenile specimens of *O. mossambicus* infected with *E. heterostomum* in the muscles which showed definite signs of locomotory impairment.

Severe infections of the visceral cavities of fish with *Clinostomum complanatum* is likely to cause parasitic castration. For certain water bodies in the study area Saayman (1986a and unpublished data) recorded severe visceral infections for *Schilbe intermedius* Rüppel, 1832 and *Marcusenius macrolepidotus* (Peters, 1852). These data are contained in Table 19 below to Tables 20-21, p.110.

Table 19: Extent of *Clinostomum complanatum* infections for *Schilbe intermedius* from the Olifants- and Limpopo River Drainage Systems (Saayman, 1986a).

NUMBER OF PARASITES PER HOST	1	2	3	4	5	6 - 9	10+
Number of hosts	41	27	12	6	7	14	6
Percentage of the total number of infected hosts	36.3	24.0	10.6	5.3	6.2	12.4	5.3

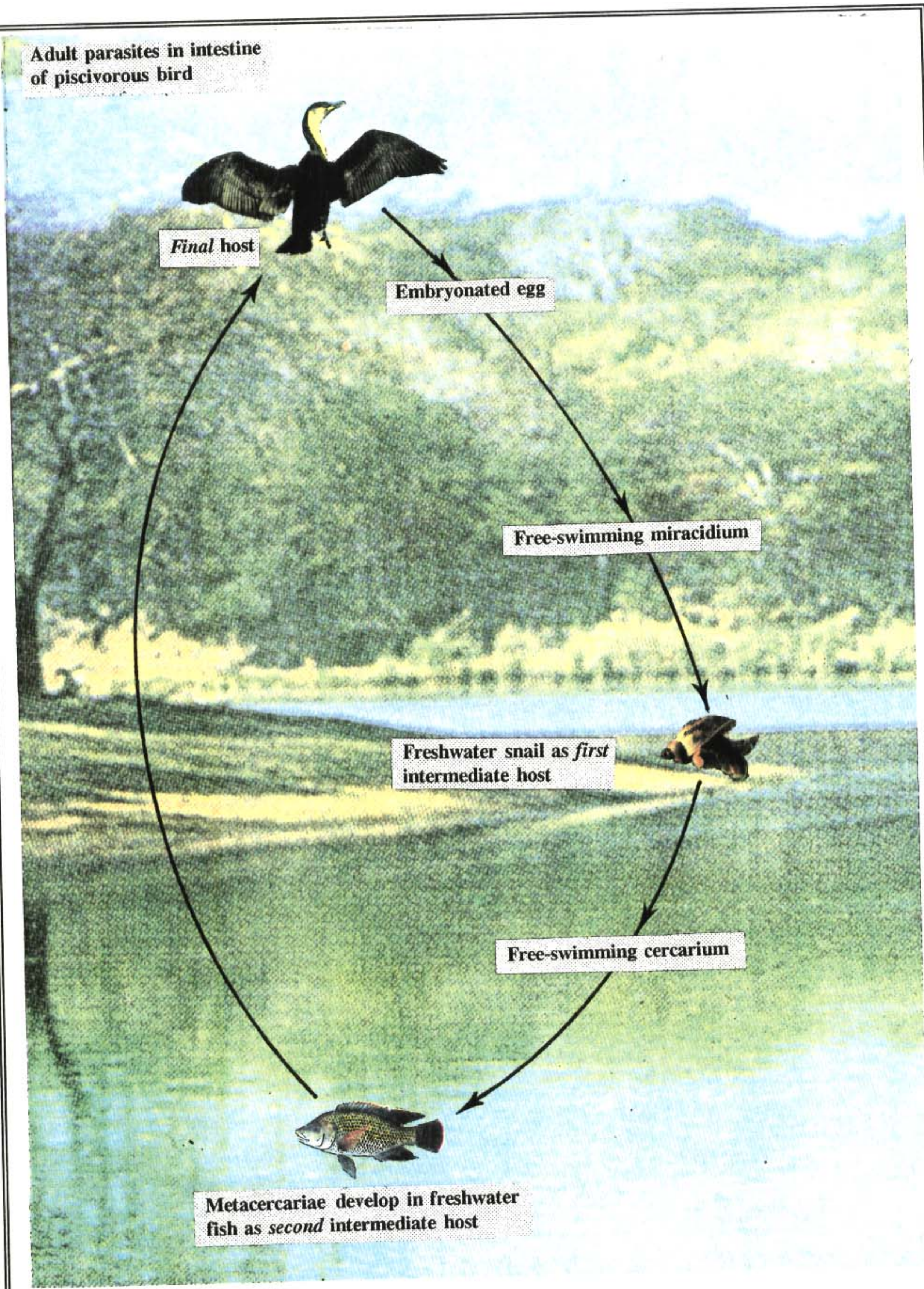


Fig. 30 - Life cycle of clinostomatid parasites

Table 20: Extent of *Clinostomum complanatum* infections of 286 infected *Marcusenius macrolepidotus* from the Olifants- and Limpopo River Drainage Systems (Saayman, 1986a and unpublished data).

NUMBER OF PARASITES PER HOST	1	2	3	4	5	6 - 10	11 - 15	16 - 20	21 - 25	25+
Number of hosts	52	39	28	19	13	48	31	26	10	21
Percentage of total number of infected hosts	18.1	13.6	9.8	6.6	4.5	16.7	10.8	9.1	3.5	7.3

Table 21: *Clinostomum complanatum*: Prevalence and intensity values for infected *Schilbe intermedius* and *Marcusenius macrolepidotus* hosts from the Olifants- and Limpopo River Drainage Systems. (Saayman 1986a and unpublished data).

FISH HOST	NUMBER EXAMINED	PREVALENCE %	INTENSITY	MEAN INTENSITY
Schilbe intermedius	399	28.71	1 - 21	3.38
Marcusenius macrolepidotus	524	54.7	1 - 122	6.70

From the above tables it is evident that both *S. intermedius* and *M. macrolepidotus* carry extremely high worm loads with *C. complanatum.* It was found that a relatively small fish like *M. macrolepidotus* may be infected by as many as 122 metacercariae of *C. complanatum* (Table 21), while 7.3% of the infected hosts carry in excess of 25+ parasites per host (Table 20). The same holds for *S. intermedius*, where intensity figures of 1 - 21 were recorded with 5.3% of the infected fish recording a parasitic load in excess of 10 parasites per host (Tables 19, p.109 and 12, p.79).

Saayman (personal communication) states that he observed many cases of parasitic castration in the above two host species which can only be ascribed to the effect of severe infestations with *C. complanatum.*

Mashego (1982) found *C. complanatum* metacercariae encysted on the mesenterium of the swimbladder of six *Barbus* spp. inhabiting aquatic ecosystems within the present study area. This author states that smaller *Barbus* spp. such as *B. paludinosus* Peters, 1852 and

B. trimaculatus Peters, 1852 registered intensity of infection levels of 1 - 11. Similarly Saayman and Schoonbee et. al. (1991) recorded prevalence figures of 100% and intensity levels of 1 - 8 for the very small *B. toppini* Boulenger, 1916 at Middle Letaba Impoundment (Fig.2 p.14). These authors do not specifically remark on parasitic castration in these smaller *Barbus* spp., but it stands to reason that the infection levels recorded may very well have a drastic influence on the development of the gonads of these hosts during the breeding season.

Severe infection with *N. intermedialis* in the branchial chambers of fish intermediate hosts is likely to cause respiratory inhibition. A study of the relevant literature does, however, not provide any definite support for this statement. The only reference is that of Paperna (1980) who noted that in *massive* infections of the *gills* of juvenile cichlids in lakes in Africa, the major part of the respiratory tissue of the gill filaments was displaced by the encysted trematodes, resulting in loss of fine lamellar structure and eventual deformation and even atrophic degeneration of the entire filament. Such changes must undoubtedly inhibit gaseous exchange across the gill surfaces.

Adherence of adult clinostome parasites to the lining of the oesophagus and buccal cavity of avian hosts does cause severe histological effects as was discussed by Cort (1913) and Ukoli (1970). These observations were also noted during the present study. Cort (1913) states that:

In the bird's mouth the worms were very much contracted, and adhered so firmly to the mucous membrane that it was very difficult to loosen them. Their position was well suited to resist the friction of food taken into the mouth of the heron. Not only was the acetabulum firmly attached but also the oral field functioned as a sucker. The pre-acetabular region was bent over so that the oral field was almost in contact with the acetabulum. The anterior end was given very firm attachment by the sucking action of both these structures. The post-acetabular region was much contracted longitudinally and arched so that it was quite convex. The edges were pressed closely into the mucous membrane, and evidently by drawing up of its central part this whole region also acted as a sucker. In fact the posterior end was so firmly attached that it was almost as difficult to loosen as the anterior. Such a sucking activity of the post-acetabular region accounts for the great development of the dorso-ventral parenchymatous muscles which has been noted for this species. (p. 193)

The above rather elaborate citation from Cort (1913) is included because it describes in exact detail what was observed during the present study with regard to avian infections with *C. complanatum, N. intermedialis* and *E. heterostomum.*

Ukoli (1970) examined histological damage caused by the attachment of *N. intermedialis* (= *C. tilapiae* Ukoli, 1966) to avian hosts at the hand of serial sections. This author reveals that the oral field of the parasite is deeply embedded in the connective tissue of the corium of the oesophagus (Fig.25 p.94). The same publication also mentions that the stratified epithelium and the mucous glands are gradually digested away by secretions from the parasites leaving deeply pitted marks on removal of the parasites. Baugh and Pandey (1969) observed that when the worms were removed from the oesophageal lining, part of the host tissue was also torn away to leave a deep circular defect which bled profusely.

During the present study the above observations of Baugh and Pandey (1969) and Ukoli (1970) were verified in almost all the infected avian hosts. There is, therefore, no doubt that infection by clinostomatid parasites does cause serious harm to their avian hosts.

With regard to the utilisation of freshwater fish as a food source for humans, it is evident that clinostomatid metacercariae could present a problem as these cysts are undesirable in food fish. Muscle infections (mostly with *E. heterostomum*) feature more prominently as a problem because even if only one metacercarial cyst is present in the body musculature of a fish market resistance to the product could develop.

Prudhoe and Hussey (1977) mentioned that in some regions of the world fish carry such heavy infections of clinostomes that they are condemned for human consumption by the Health Authorities.

There is a distinct possibility that clinostomatid trematodes could utilise mammals as their final hosts. Although this phenomenon has not been reported specifically for southern Africa, several cases are reported in the literature. Six cases of human infection with *Clinostomum* spp. have been reported (Yamashita 1938; Witenberg 1944; Kamo, Ogino and Hatsushika 1962; Sakaguchi, Yamamoto and Yamada 1966; Sano, Mogi and Kamegai 1980 and Hirai, Ooiso, Kifune, Kiyota and Sakaguchi 1987). With the exception of the record from Israel reported on by Witenberg (1944), all the other cases mentioned above are from Japan.

Hirai et. al. (1987) mentioned that an otorhinolaryngological examination of the patient in their care revealed the following signs and symptoms:(*cough, bleeding, sputum, fever, pain of deglutition, pruritic feeling, flare of pharynx, swelling of lymphonodes, swelling of mucous membrane and hypertrophy of the tonsils.*) All these are symptoms normally associated with laryngitis and the authors mentioned that removal of the parasites *immediately resulted in the patient free from above symptoms.*

Beliappa (1944) removed 21 *Clinostomum* specimens from the mouth of a cat in India and Candy (1971) found 11 *Clinostomum* sp. parasites attached to the upper gum region of a cat from Zimbabwe. The foregoing observations are ample proof that Clinostome parasites may cause a health risk to mammals, including man, in areas where this parasite occurs in abundance. It is a particular hazard if raw or insufficiently cooked fish is consumed.

In conclusion, the following remarks are relevant:

- The present study reveals that in the Northern Province of South Africa at least seven piscivorous birds do play a determinant role in the transmission of trematodan parasites of freshwater fish. These hosts are:-

Phalacrocorax carbo
P. africanus
Anhinga melanogaster
Ardea cinerea
A. melanocephala
A. purpurea
Nycticorax nycticorax;

- The trematodan parasites transmitted by the above hosts not only affect the ecological well-being of their fish intermediate hosts, but may, in addition, have a serious economic influence on piscatorial and aquacultural enterprises in the region;

- Infection of mammals, including humans, with clinostome parasites is not a far-fetched possibility for the area, particularly in cases where fish are consumed that are not cooked to the consistency of at least a hard-boiled egg;

- *Oreochromis mossambicus, Schilbe intermedius* and *Marcusenius macrolepidotus* which are particularly sought-after fish for human consumption in the Northern Province of South Africa, are the most prominent candidates to become infected with metacercariae of diplostomatid and clinostomatid metacercariae (Tables: 7, p.48; 17, p.103; 18, p.104; 19, p.109 and 20-21, p. 110).

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3

Cestodan Parasites of *Phalacrocorax carbo*, *P. africanus* and *Anhinga melanogaster* involving a fish intermediate host in the life history.

3

The avian hosts used in the investigation of cestodan parasites were the same as those used for the survey of trematodan parasites. The hosts were also collected from the same localities mentioned in Chapter 1 (Fig.2, p.14).

All the information provided in the introduction to Chapter 2 also applies to this chapter.

The role of aquatic birds, particularly piscivorous birds, as final hosts for South African fish cestodes has, as yet, received little attention. Literature searches revealed only two publications dealing with this aspect, namely, Ortlepp (1938) and Prudhoe and Hussey (1977).

In contrast, the cestode parasites of South African freshwater fish fauna were recorded in 14 reports/publications by Ortlepp (1938); Lombard (1968); Mashego (1977); Prudhoe and Hussey (1977); Whitfield and Heeg (1977); Boomker, Huchzermeyer and Naude (1980); Brandt (1980): Brandt, Schoonbee and Van As (1980); Hamilton-Attwell, Tied and Van As (1980); Brandt, Van As, Schoonbee and Hamilton-Attwell (1981); Van As and Schoonbee (1981); Mashego (1982); Hänert (1984); Mashego and Saayman (1989) and Saayman and Schoonbee, et. al. (1991).

Ortlepp (1938) described *Hymenolepis cormoranti* from *Phalacrocorax africanus* collected in the Pretoria District, while Prudhoe and Hussey (1977) recorded *Ligula intestinalis* (Linnaeus, 1758), Gmelin 1790 and *Paradilepis delachauxi* (Fuhrmann, 1909) from *Phalacrocorax africanus* from the Central Transvaal Region.

This chapter deals with the cestode parasites of *Phalacrocorax carbo, P. africanus* and *Anhinga melanogaster* which involve indigenous freshwater fish species in their life cycles. The study area was restricted to the aquatic ecosystems of the Northern Province of South Africa (Fig.2, p.14). At one sampling locality, Middle Letaba Impoundment (Fig.2, p.14), very limited numbers of 13 other potential avian final hosts for freshwater fish cestodes were also investigated. This list included: *Ardea cinerea, A. melanocephala, A. purpurea, Egretta garzetta, Bubulcus ibis, Nycticorax nycticorax, Butorides striatus, Ixobrychus minutus, Platalea alba, Actiphilornis africanus, Ceryle rudis, C. maxima* and *Alcedo cristata*. Only one of the above 13 potential hosts harboured a fish related cestode, namely, *P. alba*, which is host to *Paradilepis urceus* (Wedl 1855). The occurrence of this parasite in the study area will also be discussed in this chapter.

Resident and resident/breeding populations of *P. carbo, P. africanus* and *A. melanogaster* at aquatic ecosystems in the Northern Province were found to harbour four Cestode parasites which involve a fish intermediate host in their life histories. These are:

Order: Pseudophyllidea Carus, 1863
Ligula intestinalis (Linnaeus, 1758)
Gmelin, 1790.

Order: Cyclophyllidea Van Beneden in
Braun, 1900.
Paradilepis scolecina (Rudolphi, 1819)
P. delachauxi Fuhrmann, 1909
Amirthalingamia macracantha (Joyeux and Baer, 1935).

LIGULA INFECTIONS OF PISCIVOROUS BIRDS IN THE NORTHERN PROVINCE, SOUTH AFRICA.

Phylum Platyhelminthes

Class Cestoda

Order Pseudophyllidea Carus, 1863

Family Diphyllobothriidae Lühe, 1910
(= Dibothriocephalidae Lühe, 1902)

Genus *Ligula* (Bloch, 1782)
(= *Braunia* Leon, 1908)
L. intestinalis (Linnaeus, 1758) Gmelin, 1790.

The genus *Ligula* (Bloch, 1782) has a cosmopolitan distribution occurring as adults in a variety of piscivorous birds. The plerocercoid larvae inhabit the visceral cavity of cyprinid fish hosts where they grow to a considerable size (Yamaguti, 1959, 1971; Bykhovskaya-Pavlovskaya, et. al., 1964; Orr, 1967; Khalil, 1971a and 1971b). In Britain, for example, *L. intestinalis* parasitises no less than eight cyprinid fish species (Kennedy, 1974) while Dogiel, Petrushevski and Polyanski (1958) reported *Ligula* infections from 26 different cyprinid hosts worldwide. Khalil, Jones and Bray (1994) give the following diagnostic characteristics for the genus *Ligula* as well as the closely related genus *Digramma* Cholodkowsky, 1915:

Fleshy worms up to 400 mm long by 7 - 8 mm wide. Anterior portion of strobila segmented, rest unsegmented but transversely wrinkled. Anterior end of strobila bluntly pointed with poorly developed scolex; bothria represented only by two shallow tiny slits. One set of reproductive organs per proglottid. Adults in fish-eating birds. Large fleshy plerocercoids in body cavity of cyprinids. Circumboreal. Type species ***L. intestinalis*** *(Linnaeus, 1758).*

Genus ***Digramma*** *Cholodkowsky 1915, as* ***Ligula*** *except two sets of genitalia per proglottid, Type species* ***D. alternans*** *(Rudolphi, 1810).* (p. 239)

Material collected during the present study from piscivorous birds in the Northern Province of South Africa, as well as plerocercoids from a number of freshwater fishes of the area (Prudhoe and Hussey, 1977; Brandt, 1980; Mashego, 1982; Saayman and Schoonbee et. al., 1991) were identified as *L. intestinalis*.

Prudhoe and Hussey (1977) state that modern determinations of *L. intestinalis* appear to have been based principally on the description of the species given by Cooper (1919), but that this description was concerned only with European and North American specimens. The same authors (Prudhoe and Hussey, op. cit.) claim that *the presence of* ***L. intestinalis*** *in Africa was first recognised by Baer (1933) from* ***P. africanus*** *in Mozambique, and he (Baer, 1933) described material which differed from that of Cooper in a number of morphological details. Joyeux and Baer (1942), on the other hand, decided that these differences were only of sufficient importance to recognise a variety, which they called* ***Ligula intestinalis*** *var.* ***africana****. Subsequently, Fuhrmann (1943) recorded* ***L. intestinalis*** *var.* ***africana*** *from* ***P. africanus*** *in Angola...* (p. 139)

Khalil (1971b, 1973) and Khalil and Thurston (1973) gave the following fish host list for positively identified infections with plerocercoids of *L. intestinalis* in Africa:

FISH HOST SPECIES	REFERENCE
Barbus komolondoensis	Mahon (1954), Zaïre
B. lukusiensis	Mahon (1954), Zaïre
B. microbarbis	Mahon (1954), Zaïre
B. lineomaculatus	Mettrick (1960), Zimbabwe
B. longicauda	Mettrick (1960), Zimbabwe
B. paludinosus	Mettrick (1960), Zimbabwe
Barbus sp.	Khalil (1973), Zaïre
Labeo sp.	Khalil (1973), Zaïre
Eugraulicypris argenteus	Khalil and Thurston (1973), Uganda
Haplochromis sp.	Khalil and Thurston (1973), Uganda

In addition, the following hosts harbouring unidentified pseudophyllidean plerocercoids {recorded by Williams and Chaytor (1966) in Sierra Leone} were listed by Khalil (1971):

Barbodes (= *Barbus*) *trispilus*
Barbodes (= *Barbus*) *wurtzi*
Ctenopoma kingsleya
Epiplatys senegalensis

The above infections may well have been with *L. intestinalis*. It is interesting to note that the preceding list does not include *Ligula* infections recorded from South African freshwater fish species. In fact, the first record of *L. intestinalis* plerocercoids from Transvaal waters was by Brandt (1980) who recorded it from *B. unitaeniatus* from Bronkhorstspruit Dam in the Eastern Transvaal (Mphumalanga Province). Mashego (1982) recorded *L. intestinalis* plerocercoids from four *Barbus* spp. in water bodies from the Limpopo- and Olifants River Drainage Systems in South Africa. These fish host species are:

B. paludinosus	Peters, 1852
B. radiatus	Peters, 1853
B. unitaeniatus	Günther, 1866
B. marequensis	Smit, 1841

Saayman and Schoonbee et. al., (1991) found four *Barbus* spp. at Middle Letaba Impoundment (Letaba River Drainage System) to be infected with plerocercoids of *L. intestinalis*. These hosts are: *B. trimaculatus* Peters, 1852; *B. unitaeniatus* Günther, 1866; *B. bifrenatus* Fowler, 1935; *B. toppini* Boulenger, 1916. Seven *Barbus* hosts from the study area are therefore identified second intermediate hosts for *L. intestinalis* (Table 23, p.131).

The life cycle of *L. intestinalis* (Fig.37, p.153) is completed in three hosts. The first intermediate host, which harbours the procercoid larval stage, is a copepod. If infected copepods are swallowed by a suitable fish as second intermediate host, the procercoids are released in the intestine from where they burrow through the intestinal wall to develop into plerocercoid larvae in the coelomic cavity. In the second intermediate host the plerocercoid larvae develop rudimentary reproductive organs and become very large (67 - 245 mm, Mashego, 1982). According to Bykhovskaya-Pavlovskaya et. al., (1962) this development may take anything from 2 - 14 months. On entering the alimentary canal of a fish eating bird as the final host, the invasive plerocercoids become sexually mature worms in two to three days (Joyeux and Baer, 1936, 1938; Orr, 1967 and Prudhoe and Hussey, 1977).

Prudhoe and Hussey (1977) are of the opinion that *L. intestinalis* completes its life history in the avian host within twelve days *when the strobila breaks up and is evacuated along with the faeces of the host. For a certain period following the loss of the worm the bird is resistant to further infestation, but later it becomes susceptible again.*

Data obtained during the present study, supplemented by infection statistics of fish intermediate hosts (Table 23, p.131 and Table 24, p.133), are not supportive of the statement of Prudhoe and Hussey (1977) as quoted in the previous paragraph. Prevalence levels for avian hosts often reached 100%, while those for some *Barbus* intermediate hosts go up to 95%+ levels.

Table 22: Prevalence, intensity and mean intensity values for infection of *Phalacrocorax carbo, P. africanus* and *Anhinga melanogaster* with *Ligula intestinalis* in the Northern Province of South Africa.

AVIAN HOST	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
P. carbo	39	Seshego Dam	46	1 - 21	6
	8	Middle Letaba Impoundment	75	7 - 143	38
	2	Piet Gouws Dam	100	1	1
	2	Glen Alpine Dam	100	2 - 7	5
	1	Ebenhaezer Dam	100	5	5
P. africanus	44	Seshego Dam	36	1 - 5	2
	9	Middle Letaba Impoundment	78	3 - 18	7
	3	Hudson Ntsanwisi Dam	100	2 - 5	4
	1	Turfloop Dam	-	-	-
	2	Olifants River	-	-	-
A. melanogaster	24	Seshego Dam	42	1 - 9	3
	12	Middle Letaba Impoundment	42	1 - 13	5
	11	Hudson Ntsanwisi Dam	55	2 - 17	5
	2	Luphephe Dam	-	-	-
	6	Piet Gouws Dam	50	1 - 3	2
	4	Glen Alpine Dam	75	2 - 3	2
	1	Tzaneen Dam	-	-	-
	4	Olifants River	75	1 - 2	1

Table 22 above and Table 23, p.131, indicate that the life history of *L. intestinalis* is very well established in the Northern Province of South Africa. In the study area no less than three avian final hosts and seven fish intermediate hosts were identified as carriers of life cycle stages of this parasite. The parasite is also geographically well represented within the study area as it occurs in aquatic ecosystems of the Limpopo- as well as the Olifants River Drainage Systems.

The three avian hosts that were identified as carriers of *L. intestinalis* seem to contribute equally to the suprapopulation status of this parasite in the study area. However, *A. melanogaster*, due to its numerical dominance at all the major aquatic ecosystems that were investigated must play a principal role in this regard.

Table 23: Prevalence, intensity and mean intensity values for infection of fish intermediate hosts with *Ligula intestinalis* plerocercoids in the Northern Province of South Africa. After Mashego [=M] (1982) and Saayman and Schoonbee et. al. [= S and S] (1991).

FISH HOST AND REFERENCE	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
Barbus unitaeniatus [M]		Luphephe and Nwanedzi Dams and river systems	19	1 - 2	1
B. radiatus [M]		Luphephe Dam	5	1	1
B. paludinosus [M]		Luphephe and Nwanedzi Dams and river systems	13	1 - 3	2
B. marequensis [M]		Piet Gouws Dam	1	1	1
B. unitaeniatus [S and S]	98	Middle Letaba Impoundment	77.6	1 - 9	2.04
B. bifrenatus [S and S]	33	Middle Letaba Impoundment	33.3	1 - 2	1.36
B. toppini [S and S]	178	Middle Letaba Impoundment	95.5	1 - 5	1.57
B. trimaculatus [S and S]	72	Middle Letaba Impoundment	2.78	1 - 1	1

At Middle Letaba Impoundment (Letaba River Drainage System) *B. unitaeniatus, B. bifrenatus* and *B. toppini* are the principal carriers of plerocercoids of this parasite with *B. trimaculatus* as a mere reservoir host. In the Luphephe/Nwanedzi aquatic ecosystem (Limpopo River Drainage System), *B. unitaeniatus* and *B. paludinosus* seem to act as principal secondary intermediate hosts for *L. intestinalis*.

If the data for fish intermediate hosts of *L. intestinalis* obtained by Mashego (1982) are compared with the findings of Saayman and Schoonbee et. al., (1991) at Middle Letaba Impoundment some interesting observations come to light:

- From the eleven *Barbus* spp. investigated by Mashego (1982), four species (*B. unitaeniatus, B. paludinosus, B. trimaculatus* and *B. marequensis*) also occur in the Middle Letaba Impoundment.

- Mashego (op. cit.) found *B. paludinosus* specimens from three water bodies in the Limpopo Drainage System to register a prevalence figure for *L. intestinalis* plerocercoids of 13%, while Saayman and Schoonbee (op. cit.) failed to find any *Ligula* infection amongst the *B. paludinosus* population of Middle Letaba Impoundment. The same comparison holds for *B. marequensis*.

- Mashego (1982) did not find *Ligula* infections in the *B. trimaculatus* populations investigated by him, while this species acts as an intermediate host for *L. intestinalis* in the Middle Letaba aquatic ecosystem;

- The Middle Letaba populations of *B. unitaeniatus, B. bifrenatus* and *B. toppini* registered an extremely high level of infection with *L. intestinalis* ranging from 33% for *B. bifrenatus* to 95.5% for *B. toppini*. In his studies Mashego (1982) found prevalence figures ranging between 1 - 19%, while Brandt (1980) found *B. unitaeniatus* at Bronkhorstspruit Dam to register a prevalence figure of 85%. Sweeting (1977) found more than 90% of the roach, *Rutilus rutilus*, in England to be infected with *Ligula* plerocercoids registering intensity and mean intensity levels of 1 - 30 and 4.2 respectively. This latter figure is more in line with the infection levels in Middle Letaba Impoundment and the observations of Sweeting (1975, 1977) and Kennedy and Burrough (1981) should therefore be very relevant to the Middle Letaba situation. This aspect will be dealt with in more detail under the subsection, Pathological, economic and ecological importance. (see pp.133-135).

If prevalence indexes alone are used to measure and compare parasitic infestation of fish hosts with plerocercoids of *L. intestinalis*, the real picture may well evade the less careful observer. This is particularly true of the situation in Middle Letaba Impoundment. Saayman and Schoonbee et. al. (1991) therefore decided to analyse the incidence of *Ligula* in this impoundment at the hand of two additional indexes, namely, parasitic- and intensity indexes. Table 23, p.131 and Table 24, p.133 summarise the numerical extent of the worm burden, while Table 25, p.133 indicates the parasitic index.

$$\textbf{Parasitic index} = \frac{\textbf{Mass of parasite(s)}}{\textbf{Mass of host + parasite(s)}} \times \textbf{100}$$

Table 24: Extent of *Ligula intestinalis* infection in fish intermediate hosts in Middle Letaba Impoundment. Percentage of total number of infected fish is indicated. After Saayman and Schoonbee et. al. (1991).

HOST SPECIES	Number of parasites/host and percentage of total number of infected hosts								
	1	2	3	4	5	6	7	8	9
Barbus unitaeniatus	33 43.4%	27 35.5%	7 9.2%	4 5.3%	3 4.0%	-	1 1.3%	-	1 1.3%
B. bifrenatus	6 54.6%	5 45.5%	-	-	-	-	-	-	-
B. toppini	103 60.6%	46 27.0%	13 7.7%	7 4.1%	1 0.6%	-	-	-	-
B. trimaculatus	1 100%	-	-	-	-	-	-	-	-

Table 25: Parasitic index for *Ligula intestinalis* infection amongst fish intermediate hosts in Middle Letaba Impoundment. After Saayman and Schoonbee et. al. (1991)

HOST SPECIES	N.	MEAN PARASITIC INDEX	RANGE
Barbus toppini	128	24.31	8.14 - 49.33
B. unitaeniatus	54	16.26	5.57 - 34.40
B. bifrenatus	4	19.02	11.33 - 33.49

Wyatt and Kennedy (1988) and Szalai, Yang and Dick (1989) noted a significant decline in growth rate and condition factor of ligulosed *Rutilus rutilus* and *Notropis hudsonius* respectively. In Ireland, Baen and Winfield (1989) could not find any drastic effects of ligulosis on the growth of a population of *Gobio gobio*. The same observation was recorded by Weekes and Penlington (1986) for *Ligula* infection of rainbow trout (*Salmo gairdneri*) and common bully (*Gobiomorphus cotidianus*) in New Zealand.

Despite the fact that three of the smaller *Barbus* spp. of Middle Letaba Impoundment register substantial parasitic index values for *Ligula* infection (Table 25 above) Saayman and Schoonbee et. al. (1991) found the relative condition factor for these species still well above normal levels. It would therefore seem that other ecological factors may have a positive counter effect on heavily ligulosed fish in tropical and sub-tropical environmental conditions.

PATHOLOGICAL, ECONOMIC AND ECOLOGICAL IMPORTANCE OF *LIGULA* INFECTION.

Infection with *Ligula intestinalis* does not seem to have any pronounced pathological effects on avian final hosts. In contrast to this a great many literature references (Furhmann, 1934; Kerr, 1948; Kirshenblat, 1951; Shopolyanskaya, 1953; Kozareva, 1961; Arme, 1964, 1968; Arme and Owen (1968); Harris and Wheeler, 1974; Sweeting, 1977; Arme, Bridges and Hoole, 1983; Rzeczhowska and Honowska, 1988 and Taylor and Hoole, 1989) reported on pronounced pathological effects on fish intermediate hosts infected with *L. intestinalis*.

Fuhrmann (1934) (cited from Sweeting, 1977), was the first to describe the inhibitory effect of ligulosis on gonadal development and reduction in liver size. Kerr (1948) and Kirshenblat (1951) related this gonadal inhibition to changes in the size and granulation of basophilic cells in the meso-adenohypophysis. Further observations on gonadal regression in fish intermediate hosts were reported by Arme (1968), Arme and Owen (1968) and Pollard (1974). Claridge, Hardisty, Potter and Williams (1985) on the other hand, did not find significant signs of gonadal inhibition in the gobies, *Pomatoschistus minutus* and *P. lazanoi* infected with *Ligula* in the Inner Severn Estuary in Great Britain.

Metabolic disturbances such as depleted glycogen content of the liver were ascribed to ligulosis by Kozareva (1961), while Shpolyanskaya (1953) reported a decrease in the fat and protein content of *Leucaspius delineatus* and *R. rutilus* that were heavily infected with *L. intestinalis*. (The publications of the latter two authors were not available - cited from Sweeting, 1977). Harris and Wheeler (1974) also commented on a decrease in fat reserves in infected *Alburnus alburnus*. Other pathological effects are distension of the abdomen with loss of streamlining and camouflage as well as separation of scales (Sweeting, 1977).

The effect of ligulosis on the thickness of the body wall musculature of fish hosts was reported by Arme (1964), while Sweeting (1977) assessed this effect quantitatively in the roach, *R. rutilus*. The latter author established that the musculature degenerates uniformly as the parasitic index increases. In roach, with a **p.i.** of more than 30%, the musculature of the ventral body wall was completely degenerate and resulted in ruptures. Distension of the abdomen with associated inhibition of locomotion serves to render fish hosts more vulnerable to predation as reported by Van Dobben (1952) and Sweeting (1977).

In their studies on *Ligula* infection of *Barbus* spp. at Middle Letaba Impoundment, Northern Province, South Africa, Saayman and Schoonbee et. al. (1991) did not attempt to establish exact pathological effects ascribable to ligulosis. However, these authors regularly noted the following very obvious and adverse signs:

- Extensive distension of the abdomen resulting in locomotory inhibition in heavily ligulosed fish. This was especially noticeable in *B. toppini* and *B. unitaeniatus*;
- Abnormal distension was in all cases associated with atrophy of the abdominal musculature resulting in enhanced reduction in swimming performance. This renders the fish more susceptible to predation (Van Dobben, 1952) and thereby promotes continuation of the life history in the avian final host;
- Inhibition of gonadal development to such an extent that it became impossible to determine the sex of fully grown specimens by means of gonadal classification. This was particularly evident for *B. toppini* and *B. bifrenatus*.

From the above observations it is evident that ligulosis does have pronounced pathological and ecological effects on small fish intermediate hosts in the study area. Small *Barbus* spp. do play a significant role in the dietary budgets of predatory fish species and piscivorous birds. Any aspect which intervene with their normal reproductive capacities must, therefore, have pronounced effects on the nutrient ecology of a major aquatic ecosystem.

DILEPIDID INFECTIONS OF PISCIVOROUS BIRDS IN THE NORTHERN PROVINCE OF SOUTH AFRICA.

The present study accounted for four different species of dilepidid cestodes parasitising piscivorous birds in the Northern Province. These are:

Paradilepis scolecina (Rudolphi, 1819)
P. delachauxi Fuhrmann, 1909
P. urceus (Wedl, 1855)
Amirthalingamia macracantha
(Joyeux and Baer, 1935)

The taxonomic hierarchy of these cestodes is as follows:

Phylum Platyhelminthes

Class Cestoda

Order Cyclophyllidea Van Beneden in Braun, 1900

Family Dilepididae Railliet and Henry, 1909

Genus: ***Paradilepis*** Hsü, 1935
(= *Dilepis* Weinland, 1858;
Hymenolepis Weinland, 1858;
Oligorchis Fuhrmann, 1906;
Meggittiela Lopez-Neyra, 1942;
Skrjabinolepis Matevosyan, 1945;
Ascodilepis Guildal, 1960;
Neodilepis Baugh and Saxena, 1974).

The taxonomy of the genus *Paradilepis* Hsü, 1935 and its complement of valid/invalid species have been dealt with by a number of workers (Joyeux and Baer, 1935, 1950; Freeman, 1954; Spassky, 1952, 1954, 1959; Mahon, 1955; Baer and Bona, 1960; Spassky and Spasskaya, 1960; Matevosyan 1963; Baugh and Saxena, 1973; Bray, 1974 and Bona, 1975).

Baugh and Saxena (1973) summarised the taxonomic history of the genus in rather elaborate detail and list 17 species as valid for the genus. Their list of species included *P. maleki* described by Khalil (1961) from *Threskiornis aethiopicus* (Latham) in the Sudan. Also included in the list is *P. macracantha* Joyeux and Baer, 1935. The latter species was restudied by Bray (1974) and transferred to the new genus *Armithalingamia* Bray, 1974. Rysavy and Macko (1973) described a new species, *P. cabelleroi*, from *Phalacrocorax auritus floridanus* Audubon from Cuba, while Bona (1975) described *P. urceina* from Australia with *Threskiornis molucca strictipermis* (Gould) as the host.

For the present study various literature searches were conducted, but none came up with any additional information on the taxonomy of the genus or on any species described since 1975.

Khalil et. al. (1994) gave the following diagnosis for the genus *Paradilepis* Hsü, 1935:

> *Rostellar apparatus cyclusteroid. Pouch large, subspherical. Rostellum wide, superficial layer of the two-layered wall, consisting of densely packed, longitudinal, slightly spiral fibres when rostellum retracted, loses compactness and adhesion to underlying layer during protrusion. Hooks in two circles (20 - 26); two patterns: Blade thin, much longer than handle, slightly curved, guard slightly protruding (**urceus** pattern); blade as long as handle at times sharply curved at end (**scolecina** pattern). Strobila small to large. Proglottids acrespedote, wider than long. Genital pores unilateral, left. Genital ducts dorsal to osmoregulatory canals. Vagina short, carrot-shaped with pre-atrial sphincter. Atrium simple. Testes four, exceptionally in some species most proglottids have five, seldom only three. Cirrus sac oval, rather large. Cirrus strong heavily armed with rosethorn spines and long fine apical spines. No internal vesicle. Vas deferens anteroaporal. In Ciconiiformes, Ciconiae, Pelecaniformes, Accipitriformes. Cosmopolitan. Type-species **P. scolecina** (Rudolphi, 1819).*

Dilepidid cestodes parasitising African piscivorous birds have been recorded by, amongst others, Southwell (1926); Meggitt (1927); Joyeux and Baer (1936, 1950); Southwell and Lake (1939); Khalil (1961); Ukoli (1968) and Karstad, Sileo, Okeck and Khalil (1982). Khalil (1971) does not include any dilepidid cysticercoids in his Check List of *Helminth Parasites of African Freshwater Fishes*. However, in the revised edition of the latter work (Khalil, in press) this author lists dilepidid cestode larvae from a number of African freshwater fishes from Sudan (Bray, 1974); Nigeria (Aderounmu and Adniyi, 1972); Uganda (Khalil and Thurston, 1973) and South Africa (Mashego, 1982). It is interesting to note that all these records, except those of Mashego (1982) are from Africa north of the Equator.

Dilepidid material procured during the present study is therefore the first records of dilepidid cestodes from piscivorous birds in South Africa, while the recorded cysticercoids from freshwater fish hosts in the study area supplement the findings of Mashego (1982).

PARADILEPIS SCOLECINA IN THE NORTHERN PROVINCE, SOUTH AFRICA.

Paradilepis scolecina (Rudolphi, 1819) Hsü, 1935
(= *Taenia scolecina* Rudolphi, 1819;
T. scolecina Rudolphi, 1819 nec. Joyeux and Baer, 1928;
Dilepis scolecina Fuhrmann, 1908;
Paradilepis duboisi Hsü, 1935;
P. brevis Burt, 1940;
D. minima Goss, 1940).

During the present study *P. scolecina* was found parasitising three piscivorous birds in the Northern Province of South Africa. These hosts are:

Phalacrocorax carbo
P. africanus
Anhinga melanogaster

Larval cestodes identified as cysticercoids of *P. scolecina*, on the strength of the arrangement and structure of the rostellar hooks (Fig.32, p.148) were recovered by Mashego (1982) and Saayman and Schoonbee et. al. (1991) from the following fish intermediate hosts:

Barbus unitaeniatus
B. radiatus
B. trimaculatus
B. argenteus
B. paludinosus

Very excellent descriptions and/or morphological detail on *P. scolecina* are available in the literature (Mahon, 1955; Clark, 1957 and Matevosyan, 1963). The present material agrees in every detail with these accounts as is evident from Fig.31, p.147, Fig. 32, p.148 and Fig.35, p.151.

Table 26: Prevalence, intensity and mean intensity values for infection of *Phalacrocorax carbo, P. africanus* and *Anhinga melanogaster* with *Paradilepis scolecina* in the Northern Province of South Africa.

AVIAN HOST	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
P. carbo	39	Seshego Dam	92	5 - 436	67
	8	Middle Letaba Impoundment	88	8 - 2168	727
	2	Piet Gouws Dam	100	45 - 321	183
	2	Glen Alpine Dam	100	43 - 67	55
	1	Ebenhaezer Dam	100	14	14
P. africanus	44	Seshego Dam	32	7 - 57	18
	9	Middle Letaba Impoundment	44	1 - 11	7
	3	Hudson Ntsanwisi Dam	100	12 - 31	22
	1	Turfloop Dam	100	53	53
	2	Olifants River	-	-	-
A. melanogaster	24	Seshego Dam	50	10 - 53	26
	12	Middle Letaba Impoundment	-	-	-
	11	Hudson Ntsanwisi Dam	36	12 - 22	18
	2	Luphephe Dam	-	-	-
	6	Piet Gouws Dam	100	21 - 81	43
	4	Glen Alpine Dam	33	21	21
	4	Tzaneen Dam	-	-	-
		Olifants River	-	-	-

Table 26 clearly indicates *P. carbo* to be the host that is the most heavily infected with *P. scolecina* registering prevalence values between 88% and 100% for all the aquatic ecosystems from where hosts have been collected. Not only does this host register high prevalence of infection values but mean intensity and intensity infection figures could reach levels as high as 727 and 8 - 2168 respectively for the water bodies investigated.

P. africanus and *A. melanogaster* as host species to *P. scolecina*, seem to be equally susceptible to infection with this parasite. *A. melanogaster*, due to its numerical dominance at all the major aquatic ecosystems in the study area, probably plays a more prominent role in sustaining the life history of *P. scolecina* than do either *P. carbo* or *P. africanus*.

Table 27: Prevalence, intensity and mean intensity values for infection of fish intermediate hosts with cysticercoids of *Paradilepis scolecina* in the Northern Province of South Africa. After Mashego [=M] (1982) and Saayman and Schoonbee et. al. [=S and S] (1991).

FISH HOST AND REFERENCE	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
Barbus unitaeniatus [M]		Luphephe Dam	10	1 - 2	1
B. radiatus [M]		Luphpephe Dam	4	1 - 2	1
B. trimaculatus [M]		Luphephe, Nwanedzi, Seshego and Piet Gouws Dams	7	1 - 10	6
B. argenteus [M]		Piet Gouws Dam	9	1 - 2	1
B. paludinosus [M]		Luphephe, Nwanedzi, and Piet Gouws Dams and Olifants River	13	1 - 10	5
B. unitaeniatus [S and S]	82	Middle Letaba Impoundment	4.88	1 - 4	2.25
B. trimaculatus [S and S]	72	Middle Letaba Impoundment	5.55	1 - 3	1.50
B. paludinosus [S and S]	28	Middle Letaba Impoundment	3.57	1 - 1	1.00

From the above table it is evident that no less than five fish intermediate hosts play a role in the life cycle of *P. scolecina* in the Northern Province of South Africa. Infection statistics are such that piscivorous birds susceptible to *P. scolecina* could readily become infected/re-infected. *B. unitaeniatus, B. trimaculatus* and *B. paludinosus*, due to their almost continuous distribution throughout the study area (Gaigher 1969; Hecht and Saayman 1981; Hecht, Polling and Mokgalong 1981; Hecht and Scholtz 1983; Kleynhans 1984; Saayman 1986 and Schoonbee, Hecht, Saayman and Polling 1995) probably play major roles in the ecology of this parasite within the study area.

In conclusion, it may be stated that the ecological and life cycle requirements of *P. scolecina* are well met in the northern subtropical regions of South Africa. This parasite would therefore remain a factor in the ecoparasitological scene of the region and the chances of it being introduced to newly constructed man-made aquactic ecosystems in the Limpopo and Olifants Drainage Systems, are almost ensured.

THE STATUS OF *PARADILEPIS DELACHAUXI* IN THE NORTHERN PROVINCE OF SOUTH AFRICA

Paradilepis delachauxi (Fuhrmann, 1909)
(= *Oligorchis delachauxi* Fuhrmann, 1909;
Dilepis scolecina Joyeux and Baer, 1928
nec. (Rudolphi, 1819)
Dilepis lepidocolpos Burt, 1936).

This parasite was first described by Fuhrmann (1909) from *Phalacrocorax africanus* in Egypt. The material described by Fuhrmann (op. cit.) did not possess a scolex. Joyeux and Baer (1928) described a contracted specimen (with scolex) from a cormorant from West Africa as *Dilepis scolecina*. This species was subsequently transferred by the authors to the genus *Paradilepis* Hsü (1935) with the species becoming *P. delachauxi* (Fuhrmann, 1909).

Detailed morphological descriptions of *P. delachauxi* with complete measurements of diagnostic anatomical parts, were provided by Mahon (1955); Matevosyan (1963); Bona (1975) and Prudhoe and Hussey (1977). The material collected during the present investigation conforms in diagnostic detail to the abovementioned descriptions as is evident from Fig.31, p.147, Fig.32, p.148 and Fig.36, p.152.

During the present study *P. delachauxi* was found to be specific to the cormorants *P. carbo* and *P. africanus*. Cysticercoids of *P. delachauxi* were positively identified on the structure and arangement of the rostellar hooks. In the study area only the cichlids, *Oreochromis mossambicus* and *Pseudocrenilabris philander* were thus far positively identified as intermediate hosts for *P. delachauxi*. This apparent specificity to cichlid intermediate and phalacrocoracid final hosts in the study area is not surprising. Although this parasite seems to have a wide distribution in the southern hemisphere, all recorded intermediate fish and final avian hosts are from the cichlids and cormorants respectively.

Table 28: Prevalence, intensity and mean intensity levels of infection of *Phalacrocorax carbo* and *P. africanus* with *Paradilepis delachauxi* in the Northern Province of South Africa.

AVIAN HOST	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
P. carbo	39	Seshego Dam	85	3 - 588	71
	8	Middle Letaba Impoundment	88	2 - 1308	229
	2	Piet Gouws Dam	100	12 - 45	29
	2	Glen Alpine Dam	100	51 - 68	60
	1	Ebenhaezer Dam	100	29	29
P. africanus	44	Seshego Dam	89	1 - 18	8
	9	Middle Letaba Impoundment	44	1 - 8	4
	3	Hudson Ntsanwisi Dam	67	7	7
	1	Turfloop Dam	100	38	38
	2	Olifants River	100	2 - 4	3

The stastistics provided in Table 28 on the preceding page clearly indicate *P. carbo* to be substantially more susceptible to infection with *P. delachauxi* than is the case with *P. africanus*. This susceptibility may either be due to ecological or physiological factors. The present study did not attempt to verify physiological factors and an opinion upon this can therefore not be given. Ecological factors, in this particular context, can only be on a dietary level. The study did not include an analysis of the preferred dietary items of the two hosts in question. The noted higher susceptibility of *P. carbo* can therefore also not be explained at the hand of definite observations in this regard.

Table 28, p.140 also indicates that *P. delachauxi* has a well-established and widespread occurrence within the study area. This is to be expected because both *P. carbo* and *P. africanus* have an almost continuous distribution throughout the region. The avian host distributional factor is further enhanced by the occurrence and distribution of the identified intermediate fish hosts, namely, *O. mossambicus* and *P. philander* (see table 29). Extensive surveys (see chapter 7) indicate these two fish species to occur in almost all the water bodies in the area, and that *O. mossambicus* is without doubt the numerically dominant fish species in all the major impoundments. Fish ecological studies like those of Gaigher (1969) and Kleynhans (1984) have indicated that *P. philander* can overcome adverse climatological and water quality conditions and this, coupled with their aggressive breeding behaviour (Skelton, 1993), allow the species to recolonise aquatic habitats with measurable success following adverse environmental conditions.

Saayman (1986) and Saayman and Schoonbee et. al. (1991) recorded dilepidid cysticercoids from the gall bladder and duodenum of *O. mossambicus* and *P. philander* from water bodies in the region of the present study area. Examination of preserved material from these studies revealed the cysticercoids to belong to two different species. Comparison of the arrangement and morphological structure of the rostellar hooks clearly indicate these cysticercoids to belong to *P. delachauxi* and *Amirthalingamia macracantha*. The infection statistics of fish intermediate hosts infected with cysticercoids of *P. delachauxi* and *A. macracantha* are presented in Table 29 below.

Table 29: Prevalence, intensity and mean intensity values for infection of *Oreochromis mossambicus* and *Pseudocrenilabris philander* with cysticercoids of *Paradilepis delachauxi* and *Amirthalingamia macracantha* in the Northern Province of South Africa. After Saayman (1986) and Saayman and Schoonbee et. al. (1991).

FISH HOST	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
O. mossambicus	36	Piet Gouws Dam	66.6	1 - 118	13
O. mossambicus	128	Middle Letaba Impoundment	30.84	1 - 43	10.92
P. philander	48	Middle Letaba Impoundment	72.92	1 - 27	7.66

The preceding table clearly indicates that the rate of infection of both *O. mossambicus* and *P. philander* with cysticercoids of *P. delachauxi* is indicative of a reasonably high rate of infection of avian final hosts with this parasite. The rate of infection of susceptible final hosts in the Northern Province of South Africa is indicated in Table 29, p.140.

These statistics, read together with the ecological status of second intermediate and final hosts provided in the foregoing discussion, supports the conclusion that the life cycle requirements of *P. delachauxi* are very well established in the present study area.

PARADILEPIS URCEUS IN THE NORTHERN PROVINCE OF SOUTH AFRICA.

Paradilepis urceus (Wedl, 1855) Joyeux and Baer, 1950
(= *Taenia urceus* Wedl, 1855;
Dilepis urceus (Wedl, 1855) Fuhrmann, 1908;
Hymenolepis urceus (Wedl, 1855) Lopez-Neyra, 1942;
Hymenolepis multihamata Meggitt, 1927;
Meggittiella urceus (Wedl, 1855) Lopez-Neyra, 1942;
Meggittiella multihamata (Meggitt, 1927) Lopez-Neyra, 1942;
Skrjabinolepis multihamata (Meggitt, 1927) Mathevosyan, 1945;
Paradilepis hierticos Saxena, 1970 nec. Johri, 1934).

Paradilepis urceus was first described by Wedl (1855) as *Taenia urceus* from *Plegadis falcinellus* (Linnaeus) from Austria. Krabbe (1869)* re-described the species at the hand of material obtained from *Platalea* sp.

Mahon (1955) provided morphometric measurements of the hooks of *P. urceus* material from various researchers such as Wedl (1855); Krabbe (1869); Meggitt (1927) and Johri (1934). The same author (Mahon, op. cit.) also compared the structure and size of the hooks of *P. scolecina* and *P. urceus* and came to the following conclusion:

> *The dimensions of the large hooks of* ***P. scolecina*** *and* ***P. urceus*** *fall within the same range. The shapes are somewhat different, however, the tip of the hook of* ***P. urceus*** *being slightly more curved. The appearance of the entire worm is also different;* ***P. urceus*** *having a short stumpy form.* ***P. urceus*** *has three to four testes, and* ***P. scolecina*** *has four.* (p. 75)

From literature references such as Mahon (1955); Matevosyan (1963) and Bona (1975) it would appear as if *P. urceus* and *P. scolecina* are morphologically very closely related. During the present study cestodes considered to be *P. urceus* were obtained from the intestine of *Platalea alba* resident/breeding at Middle Letaba Impoundment. Like *P. scolecina* and unlike *P. delachauxi* these worms were not attached to the intestinal mucosa but occur free amongst the intestinal contents. Squashed preparations of the rostellum tend to indicate hooks which differ in shape from those of *P. scolecina* (Fig.32, p.148) The material obtained from *P. alba* is provisionally ascribed to *P. urceus* (Wedl, 1855).

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* Original paper with description was not available for the present study.

Table 30: Prevalence, intensity and mean intensity values for *Platalea alba* infection with *Paradilepis urceus* : Middle Letaba Impoundment, Northern Province, South Africa.

AVIAN HOST	N.	PREVALENCE	INTENSITY	MEAN INTENSITY
Platalea alba	3	100	436 - 658	545

AMIRTHALINGAMIA MACRACANTHA INFECTIONS IN THE NORTHERN PROVINCE, SOUTH AFRICA.

Amirthalingamia macracantha (Joyeux and Baer, 1935)
(= *Dilepis delachauxi* Joyeux and Baer, 1930 nec. Fuhrmann, 1909;
Paradilepis macracantha Joyeux and Baer, 1935).

This dilepidid species was first described by Joyeux and Baer (1930) as *Dilepis delachauxi* (Fuhrmann, 1909), from *Phalacrocorax africanus* from the Niger Valley, in Mali. In a later study Joyeux and Baer (1935) renamed their material as *Paradilepis macracantha*.

Bray (1974) examined material from the Sudan donated to the British Museum (Natural History) by Dr. C. Amirthalingam of the University of Khartoum. The material included cysticercoids from the liver and intestine of *Tilapia nilotica* and adult worms from the intestine of *P. carbo*. The same author (Bray, op. cit.) also re-examined the original material from which Joyeux and Baer (1930, 1935) described their *P. macracantha*. Because the material from the Sudan as well as the material of Joyeux and Baer differed from other Dilepididae in having large rostellar hooks of three sizes, in two rows and arranged in a bilaterally symmetrical pattern (Fig.32, p.148 and Fig.35, p.151) Bray (1974) erected a new genus *Amirthalingamia* Bray, 1974, with type-species *A. macracantha* (Joyeux and Baer, 1935).

Material collected during the present study from *P. carbo* and *P. africanus* agrees most closely with the morphological description and morphometric data provided by Bray (1974). (Fig.32, p.148, Fig.33, p.149, Fig.34, p.150 and Fig.35, p.151). The material from the present study is therefore assigned to *A.macracantha* (Joyeux and Baer, 1935).

A. macracantha is widespread throughout the study area (Table 31, p.144) and utilises two final hosts, namely, *P. carbo* and *P. africanus*. Infection levels of final hosts with this parasite are not very high as is evident from Table 31, p.144. If this is compared to the infection statistics of the same two hosts with *P. delachauxi* (Table 28, p.140) the difference is pronouncedly in favour of the latter parasite.

Table 31: Prevalence, intensity and mean intensity values for infection of *Phalacrocorax carbo* and *P. africanus* with *Amirthalingamia macracantha* in the Northern Province of South Africa.

AVIAN HOST	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
P. carbo	39	Seshego Dam	62	1 - 11	3
	8	Middle Letaba Impoundment	13	2	2
	2	Piet Gouws Dam	100	1 - 3	2
	2	Glen Alpine Dam	100	1	1
	1	Ebenhaezer Dam	100	2	2
P. africanus	44	Seshego Dam	61	1 - 5	2
	9	Middle Letaba Impoundment	22	1 - 2	1.5
	3	Hudson Ntsanwisi Dam	67	1 - 2	1.5
	1	Turfloop Dam	-	-	-
	2	Olifants River	-	-	-

It appears as if there had been no direct competition between *A. macracantha* and *P. delachauxi* within the intestine of the final host. *A. macracantha* is always located in the posterior third of the intestine, whereas *P. delachauxi* occurs in the anterior two-thirds of the intestinal tract. A further difference between these two dilepid cestodes is that *A. macracantha* occurs free amongst the intestinal contents while *P. delachauxi* is always firmly attached to the inner lining of the intestinal wall (Fig.32, p.148).

The location of *A. macracantha* in the distal portion of the intestinal tract may explain the greater development of the rostellar hooks if compared with other Dilepididae. This part of the intestine normally contains very densely packed undigestible remains and it should be difficult for a parasite to maintain its station in these circumstances unless it is provided with well equipped holdfast stuctures.

During the present study two fish intermediate hosts for *A. macracantha* have been identified. These are:

Oreochromis mossambicus
Pseudocrenilabris philander

Saayman (1986) and Saayman and Schoonbee et. al. (1991) provided infection statistics for the above fish hosts with cysticercoids of *P. delachauxi* and *A. macracanta* (Table 29, p.141). These authors, however, did not separate the cysticercoids of these two parasites but considered it only as dilepidid cysticercoids. An examination of their preserved material indicated two distinct types of cysticercoids. On the strength of the anatomy as well as the arrangement of the rostellar hooks the present study identified these cysticercoids as belonging to *P. scolecina* and *A, macracantha*. Bray (1974) identified cysticercoids of *A. macracantha* from *Tilapia nilotica* from the Green Belt of Sudan which he considered to be conspecific with adult *A. macracantha* from *P. carbo* in the same area.

It would therefore appear as if *A. macracantha* is a parasite that is host specific to members of the Phalacrocoracidae (adults) and Cichlidae (larval forms).

LIFE CYCLES OF DILEPIDID PARASITES.

The life cycles of Dilepidid cestodes have not been studied in any great detail. The cycle generally involves three hosts, namely, an invertebrate host in which the egg develops; a fish intermediate host in which development proceeds to infective larval stages, variously referred to by different authors as plerocercus, plerocercoid and cysticercus. Final hosts are fish-eating pelecaniform birds, and for Africa, apparently mainly members of the family Phalacrocoracidae. Species have been reported parasitising piscivorous avian hosts from Africa, Europe, Australia, the Far East and from North America (Khalil and Thurston, 1973).

PATHOLOGY OF DILEPIDID INFECTIONS.

The literature reveals hardly any reference to specific pathological damage caused by dilepidid cestodes to their fish intermediate hosts. The present study also did not reveal any observable effects ascribable to infection by dilepidid cysticercoids. In very heavy infestations these parasites must surely be capable of blocking the biliary system, while encystment on the intestinal epithelium or penetration of the intestinal wall must surely result in cytological damage.

P. delachauxi is always firmly attached to the intestinal lining of its final host. The scoleces are usually very firmly embedded in the intestinal wall. Karstad et. al. (1982) described serious pathological damage to the intestinal wall of *P. carbo* from Lake Nakuru, Kenya. This damage was ascribed to infection with *P. scolecina*. The authors stated that the parasites were embedded so deeply into the wall of the intestine *that they had penetrated the mucosa, submucosa and all but a very thin layer of muscle beneath the serosa*.

The material from which Karstad et. al. (1982) described this pathological condition was deposited in the Commonwealth Institute of Parasitology, Helminth collection Number 3586. The present author examined this material, squashed a rostellum in Berlese Fluid and identified the parasite not as *P. scolecina* but as *P. delachauxi*.

Baer (1959) also noted considerable histological damage caused by *P. delachauxi* in *P. africanus*, while Prudhoe and Hussey (1977) also reported on the method of attachment of the parasite to the intestinal layers of *P. africanus*.

The present study demonstrated *P. delachauxi* to implant very firmly into the intestinal layers. Locations of the implanted scoleces are clearly visible as white hemispherical nodules on the outside of the intestinal wall (Fig.32, p.148).

FIG. 31

PARADILEPIS SCOLECINA AND P. DELACHAUXI
(Scanning Electron Microscopy)

A. *Scolex of Paradilepis scolecina*

B. *Rostellum of Paradilepis scolecina illustrating two sizes of hooks*

C. *Scolex of Paradilepis delachauxi*

D. *Rostellum of Paradilepis delachauxi showing two sizes of hooks*

Key:

rh. - rostellar hooks

ro. - rostellum

sc. - scolex

su. - sucker

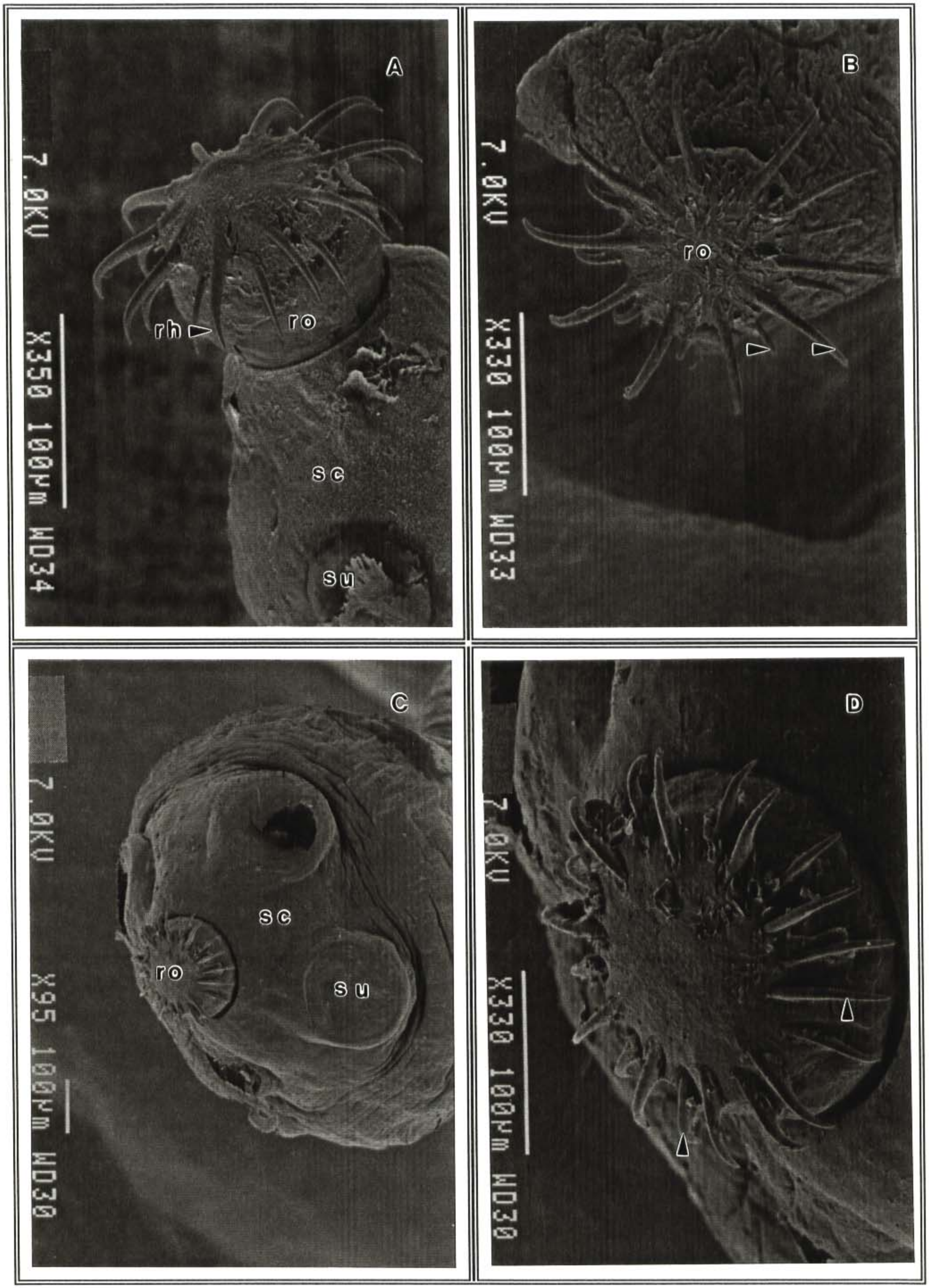

A
7.0KV X350 100µm WD34
rh
ro
sc
su
B
7.0KV X330 100µm WD33
ro
C
7.0KV X95 100µm WD30
ro
sc
su
D
7.0KV X330 100µm WD30

FIG. 32.

PARADILEPIS SCOLECINA, P. DELACHAUXI AND AMIRTHALINGAMIA MACRACANTHA
(Light Microscopy)

A. ***Rostellar hooks of Paradilepis scolecina x 125***

B. ***Rostellar hooks of Paradilepis delachauxi x 125***

C. ***Rostellar hooks of Amirthalingamia macracantha x 50***

D. ***Intestine of Phalacrocorax africanus showing nodules caused by Paradilepis delachauxi x 6***

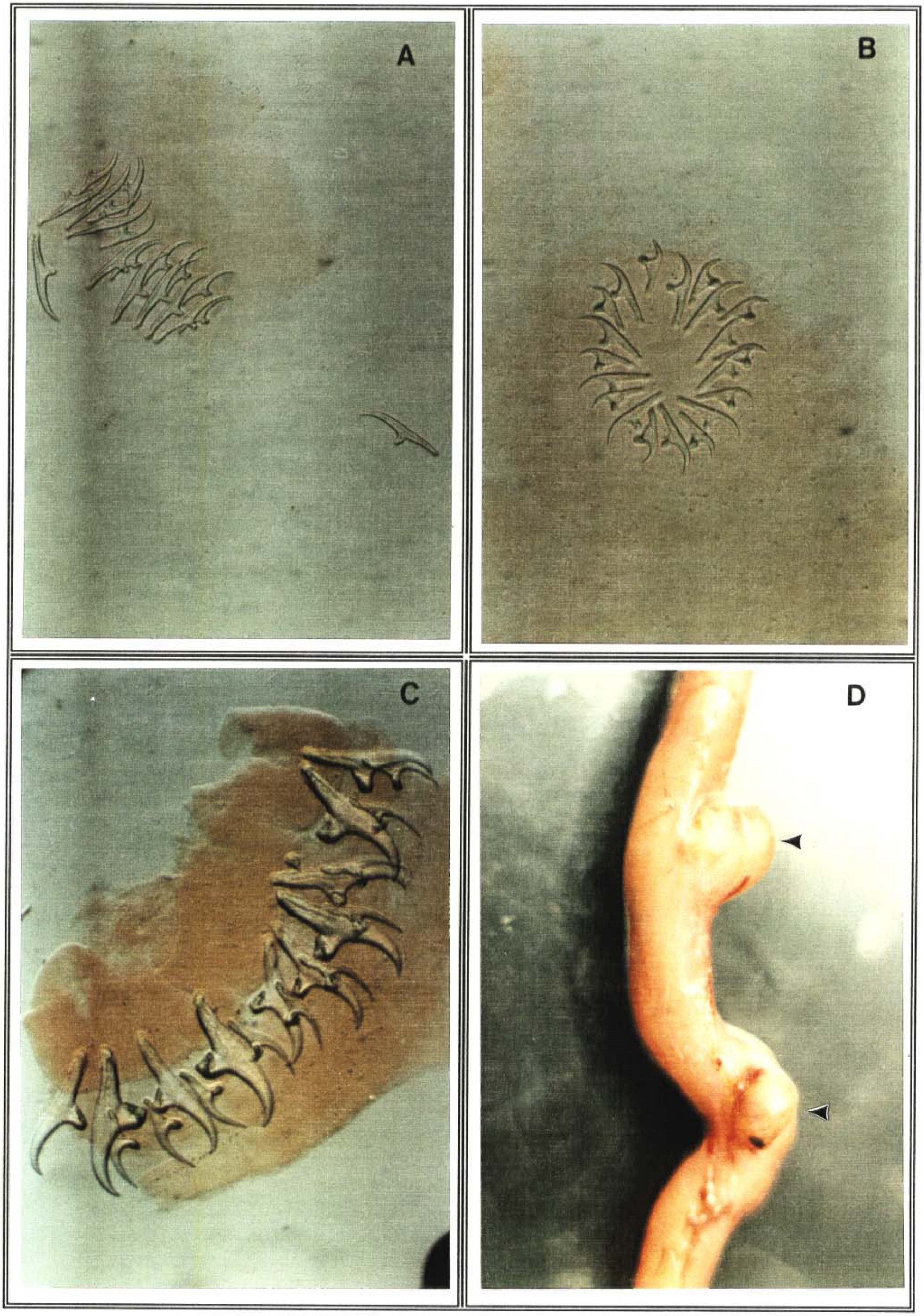

A
B
C
D

FIG. 33.

AMIRTHALINGAMIA MACRACANTHA AND LIGULA INTESTINALIS
(Scanning Electron Microscopy)

A. *Scolex of Amirthalingamia macracantha illustrating rostellar hooks and suckers*

B. *Rostellum of Amirthalingamia macracantha illustrating the three different sizes of hooks*

C. *Scolex of Amirthalingamia macracantha*

D. *Scolex of Ligula intestinalis illustrating the bothridium*

Key:

bo. - bothridium

rh. - rostellar hooks

ro. - rostellum

sc. - scolex

su. - sucker

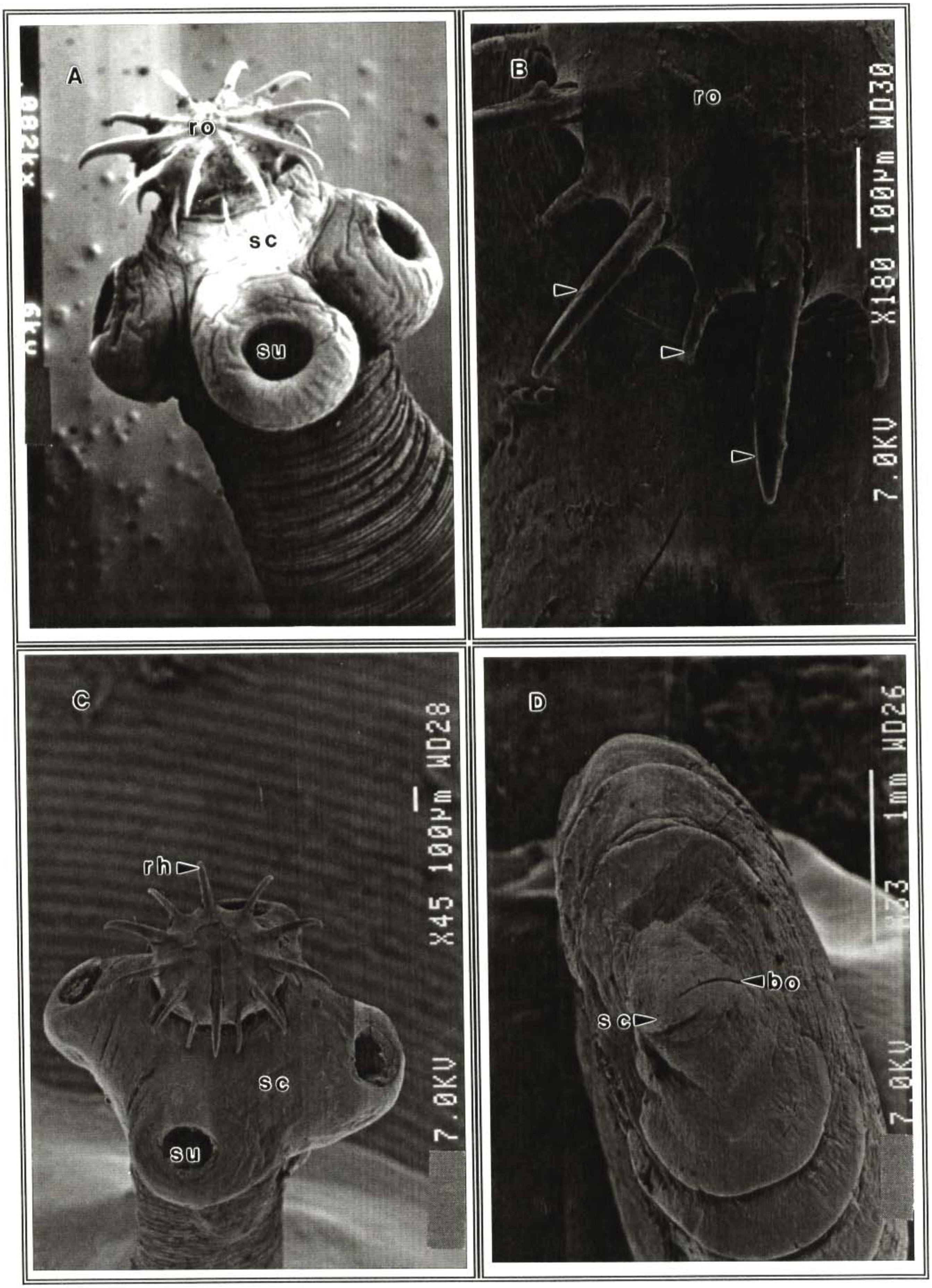

A
ro
sc
su
6kv
B
ro
7.0KV X180 100μm WD30
C
rh
sc
su
7.0KV X45 100μm WD28
D
bo
sc
7.0KV 1mm WD26

FIG. 34

AMIRTHALINGAMIA MACRACANTHA

Morphology
(After Bray, 1974)

A. ***Three different sizes of rostellar hooks***

B. ***En face diagram illustrating the symmetry of the rostellar hooks in the anterior row. (Refer also figure 32 C)***

C. ***Larval form in liver of*** *Tilapia nilotica*

D. ***Adult scolex***

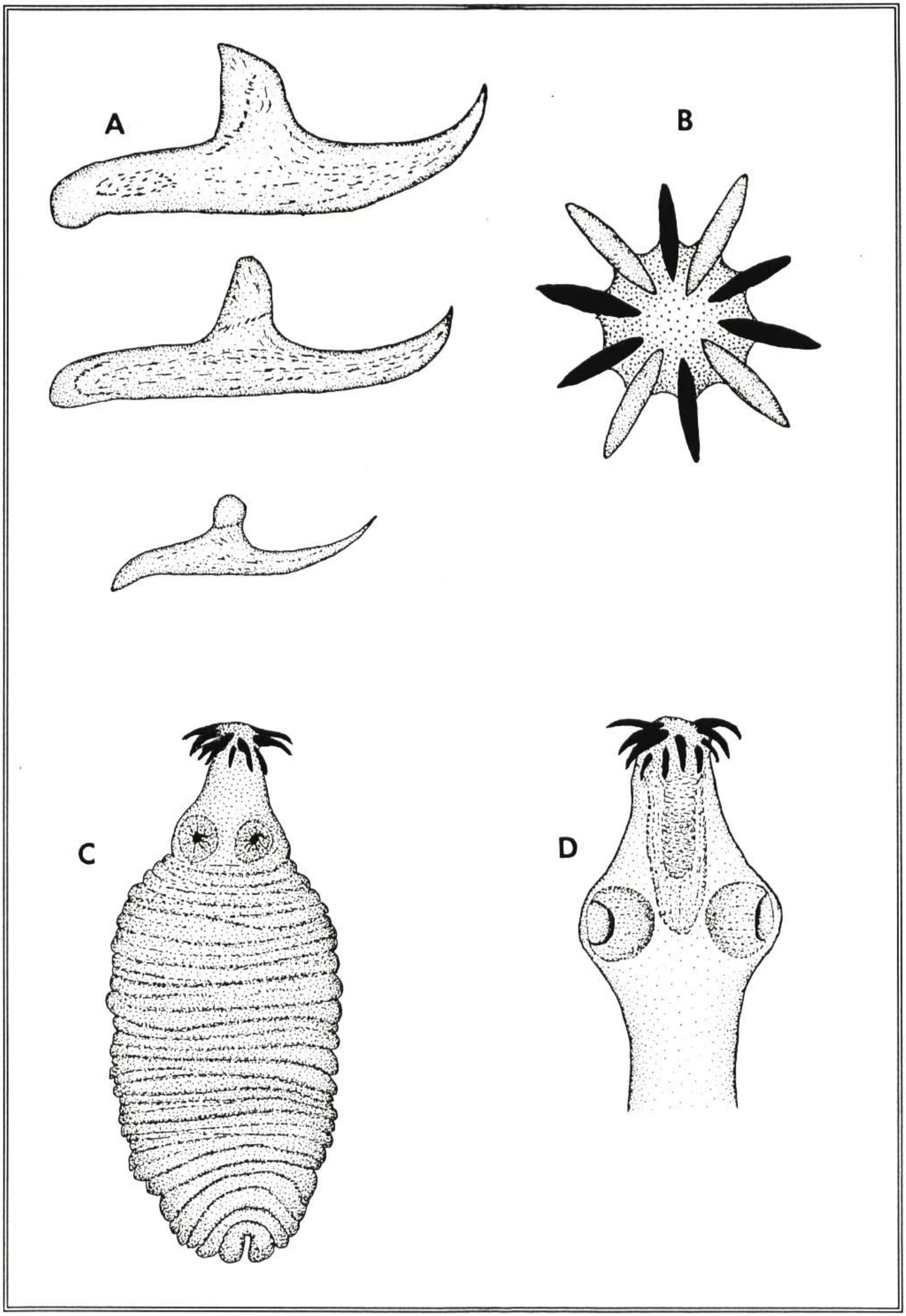

A
B
C
D

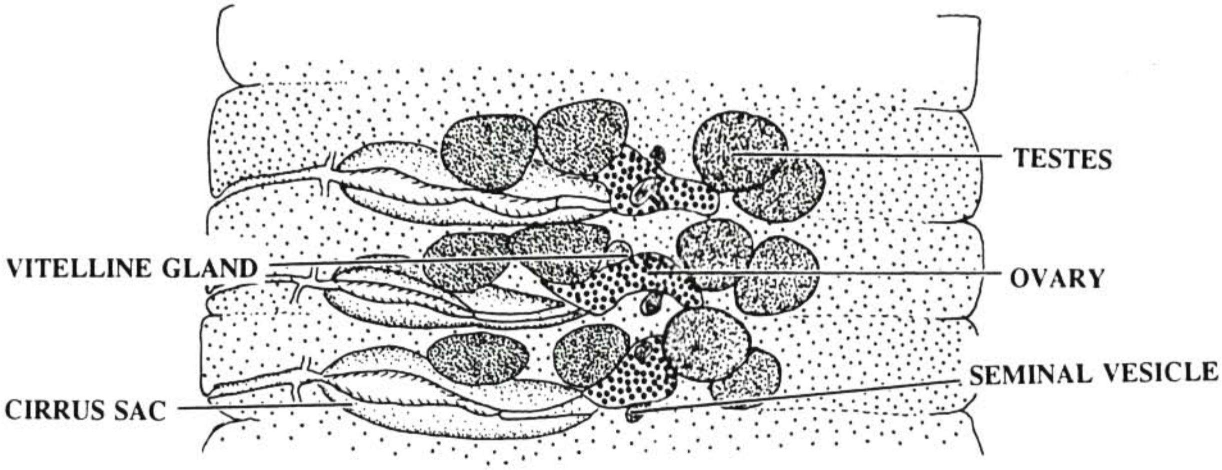
FIG. 35

PARADILEPIS SCOLECINA AND AMIRTHALINGAMIA MACRACANTHA

A. *Line drawing illustrating the morphology of a mature proglottid of Paradilepis scolecina (After Mahon, 1955)*

B. *The morphology of a mature proglottid of Amirthalingamia macracantha (After Bray, 1974)*

A


TESTES
VITELLINE GLAND
OVARY
SEMINAL VESICLE
CIRRUS SAC

B

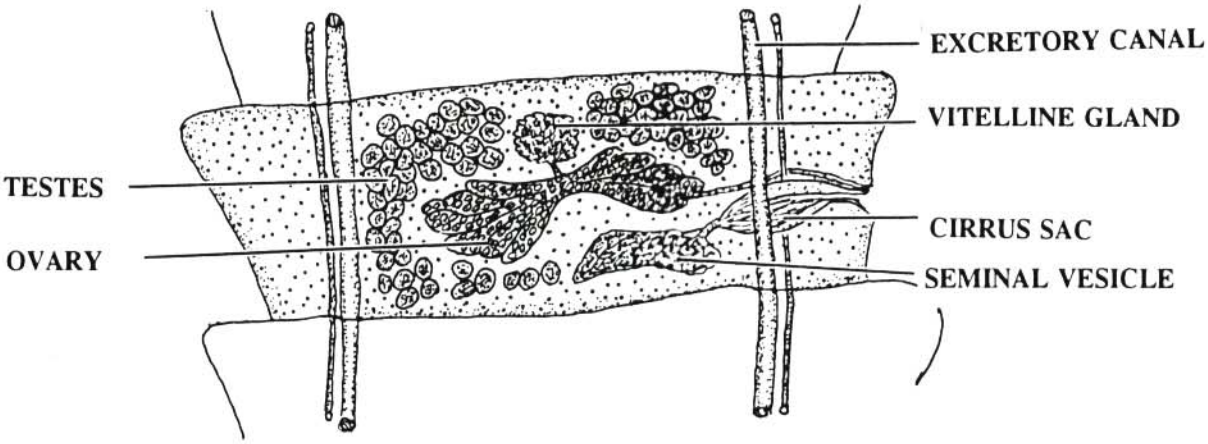

EXCRETORY CANAL
VITELLINE GLAND
TESTES
CIRRUS SAC
OVARY
SEMINAL VESICLE

FIG. 36

LIGULA INTESTINALIS AND PARADILEPIS DELACHAUXI
(Light Microscopy)

A. ***Fish (Barbus sp.) infected with Ligula intestinalis (photo)***

B. ***Mature proglottids of Paradilepis delachauxi x 40***

C. ***Developing proglottids of Paradilepis delachauxi x 40***

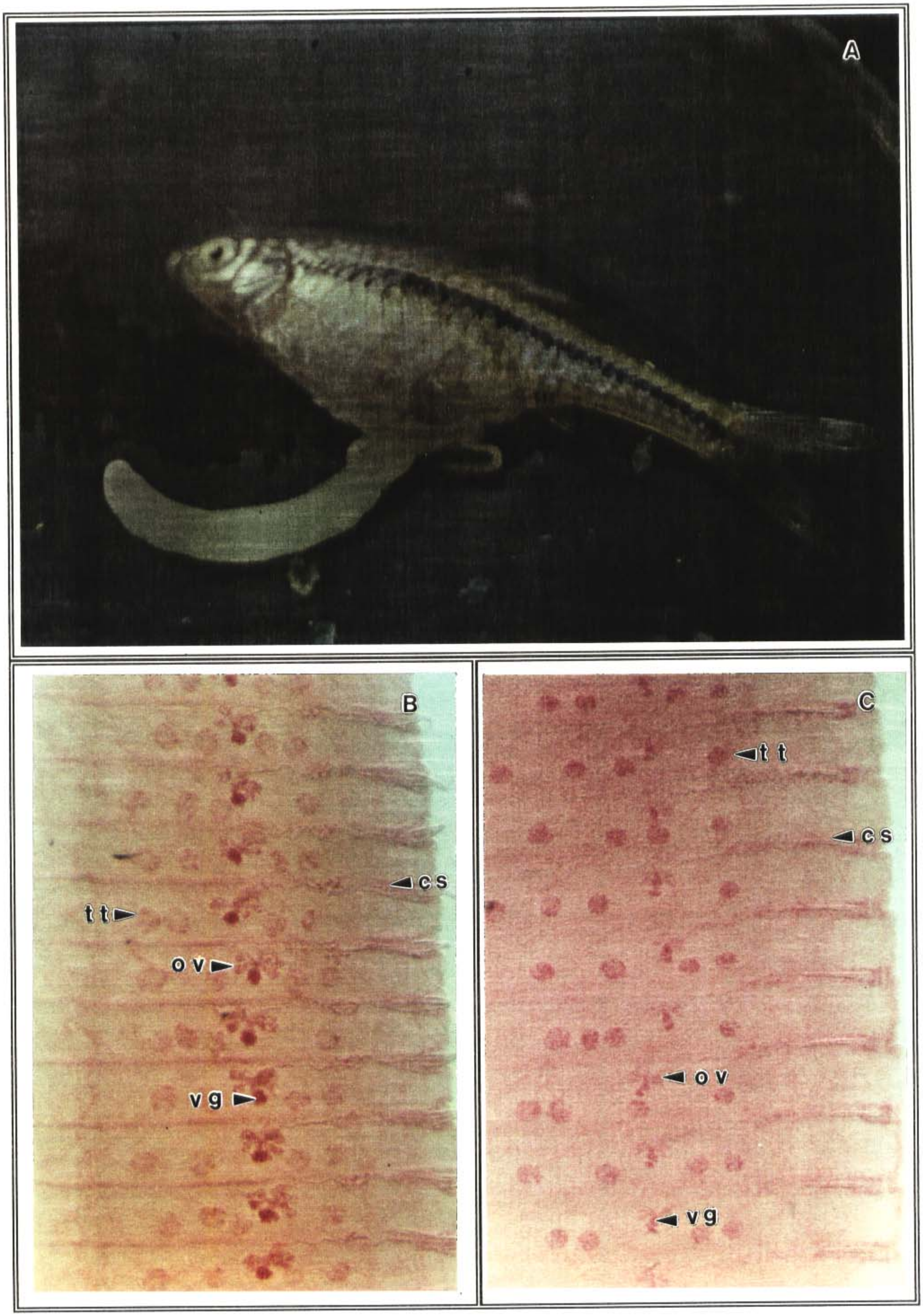
Key:

cs. - cirrus sac

ov. - ovary

tt. - testes

vg. - vitelline gland


A
B
cs
tt
ov
vg
C
tt
cs
ov
vg

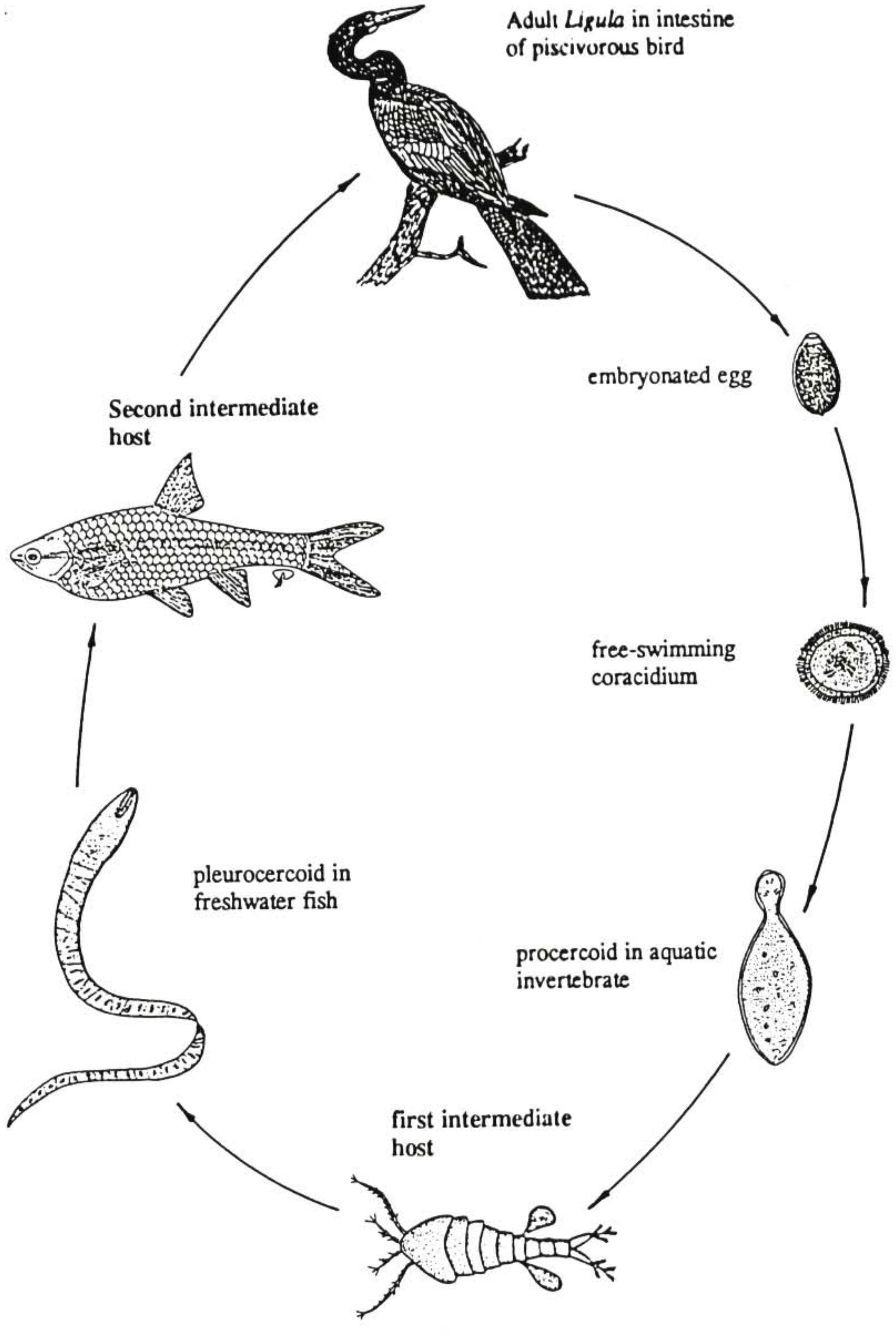


Fig. 37 - Life cycle of *Ligula intestinalis*

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4

Nematodan Parasites of *Phalacrocorax carbo*, *P. africanus* and *Anhinga melanogaster* involving a fish intermediate host in the life cycle.

4

During the present study only one nematode genus was recovered from the piscivorous birds investigated. This genus, *Contracaecum*, was represented by no less than six known and one undescribed species.

The genus *Contracaecum* has a very wide geographical as well as host distribution as parasites of marine and freshwater fish, birds and mammals. *Contracaecum*, as defined at present, is one of the largest ascaridoid genera. Although some species parasitise seals and dolphins, the most prevalent final hosts appear to be piscivorous birds (Hartwich, 1957). Second and third stage larvae parasitise a wide range of freshwater and marine fish intermediate hosts.

A vast literature exists on the biology of *Contracaecum* spp. A literature search revealed that between 1970 and 1995 no less than 208 published works appeared. On analysis these 208 publications indicate that the areas of interest in studies of *Contracaecum*, in descending numerical sequence, are as follows:

Parasites of freshwater fish:	65 publications
Parasites of birds:	43 publications
Parasites of marine fish:	39 publications
Infection statistics in fish and birds:	24 publications
Life cycle studies:	14 publications
Pathology:	8 publications
Parasites of mammals:	6 publications
Morphology, Histology and Biochemistry:	4 publications
Taxonomy:	3 publications

Nine publications deal with *Contracaecum* from South African fish and avian hosts (Ortlepp, 1938; Bisseru, 1955; Prudhoe and Hussey, 1977; Whitfield and Heeg, 1977; Mashego and Saayman, 1981, Boomker, 1982, 1994a and b and Saayman, Mashego and Mokgalong, 1986). Very few literature records exist on *Contracaecum* infections of South African piscivorous birds. The only records that could be traced are those of Ortlepp (1938); Prudhoe and Hussey (1977) and Whitfield and Heeg (1977). Only members of the Phalacrocoracidae together with *Pelecanus onocrotalus* and *Ceryle rudis* were positively identified as carriers of *Contracaecum* spp. This is in stark contrast with a vast literature on *Contracaecum* infections of birds elsewhere in the world. Barus, Sergeeva, Sonin and Ryzhikov (1978) list the following avian species that act as final hosts for some 51 species of *Contracaecum* from around the world:

Podiceps auritus
P. capensis
P. cristatus
P. griseigena
P. nigricollis
P. ruficollis
Procellaria diomedea
Fulmarus glacialis
Pelecanus onocrotalus
P. crispus
Phalacrocorax cappilatus
P. carbo
P. pelagicus
P. pigmaeus
Haliaetus albicilla
H. leocoryphus
Mergus albellis
M. serrator
M. squamatus
Pandion haliaetus
Ardea cinerea
A. purpurea
Egretta alba
E. garzetta
Ardeola bacchus
A. ralloides
Botauras stellaris
Bubulcus ibis
Nycticorax nycticorax
Butorides striatus
Ixobrychus minutus
Platalea leucoridia
Sterna alaeutica
S. paradisea
S. sandvicensis
Plegadis falcinellus
Stercorarius longicaudatus
S. parasiticus
Rissa brevirostris
R. tridactyla
Ciconaria nigra
Larus canus
L. crassirostris
L. fuscus
L. genei
L. hyperboreus
L. ichthyaetus
L. marinus
L. minutus
L. rudibundus
Alca torda
Uria aalge
U. romvia
Gavia adamsii
G. arctica
G. immer
G. stellata

The present study represents the first comprehensive survey of South African piscivorous birds as hosts for *Contracaecum* infections. In this study only 16 avian species from freshwater ecosystems were investigated (cf.pp. 15 and 282) for the presence of *Contracaecum*. Consulting the most widely used field guide to the birds of South Africa, namely, **Roberts' Birds of southern Africa** (Fifth Edition, revised by G.R. McLachlan, 1985), it comes to light that no less than 39 species of piscivorous marine birds are common residents/migrants to the South African marine environment. Some of these species are so numerous on the coast and offshore islands that South Africa has, for many decades already, had a flourishing guano industry. If the abundance and variety of marine piscivorous birds are coupled with the fact that the South African oceans host in excess of 2 200 marine fish species (Smith and Heemstra, 1988) it is surprising that no records exist of *Contracaecum* spp. from the South African marine avifauna. This must surely provide an excellent and worthwhile field for future investigations. The 39 species of piscivorous marine birds mentioned above belong to the families:-

Spheniscidae - Penguins
Diomedeidae - Albatrosses
Procellariidae - Petrels and Shearwaters
Oceantidae - Storm Petrels
Pelecanidae - Pelicans
Sulidae - Gannets and Boobies
Phalacrocoracidae - Cormorants

The taxonomic hierarchy for the genus *Contracaecum* is as follows:

Phylum : Aschelminthes

Class : Nematoda

Order : Ascarididae Yamaguti, 1961 (= Ascaroidea Railliet and Henry, 1915)

Superfamily : Ascaridoidea Baird, 1853.

Family : Anisakidae (Railliet and Henry, 1912 Subfamily) Skrjabin and Karokhin, 1945. (= Heterocheilidae Railliet and Henry, 1915 in part;) Stomachidae (Johnston and Mawson 1945 Subfamily) Hartwich, 1945)

Subfamily : Anisakinae Railliet and Henry 1912 (= Capsulariinae Johnston and Mawson, 1943; Filocapsulariinae Yamaguti, 1961, in part; Stomachinae Johnston and Mawson, 1945).

Genus: ***Contracaecum*** **(Railliet and Henry, 1912)**

(= *Kathleena* Leiper and Atkinson, 1914;
Hysterothylacium Ward and Magath, 1917;
Amphicaecum Walton, 1927;
Cerascaris Cobb, 1929;
Iheringascaris Pereira, 1935;
Contracaecum (ornitocaecum) Mozgovoi, 1951;
Contracaecum (Synthetonema) Kreis, 1952).

The original definition of the genus *Contracaecum* by Railliet and Henry (1912) was based on the morphology of the oesophago-intestinal region. *C. spiculigerum* (Rudolphi, 1809) (= *Ascaris spiculigerum* Rudolphi, 1809) was designated as the type species. The original material of *C. spiculigerum* was later identified as *C. microcephalum* (Rudolphi, 1809) by Hartwich (1964) and the latter species was accordingly designated as the new type species for the genus.

Hartwich (1957) defined the genus in more detail by adding additional diagnostic features such as the presence of interlabia and the excretory pore at the base of the ventral interlabium. Berland (1964) suggested an emendation of the genus *Contracaecum*. His proposal was to retain within *Contracaecum* all the species from fish and avian hosts. The genus *Phocascaris* Host, 1932, would then include all the species from mammals. Hartwich (1975) did not accept this emendation noting that *Phocascaris* was erected to contain species devoid of interlabia.

A great many *Contracaecum* species have been described from freshwater and marine fishes, piscivorous birds and fish-eating mammals. A review of the valid/invalid species or the variability of the diagnostic characteristics on which species seperation is based, would be a major if not impossible task - and clearly falls outside the scope of the present study. The following synopsis clearly substantiates this statement:-

- Yamaguti (1961), lists the following numbers of *Contracaecum* species from the various intermediate and final hosts:

Fishes : 77 species
Birds : 61 species
Mammals : 10 species

- Barus, Sergeeva, Sonin and Ryzhikov (1978) maintain that fish-eating birds are parasitised by no less than 51 known species of *Contracaecum*. 15 species are from the Palaeartic Region;

- Bykhovskaya-Pavloskaya et. al. (1962) state that the genus *Contracaecum* contains various larval forms that are extremely difficult to diagnose and *for which the compilation of synoptic keys appears impossible* - p 623;

- The preceding quotation is supported by more recent workers like Fagerholm (1988a) who states:

  Species of the genus ***Contracaecum*** *Railliet and Henry, (1912) are common parasites, mainly of seals and piscivorous hosts throughout the world. Whereas the fourth-stage larvae and adult worms develop in the final host, the infective third-stage larvae in marine regions are found mainly in fishes. Because of morphological similarities between the third-stage larvae of different species of the genus and the neighbouring genus* ***Phocascaris*** *(Host, 1932), it is not possible to differentiate between the species at that stage of development using morphological criteria* - p. 57.

  The above quotations from Bykhovskaya-Pavlovskaya et. al. (1962) and Fagerholm (1988) supported by observations on *Contracaecum* infections of freshwater fish species in the present study area, must cast considerable doubt on the validity of most of the 77 species which Yamaguti (1961) lists from freshwater fish hosts. Any third-stage larval *Contracaecum* from a fish intermediate host can only be designated species status if it is verified by experimental life cycle studies.

- Even the validity of some species of *Contracaecum* described from sexually mature specimens parasitising piscivorous birds and mammals is all but certain. The problem seems to lie in the taxonomic validity of the anatomical structures that are used for classificatory purposes. Another factor responsible for such a situation may also be intra-specific variability of the morphology in a single host population of a *Contracaecum* species in question. This aspect has been specifically dealt with by Fagerholm (1989) who concluded that: *Good taxonomic criteria which have been used in defining species of the genus* ***Contracaecum*** *are few. This problem was to a certain degree analysed by Hartwich (1964) in relation to some species occurring in birds* - p.40.

  Fagerholm (op. cit.) analysed the feasibility of using certain morphological features and came to the following conclusions:

  - **Spicule length** *Spicules do not attain full length until the worm has reached its full size. The distal part of the spicule is first formed and additional growth occurs proximally. Thus the length increase in the spicules goes on for an extended period of time which should be considered in choosing material for morphological analyses* - p. 40;

- **Number and distribution of caudal papillae** *Although the number of the subventral precloacal papillae is usually provided in descriptions of species, the amount of intra-specific variation in this feature is generally not known* - p. 40;

Fagerholm's research (1989b) on *Contracaecum osculatum* indicated that the number of papillae, which is set at the last ecdysis, does not change as the worm increases in size. This feature can, therefore, be used in delimiting species described from fully mature specimens;

- **Morphometric data on oesophago-intestinal region** McClelland and Ronald (1979) found that the width of the oesophagus (for *C. osculatum*), which in *Contracaecum* is of taxonomic importance only in exceptional cases, is rather isodiametric throughout its length attaining its maximum width near the posterior end. This observation for the development of *C. osculatum* may very well be valid for other species of *Contracaecum*. McClelland and Ronald (1979) also found that *C. osculatum* shows allometric growth of the ventricular appendix and the intestinal caecum in relation to body length: The caecum grows faster than the appendix. In addition the relative length of the oesophagus increases faster than the appendix.

The above observations, unless otherwise proved, may well apply to other species of the genus. If this should be the case, or even in the event of unproven clarity, it casts doubt on the intra-specific variability and/or validity of these characteristics as used in previous descriptions.

- **Phenotypic variation in the distribution of subapical and proximal caudal papillae** *In vivo* cultured specimens of *C. osculatum* in an experimental host indicated obvious phenotypic variation in the distribution of the subapical and proximal caudal papillae (Fagerholm, 1989a). Should this be the case for other species of the genus, or even for specimens of the same species from different final hosts or zoogeographical areas, the validity of isolating this feature for taxonomic purposes remains insecure or even doubtful.

The intra-specific and inter-specific variability of, and the suitability of using certain anatomical features in the taxonomic designation of species of the superfamily Ascaridoidea (Baird, 1853) have been dealt with by a number of workers (Campana-Rouget and Paulian, 1950; Hartwich, 1964; McClelland and Ronald, 1974; Gibson and Taylor, 1976; Lichtenfels, Bier and Madden, 1978; Gibson, 1983; Sprent, 1983; Fagerholm and Gibson, 1987; Fagerholm, 1988, 1989a and b, 1991).

The introduction of Scanning Electron Microscopy (SEM) to the study of nematode morphology and taxonomy has brought a completely new dimension to this field of scientific endeavour. This instrument, with its high magnification and power of resolution, revealed accurate morphological details that were not possible with light microscope studies (Gibbons, 1986; Fagerholm and Gibson, 1987). In this regard Hirschmann (1983) noted that closely related species or sibling species which had appeared morphologically identical by light microscopy can clearly be distinguished with SEM studies. The same author also remarked that differences between populations or races of species can now easily be demonstrated. In the same vein, this instrument has opened up new possibilities for the grouping of species within a genus, or genera within a family and, has in a number of instances, led to the reconstruction of phylogenies (Hirschmann, 1983).

At present there are a number of biochemical methods available to use in the differentiation of *Contracaecum* species. These methods which include Electrophoretic enzyme analysis (Fagerholm, 1991; Koie and Fagerholm, 1995) would be extremely useful in future studies on the lower order taxonomy of this group of nematodes. However, judging from the publication analysis on *Contracaecum* (p.162), it would appear that this procedure has, as yet, not been widely applied to *Contracaecum* systematics. Therefore, an attempt to revise *Contracaecum* systematics at this stage would be somewhat premature.

From the foregoing it is evident that the generic taxonomy of *Contracaecum* may change considerably within the foreseeable future. It is for these and other reasons (p.169) that it was decided to designate species of *Contracaecum* procured during the present study to fit in with well substantiated existing species descriptions.

GENERIC DIAGNOSIS OF *CONTRACAECUM*:

Yamaguti (1961), as ammended by Barus et. al. (1978), gave the following generic diagnosis for *Contracaecum*

> *Lips without dentigerous ridges; interlabia present, usually well developed. Ventriculus reduced, with solid posterior appendix. Intestinal caecum present. Male without definite caudal alae. Postanal papillae number up to eight pairs, partly subventral and partly lateral. Precloacal papillae numerous. Spicules long, alate, equal or subequal; gubernaculum absent. Female with vulva in anterior region of body. Oviparous. Parasites of fishes, birds and piscivorous mammals.*

The present investigation attempted to evaluate the usefulness of some morphological characters previously used in species designation of the genus *Contracaecum*. This was done at the hand of observations on sexually matured specimens procured during the study. The characters evaluated included the following:-

- Variability in the length of the spicules;
- Variability in the morphology of the distal end of the spicules;
- The number, shape and distribution of the caudal papillae.

Light microscopical examinations of wet specimens as well as whole mount permanent preparations, supplemented by SEM studies of the material collected during the present study revealed the following:-

- The length of the spicules is constant, and within a very narrow range, for a particular species;

- The morphology of the distal end of the spicules is a very valuable morphological entity for species diagnosis provided that inter-specific variation is recognized;

- An evaluation of the significance of the numbers and distribution patterns of caudal papillae and papilla-like structures in *Contracaecum* spp. revealed that these features are valuable diagnostic entities to separate different species. As it can be observed from Figs.38 - 45, pp. 193 - 200 the numbers and distribution of these structures were constant per given species even despite the size (or developmental stage) of the adult male.

An evaluation of the taxonomic significance of the numbers and distribution patterns of caudal papillae and papilla-like structures in the superfamily Ascaridoidea was initiated by Fagerholm (1989a, 1990). This was based on the observation that the results for *Contracaecum*, one of the fifty ascaridoid genera, suggested a considerable stability in these features (Fagerholm, 1988, 1989a). Observations recorded during the present study verify the results of Fagerhalm (1988, 1989a) (see previous paragraph).

Analysis of previous investigations, as summarized on the foregoing pages, together with observations recorded during the present study, tempted this investigation to designate recorded *Contracaecum* material to species level at the hand of a *pot pourri* of characteristics. For each of the suspected species obtained during the study, the relevant anatomical features observed are tabled together with information on the particular characteristic as was supplied in the original species description.

The morphological features used during the present study are summarised in Table 32 below.

Table 32: Morphological features used in identification of species of *Contracaecum* for the present study

MORPHOLOGICAL CHARACTERISTICS	ORIGINAL DESCRIPTION	PRESENT MATERIAL
Body length		
Body width		
Head diameter		
Lip length		
Interlabia length		
Oesophagus length		
Ventriculus length		
Ventriculus width		
Ventricular appendix length		
Ventricular appendix width		
Intestinal caecum length		
Intestinal caecum width		
Intestine length		
Intestine width		
Spicules length		
Tail length		
Shape and number of labial papillae		
Shape of interlabia		
Number of precloacal papillae		
Number and topography of caudal papillae		

Contracaecum microcephalum (Rudolphi, 1809)

(= *Ascaris microcephala* Rudolphi, 1809;
A. ardearum (Rudolphi, 1809)
Kathleena arcuata Gedoelst, 1916
Contracaecum quadricuspe Walton, 1923.

This species was first described as *Ascaris microcephala* by Rudolphi (1809) from material obtained from *Ardeola ralloides* from Central Europe. During the years an extensive bibliography built up around this species, which is summarised by Barus et. al. 1978. Baylis (1920) transferred *Ascaris microcephala* to the genus *Contracaecum*.

Baylis and Daubney (1922, 1923) re-examined the type specimens of *K. arcuata* Gedoelst, 1916 and synonymised it with the orginal material of Rudolphi (1809), while Cram (1927) also synonymised *C. quadricuspe* Walton, 1923, with *C. microcephalum* (Rudolphi, 1809). The latter, *C. microcephalum*, has a very wide host- as well as geographical distribution. Cram (1927), Yamaguti (1961) and Barus et. al. (1978) provide no less than 38 avian hosts species for this particular parasite. The most important avian families seem to be Pelecanidae, Phalacrocoracidae, Anhingidae, Ardeidae, Ciconiidae, Plataleidae, Anatidae, Laridae and Sternidae. It is interesting to note that Cram (1927) lists two species of the Anatidae, namely, *Anas boschas* and *A. domestica* as hosts, whereas Yamaguti (1961) and Barus et. al. (1978) do not list any anatid species as hosts. The latter two authors also list the Pelecanidae, Phalacrocoracidae, Anhingidae, Ciconiidae, Plataleidae, Laridae and Sternidae, which families are not mentioned by Cram (op. cit.).

C. microcephalum has, according to Cram (1927); Yamaguti (1961) and Barus et. al. (1978), a world-wide distribution occurring in Europe (almost all the major regions), Africa, Asia, North and South America.

During the present study seven different species of *Contracaecum* were recovered from *Phalacrocorax carbo, P. africanus, Anhinga melanogaster, Ardea cinerea* and *A. melanocephala*. Some of this material were positively identified as *C. microcephalum*. (see Table 33 below, as well as Fig.38, p. 193).

Table 33: Morphometric and diagnostic characteristics on which *Contracaecum microcephalum* from the Northern Province of South Africa was identified.

MORPHOLOGICAL CHARACTERISTIC	CRAM (1927)	BARUS *et*. *al*. (1978)	PRESENT MATERIAL
Body length	18.000-26.000	13.100-36.920	13.600-25.900
Body width	0.900-1.000	0.270-0.700	0.672-1.110
Head diameter			0.118-0.250
Lip length			0.112-0.180
Interlabia length			0.100-0.175
Oesophagus length		1.690-4.100	1.430-3.812
Oesophagus width			0.091-0.116
Ventriculus length			0.216-0.366
Ventriculus width			0.222-0.385
Ventricular appendix length		0.660-1.180	0.580-1.122
Ventricular appendix width			0.148-0.244
Intestinal caecum length		1.340-3.220	1.440-2.822
Intestinal caecum width			0.260-0.358
Intestine length			11.412-21.662
Intestine width			0.210-0.454
Spicules length	2.300-2.800	1.410-3.650 1.410-3.500	2.000-2.662
Tail length	0.240		0.255-0.260
Shape & number of labial papillae:Dorsal Ventr.	2 double 1 double	2 double 1 double	2 double 1 double
Shape of interlabia	$^4/_5$ & simple	$^4/_5$ & simple	$^4/_5$ & simple
Number of precloacal papillae	22-30 pairs	22-30 pairs	22-30 pairs
Number and topography of caudal papillae	7 pairs	7 pairs	7 pairs

Contracaecum rodhaini **(Gedoelst, 1916)**

(= *Kathleena rodhaini*, Gedoelst, 1916.)

Contracaecum rodhaini was first described from parasites collected from *Plotus rufus* from Zaïre. Baylis (1920) transferred *Kathleena* to the genus *Contracaecum*.
Yamaguti (1961) also gives *Megaceryle torquata* from Mexico as a host. Apart from the

original description (with measurements) by Gedoelst (1916) the description and measurements of Cram (1927) were also used in the species identification of this parasite from the northern subtropical area of South Africa.

Table 34 below and Fig.39, p. 194 clearly indicate the morphological features on which this species was separated from the other seven recorded *Contracaecum* spp. from the study area.

Table 34: Morphometric and diagnostic characteristics on which *Contracaecum rodhaini* from the Northern Province of South Africa was identified.

MORPHOLOGICAL CHARACTERISTICS	GEDOELST (1916)	PRESENT MATERIAL
Body length	18.500-20.000	18.000-21.010
Body width	0.830-1.120	0.810-1.210
Head diameter	0.300	0.190-2.580
Lip length	0.150	0.144-0.158
Interlabia length	0.144	0.138-0.148
Oesophagus length	3.300	2.800-3.800
Oesophagus width		0.212-0.310
Ventriculus length		0.150-0.244
Ventriculus width		0.210-0.230
Ventricular appendix length	0.722	0.750-0.820
Ventricular appendix width		0.078-0.126
Intestinal caecum length	2.600	1.820-2.440
Intestinal caecum width		0.236-0.370
Intestine length		14.750-18.510
Intestine width		0.390-0.510
Spicules length	3.600	3.120-3.610
Tail length	0.210	0.200-0.240
Shape and number of labial papillae : Dorsal Ventr.	2 simple 1 double	2 simple 1 double
Shape of interlabia	$^4/_5$ & simple	$^4/_5$ & simple
Number of precloacal papillae	28 pairs	28-30 pairs
Number and topography of caudal papillae	6 pairs	6 pairs

Contracaecum tricuspe (Gedoelst, 1916) Baylis, 1920.

[(= *Kathleena tricuspis* (Gedoelst, 1916)]

Like *C. rodhaini, C. tricuspe* was also described by Gedoelst (1916) from a heron (*Ardea* sp.) from Zaïre. The original identification and description was given as *Kathleena tricuspis* which was later reclassified as *C. tricuspe* (Baylis, 1920).

Table 35 and Fig.40, p. 195 illustrate the morphological features on which the present material from *Anhinga melanogaster* was identified as *C. tricuspe* (Gedoelst, 1916) Baylis, 1920.

Table 35: Morphometric diagnostic characteristics on which *Contracaecum tricuspe* from the Northern Province of South Africa was identified.

MORPHOLOGICAL CHARACTERISTICS	GEDOELST (1916)	PRESENT MATERIAL
Body length	13.800	11.500-14.500
Body width	0.785	0.680-0.810
Head diameter		0.180-0.220
Lip length		0.136-0.144
Interlabia length		0.138-0.145
Oesophagus length	3.800-3.900	3.540-4.100
Oesophagus width	0.100-0.160	0.098-0.168
Ventriculus length		0.150-0.275
Ventriculus width		0.110-0.261
Ventricular appendix length	1.600-2.000	1.522-2.110
Ventricular appendix width	0.190-0.225	0.185-0.235
Intestinal caecum length		1.112-1.780
Intestinal caecum width		0.198-0.222
Intestine length		8.424-10.825
Intestine width		0.282-0.310
Spicules length	4.600	3.850-4.660
Tail length	0.140	0.136-0.144
Shape and number of labial papillae : Dorsal Ventr.	2 simple 1 double	2 simple (i) 1 double (ii) 1 ventral double
Shape of interlabia	Pointed	with three prongs
Number of precloacal papillae	50 pairs	50-60 pairs
Number and topography of caudal papillae	6 pairs	6 pairs

Contracaecum carlislei Ortlepp, 1938.

C. carlislei was described by Ortlepp (1938) from *Contracaecum* material obtained from the *oesophagus and stomach* of *Microcarbo africana africana* (A. Smith)(= *Phalacrocorax africanus*) from the Pretoria District, Transvaal, South Africa.

The original species description was based on about 12 specimens, representing fourth stage larval, adolescent and sexually mature worms. Ortlepp (op. cit.) described the material as a new species, *C. carlislei*, and remarked as follows on its affinities:

> *The nature of the labial papillae and the arrangement of the male postcloacal papillae shows that this species is closely related to* ***C. rodhaini*** *(Gedoelst 1916) from* ***Plotus rufus*** *: The only difference being that in Gedoelst's species the subventral lips each carry only a double papilla and the first postcloacal papilla is double; however, more important differences are that in* ***C. rodhaini*** *the spicules are much longer (3.6mm), the vulva is more anterior in position (divides body in ration of 3:7), the mail tail is shorter (0.75mm.), the female tail is longer (0.336mm.), and the bases of the lips are more cut-in than in the writer's species.*
>
> *The size and shape of the spicules and position of the vulva are very similar to those of* ***C. microcephalum*** *(Rudolphi, 1809), but this species has two double papillae to each dorsal lip and a single double papilla to each sub-lateral lip, in addition the arrangement of the post-cloacal papillae are also different.*
>
> *The size of the spicules distinguishes the writers species from the recently described species* ***C. torquatum*** *Yamaguti, 1935,* ***C. milvi*** *Yamaguti, 1935 and* ***C. hagedashiae*** *Sandground, 1933.*

The preceding paragraphs quoted come from Ortlepp (1938), p.80.

Table 36 below as well as Fig.41, p.196 indicate why some material from the present study was referred to *C. carlislei*. The discussion (p.177) as well as Tables 36, p.176 and 37, p.179 also compare this species with other species of *Contracaecum* recorded during the present study.

Table 36: Morphometric and diagnostic characteristics on which *Contracaecum carlislei* from the Northern Province of South Africa was identified.

MORPHOLOGICAL CHARACTERISTICS	ORTLEPP (1938)	PRESENT MATERIAL
Body length	15.000	14.100-16.510
Body width	0.500	0.485-0.552
Head diameter	0.175	0.166-0.180
Lip length	0.075	0.075-0.080
Interlabia length	0.062	0.060-0.076
Oesophagus length	3.100-3.700	3.000-3.910
Oesophagus width	0.084-0.120	0.080-0.125
Ventriculus length	0.129	0.122-0.131
Ventriculus width	0.110	0.108-0.116
Ventricular appendix length	0.780	0.750-0.810
Ventricular appendix width	0.135	0.126-0.142
Intestinal caecum length	2.760	2.510-2.822
Intestinal caecum width		0.196-0.226
Intestine length		10.100-14.250
Intestine width		0.370-0.412
Spicules length	2.200-2.400	2.186-2.444
Tail length	0.250	0.234-0.280
Shape and number of labial papillae : Dorsal Ventr.	2 simple (i) 1 dorsal single (ii) 1 ventral double	2 simple (i) 1 double (ii) 1 ventral double
Shape of interlabia	Simple	$^4/_5$ & simple
Number of precloacal papillae	30 pairs	30-32 pairs
Number and topography of caudal papillae	6 pairs	6 pairs

Contracaecum lawrencei Bisseru, 1955.

C. lawrencei is, apart from *C. carlislei* Ortlepp, 1938, the only other species of *Contracaecum* described from South African piscivorous avian hosts. Bisseru (1955) described *C. lawrencei* from material collected from *Anhinga rufa levaillantii* (= *A. melanogster*) from the Pongola River in KwaZulu-Natal.

After providing a very detailed description of both male and female specimens, together with the necessary morphometric data (see Table 37, p.179), Bisseru (1955) went on to sketch the systematic relationships of this new species.

SYSTEMATIC RELATIONSHIP OF *C. LAWRENCEI* (AFTER, BISSERU, 1955), P. 768.

This form approaches more closely the species found mainly in Darters (Pelecaniformes), namely, ***C. rodhaini*** *(Gedoelst, 1916) Baylis, 1920;* ***C. sinulabiatum*** *Johnston and Mawson, 1941;* ***C. tricuspe*** *(Gedoelst, 1916) Baylis, 1920;* ***C. fuhrmanni*** *Kreis, 1937;* ***C. caballeroi*** *Bravo Hollis, 1939;* ***C. quincuspis*** *Lucker, 1941 and* ***C. spiculigerum*** *(Rudolphi, 1809) Railliet and Henry, 1912.*

The size of the worms, the situation of the vulva at about the anterior third of the body length, the size of the eggs, the oesophagus and the oesophageal appendix, and the length of the male and female tail show that this species is related to ***C. rodhaini****, but the differences are that this species has equal spicules which are much longer (3.6mm), the subventral lips carry only a double papilla and the interlabia are apparently broader, with rounder tips.*

C. sinulabriatum *differs from the above worms in regard to size, and the width of the head in this species is practically the same as the succeeding body. The preanal papillae are fewer (between 20 and 30 pairs), with seven postanal pairs. Besides a difference in the situation of the vulva,* ***C. sinulabiatum*** *has a different ratio of the oesophagus to the body lenth - 1: 7 - 8.6 as against 1: 5.3 - 6.6 in the present specimens.*

Amongst other differences ***C. tricuspe*** *from* ***Ardea*** *sp. and* ***Plotus melanogaster*** *has spicules which are equal and over four times as long (4.6mm.). Moreover, the lateral surfaces of the lips are notched, with points of the interlabia fitting into them.*

C. fuhrmanni *has a very short oesophagus (0.28mm. long), with fewer papillae on the male tail and spicules which are almost three times as long.*

Although ***C. caballeri*** *from* ***Anhinga anhinga*** *in the Zoological Park of Chapultepec, Mexico, is slightly smaller in size, with spherical eggs (0.041mm. in diameter), fewer papillae on the male tail, with a shorter oesophagus, while the oesophageal appendix and intestinal caecum are encircled by the nerve ring, this species nevertheless agrees with the present form in the unequal nature and size of the spicules.*

C. quincuspis*, also from* ***Anhinga anhinga*** *in North America, possesses lips and interlabia of a very complex nature, with fewer preanal and postanal papillae, while the spicules are about four times as large, and the vulva is more posteriorly placed.*

Bisseru (1955) did not compare the other South African species of *Contracaecum*, namely, *C. carlislei*, Ortlepp, 1938, with his newly described *C. lawrencei*. During the present study both these species were procured and a comparative study revealed the following ecto-morphological similarities/differences (Refer Tables 36, p.176, 37, p.179 and Figs. 41, p.196, 42, p.197.

A. Similarities:

- Both species possess two simple dorsal lip papillae, a feature which is shared with three other species found during the present study, namely, *C. rodhaini, C. rudolphi* and *C. tricuspe*;

- Shape of interlabia simple and similar in both species, a feature which they share with *C. rodhaini* (Fig.39, p.194). The tips of the interlabia in *C. rudolphi* are strongly bifurcated (Fig.43, p.198) whereas they possess three prominent tips in *C. tricuspe* (Fig.40, p.195).

B. Differences:

- *C. carlislei* exhibits one dorsal single papilla and one ventral double papilla (Fig.41, p.196) whereas *C. lawrencei* has only one large double papilla (Fig.42, p.197) a feature shared with *C. rodhaini* (Fig.39, p.194), *C. rudolphi* (Fig.43, p.198) and *C. tricuspe* (Fig.40, p.195).

- *C. carlislei* and *C. lawrencei* differ substantially with regard to the number of precloacal and postcloacal papillae. *C. carlislei* exhibits 30 pairs of precloacal and 6 pairs of postcloacal papillae (Fig.41, p.196) while the respective counts for *C. lawrencei* are 50 pairs and 12 pairs (Fig.42, p.197). *C. lawrencei* shares the number of precloacal papillae (50 pairs) with *C. tricuspe* but, in contrast *C. tricuspe* has only 6 pairs of postcloacal papillae (Fig.42, p.197). The relative numbers of pre- and postcloacal papillae for *C. rodhaini* and *C. rudolphi* are indicated on Tables 34, p.173 and 38, p.181 and illustrated in Figs.39, p.195 and 43, p.198;

- The spicule length in *C. lawrencei* is very short (0.820-1.110mm.) compared to that of *C. carlislei* (2.186-2.444mm.), *C. rodhaini* (3.120-3.610mm.), *C. tricuspe* (3.850-4.660mm.) and *C. rudolphi* (6.310-8.220mm.).

The above comparative analysis, together with other endomorphological differences (see Tables 34, p.173, 38, p.181 and 35, p.174), clearly indicate that *C. lawrencei* exhibit clearly demarcated and taxonomically justifiable differences from closely related species encountered during the present investigation.

Table 37: Morphometric and diagnostic characteristics on which *Contracaecum lawrencei* from the Northern Province of South Africa was identified.

MORPHOLOGICAL CHARACTERISTICS	BISSERU (1955)	PRESENT MATERIAL
Body length	22.000	18.000-23.100
Body width	0.850	0.750-0.850
Head diameter	0.180	0.178-0.182
Lip length	0.100	0.100-0.112
Interlabia length	0.075	0.068-0.075
Oesophagus length	3.250	3.000-3.350
Oesophagus width	0.180	0.175-0.182
Ventriculus length		0.150-0.280
Ventriculus width		0.144-0.278
Ventricular appendix length	0.645	0.510-1.010
Ventricular appendix width		0.135-0.240
Intestinal caecum length	2.400	2.100-2.512
Intestinal caecum width		0.212-0.410
Intestine length		15.000-18.100
Intestine width		0.420-0.550
Spicules length	0.820-1.000	0.820-1.110
Tail length	0.160	0.180-0.200
Shape and number of labial papillae : Dorsal Ventr.	2 simple 1 double	2 simple 1 double
Shape of interlabia	Simple	Simple
Number of precloacal papillae	50 pairs	50 pairs
Number and topography of caudal papillae	12 pairs	12 pairs

Contracaecum rudolphii **Hartwich, 1964**

(= *C. spiculigerum* (Rudolphi, 1809) Railliet and Henry, 1912;
A. spiculigerum (Rudolphi, 1809);
C. variegatum (Rudolphi, 1809);
C. himen Yamaguti, 1941;
C. urniu Yamaguti, 1941).

C. rudolphii Hartwich, 1964 must surely be regarded as the most widely studied species of *Contracaecum.* A vast bibliography of something like 169 publications on this species appeared up to 1978 (Barus et. al., 1978).

C. rudolphii has a cosmopolitan distribution occurring in all the regions of the European Continent and also in England, Africa, Asia, the Far East, North and South America, Australasia (Yamaguti, 1961; Barus et. al., 1978; Torres, Sierpe and Schlatter, 1983; Sarashina, Taniyama and Yamada, 1987).

Barus et. al. (1978) list no less than 59 avian host species which are parasitised by *C. rudolphii*. This list was appended by authors such as Torres et. al. (1983) and Sarashine et. al. (1987). A close scrutiny of the host list reveals that *C. rudolphii* utilises both freshwater and marine avian species as final hosts. Consequently the larval stages, up to third stage larvae, must then also utilise both freshwater as well as marine first and second intermediate hosts.

The remarks and observations of the previous paragraphs indicate that *C. rudolphii* is a very adaptable parasite and by no means host specific for any one of its life cycle stages. During the present study this species was also found parasitising all three the Phalacrocoracid and Anhingid species investigated. What is, however, surprising for the Northern Transvaal Region is that this species did not occur as parasites of members of the Ardeidae. Eight members of the Ardeidae occurring as resident/breeding members in the study area (refer p.282), were also investigated for the presence of *C. rudolphii*. None of these birds were found to harbour *C. rudolphii*, although it has to be pointed out that the number of Ardean hosts investigated was rather limited. A definite conclussion on members of the Ardeidae as final hosts for *C. rudolphii* in the study area can, therefore, not be framed with absolute certainty. It is, however, tempting to suggest, that at least for South African freshwater ecosystems, the preferred hosts appear to be members of the Phalacrocoracidae and Anhingidae. (See also Whitfield and Heeg, 1977).

Table 38, p.181 below and Fig.43, p.198 illustrate the morphological features on which the present investigation recognized *C. rudolphii* as a separate species identity.

Table 38: Morphometric and diagnostic characteristics on which *Contracaecum rudolphii* from the Northern Province of South Africa was identified.

MORPHOLOGICAL CHARACTERISTICS	YAMAGUTI (1941)	MOZGOVOI (1953)	PRESENT MATERIAL
Body length	29.000-40.000	20.000-40.000	23.000-37.100
Body width	0.750-0.950	0.614-1.001	0.850-1.112
Head diameter	0.170-0.260		0.170-0.220
Lip length	0.075-0.120	0.075-0.139	0.070-0.135
Interlabia length	0.075-0.110	0.061-0.120	0.060-0.110
Oesophagus length	3.000-5.200	3.033-4.450	2.800-3.200
Oesophagus width	0.180-0.250	0.213-0.320	0.162-0.310
Ventriculus length	0.250-0.310	0.226-0.375	0.240-0.360
Ventriculus width	0.200-0.230	0.210-0.320	0.200-0.280
Ventricular appendix length	0.900-1.300	0.714-1.266	0.812-1.286
Ventricular appendix width	0.120-0.250	0.076-0.192	0.095-0.210
Intestinal caecum length	2.300-3.300	2.030-2.833	2.210-2.755
Intestinal caecum width			0.144-0.180
Intestine length			19.270-33.560
Intestine width			0.480-0.860
Spicules length	7.200-9.100	6.200-7.800	6.310-8.220
Tail length	0.310-0.500	0.280-0.510	0.280-0.500
Shape and number of labial papillae: Dorsal Ventrl.	2 simple 1 double	2 simple 1 double	2 simple 1 double
Shape of interlabia	bifurcate tip	bifurcate tip	bifurcate tip
Number of precloacal papillae	27-43 pairs	31-42 pairs	28-42 pairs
Number and topography of caudal papillae	7 pairs	7 pairs	7 pairs

Contracaecum jokli n. sp.

During July of 1952 Dr. R.F. Lawrence of the Natal Museum, Pietermaritzburg, South Africa, collected *Contracaecum* specimens from *Anhinga rufa levaillantii* (= *Anhinga melanogaster*) from the Pongola River, KwaZulu-Natal, South Africa. This material was forwarded to the University of London, where Bisseru (1955) examined it and from which he described *C. lawrencei* as a new species. The same batch of material also contained a single male specimen which Bisseru (op. cit.) regarded as *an indeterminate species of the genus* ***Contracaecum*** - (p. 769).

Bisseru (1955) described some morphological details of this specimen and also remarked on possible systematic relationships as quoted below. He concluded by stating that *the present nematode would thus probably warrant the erection of a distinct species, but such a step at present is considered unjustified in view of the very limited material available* (p. 770).

Systematic relationships as viewed by Bisseru (1955) - p.770

This species differs from all the known forms of the genus ***Contracaecum****, but resembles in some respects the males of both* ***Contracaecum lawrencei*** *n. sp., described above and* ***C. caballeroi*** *Bravo Hollis, 1939, from an allied host,* ***Anhinga anhinga*** *in Mexico. The present male differs from the former species in size, nature and length of the spicules and in the arrangement of the postanal papillae. It approaches* ***C. caballeroi*** *in length and width of body and in the unequal size and length of spicules, but differs in possessing a far greater number of preanal papillae, a longer oesophageal appendix, intestinal caecum and oesophagus. Furthermore in* ***C. caballeroi*** *the nerve ring encircles the intestinal caecum, and although there are six pairs of postanal papillae their disposition on the male tail is neither figured nor stated.*

During the present study a substantial volume of *Contracaecum* material was procured from the two phalacrocoracid hosts as well as from *A. melanogaster*. In morphological detail this material differed considerably from the other six species of *Contracaecum* encountered from the same hosts and study area. On a comparative analysis this material fitted in very closely with Bisseru's (1955) description of the indeterminate species from the material obtained from KwaZulu-Natal. This tempted the present investigation to obtain a full range of morphometric data from male and female specimens. These data are supplemented by ectomorphological observations on a number of diagnostic structures, and these are presented in Table 39 below. For SEM micrographs on morphological detail see Fig(s).44, p.199 and 45, p.200.

Table 39: Morphometric and diagnostic characteristics on which *Contracaecum jokli* from the Northern Province of South Africa was identified.

MORPHOLOGICAL CHARACTERISTICS	BISSERU (1955)	PRESENT MATERIAL
Body length	16.000	15.220-18.570
Body width	0.720	0.620-0.862
Head diameter	0.192	0.177-0.199
Lip length	0.100	0.935
Interlabia length	0.080-0.090	0.072-0.095
Oesophagus length	2.800	2.800-3.110
Oesophagus width	0.200	0.196-0.215
Ventriculus length		0.144-0.155
Ventriculus width		0.144-0.150
Ventricular appendix length	0.670	0.495-0.522
Ventricular appendix width		0.120-0.211
Intestinal caecum length	2.300	1.577-2.442
Intestinal caecum width		0.242-0.319
Intestine length		11.210-14.922
Intestine width		0.411-0.510
Spicules length	(i) 0.900 (ii) 1.200	0.810-1.250
Tail length	0.130	0.110-0.138
Shape and number of labial papillae : Dorsal Ventr.	2 simple (i) dorsal single (ii) ventr. double	2 simple (i) dorsal single (ii) ventr. double
Shape of interlabia	$^4/_5$ & Simple	$^4/_5$ & Simple
Number of precloacal papillae	51 pairs	55-60 pairs
Number and topography of caudal papillae	6 pairs	6 pairs

Tables 33 - 38, pp. 172 - 181 as well as Figs.38 - 43, pp. 193 - 198 indicate that *C. jokli* n.sp. differs from the other six *Contracaecum* species recovered during the present study in some diagnostic morphological detail. The new species has more precloacal papillae (55-60 pairs) than any one of the other six species. In this regard *C. lawrencei* and *C. tricuspe* are the closest to *C. jokli* each exhibiting 50 pairs of precloacal papillae. Like *C. tricuspe* and *C. carlislei* the present species also possesses 6 pairs of postcloacal papillae (Figs.40, p.195 and 41, p.196). However, it differs substantially from *C. tricuspe* in the shape of the interlabia as well as in the length of the spicules (Tables 35, p.174 and 39, p.183).

It differs from *C. lawrencei* in that it possesses 6 pairs of postcloacal papillae whereas *C. lawrencei* exhibits 12 pairs (Figs. 44 and 45, pp. 199 - 200 and 42, p.197).

As far as spicule length is concerned the new species [(0.810 - 1.250mm. present material and 0.900 - 1.200mm. Bisseru (1955) material)] closely approaches *C. lawrencei* (0.820 - 1.110), but it again differs from the latter species in that it has one single and one double papilla on each ventro-lateral lip compared to *C. lawrencei* which possess only one double papillae to each ventro-lateral lip.

The present study therefore agrees with Bisseru (1955) that the material warrants the erection of a new species. It is proposed to call this species *C. jokli* in honour of Prof. J.E. Saayman, former Head of the Department of Zoology at the University of the North, South Africa.

SYSTEMATIC AFFINITIES:

The above discussion as well as the discussion by Bisseru (1955), as quoted on p.182, indicate that this species is closely related to the following *Contracaecum* species:

C. carlislei Ortlepp, 1938;
C. caballeroi Bravo Hollis, 1939;
C. lawrencei Bisseru, 1955.

Morphological details of male and female specimens of this species appear in Table 39, p.183, while Figs. 44 and 45, pp. 199 - 200 illustrate SEM studies of the material.

Host: *Anhinga melanogaster*

Distribution: Transvaal and KwaZulu-Natal, South Africa

Type material: Deposited in the Parasite Collection of the Department of Zoology, University of the North, South Africa. Additional material will be deposited in the Helminth Collection of the International Institute of Parasitology, St. Albans, United Kingdom.

The present investigation found it impossible to separate the various *Contracaecum* species during autopsy of the host specimens. Subsequent light microscopic and SEM studies revealed seven distinct species of *Contracaecum* as discussed on the previous pages. Infection statistics of the relevant hosts (Tables 40 and 41 below) are therefore not given per species, but as infection with *Contracaecum* spp. The only exception being for *C. tricuspe* infection in *A. melanogaster*. In the present study area this parasite is host specific to *Anhinga* hosts. Furthermore on autopsy, these parasites could easily be distinguished by their relative smaller sizes; their location within the proventriculus and their very firm means of attachment to the proventricular wall. The infection statistics for *C. tricuspe* are presented in Table 41 below.

Table 40: Prevalence, intensity and mean intensity values for *Phalacrocorax carbo, P. africanus* and *Anhinga melanogaster* infections with *Contracaecum* spp. except *C. tricuspe* in the Northern Province of South Africa.

AVIAN HOST	N.	WATER BODY	PREVALENCE	INTENSITY	MEAN INTENSITY
P. carbo	32	Seshego Dam	97	8 - 100	52
	8	Middle Letaba Impoundment	100	41 - 319	114
	2	Piet Gouws Dam	100	28 - 40	34
	2	Glen Alpine Dam	100	27 - 29	28
	1	Ebenhaezer Dam	100	27	27
P. africanus	44	Seshego Dam	100	5 - 119	35
	9	Middle Letaba Impoundment	100	7 - 136	56
	3	Hudson Ntsanwisi Dam	100	102 - 109	105
	1	Turfloop Dam	100	26	26
	2	Olifants River	100	3 - 12	8
A. melanogaster	24	Seshego Dam	100	7 - 136	56
	12	Middle Letaba Impoundment	100	76 - 577	284
	11	Hudson Ntsanwisi Dam	100	133 - 985	418
	6	Piet Gouws Dam	100	19 - 195	70
	4	Glen Alpine Dam	100	83 - 378	196
	2	Luphephe Dam	100	581 - 910	746
	4	Olifants River	100	22 - 36	29
	1	Tzaneen Dam	100	153	153

Table 41: Pevalence, intensity and mean instensity values for *Anhinga melanogaster* infections with *Contracaecum tricuspe* in the Northern Province of South Africa.

WATER BODY	N.	PREVALENCE %	INTENSITY	MEAN INTENSITY
Seshego Dam	24	100	14 - 93	29
Middle Letaba Impoundment	12	100	13 - 181	72
Hudson Ntsanwisi Dam	11	100	27 - 161	66
Piet Gouws Dam	6	100	15 - 33	23
Glen Alpine Dam	4	100	33 - 63	46
Luphephe Dam	2	100	71 - 176	124
Olifants River	4	100	10 - 13	12
Tzaneen Dam	1	100	54	54

Tables 40 and 41 above clearly indicate that *Contracaecum* infections of piscivorous avian hosts of the families Phalacrocoracidae and Anhingidae are very prevalent in the freshwater aquatic ecosystems of the Northern Province, South Africa.

The present study recorded prevalence of infection statistics of 100 per cent for almost all of the major aquatic ecosystems in the Province. In addition to this very high prevalence rate of infection, the intensity and mean intensity levels of infection are also extremely high, providing values in the order of 133 - 985 and 746 respectively.

The above situation is to be expected if the infection statistics of fish intermediate hosts are taken into consideration. In the northern and north eastern regions of South Africa no less than nine widely distributed freshwater fish species have been identified as regular carriers of third stage *Contracaecum* larvae (Mashego, 1977; Mashego and Saayman, 1981; Boomker (1982); Mashego, 1982; Saayman 1986 and Saayman and Schoonbee et. al. 1991). Some of these hosts, notably *Clarias gariepinus* (Mashego, 1977; Mashego and Saayman, 1981 and Boomker, 1982) and *Schilbe intermedius* Saayman 1986 and unpublished data) carry very heavy infections with *Contracaecum* larvae. Of significance also is the fact that smaller *Barbus* and chiclid species do play an important role in the maintenance of the life cycles of *Contracaecum* spp. as well as the spread of this parasite in South African water bodies (Mashego, 1982; Saayman and Schoonbee et. al. 1991). The importance of the aforementioned smaller fish hosts in the parasitology of *Contracaecum* spp. is signified by the circumstances that they are considered the major item in the dietary budget of piscivorous birds, thereby enhancing the spread of these parasites from one locality to another.

In conclusion, it can be stated that *Contracaecum* infections with a number of distinct species are very well established and widespread in the aquatic ecosystems of the Northern Province of South Africa. The number of second intermediate- and final hosts, as well as the infection statistics of these hosts with *Contracaecum* parasites, supplemented by the numerical statistics and distribution of said hosts, make this one of the most well established parasites within the aquatic ecosystems of the study area.

NOTES ON THE LIFE CYCLE OF *CONTRACAECUM* SPP.

The life cycle of *Contracaecum* parasites (Fig.68, p.223) includes at least four major stages, namely, a free living larval stage (= first stage larvae); an aquatic invertebrate as the FIRST INTERMEDIATE HOST (second stage larvae); a fish as the SECOND INTERMEDIATE HOST (Third stage larvae) and a piscivorous homoithermic vertebrate as the FINAL HOST (fourth, fifth stage larvae and adults).

Observations and experimental research on the life cycle of these parasites include, amongst others, the works of Thomas (1937,1940); Sudarikov and Rizhikov (1951); Kneiz (1955); Ass (1961); Popova, Mozgovoi and Dmitrenko (1964); Mozgovoi, Shakhamatova and Semenova (1965,1968); Davey (1969); Semenova (1971,1972,1974,1982); Ellis and Williams (1973); McClelland and Ronald (1974); Bier (1976); Cheng (1976); Barus et. al. (1978); Mozgovoi and Shakmatova (1979) and Koie and Fagerholm (1995).

The following major stages in the life cycle may be distinguished:

1. Ova initially develop *in utero* where the first moult takes place within the egg capsule (Semenova, 1972). Thomas (1937) observed that larvae may even undergo two moults within the egg membrane;

2. After two moults second stage larvae hatch and live freely in the water. Temperature seems to play a very important role in the development and longevity of first and second stage larvae. Mozgovoi and Shakamatova (1979) established that first stage larvae develop in 10 - 12 days in eggs kept in water at 20 - 28°C., and moulted 2 - 3 days later into second stage larvae: Optimum temperature for egg development appears to be at 16°C. At higher temperatures development is retarded whereas in temperatures between 0 - 10°C. development is slow and hatching only occur within 2 - 6 months. (Davey, 1969);

3. Second stage larvae remains viable in water for 10 - 12 days (Semenova, 1972), but depending on temperatures this stage may even last up to one month (Popova et. al., 1964). Optimal temperatures for second stage larval development are between 20 - 25°C. (McClelland and Ronald, 1974; Bier, 1976);

4. For further development second stage larvae must enter a first intermediate host. Various invertebrates as well as vertebrates were identified as first intermediate hosts:

    - *Sagitta* - Ass (1961);
    - Cyclopoidea (*Cyclops strennus, Macrocyclops aldidus, M. fuscus, Mesocyclops leukarti*) and Clanoida (*Diaptomus gracilis*) - Mozgovoi et. al. (1968);
    - *Macrocyclops, Mesocyclops, Cyclops, Diaptomus, Cammarus* - Semenova (1971);
    - *Nereis, Lepidonotus, Harmothae* and *Cattiana* - Popova et. al. (1964);
    - Oligochaeta, Odonata, *Chironomus*, fish and *Rana* (adult and tadpole) - Semenova (1972);

5. Second stage larvae develop in the haemocoel and sometimes also in the musculature of the extremities of invertebrate intermediate hosts. The literature provides contradicting information on whether a definite moult does take place in the first intermediate host. Mozgovoi et. al. (1965) established that larvae may remain in the body cavity of *Macrocyclops* for only one to

two days and does not undergo any moulting during this phase. On the other hand, Mozgovoi and Shakmatova (1978) are inclined to believe that *Contracaecum* larvae used in their experimental infection of *Macrocyclops* must have moulted in the first intermediate host although the process was actually not observed. Semenova (1971), however, observed larvae to moult in the first intermediate hosts (Copepods) 4 - 6 days after infection;

6. Second intermediate fish hosts become infected when eating first intermediate hosts. In the second intermediate host *Contracaecum* larvae migrate to the coelomic or pericardial cavities where development to third stage larvae takes place. There seems to be a general lack of definite information on how long third stage larvae can remain viable (infective) in fish intermediate hosts. In experimental infections with larvae of *C. osculatum* Koie and Fagerholm (1995) found that at 6 months post-infection, third stage larvae in gobies had not even doubled in length, whereas in plaice considerable growth was found at 6 months, **p.i.** when some larvae were well encapsulated in the mesentries of the liver.

7. Final hosts are infected by eating fish intermediate hosts harbouring infective third stage larvae. In the final host, larvae may undergo two more moults before the worms become sexually mature. Semenova (1971) found that third stage larvae moulted while embedded in the mucous of the proventriculus of the definite hosts, while fifth stage larvae attach themselves to the mucus of the lower part of the oesophagus and muscular stomach. Koie and Fagerholm (1995) also found two moults of *C. osculatum* to occur in the final host, the seal.

   The research of Koie and Fagerholm (1995) clearly indicated that *Contracaecum* larvae can reach the final host via various routes involving different numbers of paratenic and first, second and even third intermediate hosts. Popova et. al. (1964) and Cheng (1976) are of the opinion that it is difficult to determine whether hosts in which *Contracaecum* larval forms occur, are true intermediate of paratenic hosts. This statement seems to be particularly true of marine fish hosts in which third and fouth stage larvae are common.

The preceding review on earlier life cycle stages of *Contracaecum* and the influence of environmental factors on the development, shows this parasite group to be extremely adaptable. This may very well explain their wide geographical distribution as well as the high levels of infection reached in intermediate and final hosts.

PATHOLOGY OF *CONTRACAECUM* INFECTIONS

Conclusive reference to pathological effects caused by *Contracaecum* infections remains relatively scarce in the literature on the genus.

Fish intermediate hosts may carry excessive *Contracaecum* worm burdens. These parasites apparently do not affect the fish population in any form indicative of a lethal level effect as defined by Crofton (1971). Malvestuto and Ogambo-Ongoma (1978) (in *Tilapia leucostica*), Mashego and Saayman (1981) and Boomker (1982) (in *Clarias gariepinus*) recorded relatively heavy infections with *Contracaecum* larvae but could not find conclusive evidence of any lethal effects. Paperna (1980) states that unencapsulated *Contracaecum* larvae in the abdominal and pericardial cavities and in the sinus venosus apparently do not cause any pathological damage to the fish host. The latter author could not find any significant correlation between fish mass and infection intensity among *T. leucostica* of Lake Naivasha (East Africa) hosting *Contracaecum* larvae infecting the pericardial cavity.

Bykhovskaya-Pavlovskaya et. al. (1964) quoted Dubinin (1949) as having observed inflammation of the peritoneum and rupture of the swimbladder in heavy infestation of the body cavity of young sturgeons, *Huso huso*, in the basins of the Caspian and Black Seas. The same authors also quoted Shul'man and Shul'man Al'bova (1953) who recorded a decrease in liver weight and a great reduction in the amount of Codliver oil in heavy infestations of the liver of Cod (porbably *Cadius* spp. or *Notothenia* spp.) with *Contracaecum* larvae.

Semenova (1974) noted ulceration of the mucosal wall of the proventriculus of birds at the place of attachment of *Contracaecum* specimens. This author speculated that *Contracaecum* parasites do not only feed on the gastric contents of their avian hosts, but also on the tissues of the alimentary tract. He also noticed the presence of a reddish pigmentation (presumably haemoglobin) around the anterior ends of *Contracaecum* specimens in experimentally infected avian hosts. Sarashina et. al. (1987) examined a cormorant from China infected with *C. spiculigerum* (= *C. rudolphii*). These authors noted erosions with haemorrhages in areas of the mucosa where the worms were attached. The present study also recorded severe tissue damage to the lining of the oesophagus and proventriculus in areas where *Contracaecum* parasites attach themselves. On removal of the worms some bleeding occurred.

In mammalian hosts of *Contracaecum*, Fleishman and Sqoire (1970) noted *C. osculatum* attached to gastric ulcers in the sea lion, *Zalophus californianus*, while Lïu and Edward (1971) associated gastric ulcers with *Contracaecum* in Steller's sea lion, *Eumetopias jubatus*, and the pelican, *Pelecanus onocrotalus*.

The presence of *Contracaecum* parasites, especially in heavily infected farmed fish may cause market resistance. A symposium on the role of resource evaluation in the development and management of inland fisheries held in Chad under the auspices of the Committee for **Inland Fisheries of Africa (CiFA)** of the F.A.O., Okori (1973) addressed the aspect of parasitism in pisciculture and maintained that:

> *Parasitism is considered to be an important factor in the management of African fisheries and more work on the identification of parasites, incidence and intensity of infection, pathology and biology, with a view to control, is called for.* ***Contracaecum*** *in* ***Tilapia*** *is thought to be of significant importance.*

In South Africa the three most important indigenous fish species for culture purposes are *Clarias gariepinus, Schilbe intermedius* and *Oreochromis mossambicus*. All these species are prone to heavy infections with *Contracaecum* larvae (Mashego, 1977; Mashego and Saayman, 1981; Boomker, 1982; Saayman, 1986 and Saayman and Schoonbee et. al. 1991). Studies on the aetiology of *Contracaecum* infections in South African freshwater hosts may therefore prove an excercise with definite economic advantages.

STATISTICAL EVALUATION OF DATA:

The infestation results obtained from *P. carbo, P. africanus* and *A. melanogaster* were expressed under three headings, namely:

Prevalence %
Intensity
Mean Inensity

These concepts were employed as defined by the American Society of Parasitologists (Margolis, et. al., 1982). The results of infestation with the different parasites were separated into two categories:

Parasites which utilize fish intermediate hosts.
Parasites without fish as an intermediate host.

These results were represented in table format under the foregoing headings.

Selected programmes of the Statistical Analysis System (SAS, 1985) were used to determine the possible significance of the results, while the Harvard Graphics Computer Programme was used for various graphical illustrations included as Figures 46 - 67, pp. 201 - 222 (Section A) and Figures 81 - 101, pp. 259 - 279 (Section B).

Three different impoundments, representing the three major drainage systems of the study area, were selected to demonstrate tendencies in infection rates of hosts with the various parasites recovered during the study, namely:

Piet Gouws Dam - Olifants Drainage System
Seshego Dam - Limpopo Drainage System
Middle Letaba Dam - Letaba Drainage System

For each host species at each of the preceding impoundments, the infection statistics were graphically represented according to the different seasons of the year. By following this approach it was hoped to give more relevance to an ecoparasitological approach as called for by authors such as Okori, 1973; Kennedy, 1975; Anderson, 1976; Breev, 1980; Paperna, 1980; Bauer, 1984 and Sinderman, 1987. Most parasitological surveys are carried out to satisfy taxonomic needs and, as such, are fragmentary, contain very little quantification in terms of ecological context and, on rare occasions only, touch on the very important aspect of population biology.

OBSERVATIONS ON AND DISCUSSION OF, FIGS. 46 - 67:

By allocating a numerical value of 1 - 10 based on mean intensity of infection figures for each parasite/host/aquatic ecosystem - and relative to the numerical positions occupied by the other parasites - the following remarks became relevant:

- Judging from mean intensity of infection figures, supplemented by host and locality distribution the eleven most prevalent parasites encountrered during the present study are:

Contracaecum spp.
Paryphostomum radiatum
Paradilepis scolecina
P. delachauxi
Diplostomum tregenna
Harvardia sandgroundi
Ligula intestinalis
Neutraclinostomum intermedialis
Clinostomum complanatum
D. ghanense
Euclinostomum heterostomum

- Overall (hosts, seasons as well as ecosystems) *Contracaecum* spp. top the list with the highest mean intensity figure (Figs.46 - 67, pp. 201 - 222).

- *P. radiatum* is very well established amongst all three hosts and at all three drainage systems (see particularly Figs.47,48,49,52,54,55,57,59,62 and 63). Mean intensity figures were relatively high for *P. carbo* at Seshego Dam (Winter and Spring, Figs. 47 and 48), *P. africanus* at Middle Letaba Dam (Winter and Summer, Figs. 57 and 59) and Seshego Dam (Winter, Fig. 54). Also for *A. melanogaster* at Seshego Dam (Winter, Fig. 62). Ecological conditions at Seshego Dam seem to be very favourable for the maintenance of the life cycle of this parasite;

- *Paradilepis scolecina* and *P. delachauxi* are well represented as infections of Phalacrocoracid hosts in all three drainage systems (Figs. 47,48,50,51,52,53, 54 and 58). However, *P. delachauxi* does not occur as a parasite of *A. melanogaster*;

- *D. tregenna* is capable of infecting all three hosts in relatively high numbers in aquatic ecosystems of all three drainage systems (Figs. 47,48,51,52,54,60 and 67);

- Both *P. carbo* and *P. africanus* play host to *H. sandgroundi* and this parasite infects its hosts in relatively high numbers especially at Middle Letaba Impoundment and Seshego Dam (Figures 47,48,51,52,53,54,59 and 60).

In conclusion it can be stated that all 19 parasites which involve a fish intermediate host are geographically as well as numerically well represented in the aquatic ecosystems of all three drainage systems. It is difficult to detect any seasonal tendencies for any of these parasites. The latter statement is to be expected, because the entire study area falls within the southern subtropical belt characterised by very mild winters and water temperatures which seldom drop below 16°C.

FIG. 38.

CONTRACAECUM MICROCEPHALUM
(Scanning Electron Microscopy)

A.	***Anterolateral view of head, with lips and opening of excretory duct posterior to ventral interlabium***
B.	***Male tail with arrangement of postcloacal papillae clearly visible***
C.	***Striations on both the dorsal and ventral surface of the body***
D.	***Distal end of spicule***

Key:

ep. - excretory pore

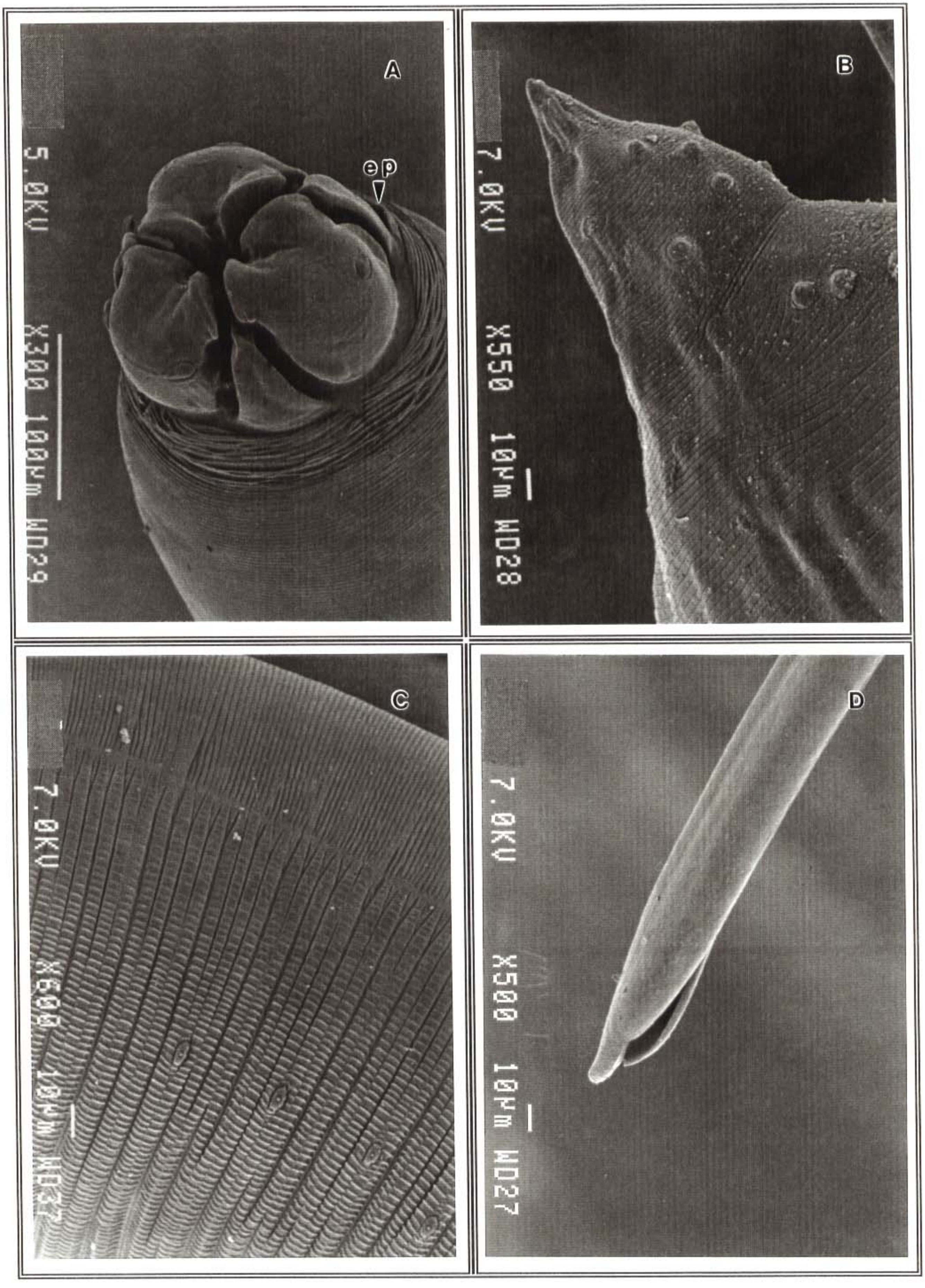

A
ep
5.0KV X300 100µm WD29
B
7.0KV X550 10µm WD28
C
7.0KV X600 10µm WD37
D
7.0KV X500 10µm WD27

FIG. 39.

CONTRACAECUM RODHAINI
(Scanning Electron Microscopy)

A. *Anterolateral view of head showing lips, interlabium and opening of excretory pore at base of ventral interlabium*

B. *Posterior portion of male worm with protruding spicules and precloacal papillae*

C. *Male tail showing arrangement of postcloacal papillae*

D. *Distal end of spicule*

Key:

ep. - excretory pore

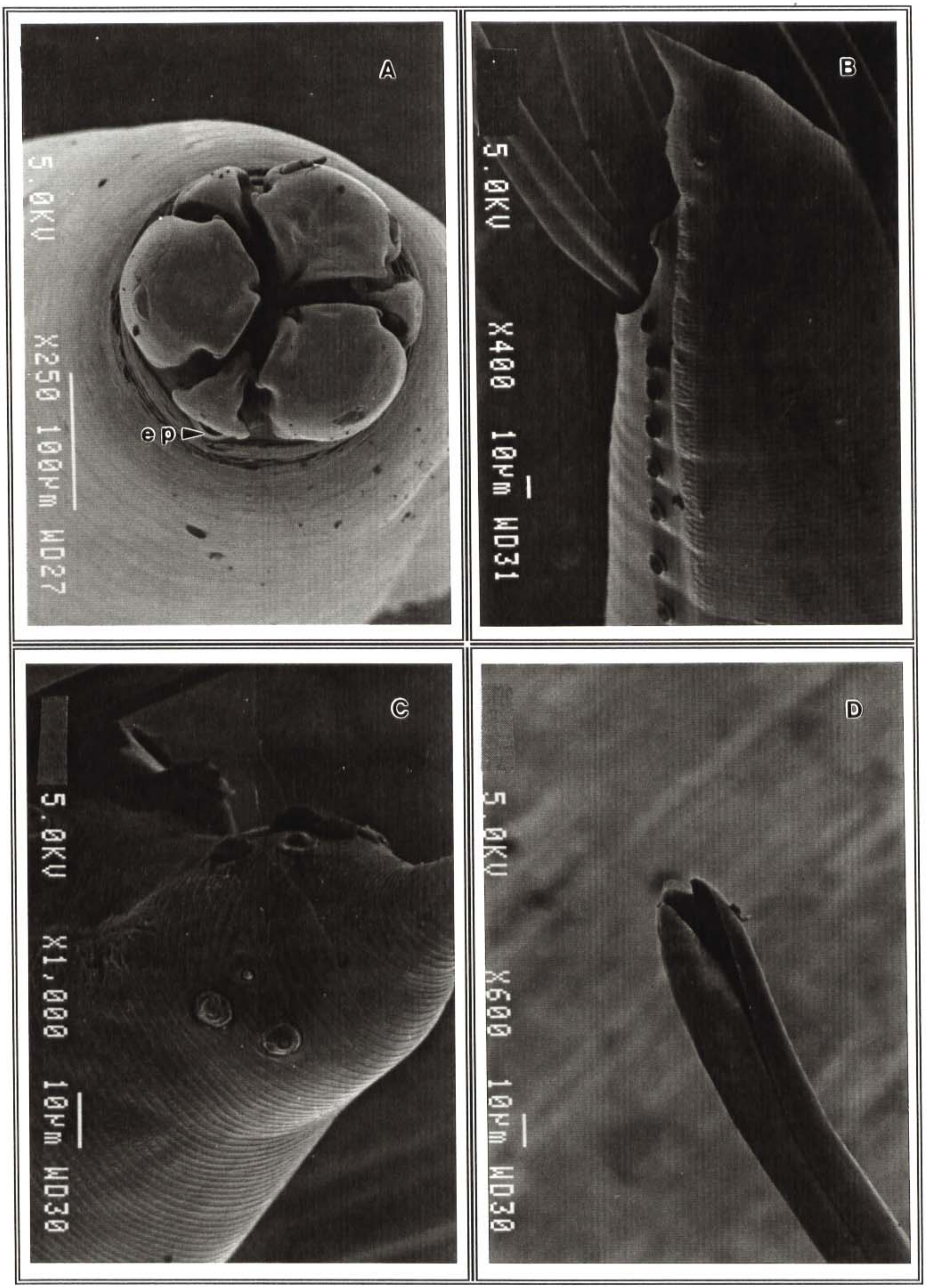

A
ep
5.0KV X250 100µm WD27
B
5.0KV X400 10µm WD31
C
5.0KV X1,000 10µm WD30
D
5.0KV X600 10µm WD30

FIG. 40.

CONTRACAECUM TRICUSPE
(Scanning Electron Microscopy)

A. *Anterolateral view of head illustrating the shape of lips and interlabia*

B. *Tail of an adult male showing the distribution of caudal papillae*

C. *Posterior portion of male showing the arrangement of postcloacal papillae*

D. *Male posterior end with protruding spicules (distal end of spicules)*

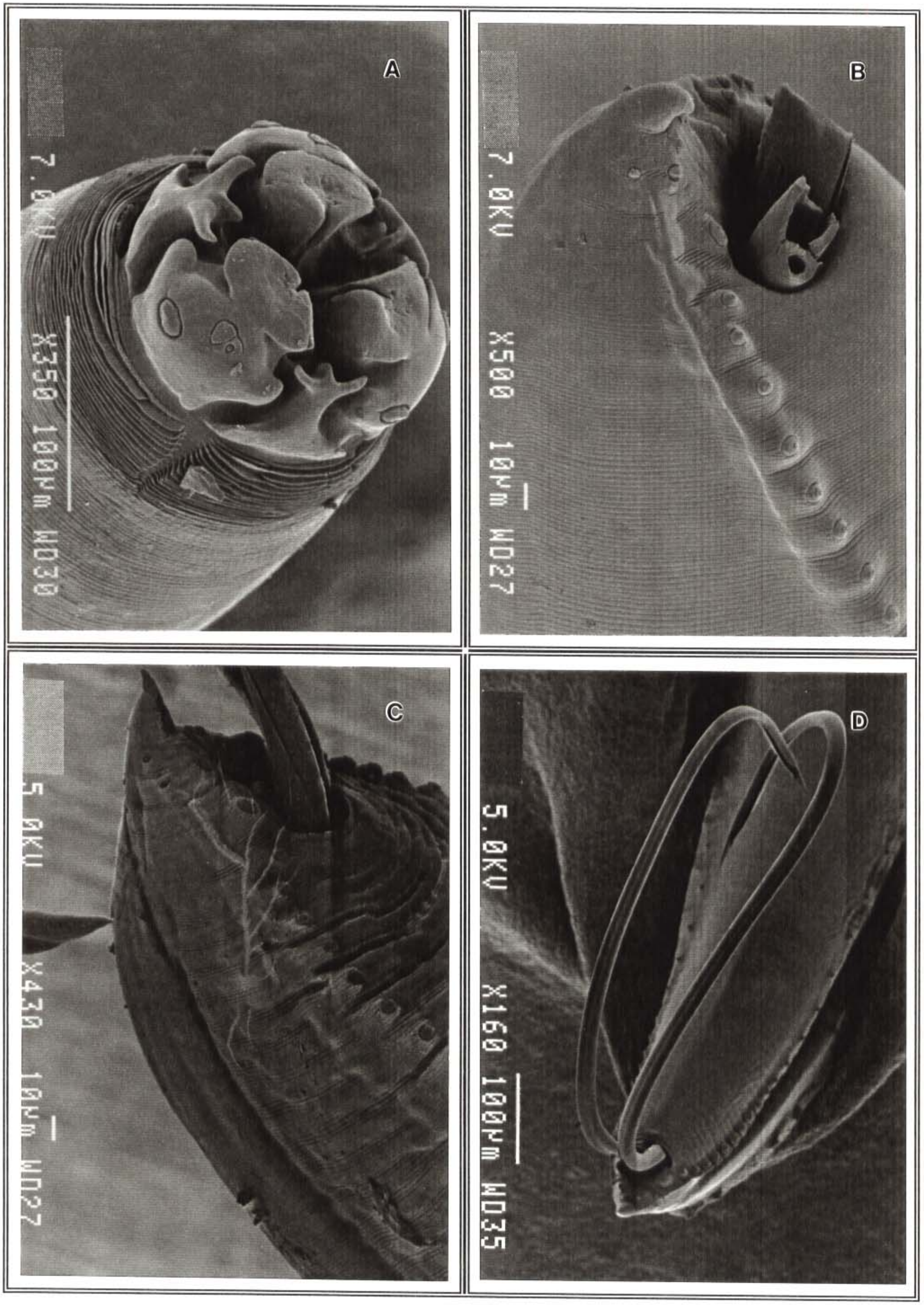

A
7.0KV X350 100µm WD30
B
7.0KV X500 10µm WD27
C
5.0KV X430 10µm WD27
D
5.0KV X160 100µm WD35

FIG. 41.

CONTRACAECUM CARLISLEI
(Scanning Electron Microscopy)

- ***A.*** ***'En face' view of head with three lips and three interlabia***
- ***B.*** ***Posterior end of male caudal portion illustrating distribution of papillae and protruding spicules***
- ***C.*** ***Enlarged ventrolateral lip***
- ***D.*** ***Distal end of spicule***

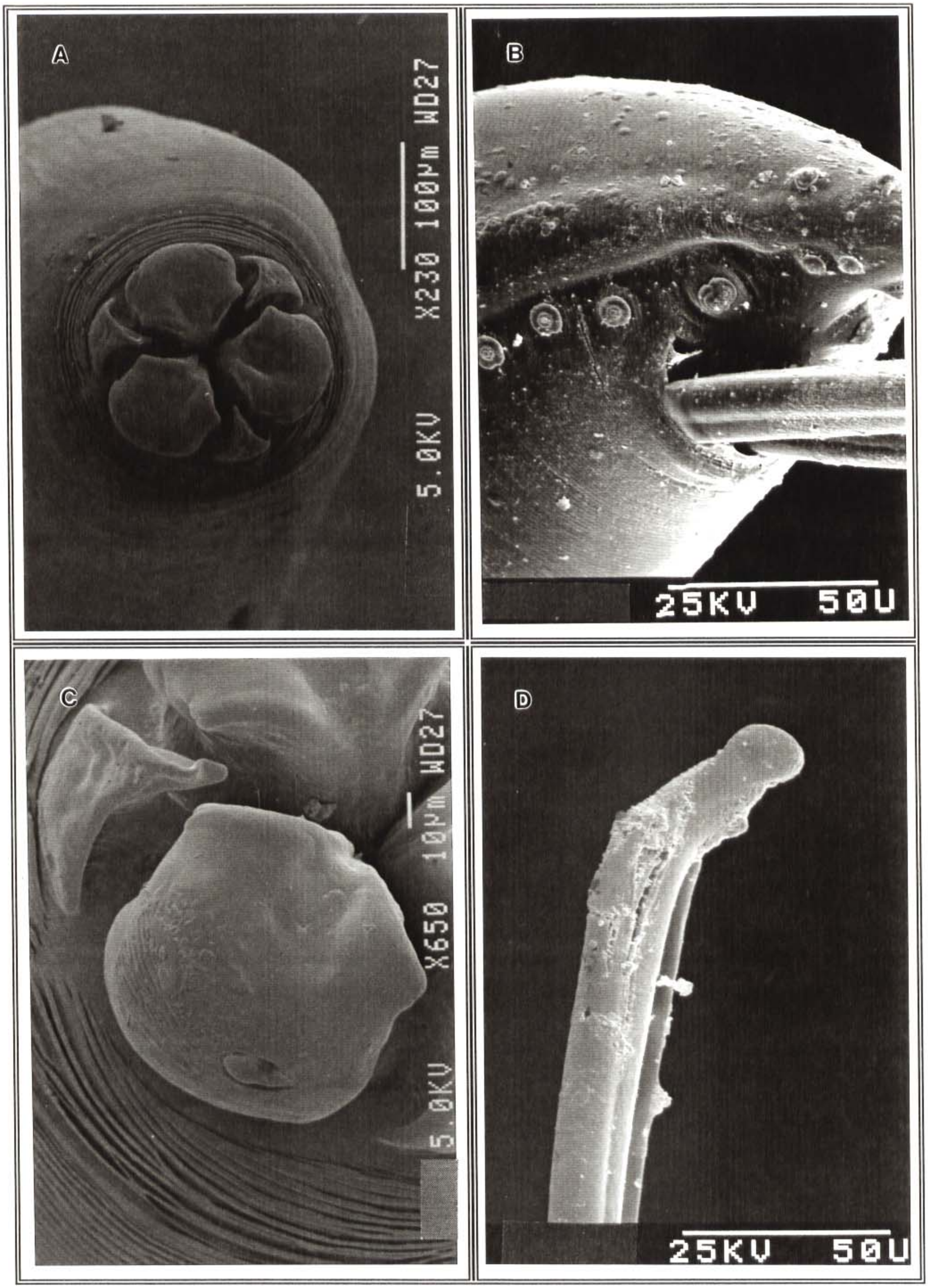

A
5.0KV X230 100µm WD27
B
25KV 50U
C
5.0KV X650 10µm WD27
D
25KV 50U

FIG. 42.

CONTRACAECUM LAWRENCEI
(Scanning Electron Microscopy)

A. *Apical view of the anterior end of an adult worm*

B. *Caudal end of male showing distribution of papillae - paracloacal papillae clearly visible*

C. *Ventrolateral lip enlarged*

D. *Tail end with distal end of spicule enlarged*

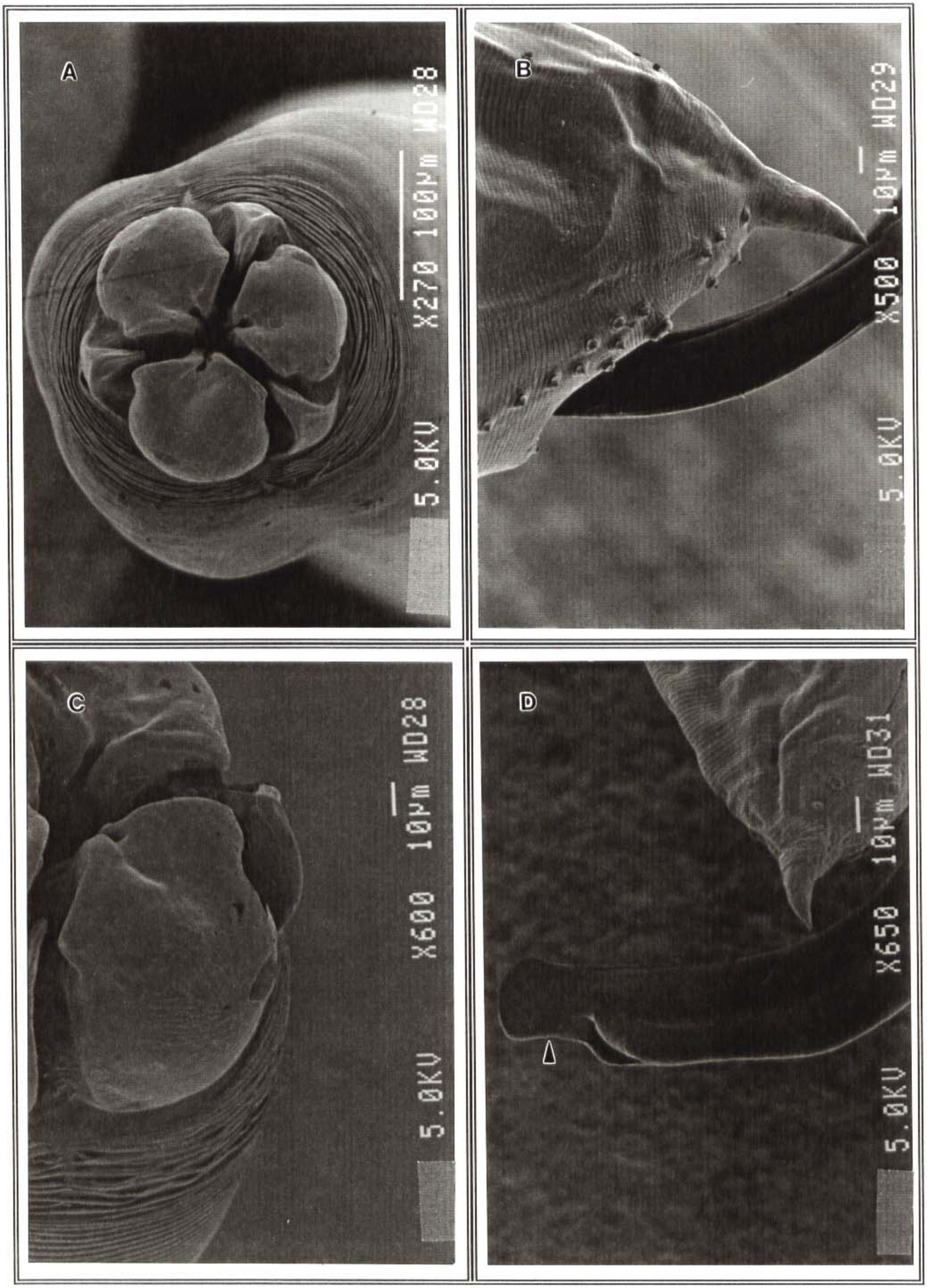

A
5.0KV X270 100μm WD28
B
5.0KV X500 10μm WD29
C
5.0KV X600 10μm WD28
D
5.0KV X650 10μm WD31

FIG. 43

CONTRACAECUM RUDOLPHII
(Scanning Electron Microscopy)

A. ***Ventrolateral view of the head illustrating shape of lips and interlabium***

B. ***Caudal end of male with protruding spicule and distribution of postcloacal papillae clearly visible***

C. ***Enlarged interlabium, to demonstrate bifurcated tip***

D. ***Distal end of spicule enlarged***

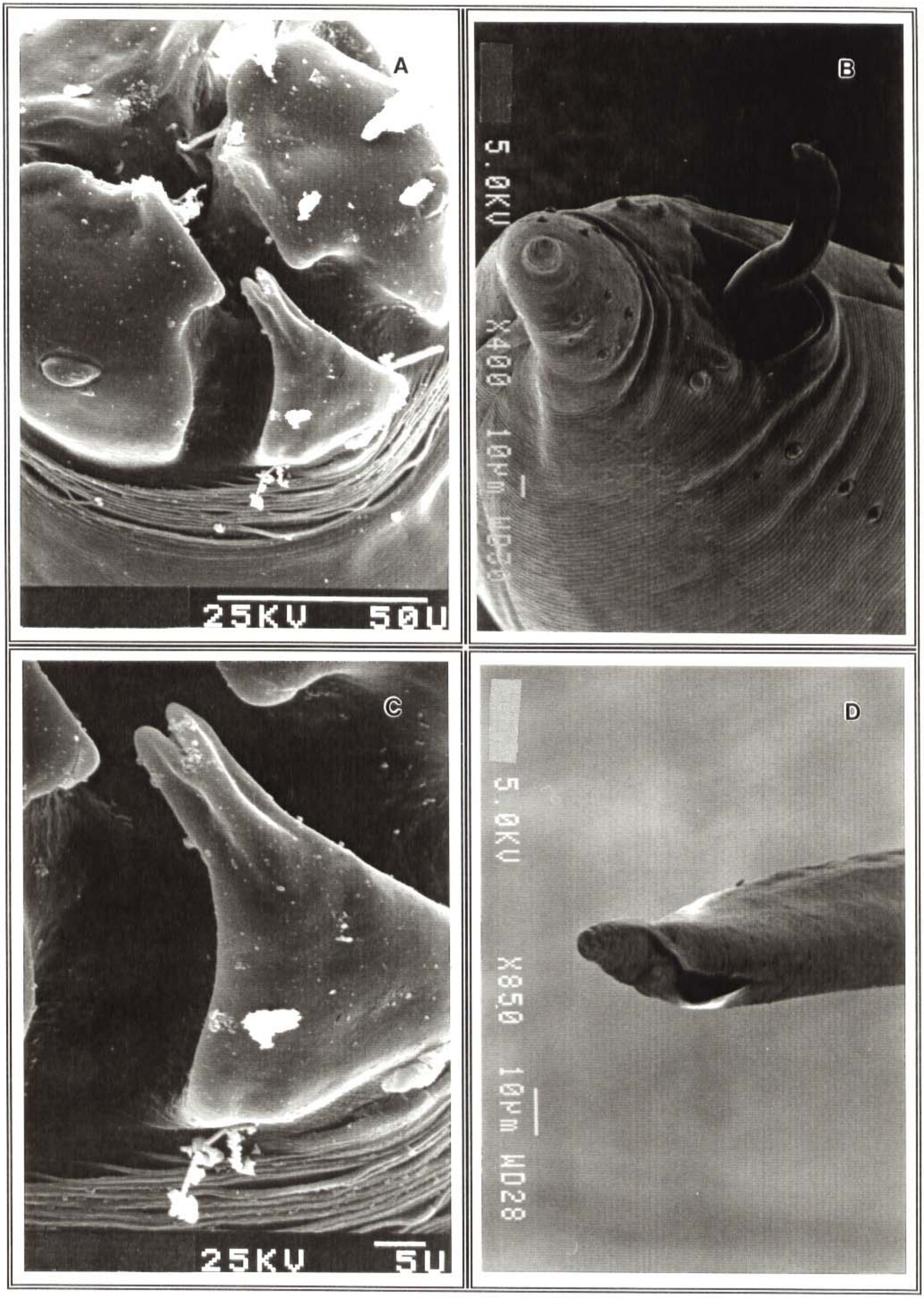

A
25KV 50U
B
5.0KV X400 10µm WD30
C
25KV 5U
D
5.0KV X850 10µm WD28

FIG. 44

CONTRACAECUM JOKLI
(Scanning Electron Microscopy)

A. ***Apical view of the head illustrating shape and arrangement of lips and interlabia***

B. ***Male postcloacal region showing distribution of papillae***

C. ***Enlarged dorsal lip and interlabia. Two double papillae clearly visible***

D. ***Anterolateral view of anterior portion of the body***

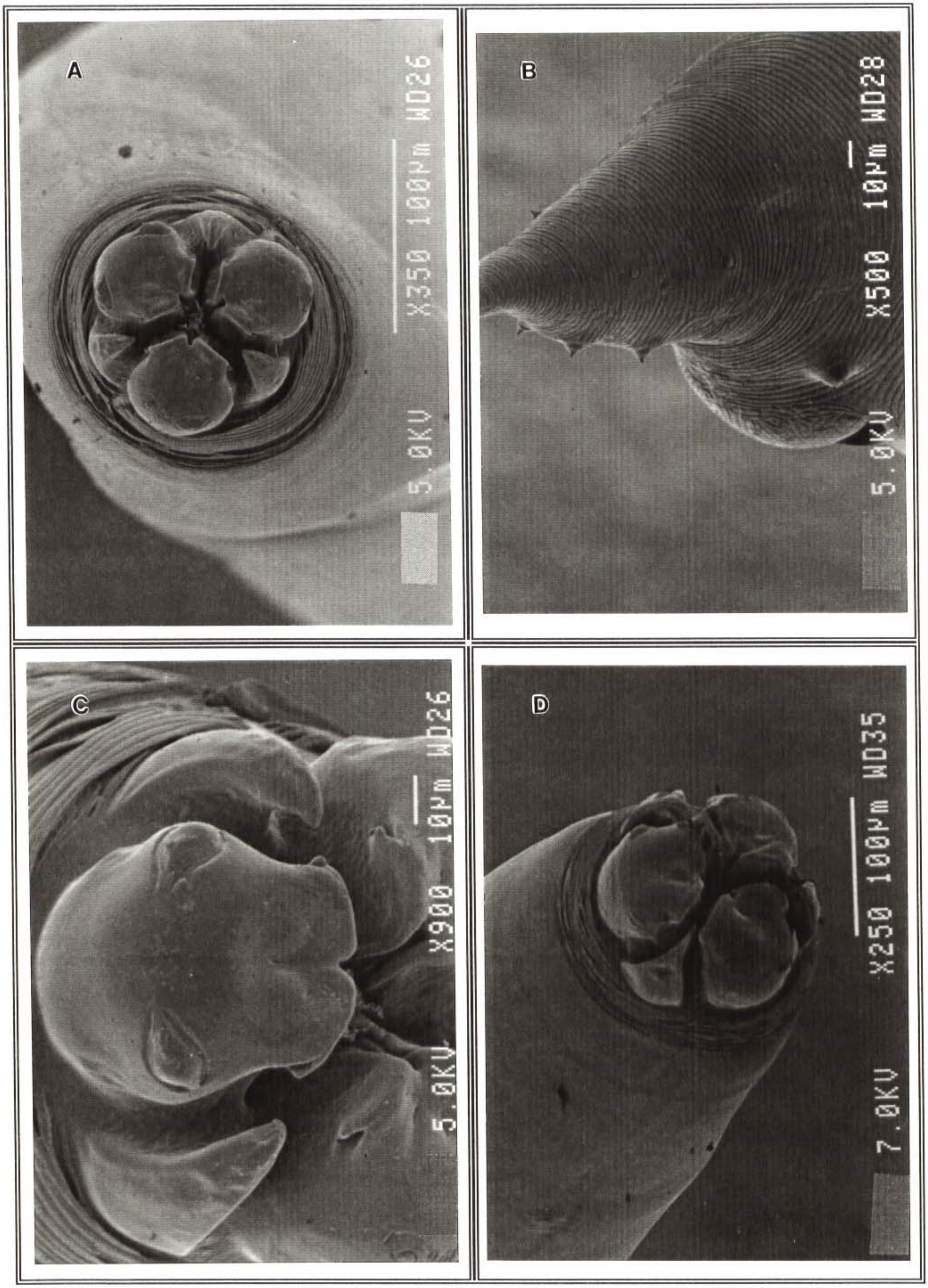

A
5.0KV X350 100μm WD26
B
5.0KV X500 10μm WD28
C
5.0KV X900 10μm WD26
D
7.0KV X250 100μm WD35

FIG. 45.

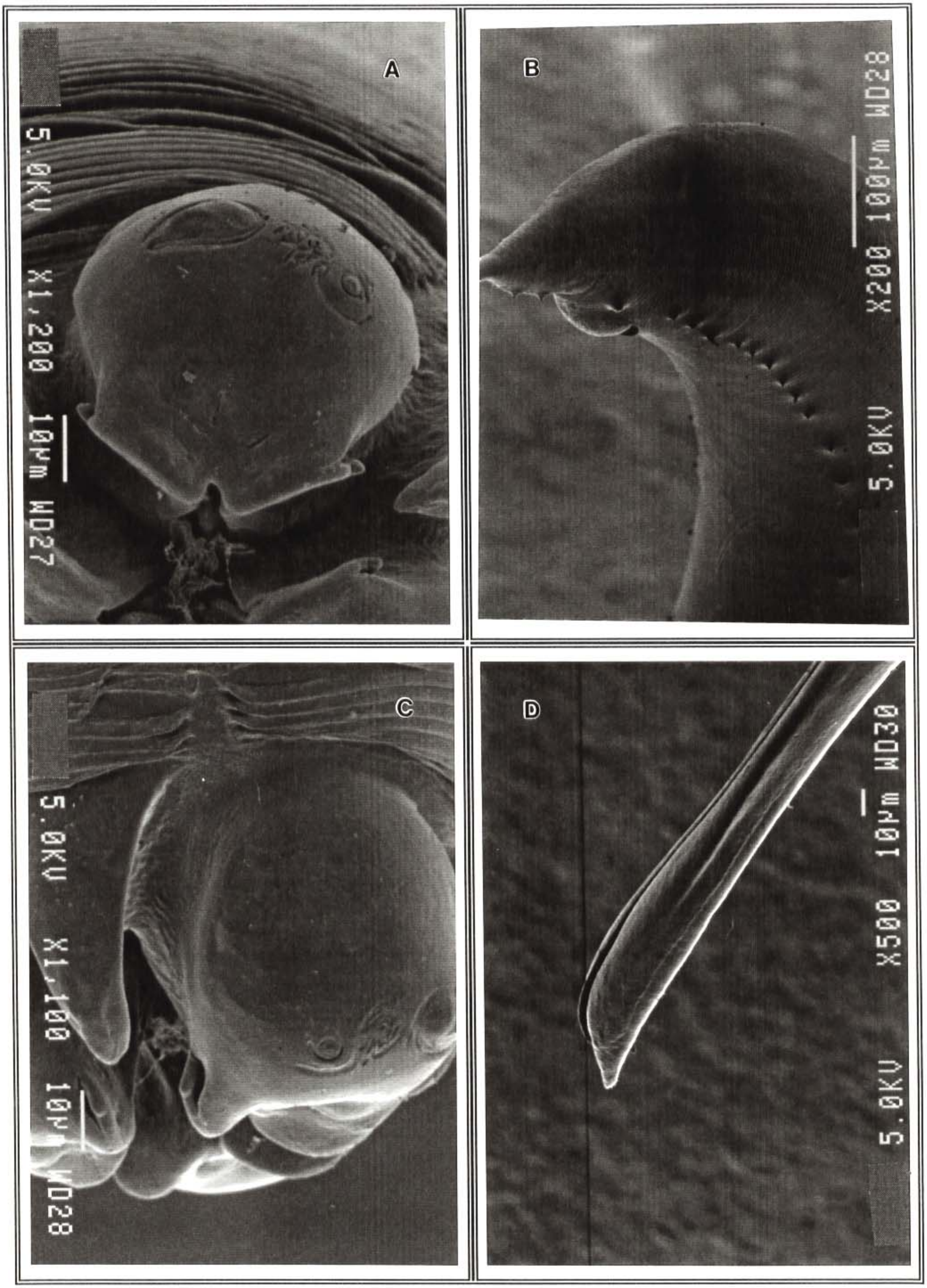
CONTRACAECUM JOKLI
(Scanning Electron Microscopy)

A. *Enlarged ventrolateral lip with well exposed dorsal double papilla and ventral single papilla*

B. *Posterior portion of male worm showing distribution pattern of caudal papillae*

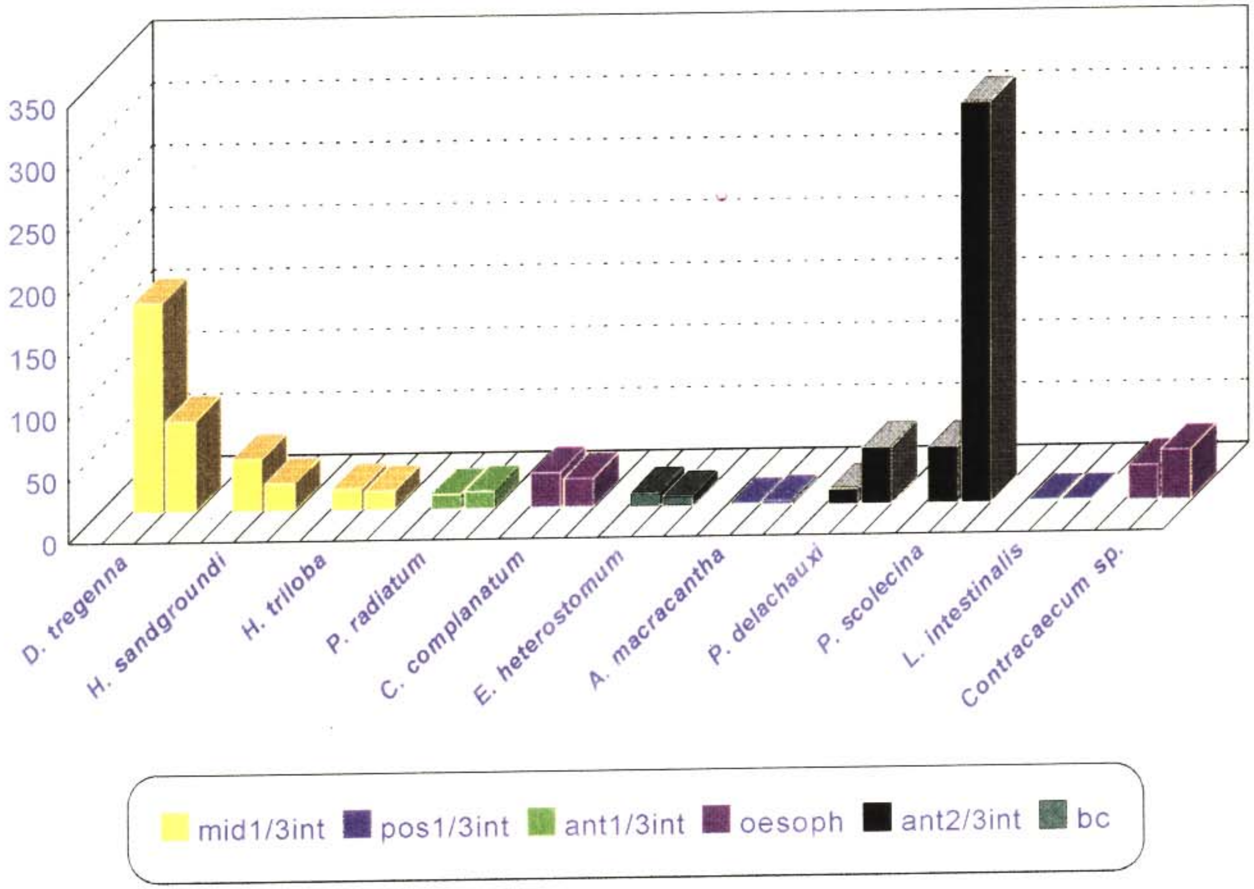
C. *Enlarged interlabium and ventrolateral lip*

D. *Distal end of spicule*


A
5.0KV X1,200 10µm WD27
B
5.0KV X200 100µm WD28
C
5.0KV X1,100 10µm WD28
D
5.0KV X500 10µm WD30

Phalacrocorax carbo

Piet Gouws Dam, Spring (n=2)

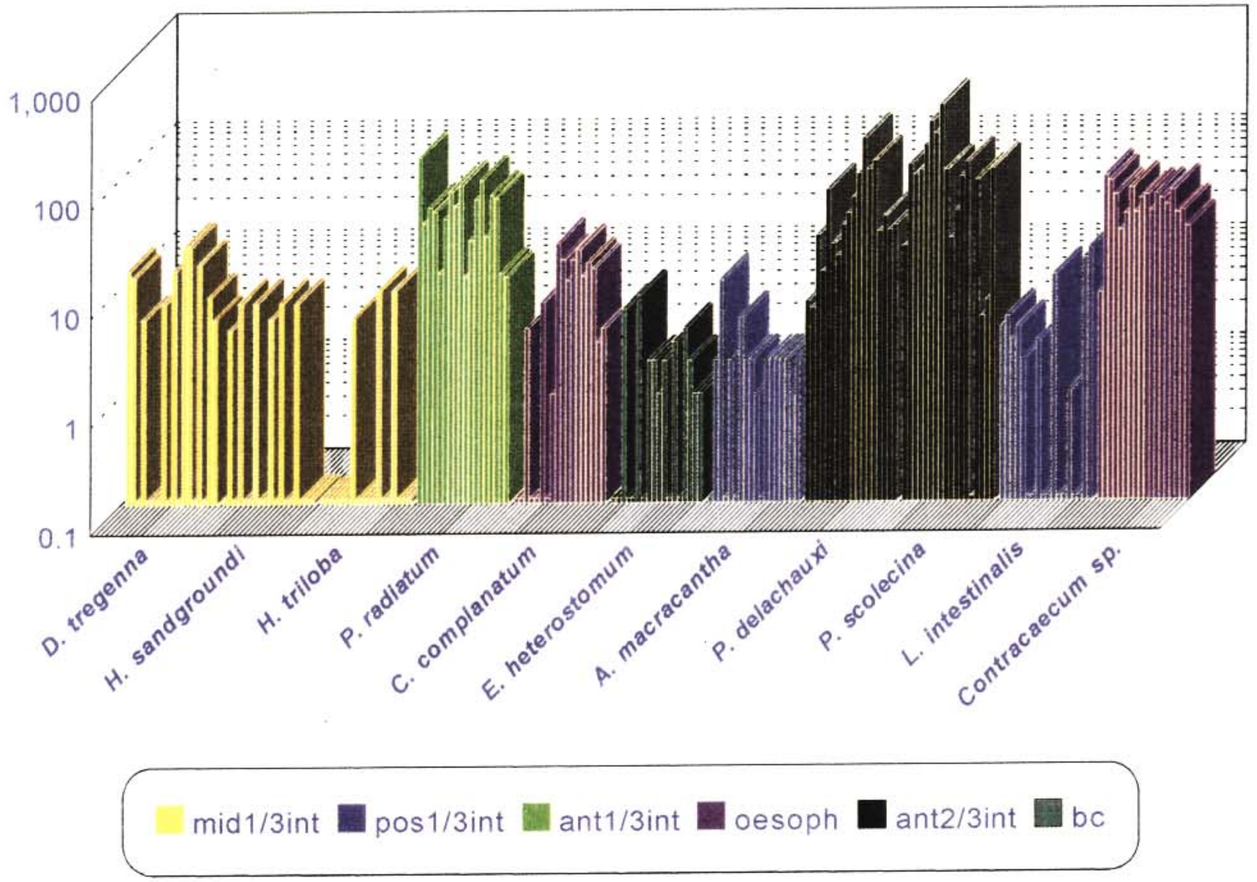


Parasites with fish intermediate host

Fig. 46

Phalacrocorax carbo

Seshego Dam, Winter (n=18)

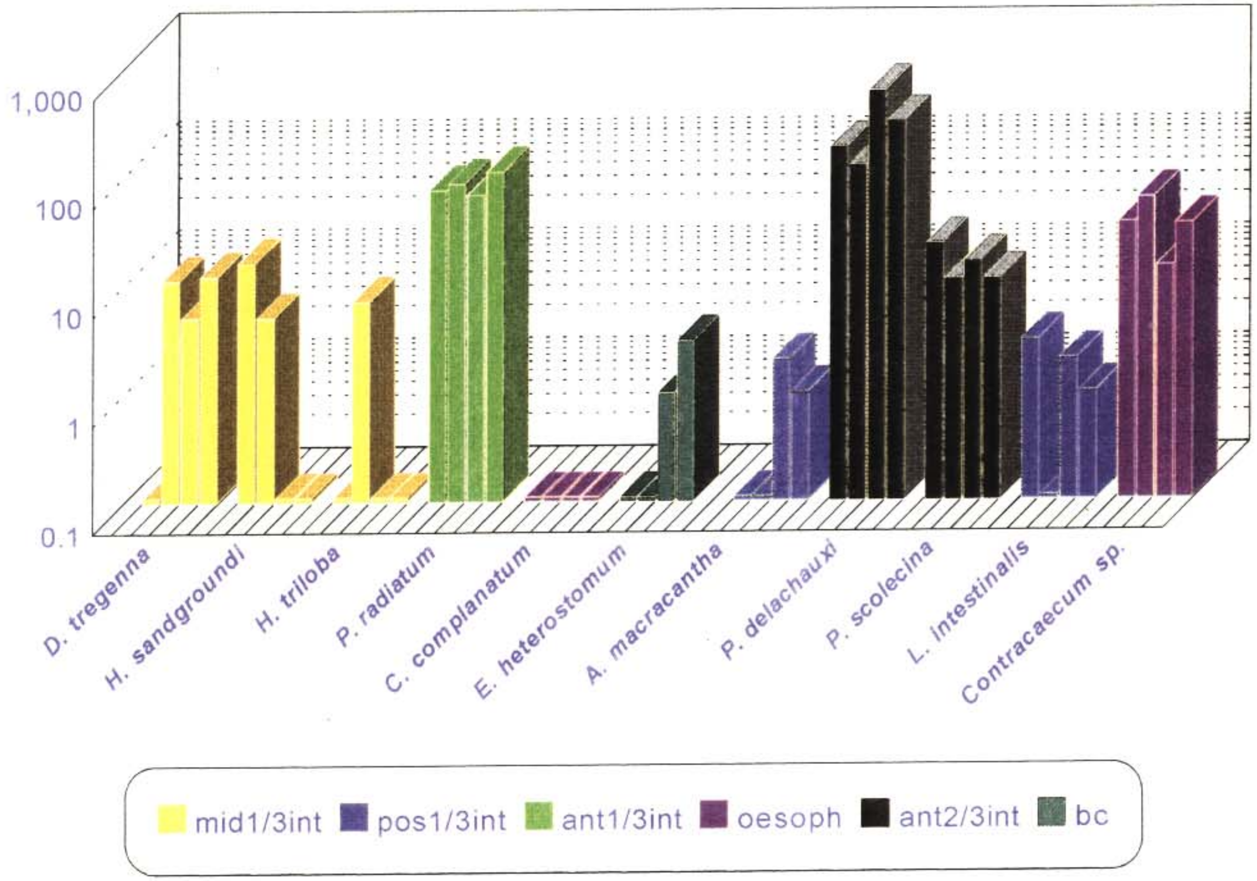


Parasites with fish intermediate host

Fig. 47

Phalacrocorax carbo

Seshego Dam, Spring (n=4)

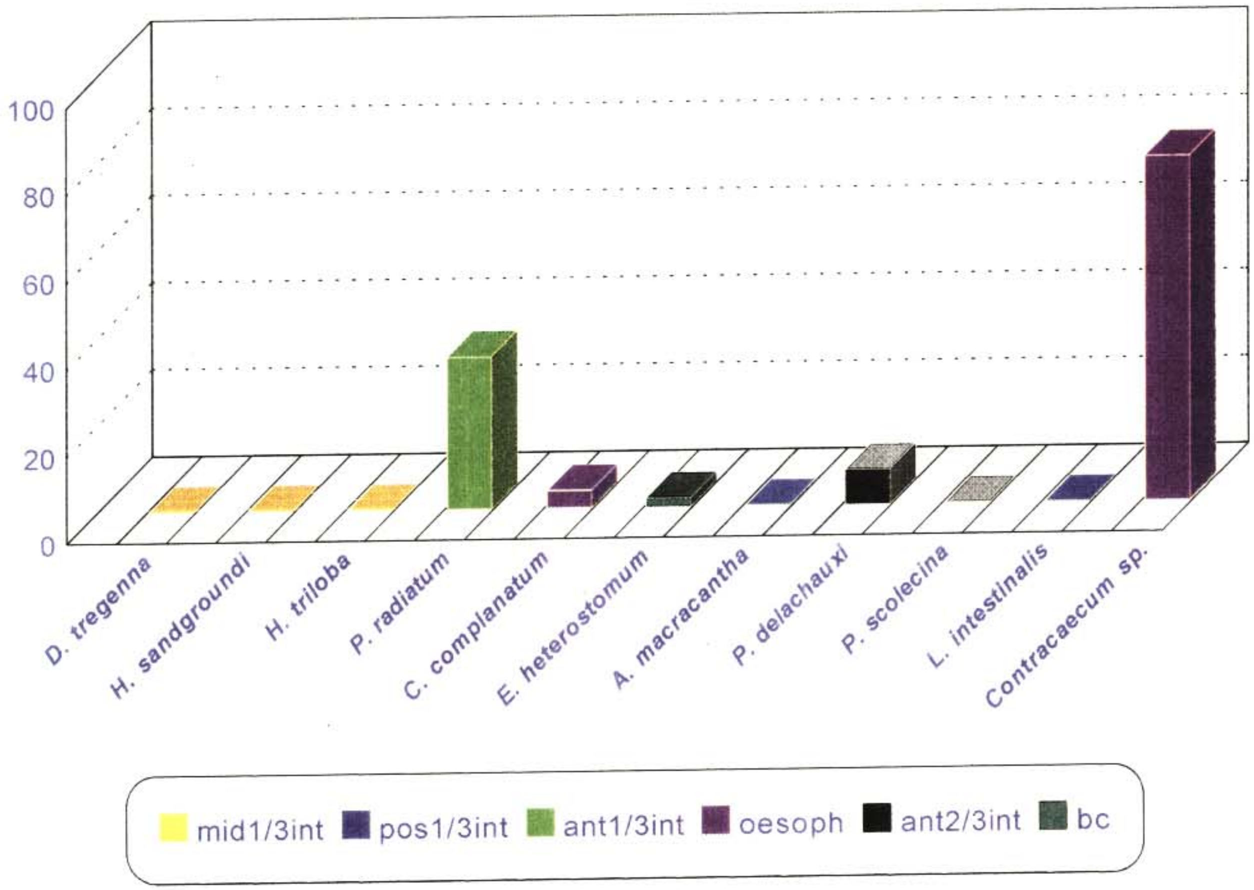


Parasites with fish intermediate host

Fig. 48

Phalacrocorax carbo

Seshego Dam, Summer (n=1)

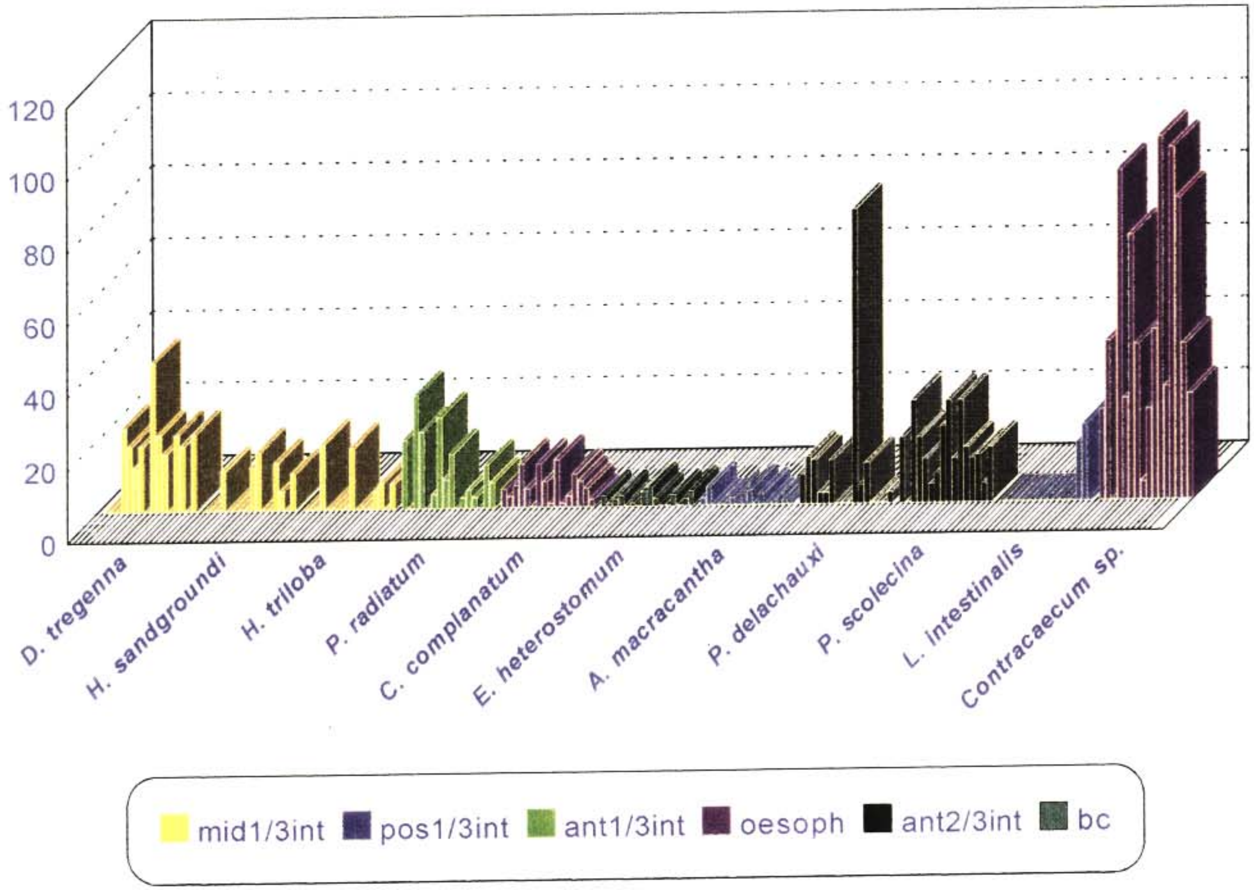


Parasites with fish intermediate host

Fig. 49

Phalacrocorax carbo

Seshego Dam, Autumn (n=16)

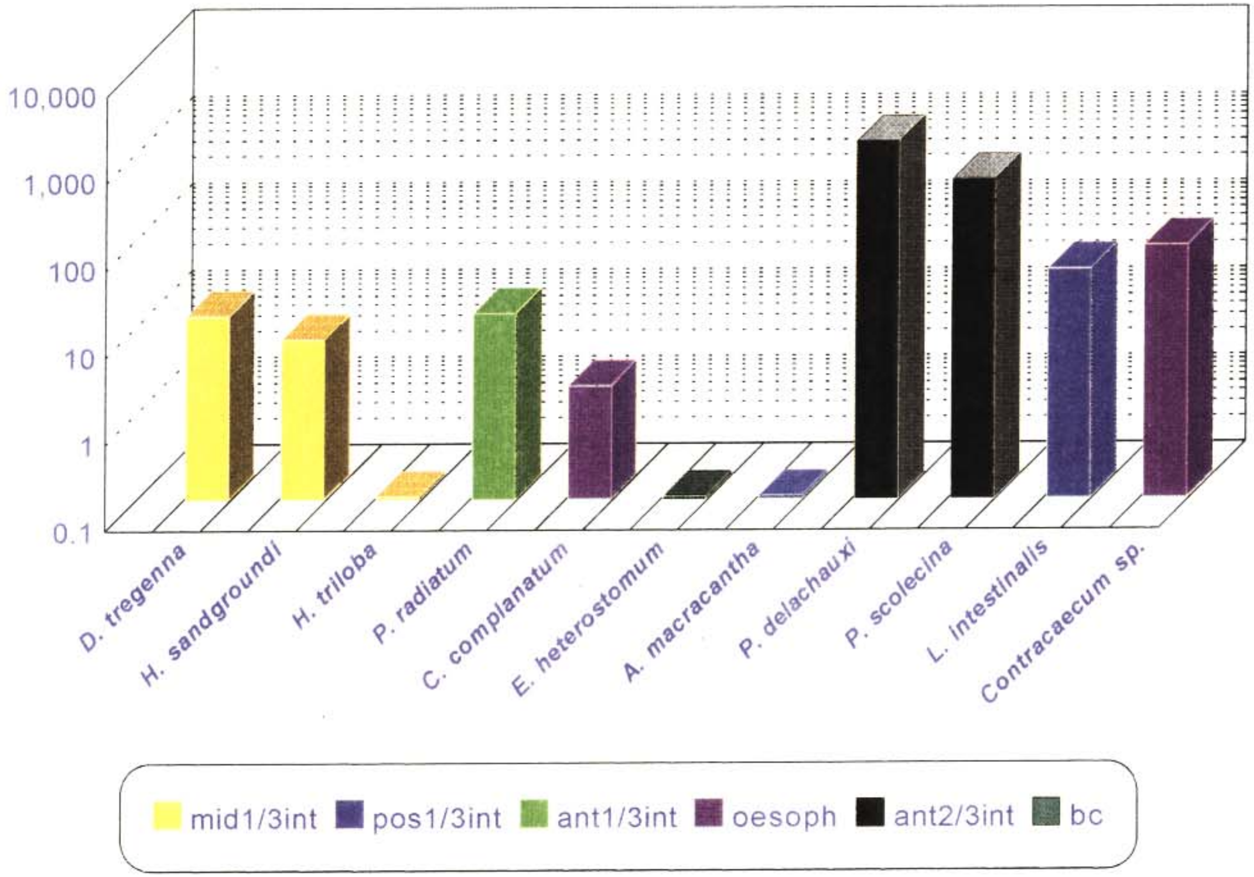


Parasites with fish intermediate host

Fig. 50

Phalacrocorax carbo

Middle Letaba Dam, Winter (n=1)

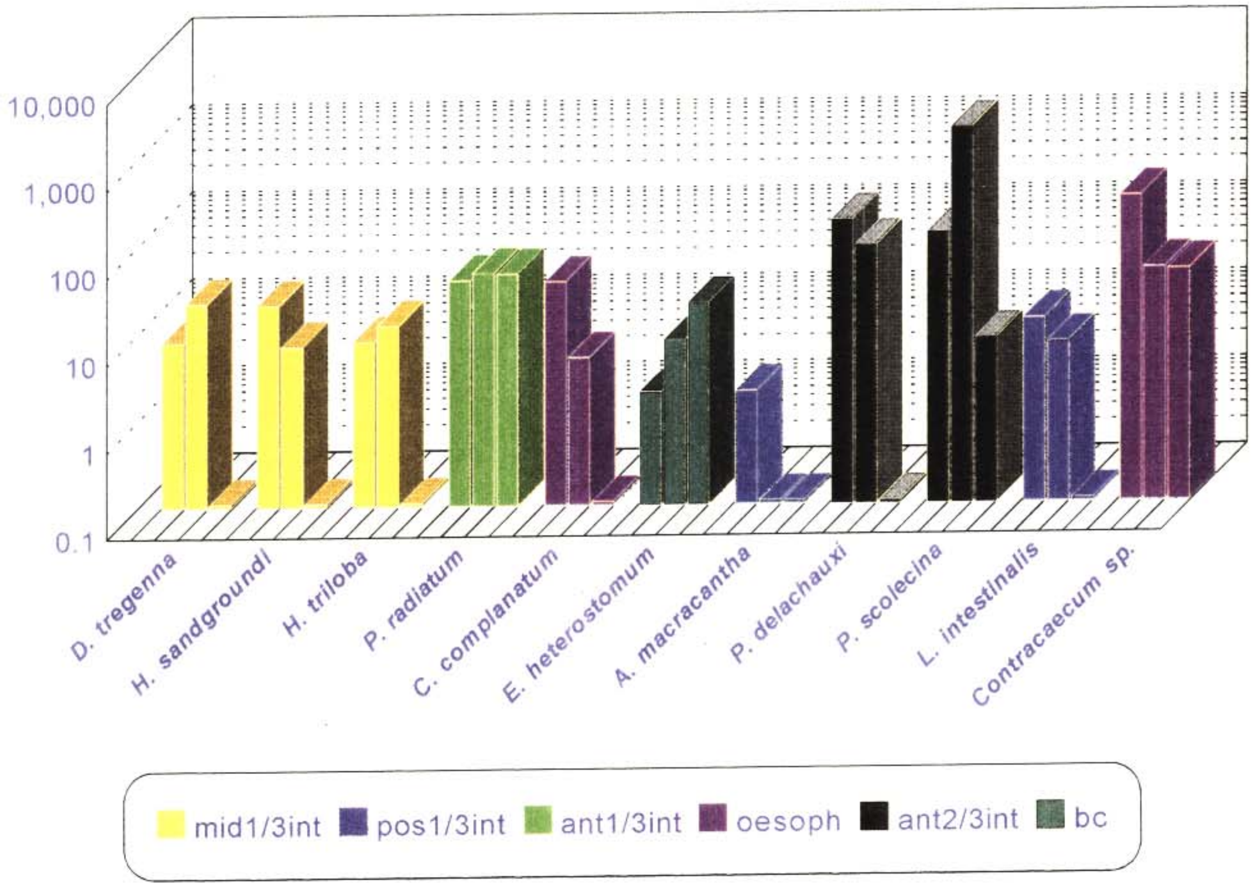


Parasites with fish intermediate host

Fig. 51

Phalacrocorax carbo

Middle Letaba Dam, Spring (3)

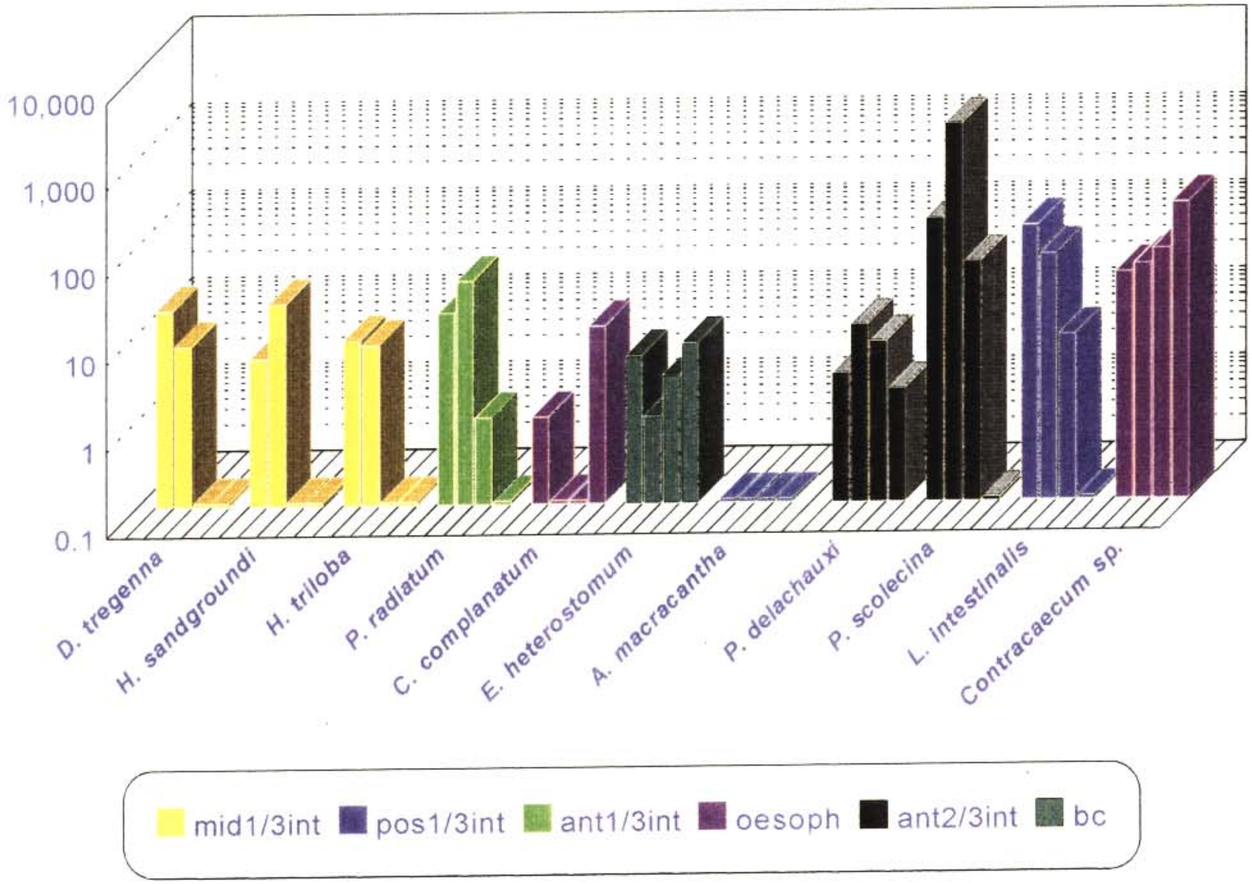


Parasites with fish intermediate host

Fig. 52

Phalacrocorax carbo

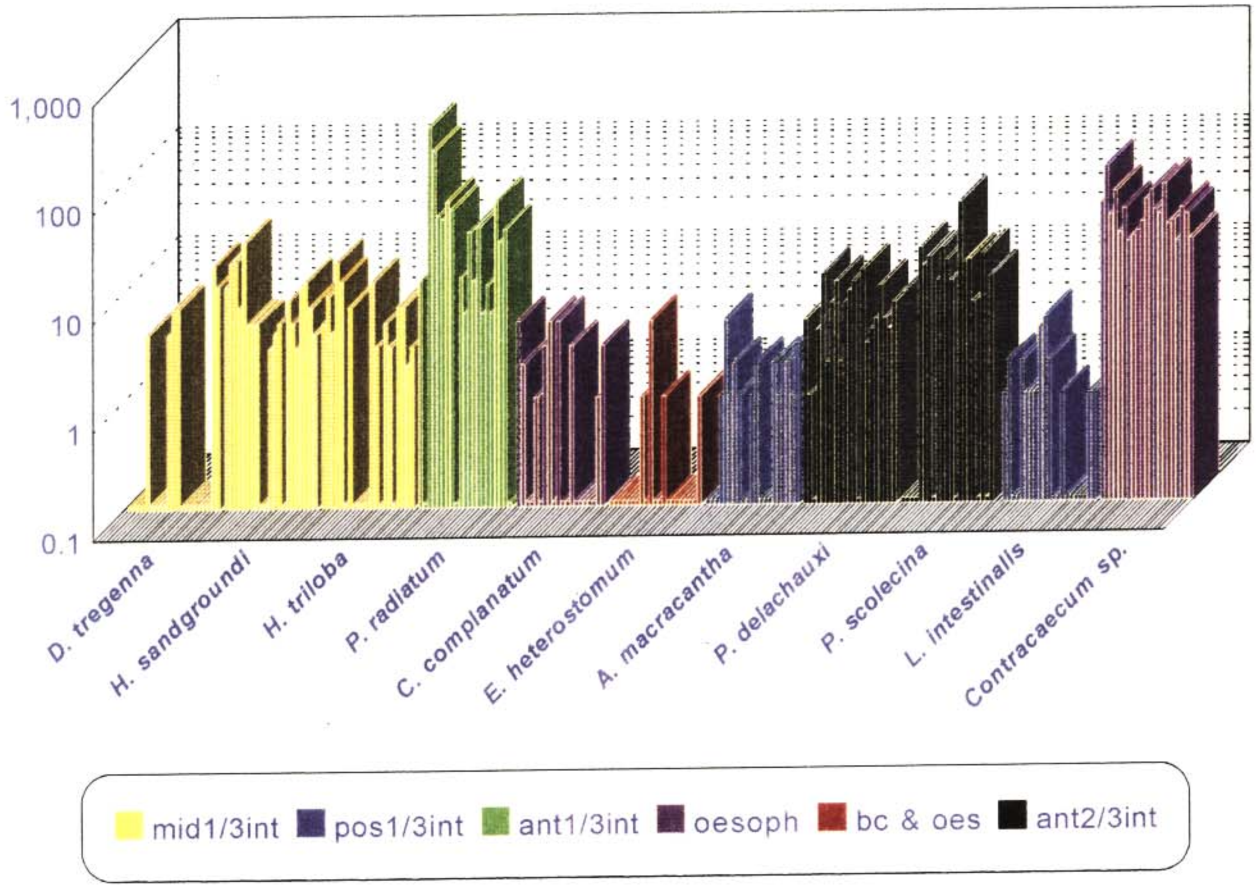
Middle Letaba Dam, Autumn (n=4)



Parasites with fish intermediate host

Fig. 53

Phalacrocorax africanus
Seshego Dam, Winter (n=21)

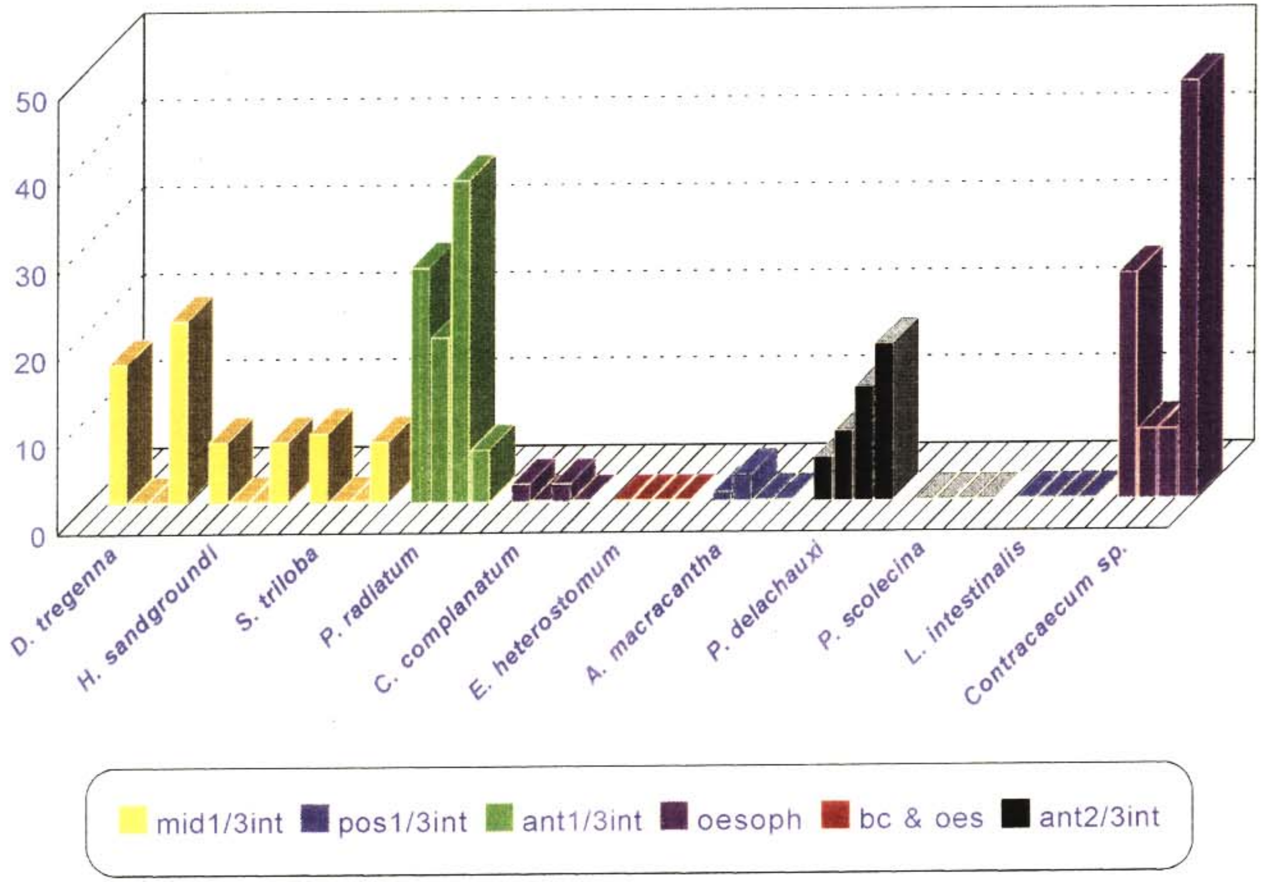


Parasites with fish intermediate host

Fig. 54

Phalacrocorax africanus

Seshego Dam, Summer (n=4)

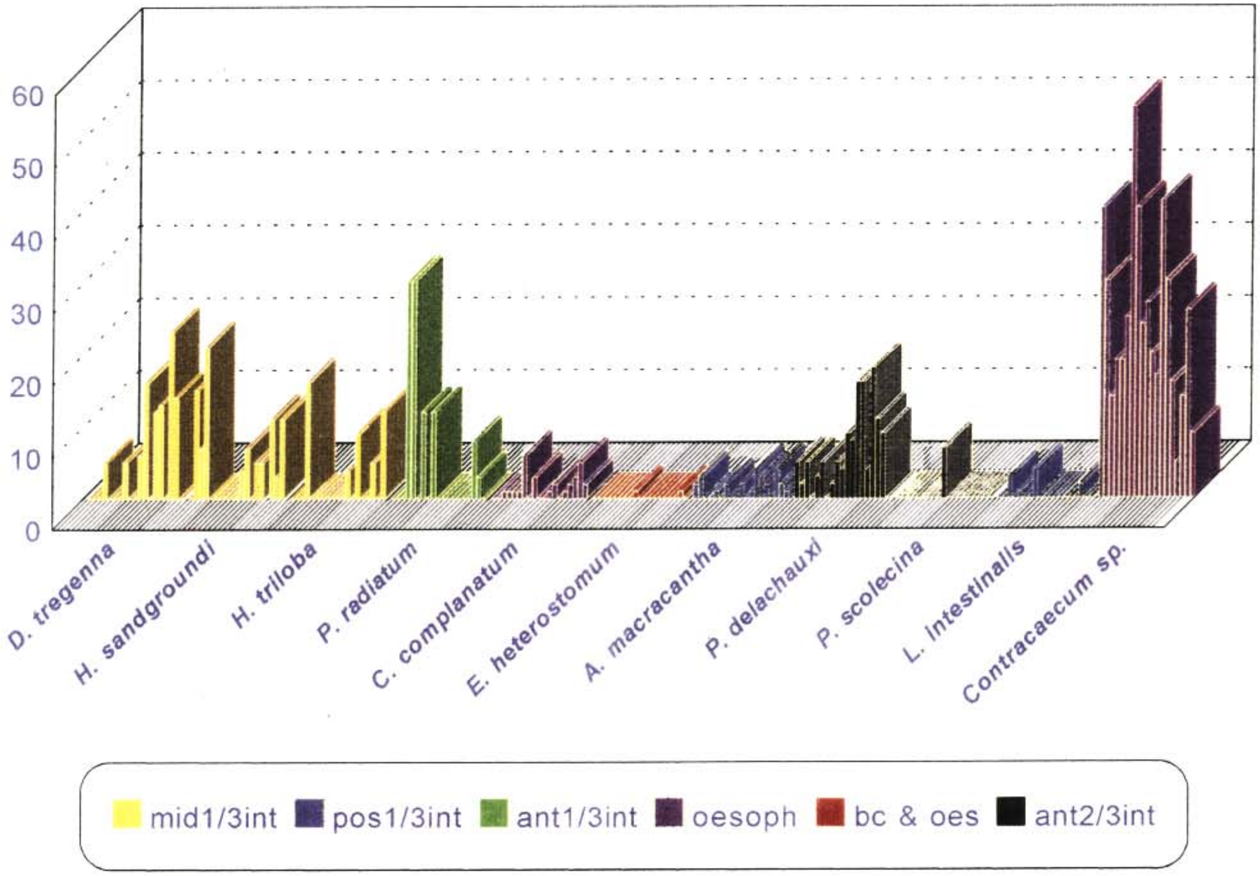


Parasites with fish intermediate host

Fig. 55

Phalacrocorax africanus

Seshego Dam, Autumn (n=19)

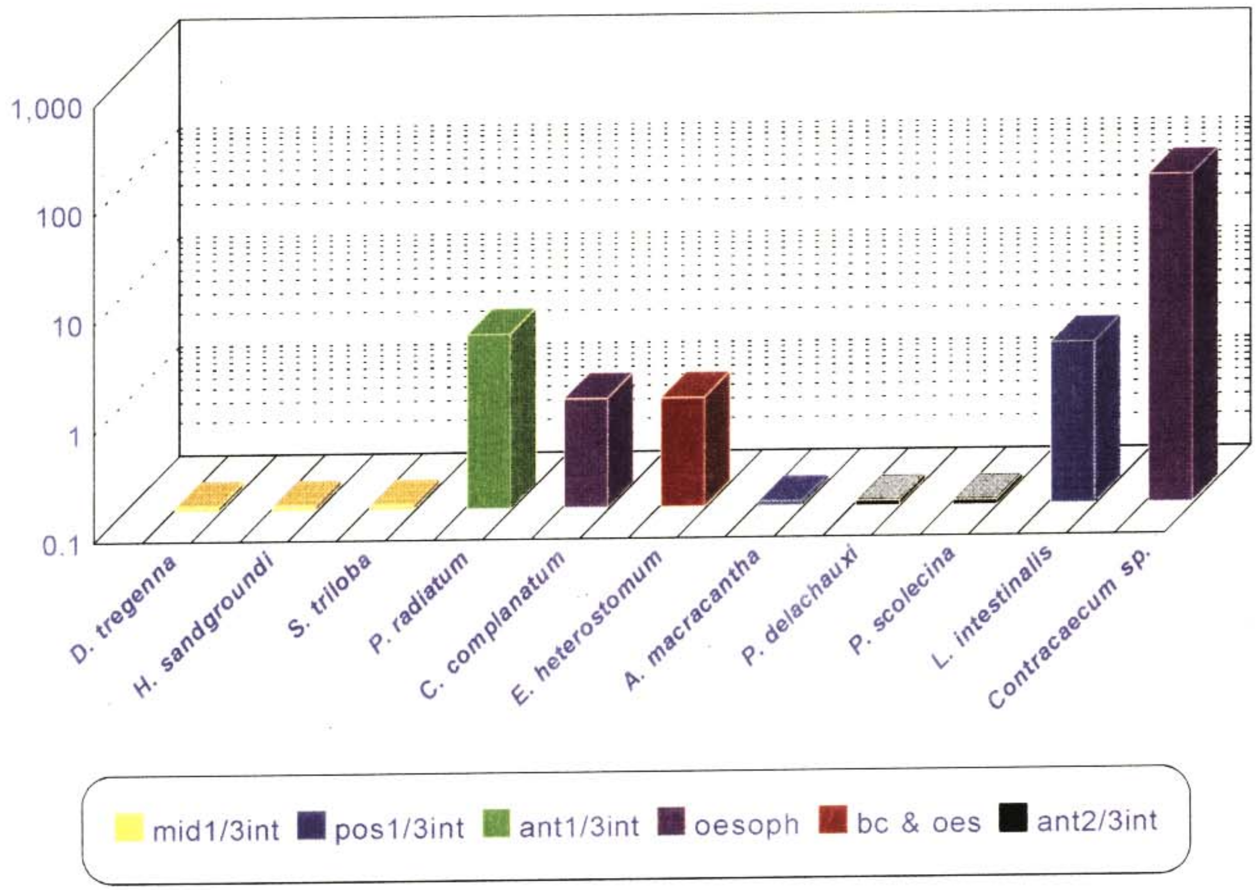


Parasites with fish intermediate host

Fig. 56

Phalacrocorax africanus

Middle Letaba Dam, winter (n=1)

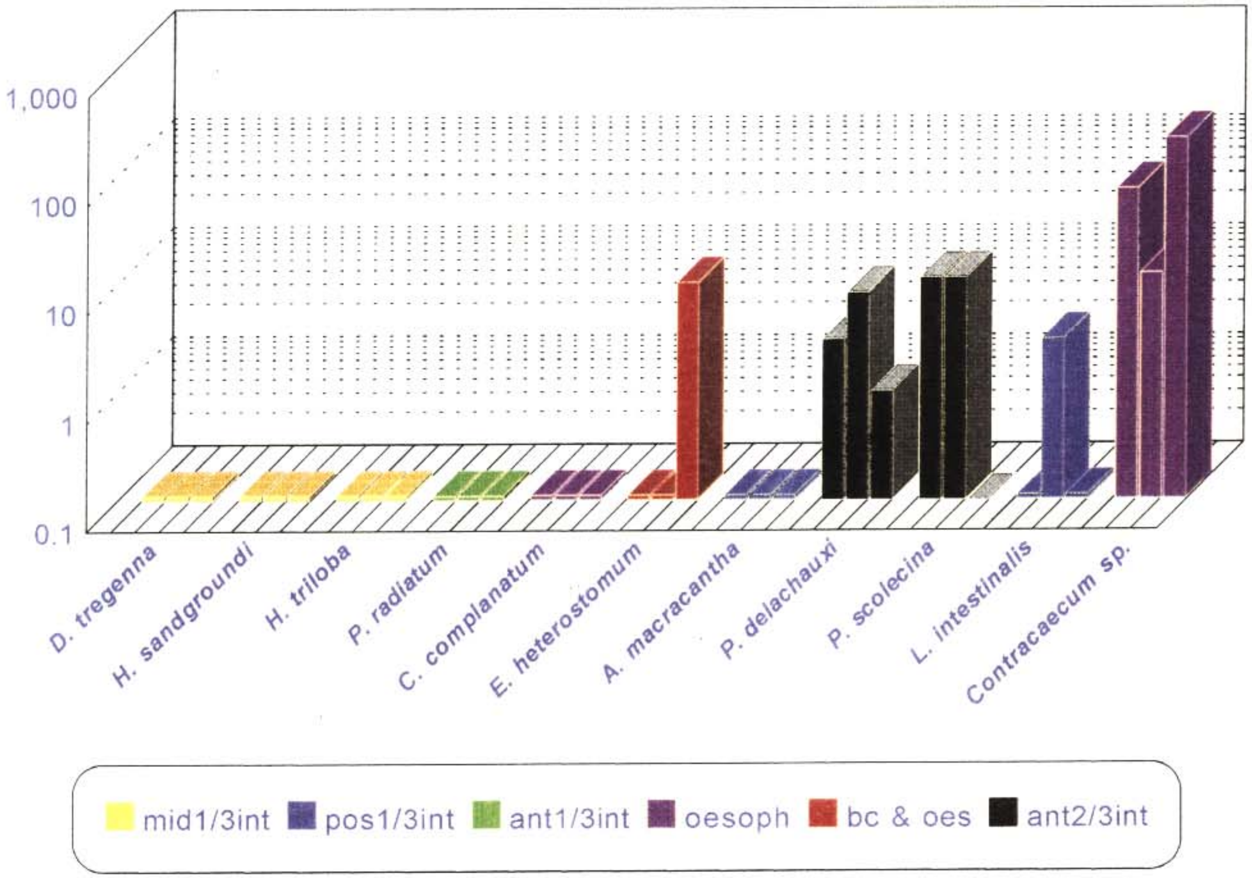


Parasites with fish intermediate host

Fig. 57

Phalacrocorax africanus

Middle Letaba Dam, Spring (n=3)

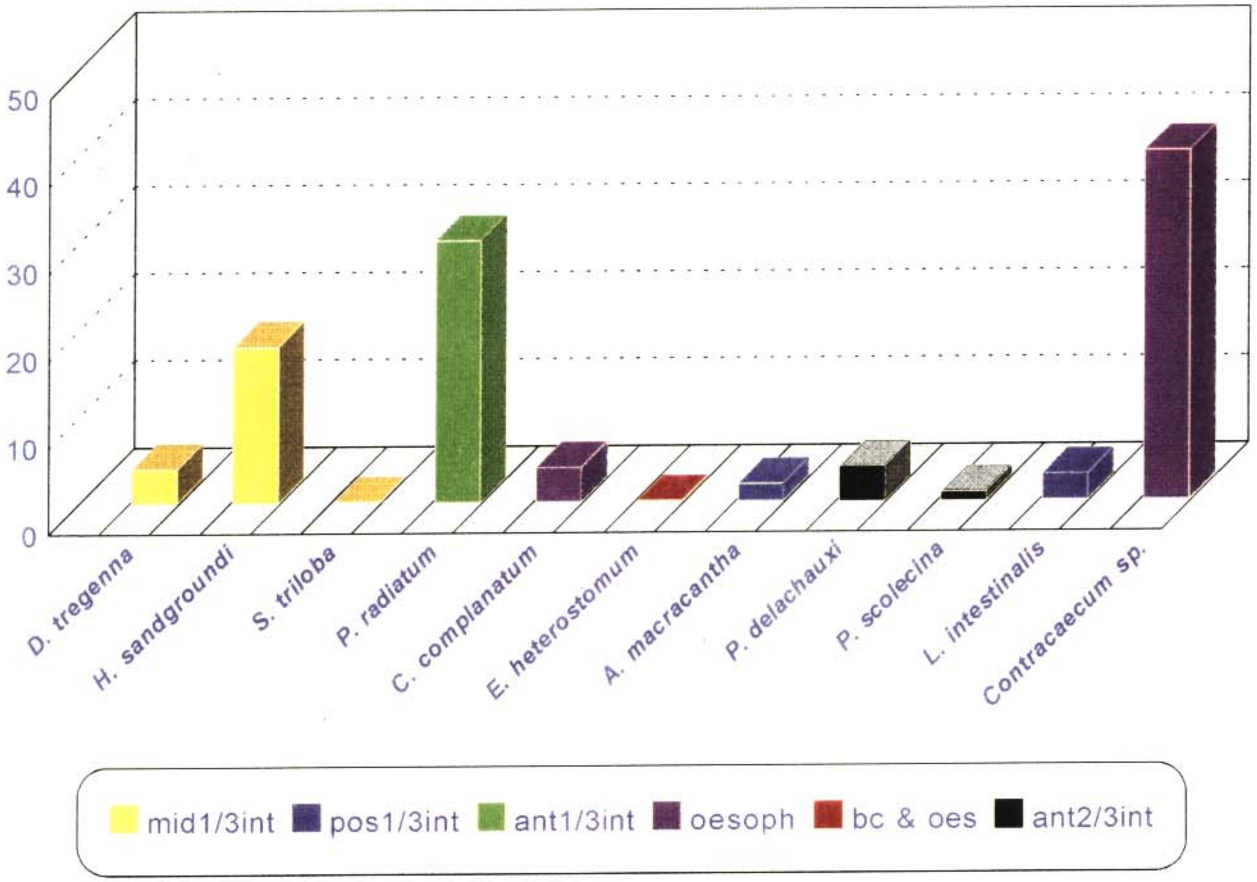


Parasites with fish intermediate host

Fig. 58

Phalacrocorax africanus

Middle Letaba Dam, summer (n=1)

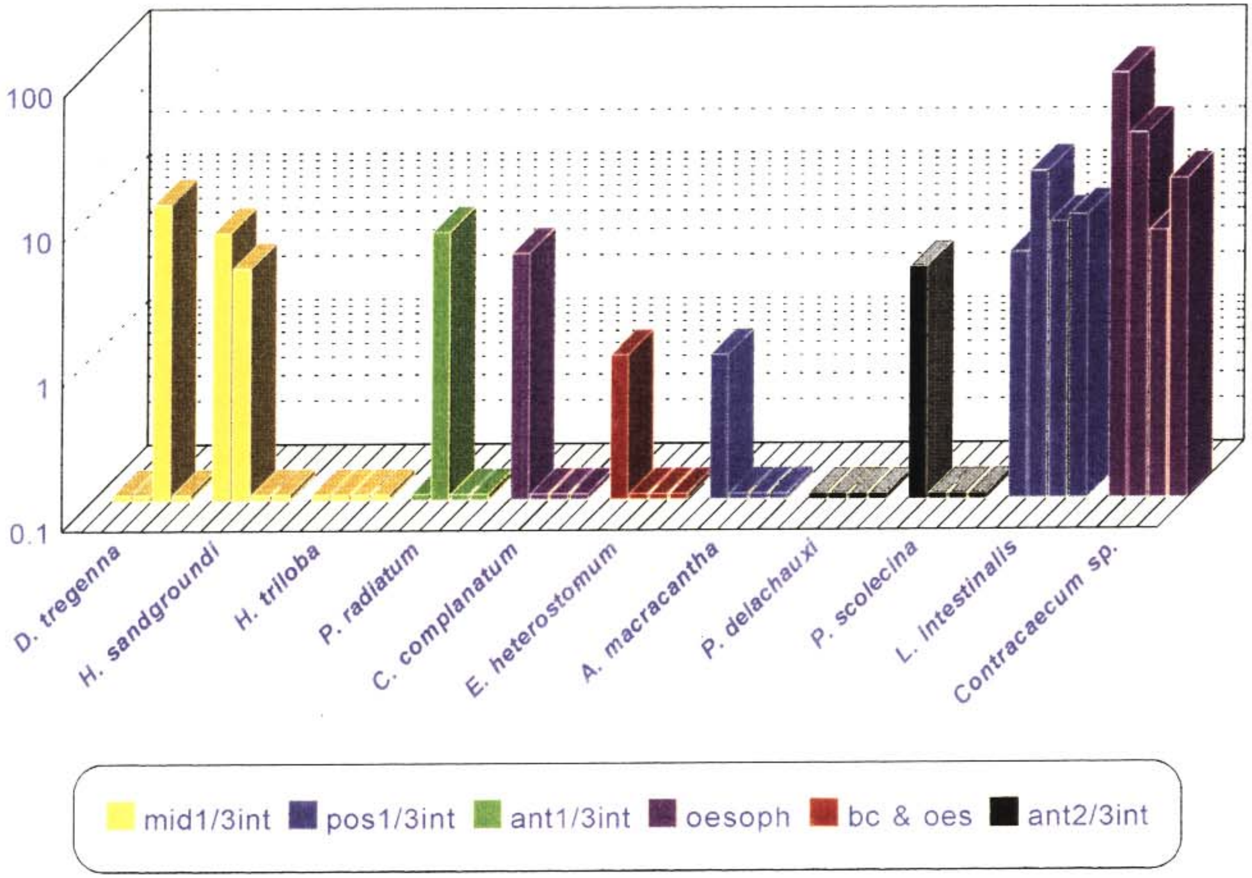


Parasites with fish intermediate host

Fig. 59

Phalacrocorax africanus

Middle Letaba Dam, Autumn (n=4)

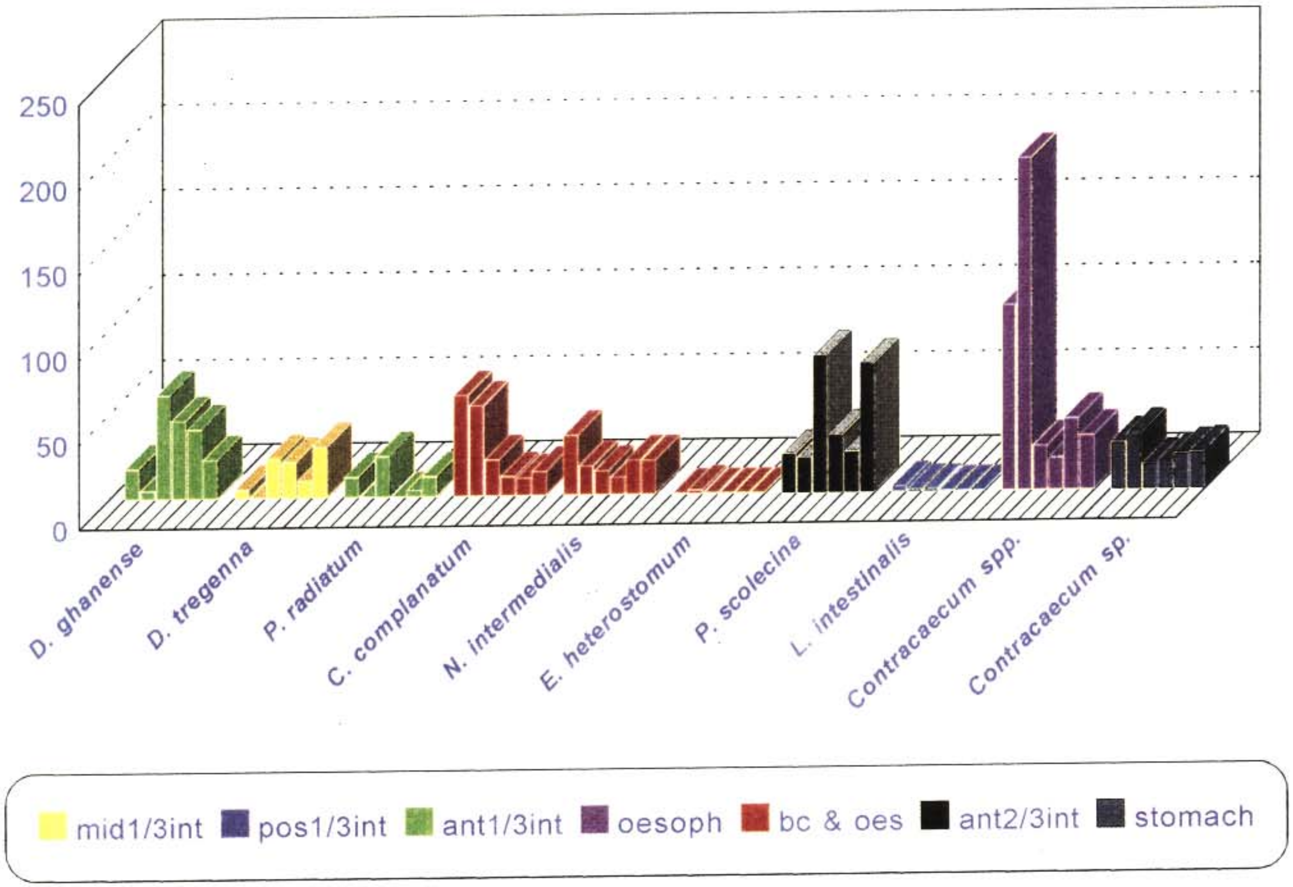


Parasites with fish intermediate host

Fig. 60

Anhinga melanogaster

Piet Gouws Dam, Spring (n=6)

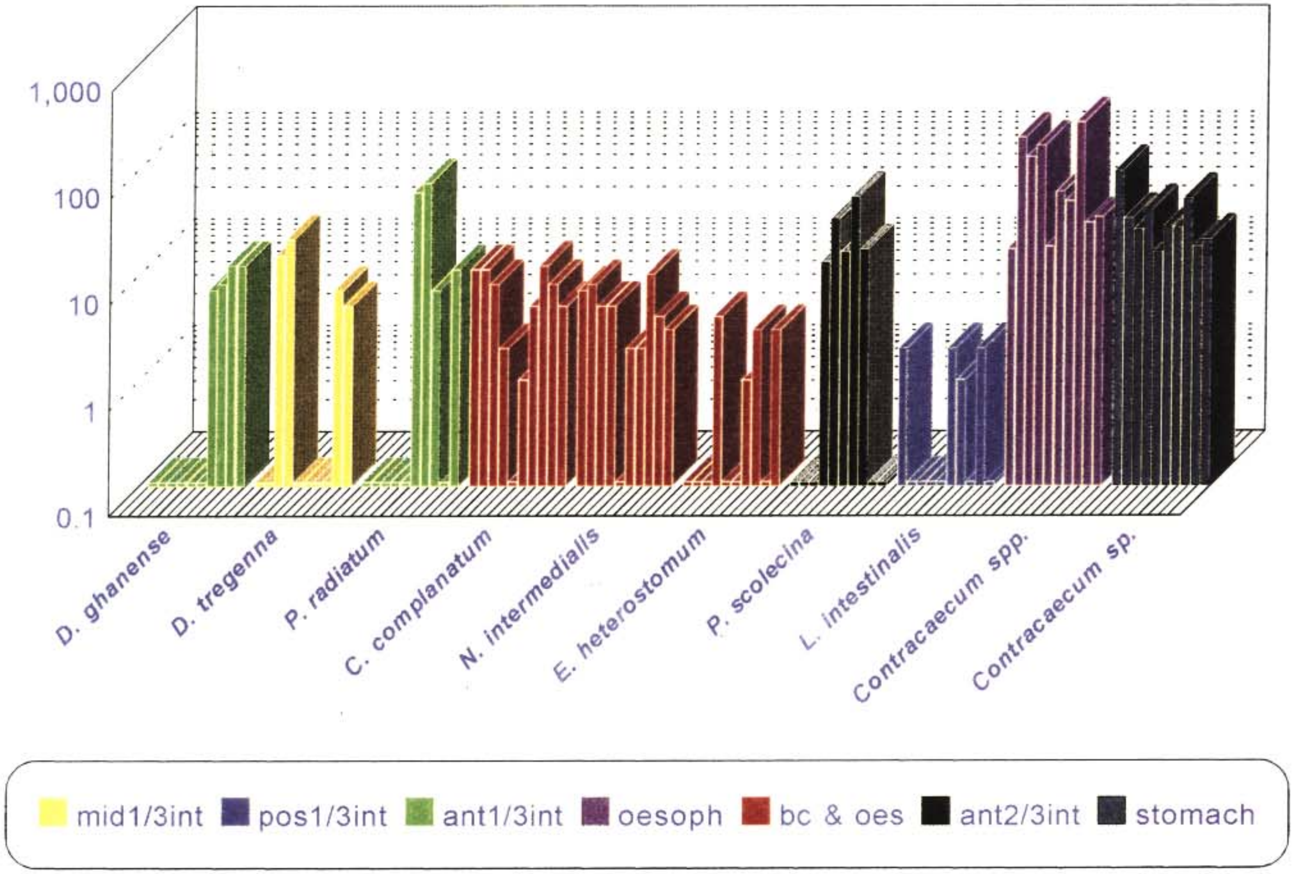


Parasites with fish intermediate host

Fig. 61

Anhinga melanogaster

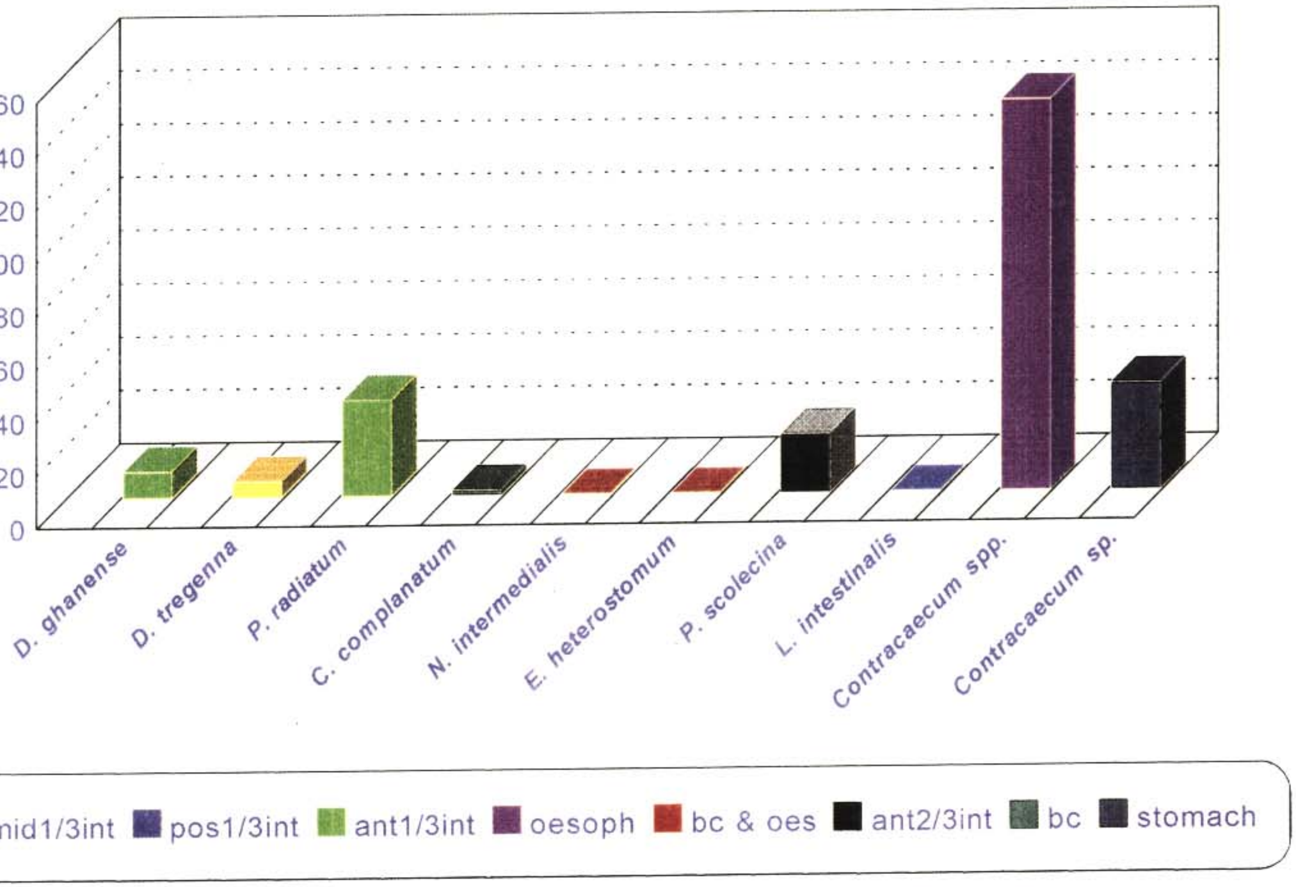
Seshego Dam, Winter (n=10)



Parasites with fish intermediate host

Fig. 62

Anhinga melanogaster
Seshego Dam, Summer (n=1)

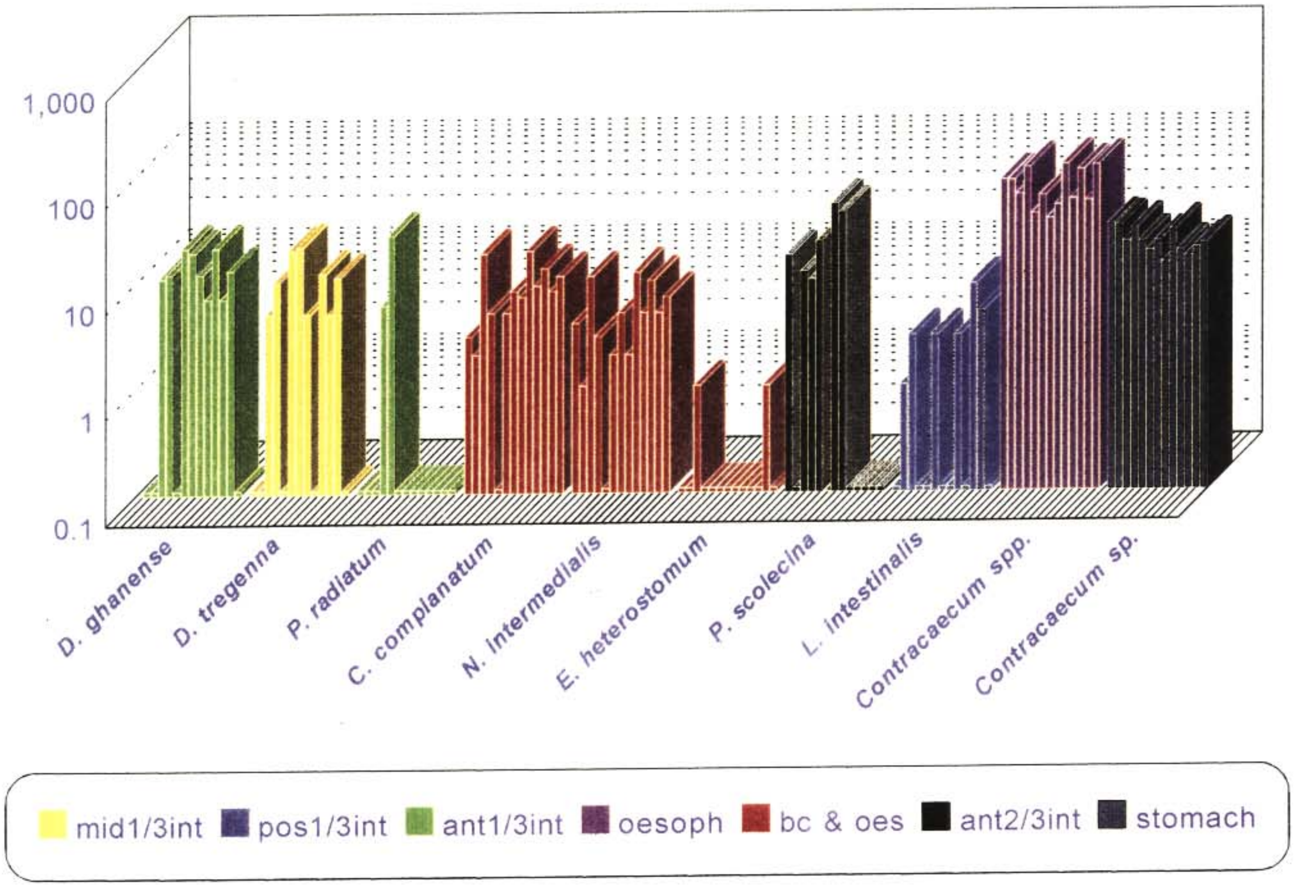


Parasites with fish intermediate host

Fig. 63

Anhinga melanogaster

Seshego Dam, Autumn (n=13)

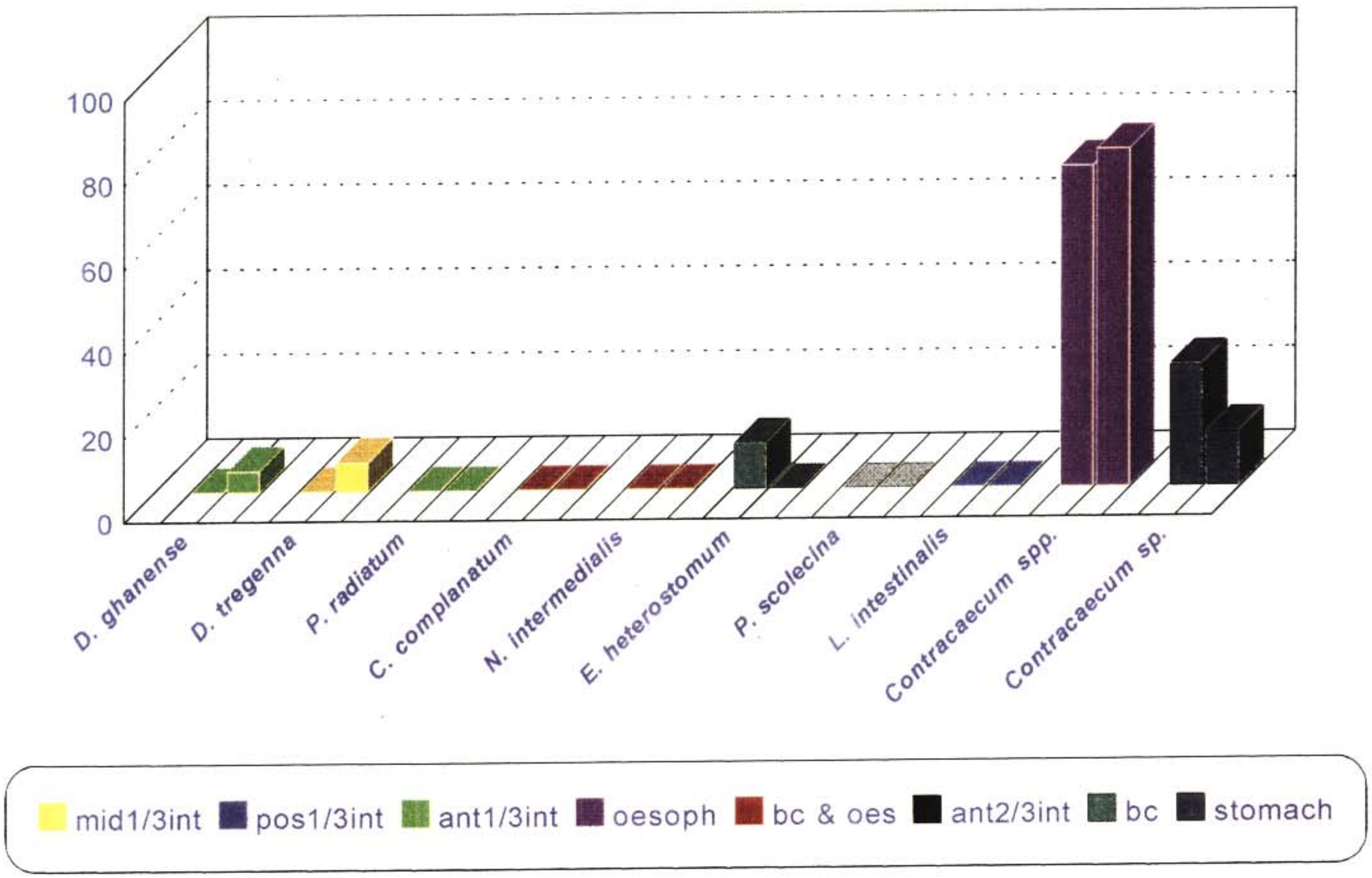


Parasites with fish intermediate host

Fig. 64

Anhinga melanogaster

Middle Letaba Dam, Spring (n=2)

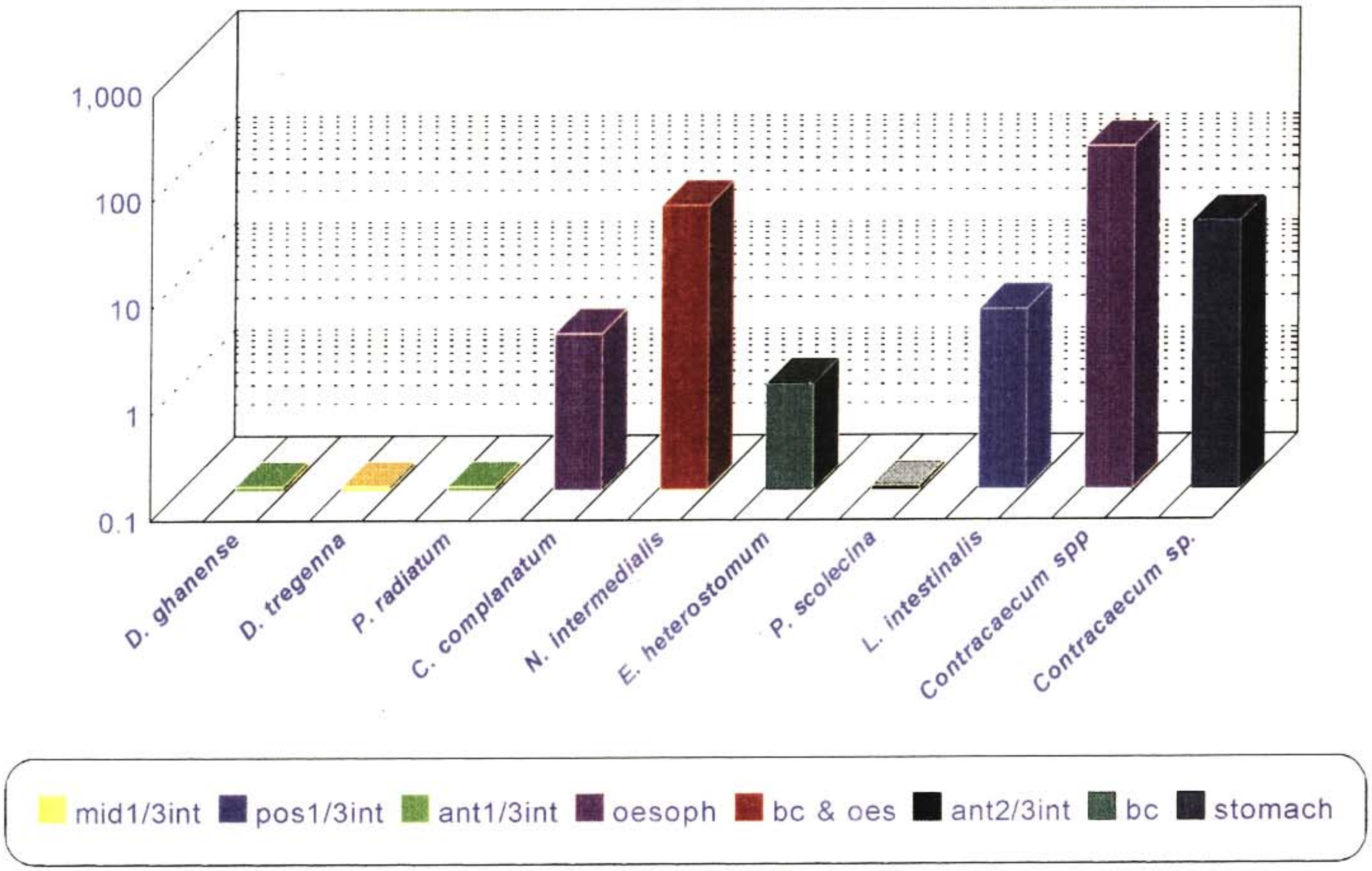


Parasites with fish intermediate host

Fig. 65

Anhinga melanogaster

Middle Letaba Dam, Summer (n=1)

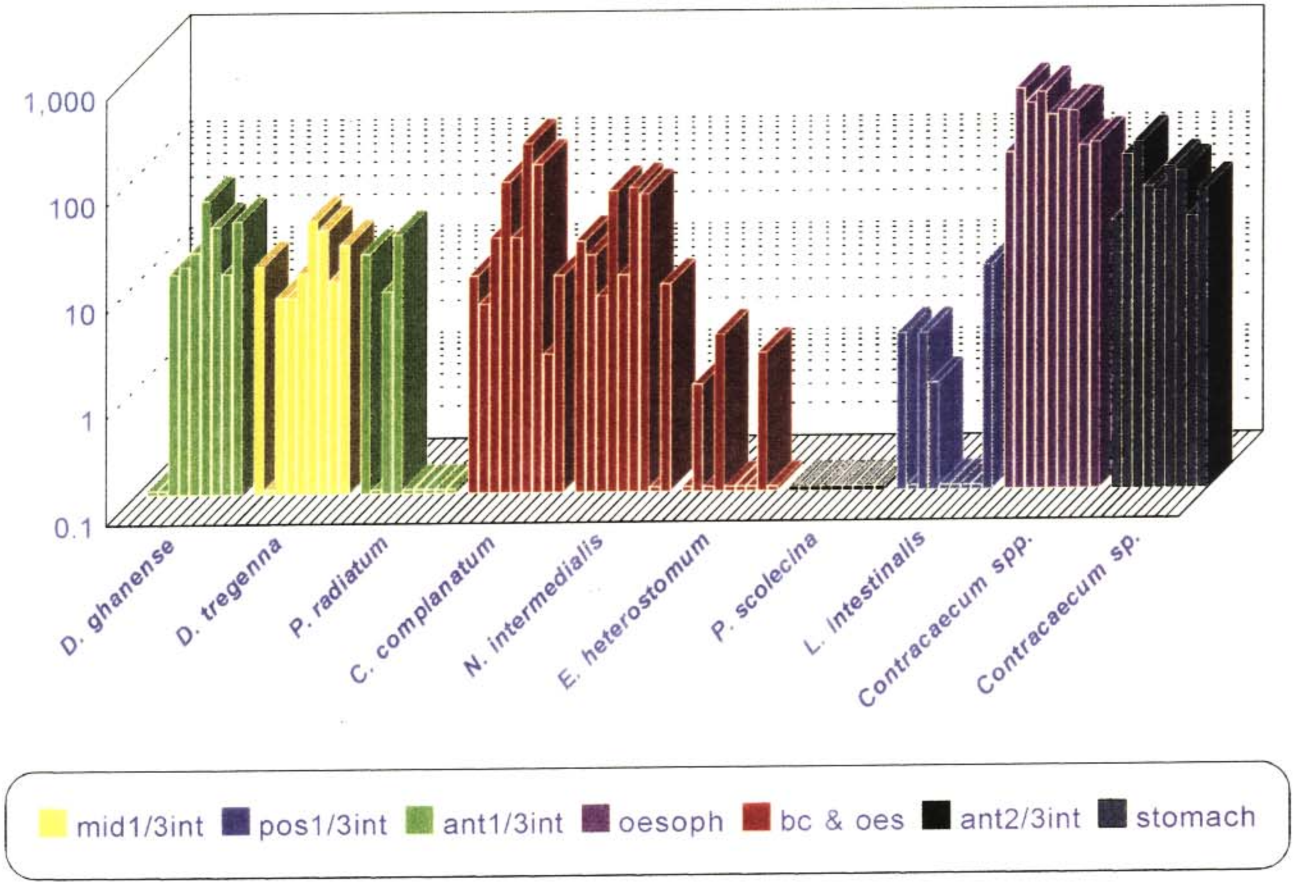


Parasites with fish intermediate host

Fig. 66

Anhinga melanogaster

Middle Letaba Dam, Autumn (n=9)



Parasites with fish intermediate host

Fig. 67

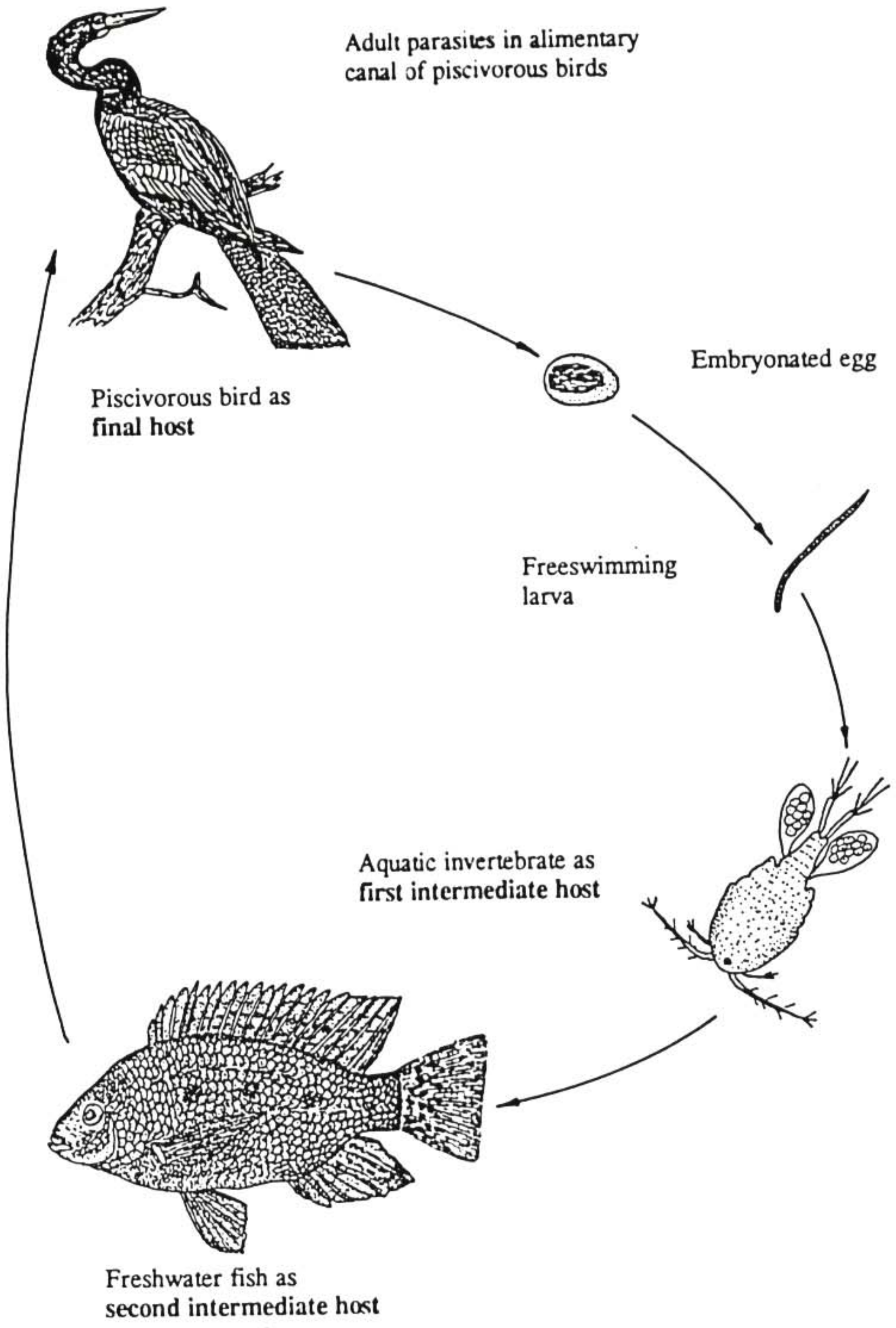


Fig. 68 - Life cycle of *Contracaecum*

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SECTION

B

Helminth Parasites of *Phalacrocorax carbo*, *P. africanus* and *Anhinga melanogaster* not dependent on fish as intermediate hosts

SECTION

B

INTRODUCTION

B

INTRODUCTION

The present study aimed at investigating the helminth parasites of the two most prevalent and widespread members of the family Phalacrocoracidae, namely, *Phalacrocorax carbo* and *P. africanus* in the Northern Province of South Africa. At all the major aquatic ecosystems of this Province the Darter, *Anhinga melanogaster*, occurs in large numbers and is the numerically dominant piscivorous bird in the region. It was, therefore, decided to include this species as a potential host for helminth parasites which include fish intermediate hosts in their life cycles.

In the introduction to Section A, (p.24) it has been mentioned that the investigation recorded 24 helminth species from the three hosts mentioned above, 19 of these parasites utilise fish intermediate hosts and were discussed in Section A. The remaining five species will be discussed in chapters 5 and 6 of this section.

The five species mentioned in the preceding paragraph include three trematodes and two cestodes and are as follows:

Class : Trematoda

Family : Strigeidae Railliet, 1919

Genus : *Strigea* Abildgaard, 1790
S. anhingae Ukoli, 1968

Genus : *Schwartzitrema* Pérez Vigueras, 1941
S. pandubi (Pande, 1939) Dubois and Pearson, 1965

Family : Echinostomatidae Poche, 1926

Genus : *Petasiger* Dietz, 1909
P. exaeretus Dietz, 1909

Class : Cestoda

Order : Cyclophyllidae Van Beneden in Braun, 1900

Family : Hymenolepididae Ariola, 1899

Genus : *Echinorhynchotaenia* Fuhrmann, 1909

E. tritesticulata Fuhrmann, 1909

Genus : *Hymenolepis* Weinland, 1858

H. cormoranti Ortlepp, 1938

As was the case with the helminth parasites involving a fish intermediate host (Section A, Chapters 2 - 4) the helminths discussed in Section B were also recorded qualitatively and quantitatively. Infection statistics on prevalence of infection (%), intensity- and mean intensity of infestation will be provided for each species. Trematodan species will be discussed in Chapter 5, while Chapter 6 deals with the cestodan parasites.

5

Trematodan Parasites of *Phalacrocorax carbo*, *P. africanus* and *Anhinga melanogaster* not dependent on fish as intermediate hosts

5

During the course of the present investigation three different trematodes were recovered from the intestines of *P. carbo, P. africanus* and *A. melanogaster* which do not require fish as intermediate hosts. These trematodes were identified as:

Strigea anhingae Ukoli, 1968;
Schwartzitrema pandubi (Pande, 1939) Dubois and Pearson, 1965;
Petasiger exaeretus Dietz, 1909.

The systematic relationships, morphology and infection statistics of these three trematodes will be discussed in this chapter.

Class : Trematoda

Order : Digenea

Family : Stigeidae Railliet, 1919

Genus : *Strigea* Abildgaard, 1790

S. anhingae Ukoli, 1968

Ukoli (1968) described a new strigeid species, *Strigea anhingae*, from the African Darter, *Anhinga rufa rufa* (= *A. melanogaster*) from Lake Nungua near Accra, Ghana.

During the present study this parasite was also recorded from *A melanogaster* resident/breeding at aquatic ecosystems in the Northern Province of South Africa. Material recovered during this investigation conforms in every morphological detail with the description of *S. anhingae* Ukoli, 1968. Specimens obtained during this study are therefore designated *S. anhingae*. The morphology of the species is illustrated at the hand of light microscope photographs from whole mount specimens supplemented by S.E.M. micrographs. The infection statistics of *A. melanogaster* with *S. anhingae* are presented in Table 42 below.

Table 42: Prevalence, intensity and mean intensity values for infection of *Anhinga melanogaster* with *Strigea anhingae* in the Northern Province of South Africa.

WATER BODY	N.	PREVALENCE %	INTENSITY	MEAN INTENSITY
Seshego Dam	24	54	5 - 18	7
Middle Letaba Impoundment	12	58	5 - 29	15
Hudson Ntsanwisi Dam	11	36	4 - 23	13
Piet Gouws Dam	6	83	7 - 21	15
Glen Alpine Dam	4	-	-	-
Luphephe Dam	2	-	-	-
Tzaneen Dam	1	-	-	-
Olifants River	4	-	-	-

In the Northern Province of South Africa *S. anhingae* was only found in one of the sixteen bird species examined during the present study, namely, *A. melanogaster*. Dubois (1968) lists 34 species of the genus *Strigea* Abildgaard, 1790. In the résume of the species Dubois (op. cit.) mentions a very extensive list of avian hosts. It is also noticeable that, apart from utilising a wide range of avian families as hosts, this parasite has a very wide geographical distribution occurring in the major regions of the Northern and Southern Hemispheres.

In Africa members of the genus *Strigea* have been described from the following localities and hosts:

Strigea falconis falconis: Viborg, 1795 - Szidat, 1928, from *Buteo buteo* and *Pernis apivorus* - Rwanda.

S. intermedia : Szidat, 1932, from *Corvus scapulatus* and *Gallus domesticus* - Guinea

S. gracilicollis : Dubois and Fain, 1956, from *Buteo rufofuscus augur* - Rwanda

S. cuncumae : Bisseru, 1956, from *Haliaeetus vocifer* - Zambia

S. lilensis : Bisseru, 1956, from *Pseudogyps africanus* - Zambia
S. neotides : Bisseru, 1956, from *Neotides denhami* - Zambia

S. rhodesiensis : Bisseru, 1956, from *Pseudogyps africanus* - Zambia

S. anhingae : Ukoli, 1968, from *Anhinga melanogaster* - Ghana

From the preceding list it is evident that on the African Continent *Strigea* spp. also have a wide geographical as well as host distribution. This genus has, hitherto, not been recorded from South Africa.

Table 42 above, indicates that *S. anhingae* does not infect *A. melanogaster* in great numbers. Despite this, the parasite has a continuous distribution in the Northern Province of South Africa occurring at some of the major aquatic ecosystems. This may be ascribed to the fact that the host, *A. melanogaster*, is a common resident at aquatic ecosystems throughout the Province. Ukoli (1968) examined fourteen *A. melanogaster* hosts from Accra, Ghana, and recorded prevalence and mean intensity figures of 57% and 19 respectively. These figures compare closely with infection statistics of *A. melanogaster* with *S. anhingae* in the present study area (Table 42, p.235).

SYSTEMATIC RELATIONSHIPS OF *STRIGEA ANHINGAE*

Ukoli (1968) considers *S. anhingae* to be very closely related to *S. falconis* Szidat, 1928, especially in the size of the body, shape and size of the gonads, size of eggs and ratio of oral to ventral suckers. The major difference between these two species is the distribution of the vitellaria in the forebody. In *S. falconis* vitellaria extend into the lobes of the holdfast organ, reaching anteriorly beyond the level of the anterior margin of the ventral sucker, while in *S. anhinga* these glands occupy only the base of the holdfast organ and do not extend anteriorly beyond the level of the posterior margin of the ventral sucker.

In the reference list to his paper (Ukoli, 1968) does not mention the publication of Bisseru (1956) on *Strigea* spp. from Zambian avian hosts. It is therefore not certain whether a close morphological comparison was made. The type specimens of both Bisseru (1956) and Ukoli (1968) are housed in the collection of the London School of Hygiene and Tropical Medicine. The present material is provisionally designated as *S. anhingae*. It is intended to compare material from the present study with the material of both Bisseru (1956) and Ukoli (1968), as well as with other material from African hosts, before a final species assignment is made.

Family : Strigeidae Railliet, 1919

Genus : *Schwartzitrema* Pérez Vigueras, 1941

S. pandubi (Pande, 1939) Dubois and Pearson, 1965
(= *Pseudostrigea pandubi* (Pande, 1939), Sudarikov in Skrjabin, 1959;
Apotemon truonis Dubois and Fain, 1956;
Pseudostrigea truonis (Dubois and Fain, 1959), Sudarikov in Skrjabin, 1959;
Strigea nigericus Gupta, 1962;
Strigea pandubi (Pande, 1939) Dubois and Pearson, 1965;
Schwartzitrema truonis (Dubois and Fain, 1956) Dubois and Pearson, 1967).

During the present investigation material that very closely resemble *Schwartzitrema pandubi* was procured from the intestines of *Phalacrocorax africanus* and *Anhinga melanogaster*. The present material was analysed with the aid of light microscope photography supplemented by S.E.M. micrographs (see Figs. 69, p.240 and 70, p. 241).

On the strength of morphological similarity the material is provisionally placed as *S. pandubi* (Pande, 1939), Dubois and Pearson, 1965.

The infection statistics of *P. africanus* and *A. melanogaster* in the present study area with *S. pandubi* are recorded in Table 43 below.

Table 43: Prevalence, intensity and mean intensity values for infection of *Phalacrocorax africanus* and *Anhinga melanogaster* with *Swartzitrema pandubi* in the Northern Province of South Africa.

AVIAN HOST	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
P. africanus	44	Seshego Dam	18	2 - 8	4
	9	Middle Letaba Impoundment	11	4	4
	3	Hudson Ntsanwisi Dam	33	4	4
	1	Turfloop Dam	-	-	-
A. melanogaster	24	Seshego Dam	17	5 - 10	7
	12	Middle Letaba Impoundment	50	4 - 11	6
	11	Hudson Ntsanwisi Dam	18	1 - 14	6
	6	Piet Gouws Dam	67	3 - 8	6
	4	Glen Alpine Dam	25	7	7
	2	Luphephe Dam	-	-	-
	1	Tzaneen Dam	-	-	-
	4	Olifants River	-	-	-

From the information presented in Table 43 above, it is concluded that *S. pandubi*:-

- Has a widespread distribution in the study area;
- Utilises two final hosts, namely, *P. africanus* and *A. melanogaster*;
- Infection levels of the two hosts are about equal;
- As is the case with *S. anhingae* (p.235) infection levels of final hosts in the study area are relatively low if compared to infection statistics with *Diplostomum* spp. (pp.46 and 55); *Clinostomatid* spp. (pp.76 and 88); *Petasiger exaeretus* (p.239) and dilepidid cestodes (pp. 138, 140 and 144).

S. pandubi has previously been recorded from other *Phalacrocorax* hosts, namely, *P. melanoleucas, P. niger* and *P. sulcirostrus* from India and Australia (Pande, 1939; Nathusius and Gupta, 1962; Dubois and Pearson, 1965) as well as *A. melanogaster* from India (Pande, 1939; Nathusius and Gupta, 1962). Dubois and Fain (1956) described *S. truonis* (= *S. pandubi*) from *P. africanus* from Rwanda. It would therefore appear as if *S. pandubi* is a parasite that is very specific to the avian families Phalacrocoracidae and Anhingidae. Should this be the case, it is surprising indeed that the present investigation did not find this parasite to utilise *P. carbo* as a host. The latter species is widespread in the study area and a co-inhabitant of aquatic ecosystems together with *P. africanus* and *A. melanogaster.*

S. pandubi has not been recorded for southern Africa prior to this investigation. It is intended to continue the research on this parasite in the subcontinent and to redescribe its morphology at the hand of graphic reconstructions (Pusey 1939, method) and detail S.E.M. studies.

Family : Echinostomatidae Poche, 1926

Genus : *Petasiger* Dietz, 1909
P. exaeretus Dietz, 1909

Dietz (1909), in his doctoral dissertation, erected the genus *Petasiger* and described *P. exaeretus* from *Phalacrocorax carbo* from "Mitteleuropa". Kotlan (1922) and Davies (1934) described the anatomy of *P. exaeretus* in great detail while Johnston (1942); Bisseru (1957); Ukoli, (1968) and Moravec, Nasincova and Scholtz (1988) all added additional anatomical detail to the original description of the species. *P. exaeretus* has also been recorded from *P. carbo* in Whales (Davies, 1934); Australia (Johnston, 1942); Czechoslovakia (Moravec et. al., 1988), while Bisseru (1957) recorded it in *A. rufa* (= *A. melanogaster*) from Zambia, and Ukoli (1968) in *P. africanus* from Accra, Ghana.

Yamaguti (1958) lists 21 additional species of the genus *Petasiger* which utilise a wide range of avian hosts. A review of the relevant literature indicates that the genus *Petasiger* occurs in all the major areas of the Northern as well as Southern Hemispheres. *P. exaeretus* also has a Northern Hemisphere distribution (Davies, 1934, Moravec et. al., 1988) and also occurs in the Southern Hemisphere (Johnston, 1942; Bisseru, 1957; Ukoli (1968) and present study).

During the present investigation *P. exaertus* was procured from the intestines of *P. carbo, P. africanus* and *A. melanogaster*, resident/breeding at aquatic ecosystems in the Northern Province of South Africa. This is the first distributional record for Africa south of the Zambezi River.

Infection statistics of phalacrocoracid and anhingid hosts of the study area are presented in Table 44 below.

Table 44: Prevalence, intensity and mean intensity values for infection of *Phalacrocorax carbo, P. africanus* and *Anhinga melanogaster* with *Petasiger exaeretus* in the Northern Province of South Africa.

AVIAN HOST	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
P. carbo	39	Seshego Dam	46	3 - 63	26
	8	Middle Letaba Impoundment	63	4 - 22	11
	2	Piet Gouws Dam	100	4 - 12	8
	2	Glen Alpine Dam	100	63 - 72	68
	1	Ebenhaezer Dam	100	7	7
P. africanus	44	Seshego Dam	68	3 - 308	37
	9	Middle Letaba Impoundment	56	4 - 46	37
	3	Hudson Ntsanwisi Dam	67	14 - 22	17
	1	Turfloop Dam	-	-	-
	2	Olifants River	-	-	-
A. melanogaster	24	Seshego Dam	25	3 - 19	12
	12	Middle Letaba Impoundment	17	4 - 14	9
	11	Hudson Ntsanwisi Dam	27	5 - 38	22
	6	Piet Gouws Dam	100	12 - 165	45
	4	Glen Alpine Dam	75	14 - 27	21
	2	Luphephe Dam	-	-	-
	1	Tzaneen Dam	-	-	-
	4	Olifants River	-	-	-

Table 44 above indicates that all three avian hosts are infected to a substantial degree with *P. exaeretus*. The investigation also indicated that the parasite is widespread in the study area, and that it has an almost continuous distribution in the drainage systems of the Northern Province of South Africa. *A. melanogaster*, due to its numerical dominance at the major aquatic ecosystems in the study area, must play the predominant role in the continuation of the life history of this parasite. Infection statistics for infection with *P. exaeretus* were also provided by Davies (1934); Ukoli (1968) and Moravec et. al. (1988). Davies (1934) ~~only~~ states that two out of five *P. carbo* investigated at Cardigan Bay, Whales, were infected with *a large number of* ***P. exaeretus*** *in the small intestine.* Ukoli (1968) examined eleven hosts of *P. africanus* in Ghana. Three of these host specimens were infected with *P. exaeretus* with a mean intensity of 16 parasites per infected host. Moravec et. al. (1988) only examined two *P. carbo* hosts from Czechoslovakia and recorded a 100 per cent prevalence figure with 31 - 112 intensity and 72 mean intensity figures of infestation.

FIG. 69

STRIGEA ANHINGAE, SCHWARTZITREMA PANDUBI AND PETASIGER EXAERETUS

(Light Microscopy)

A. ***S. anhingae entire worm*** ***x*** ***50***

B. ***S. pandubi entire worm*** ***x*** ***50***

C. and D. ***P. ecaeretus entire worm*** ***x*** ***50***

Key:

a. - ventral sucker

at. - anterior testis

c. - collar

cr. - cirrus

e. - egg

fb. - forebody

gp. - gonopore

hb. - hindbody

in. - intestine

ov. - ovary

pt. - posterior testis

s. - spines

vf. - vitelline follicles

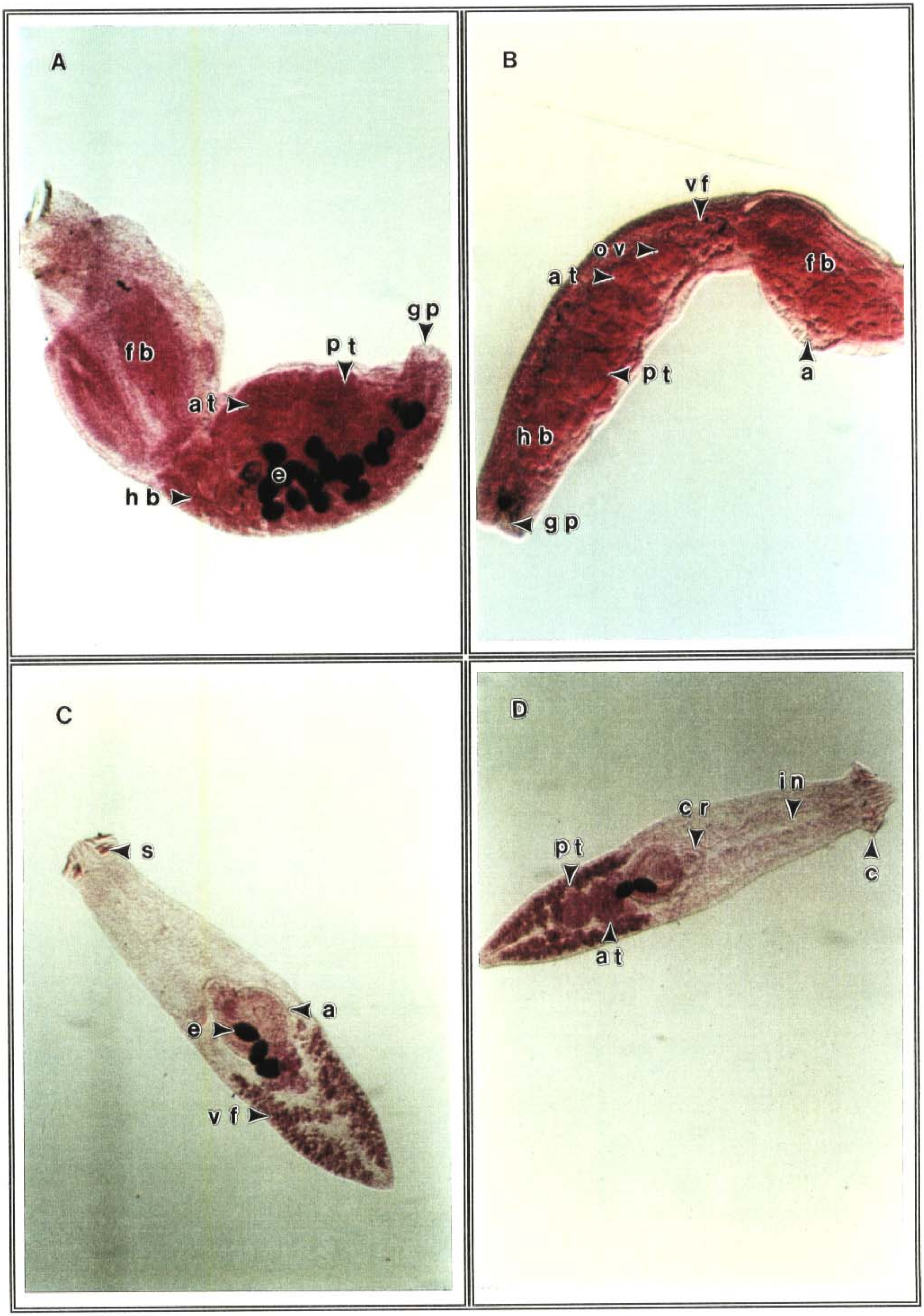

A
f b
g p
p t
a t
e
h b
B
v f
o v
a t
f b
p t
a
h b
g p
C
s
a
e
v f
D
i n
c r
p t
c
a t

FIG. 70.

STRIGEA ANHINGAE, SCHWARTZITREMA PANDUBI AND PETASIGER EXAERETUS
(Scanning Electron Microscopy)

A. *S. anhingae anterior end of forebody*

B. *S. pandubi entire worm*

C *P. exaeretus anterior portion of body*

D. *P. exaeretus collar with spines enlarged*

Key:

a. - ventral sucker

c. - collar

cr. - cirrus

fb. - forebody

hb. - hindbody

ho. - holdfast organ

os. - oral sucker

s. - spines

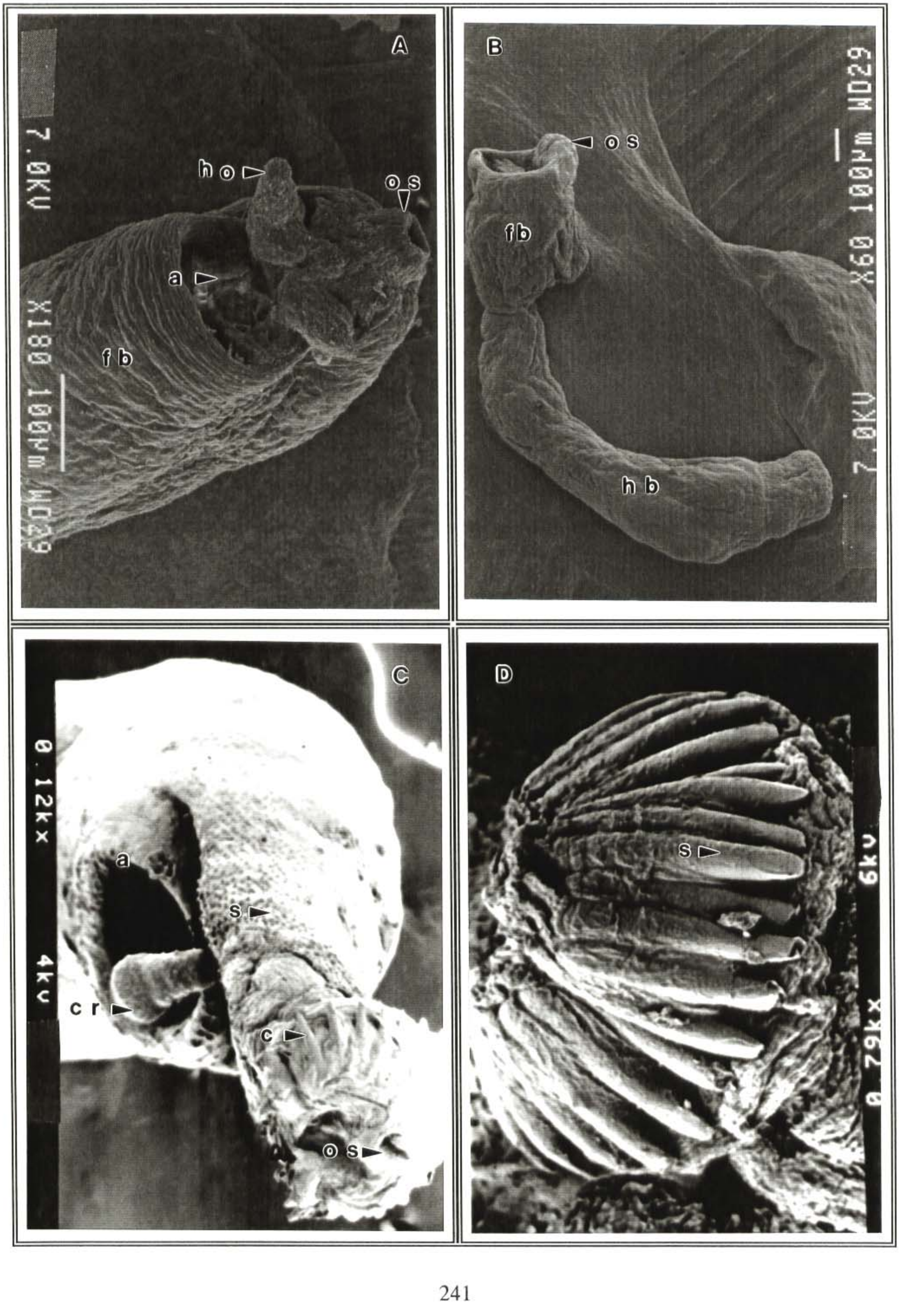

A
ho
os
a
fb
7.0KV
X180 100µm WD39
B
os
fb
hb
X60 100µm WD29
7.0KV
C
0.12kx
4kv
a
s
cr
c
os
D
s
6kv
0.79kx

FIG. 71

STRIGEA ANHINGAE

Morphology
(After Ukoli, 1968 and present material)

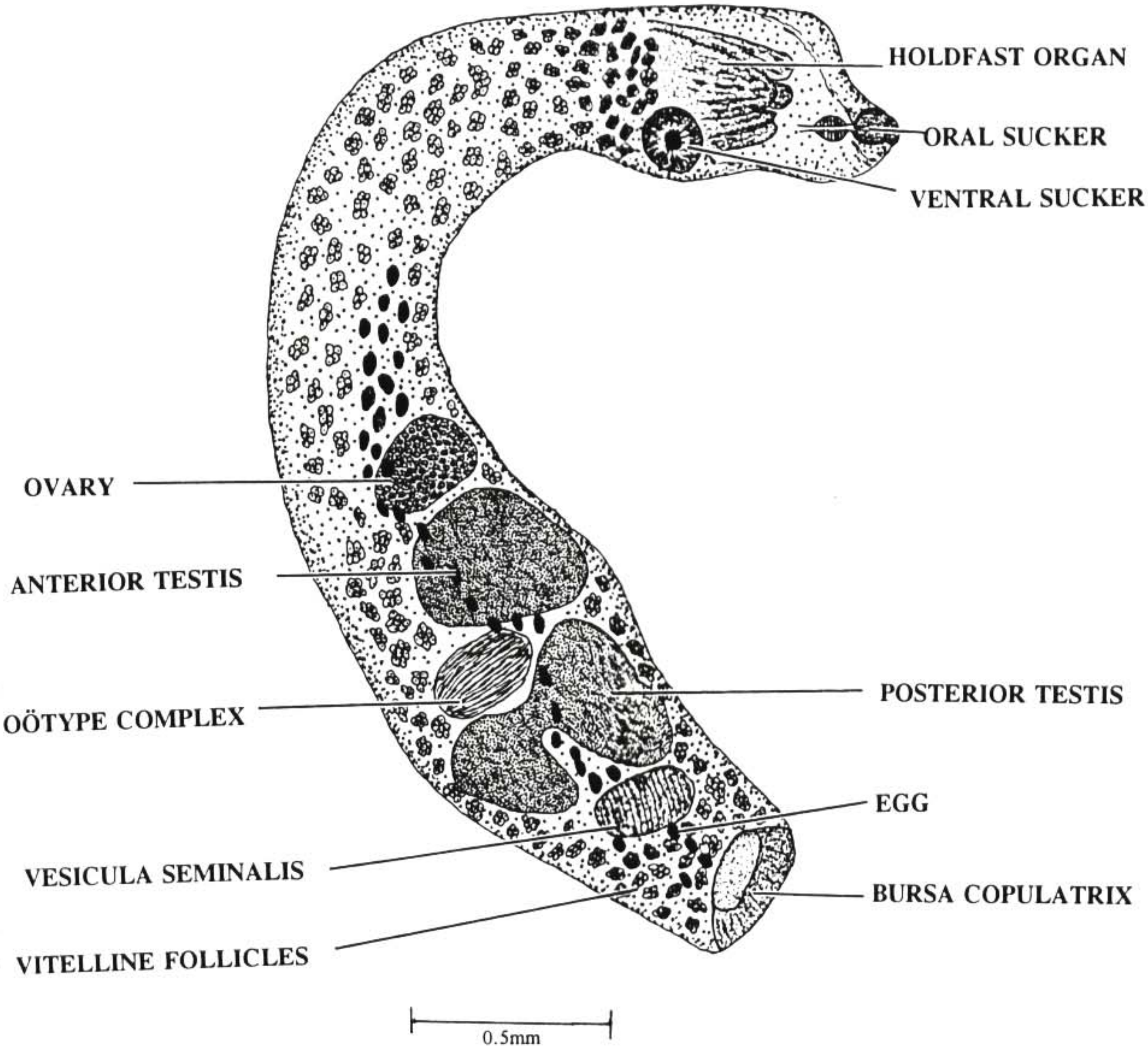

HOLDFAST ORGAN
ORAL SUCKER
VENTRAL SUCKER
OVARY
ANTERIOR TESTIS
POSTERIOR TESTIS
OÖTYPE COMPLEX
EGG
VESICULA SEMINALIS
BURSA COPULATRIX
VITELLINE FOLLICLES
0.5mm

FIG. 72

SCHWARTZITREMA PANDUBI

Diagrammatic representation of the morphology

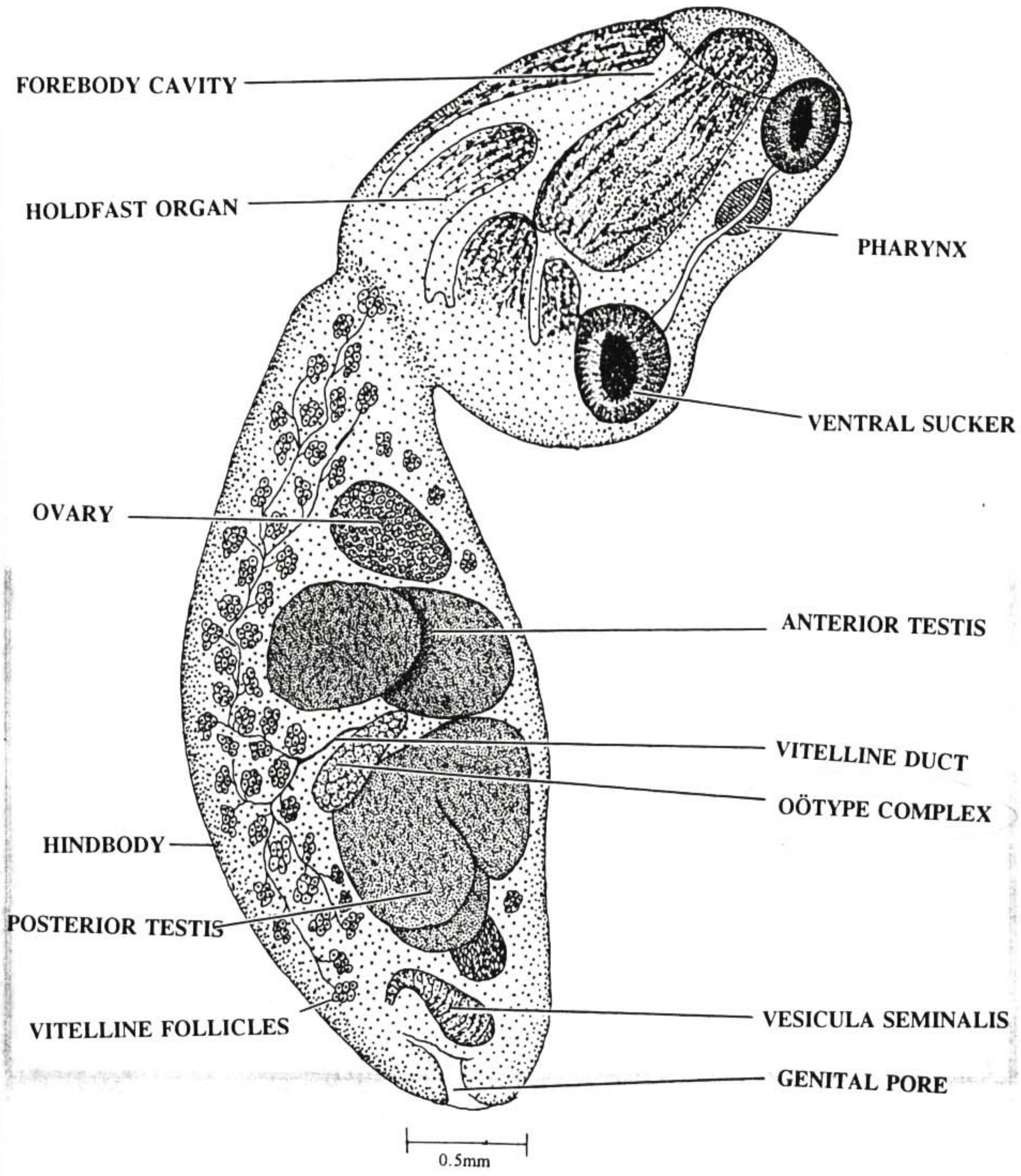
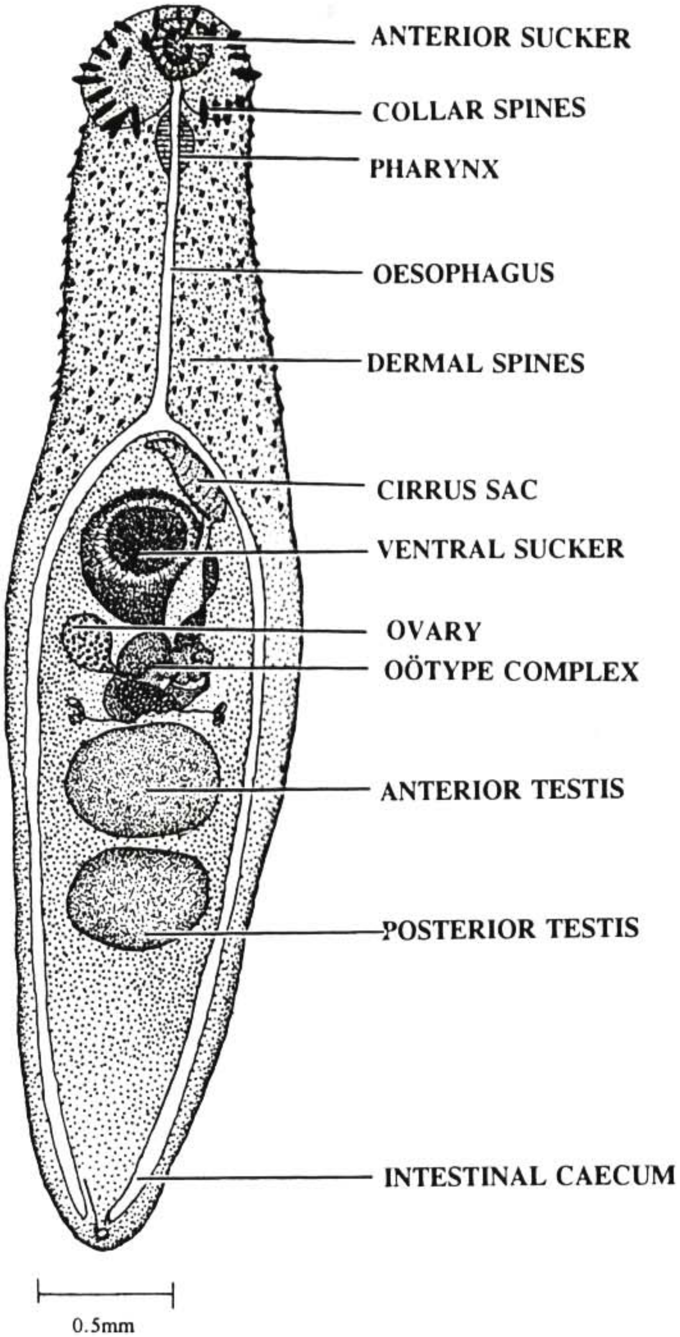

FOREBODY CAVITY
HOLDFAST ORGAN
PHARYNX
VENTRAL SUCKER
OVARY
ANTERIOR TESTIS
VITELLINE DUCT
OÖTYPE COMPLEX
HINDBODY
POSTERIOR TESTIS
VITELLINE FOLLICLES
VESICULA SEMINALIS
GENITAL PORE
0.5mm

FIG. 73

PETASIGER EXAERETUS

Diagrammatic representation of the morphology
(After Davies, 1934)



ANTERIOR SUCKER
COLLAR SPINES
PHARYNX
OESOPHAGUS
DERMAL SPINES
CIRRUS SAC
VENTRAL SUCKER
OVARY
OÖTYPE COMPLEX
ANTERIOR TESTIS
POSTERIOR TESTIS
INTESTINAL CAECUM
0.5mm

FIG. 74

PETASIGER EXAERETUS

Extent of vitellaria

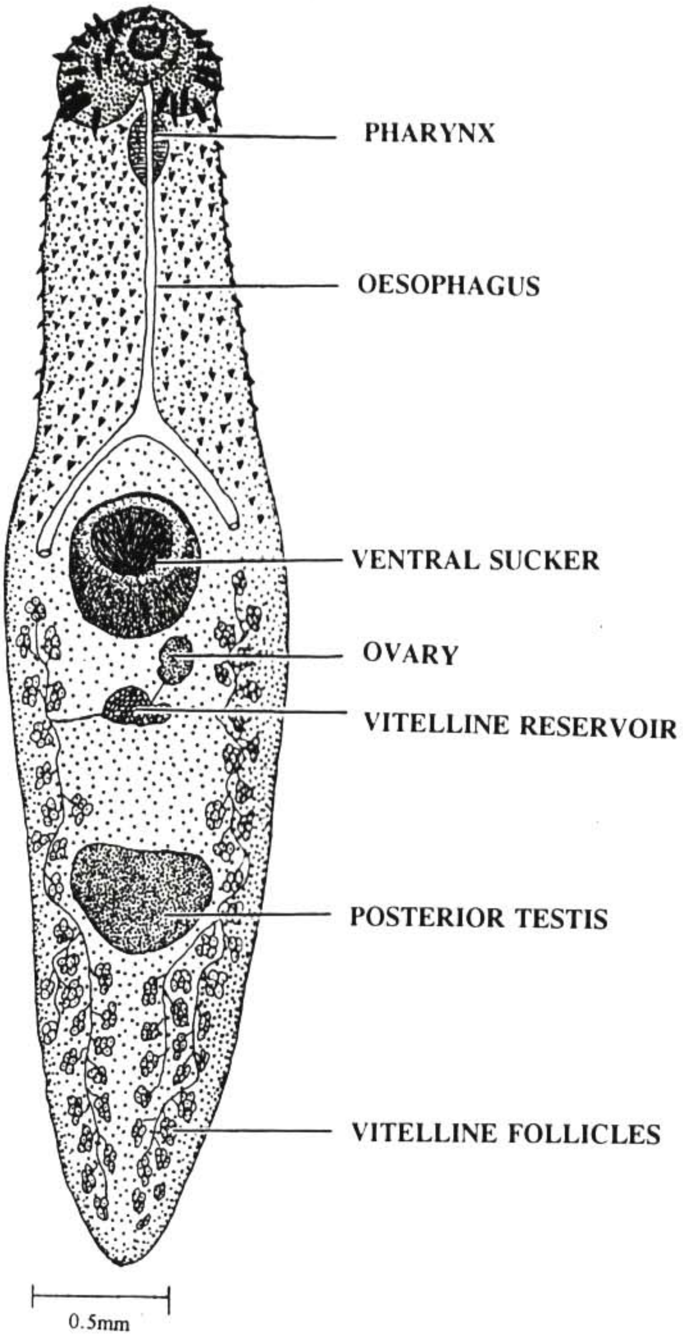
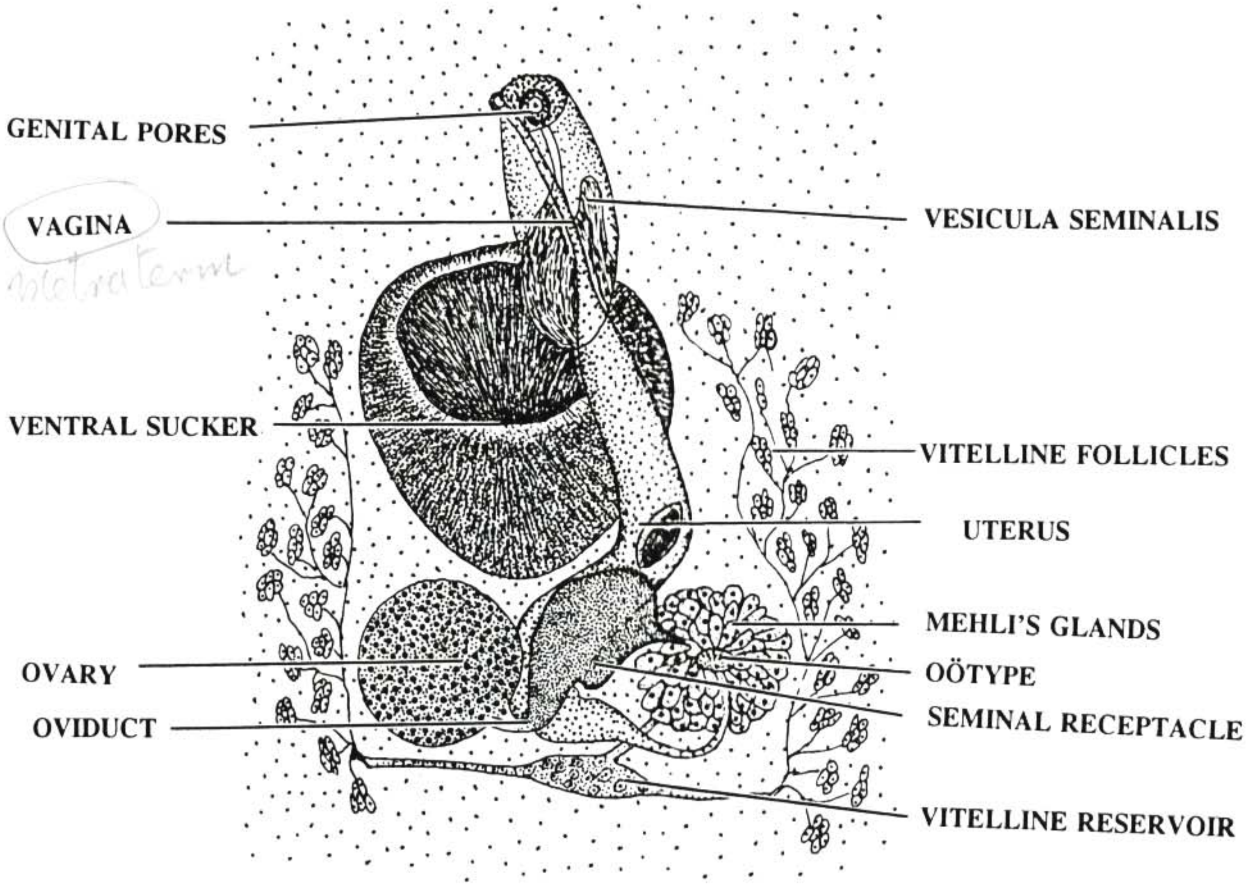

PHARYNX
OESOPHAGUS
VENTRAL SUCKER
OVARY
VITELLINE RESERVOIR
POSTERIOR TESTIS
VITELLINE FOLLICLES
0.5mm

FIG. 75

PETASIGER EXAERETUS

Diagrammatic representation of the male and female genitalia
(After Davies, 1934)


GENITAL PORES
VAGINA
metraterm
VENTRAL SUCKER
OVARY
OVIDUCT
VESICULA SEMINALIS
VITELLINE FOLLICLES
UTERUS
MEHLI'S GLANDS
OÖTYPE
SEMINAL RECEPTACLE
VITELLINE RESERVOIR

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6

Cestode Parasites of *Phalacrocorax carbo, P. africanus* and *Anhinga melanogaster* not dependent on fish as intermediate hosts

6

Class : Cestoda

Order : Cyclophyllidae Van Beneden in Braun 1900.

Family : Hymenolepididae Ariola, 1899.

Genus : *Echinorhynchotaenia* Fuhrmann, 1909
***E. tritesticulata* Fuhrmann, 1909.**

Echinorhynchotaenia tritesticulata Fuhrmann, 1909, is the type species of the genus. Yamaguti (1959) lists four species as belonging to the genus. These are:

E. tritesticulata	Fuhrmann, 1909
E. nana	Maplestone and Southwell, 1922
E biuncinata	Joyeux and Baer, 1943
E. lucknowensis	Singh, 1956

Siddiqi (1962) reviewed the genus *Echinorhynchotaenia* and included only two species, namely, *E. tritesticulata* Fuhrmann, 1909 and *E. furcouterina* (Davies, 1945) Joyeux and Baer, 1950. The latter species was described from material obtained from *A. melanogaster* at Lake Lindu, Celebes. It should, however, be pointed out that *E. furcouterina* was described from the strobila only because a scolex was not available (Mahon, 1954; Siddiqi, 1962). Mahon (1954) already synonymised *E. furcouterina* with *E. tritesticulata*.

Ukoli (1968) researched dilepidid and hymenolepidid cestodes from birds in Ghana and reviewed previously described species of *Echinorhynchotaenia*. This author came to the conclusion that the genus contained only one valid species, namely, *E. tritesticulata*, which is a parasite that is host specific to *A. melanogaster*. As such, *E. tritesticulata* would occur only in the Southern Hemisphere in the areas which mark the world distribution of the genus *Anhinga*. Mahon (1954) gave the distribution of the genus *Anhinga* as Palestine, West and Southern Africa, Madagascar, India and Sri Lanka to the Celebes, Australia and New

Guinea, and the New World from Texas to the North of Argentine. Ukoli (1968) provides a distributional map for *Anhinga* and included all the above regions. In Africa it occurs from South Africa, throughout central Africa (Fig.76).

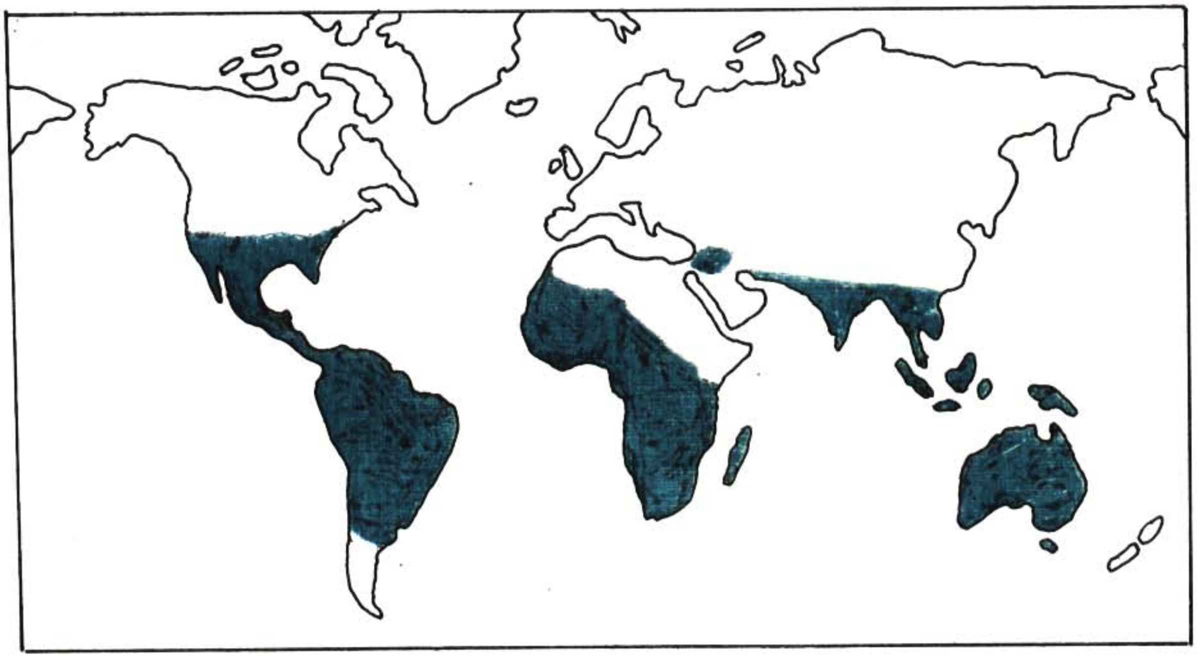

Fig. 76: Map indicating distribution of *A. melanogaster*.

Morphological descriptions of *E. tritesticulata* were provided by Fuhrmann (1909). Southwell and Lake (1939); Mahon (1954); Siddiqi (1962) and Ukoli (1968). In studying these descriptions it becomes evident that there is disagreement about the rostellum and its armature.

Most researchers agree that the rostellum is proboscis-like, fairly long, and armed with numerous small spines arranged in straight lines along its entire length (Fuhrmann, 1909; Mahon, 1954; Siddiqi, 1962 and Ukoli, 1968). Southwell and Lake (1939) also observed these spines, but remarked that they only occur on the distal part of the rostellum. There is considerable disagreement on whether the rostellum bears hooks. In the original description Fuhrmann (1909) does not mention a double crown of hooks, whereas Southwell and Lake (1939); Siddiqi (1962) and Ukoli (1968) also failed to locate any rostellar hooks. Joyeux and Baer (1928) and Joyeux and Gaud (1945) were the first to draw attention to these hooks.

Mahon (1954), after studying *E. tritesticulata* from Zaïre, also noticed a double crown of rostellar hooks. This author re-examined the original material of Fuhrmann (1909) and clearly observed these rostellar hooks. She even measured the hooks of the type material and illustrated it (Fig.). Mahon (1954) observed 24 hooks arranged in two crowns, the hooks of one differing in size from those of the other crown.

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Because of the controversy about the armature of the rostellum of *E. tritesticulata*, the present study examined in excess of 200 specimens of various sizes. Observations were done on live material under a stereo-microscope, whole mount specimens as well as S.E.M. micrographs. It can be stated with absolute certainty that the anchoring organ of *E. tritesticulata* is a long invaginable proboscis-like structure bearing a double crown of 24 hooks and numerous rose-thorn spines arranged in straight lines along its entire length (Figs.77, p.255 and 78, p.256). The rostellum is not able to move piston-like inside its pouch, but can invaginate and becomes folded inside the rostellar sac. (Fig.77, p.255).

During the present investigation it was observed that extreme care has to be taken in removing *E. tritesticulata* from the intestine of the host. The hooks, as well as the spines, tend to come off very easily. This tendency may very well explain why researchers such as Southwell and Lake (1939); Siddiqi (1962) and Ukoli (1968) failed to observe the full armature of the rostellum in their respective material.

The morphology of the present material agrees with the descriptions of Southwell and Lake (1939); Mahon (1954); Siddiqi (1962) and Ukoli (1968). Aspects of the anatomy are illustrated in Figs.77, p. 255 and 78, p.256.

Infection statistics of *A. melanogaster* with *E. tritesticulata* obtained during the present investigation are presented in Table 45 below.

Table 45: Prevalence, intensity and mean intensity values for infection of *Anhinga melanogaster* with *Echinorhynchotaenia tritesticulata* in the Northern Province of South Africa.

WATER BODY	N.	PREVALENCE %	INTENSITY	MEAN INTENSITY
Seshego Dam	24	96	1 - 63*	5
Middle Letaba Impoundment	12	75	2 - 29*	9
Hudson Ntsanwisi Dam	11	100	1 - 5	2
Piet Gouws Dam	6	100	1 - 3	2
Glen Alpine Dam	4	100	1 - 2	1.5
Luphephe Dam	2	-	-	-
Tzaneen Dam	1	100	2	2
Olifants River	4	100	1 - 2	1.5

* The abnormally high intensity of infection levels, denoted by an asterisk, represent two occasions where high numbers of juvenile specimens (± 10mm. long) were encountered.

Table 45 indicates that infection with *E. tritesticulata* is widespread amongst the *A. melanogaster* populations at major aquatic ecosystems in the study area. Intensity levels of infection are, however, not very high. This, together with records provided by the literature (Southwell and Lake (1939) and Ukoli (1968), tend to indicate that infected hosts normally carry less than five parasites.

E. tritesticulata has been identified from the following areas on the African Continent:

White Nile (Egypt)	- Fuhrmann (1909)
Zaïre	- Southwell and Lake (1939)
Cameroon	- Mahon (1954)
Dahomey	- Mahon (1954)
Ghana	- Ukoli (1968)
South Africa	- Present study (1996)

Genus : *Hymenolepis* Weinland, 1858

H. cormoranti Ortlepp, 1938

H. cormoranti was described as a new hymenolepid species by Ortlepp (1938), from material obtained from *Microcarbo africana africanoides* (= *Phalacrocorax africanus*) from the Pretoria District, South Africa. Ortlepp (op. cit.) provided the following specific diagnosis:

> *Hymenolepididae attaining a length of 150 mm. or more by 0.06 mm. broad: Scolex small, 0,138 mm. across, rostellum with 10 hooks 0,024 to 0,025 mm. long having a long handle and small blade. Genital pores unilateral. Three testes, one poral and two aporal, disappear before appearance of female glands; cirrus long, crosses excretory canal and reaches poral testes. Ovary trilobed, large: Yolk gland round; uterus a transverse bag, extends across excretory canal to edge of segment.* (p.78)

Ortlepp (1938) distinguishes his *H. cormoranti* from *H. ficticia* (Meggitt, 1929), *H. magniuncinata* Meggitt, 1927; *H. parvicirrosa* Meggitt, 1927 and *H. medici* (Stossich, 1890) from Pelecaniformes on the number, size and shape of the rostellar hooks. Ortlepp's material had the same number of rostellar hooks (10) as *H. parviumcinata* Meggitt, 1927, from Pelecaniformes, but the hooks in the latter species are much smaller and are also differently shaped.

Clark (1957) recorded very small cestodes from *Microcarbo melanoleucus* (= *Phalacrocorax ater*) from Australia. This author compared her material with the three species which have been described from Phalacrocoracidae elsewhere, viz., *H. cormoranti* Ortlepp, 1938 (South Africa); *H. childi* Burt, 1940 (Sri Lanka) and *H. gyogonha* Johri, 1941 (Burma). Clark (1957), also mentions that Joueux and Baer (1950) consider the above three species as synonyms.

The genus *Hymenolepis* Weinland, 1858 is referred to as *a widely distributed and unwieldy genus* (Wardle and McLeod, 1952) with well in excess of 300 species occuring in mammals and a wide variety of birds.

Czaplinsky and Vaucher in Khalil et. al. (1994) provided the following generic diagnosis for *Hymenolepis* Weinland, 1858:

> *Suckers lateral or apical. Proglottids craspedote. Inner longitudinal muscle bundles numerous. Ventral osmoregulatory canals often connected by transverse anastromoses. Genital ducts dorsal to osmoregulatory canals. Genital pores unilateral, dextral (except in older specimens of* ***H. diminuta****). Three testes in transverse row or triangle, mainly in medulla. Cirrus-sac may reach midline. Ovary compact, transversely elongated or lobed, median or submedian, often pretesticular, exceptionally poral to testes. Vitellarium compact, postovarian. Seminal receptacle well developed. Vagina posterior or ventral to cirrus-sac. Uterus sacciform, rarely reticulate. Oncospheres slightly oval, envelopes mostly spherical. In birds and mammals. Cosmopolitan. Type species* ***H. diminuta*** *(Rudolphi, 1819) Weinland, 1858.* (p. 617)

Generic synonymy:

Amazilolepis Schmidt and Daily, 1992; *Amphipetrovia* Spasskii and Spasskaya, 1954; *Arhynchotaenia* Saakova, 1958 nec. Pagenstecher, 1877; *Arhynchotaeniella* Schmidt, 1986; *Australiolepis* Spasskii and Spasskaya, 1954; *Cloacotaenia* Wolffhügel, 1938; *Cloacotaeniella* Schmidt, Baurle and Wertheim, 1988; *Orlovilepis* Spasskii and Spasskaya, 1954; *Schmelzia* Yamaguti, 1959; *Staphylepis* Spasskii and Oshmarin, 1954; *Triorchis* Clerc, 1903 preoccupied; *Woodlandia* Yamaguti, 1959.

The foregoing account of the synonymy of the genus *Hymenolepis* substantiates the statement of Wardle and McLeod (1952), that the genus is "unwieldy" and all but sorted out. For the present study it was decided to assign the current material to *H. cormoranti* Ortlepp (1938). In anatomical detail the material agrees most closely with the description of Ortlepp (1938), as supplemented by Clark (1957). Light microscopy photographs and line drawings (Figs.79, p.257 and 80, p.258) will clearly illustrate the morphological similarity.

During the present investigation *H. cormoranti* was recorded from *P. carbo* and *P. africanus* resident at various aquatic ecosystems in the Northern Province of South Africa. Infection levels of the hosts with this parasite are relatively low compared to infection of the same hosts with *Ligula intestinalis* (p.230); *P. scolecina* (p.138) and *Paradilepis delachauxi* (p.140). Infection statistics of hosts in the Northern Province with *H. cormoranti* are more in line with the infection of these hosts with *Amirthalingamia macracantha* (p.144).

Table 46: Prevalence, intensity and mean intensity values for infection of *Phalacrocorax carbo* and *P. africanus* with *Hymenolepis cormoranti* in the Northern Province of South Africa.

AVIAN HOST	N.	WATER BODY	PREVALENCE %	INTENSITY	MEAN INTENSITY
P. carbo	39	Seshego Dam	33	1 - 4	2
	8	Middle Letaba Impoundment	-	-	-
	2	Piet Gouws Dam	100	1 - 2	1.5
	2	Glen Alpine Dam	50	5	5
	1	Ebenaezer Dam	-	-	-
P. africanus	44	Seshego Dam	32	1 - 5	2
	9	Middle Letaba Impoundment	33	2 - 5	4
	3	Hudson Nsanwisi Dam	67	1 - 2	1.5
	1	Turfloop Dam	-	-	-

STATISTICAL EVALUATION OF DATA ON PARASITES NOT UTILIZING FISH AS INTERMEDIATE HOSTS:

During the present study 24 species of helminth parasites were found to parasitise *P. carbo, P. africanus* and *A. melanogaster*. Five of these species do not require fish as intermediate hosts in their life cycles. The table below represents the latter category of parasites encountered during the present investigation:

Strigea anhingae
Schwartzitrema pandubi
Petasiger exaeretus
Echinorhynchotaenia tritesticulata
Hymenolepis cormoranti

In evaluating the statistics of host infection with the parasites listed above, the same procedures and principles were applied as mentioned in Section A, pp 190 - 192.

Observations on and discussion of figures 81 - 101:

P. exaeretus is the only one from the five parasites listed in the preceding Table that parasitises all three hosts. Figures 81 - 101 indicate that this parasite is the most prevalent amongst its group in all three drainage systems investigated during the present study. (See especially Figs. 81, p.259; 82, p.260; 83, p.261; 87, p.265; 89, p.267; 91, p.269; 92, p.270; 93, p.271 and 94, p.272,). Ecological circumstances at all aquatic ecosystems throughout the entire study area must surely be favourable to its most essential life requirements. Because this is a parasite that does not involve fish as intermediate hosts and, because its hosts for the present investigation are exclusively piscivorous in their dietary requirements, it is not easy to explain its numerical dominant role amongst the non-fish related parasites of the hosts in question. Urgent life history studies on this parasite are therefore required before its population demographics in the Northern Province of South Africa can be explained;

Echinorhynchotaenia tritesticulata, a parasite that is host specific to members of the family Anhingidae, is well established at aquatic ecosystems of the main drainage systems of the study area. Mean intensity figures ranged between 1 and 58 specimens infecting a single host. (Figures 89, p.261 - 101, p.279);

Schwartzitrema pandubi occurs in all three drainage systems and utilises *P. africanus* and *A. melanogaster* as hosts. It is difficult to explain why this parasite does not parasitise *P. carbo* as a host in the present study area. Future experimental infestations might prove the latter host not to be susceptible at all to this parasite. Should this be the case, the lack of susceptibility can only be ascribed to physiological conditions prevailing in the intestine of *P. carbo*. Infection statistics with *S. pandubi* are relatively low and never attain more than ten parasites per given host (Figures 89, p.261 - 101, p.279).

Infections of hosts with *Hymenolepis cormoranti*, a parasite host specific to Phalacrocoracidae, is relatively low although this parasite is geographically well represented throughout the study area (Figures 81, p.259 - 94, p.272). *Strigea anhingae*, host specific to *A. melanogaster*, is also widespread throughout the drainage systems of the study area, but, like *H. cormoranti* exhibits a relatively low rate of infection of its hosts. The only exception to this occurred at Middle Letaba Impoundment and Seshego Dam during the Autumn months, when infection figures rose to 29 and 18 respectively.

FIG. 77.

ENCHINORHYNCHOTAENIA TRITESTICULATA
(Light Microscopy)

A.	*Scolex with rostellum*	*x*	*125*
B.	*Rostellar sac with rostellum, rostellar spines and rostellar hooks*	*x*	*500*
C	*Proglottids with three testes clearly visible*	*x*	*20*
D.	*Mature proglottids enlarged*	*x*	*30*

Key:

cs. - cirrus sac

ov. - ovary

rh. - rostellar hooks

ro. - rostellum

rs. - rostellar spines

rsp. - rostellar spines

sc. - scolex

su. - sucker

tt. - testes

vg. - vitelline gland

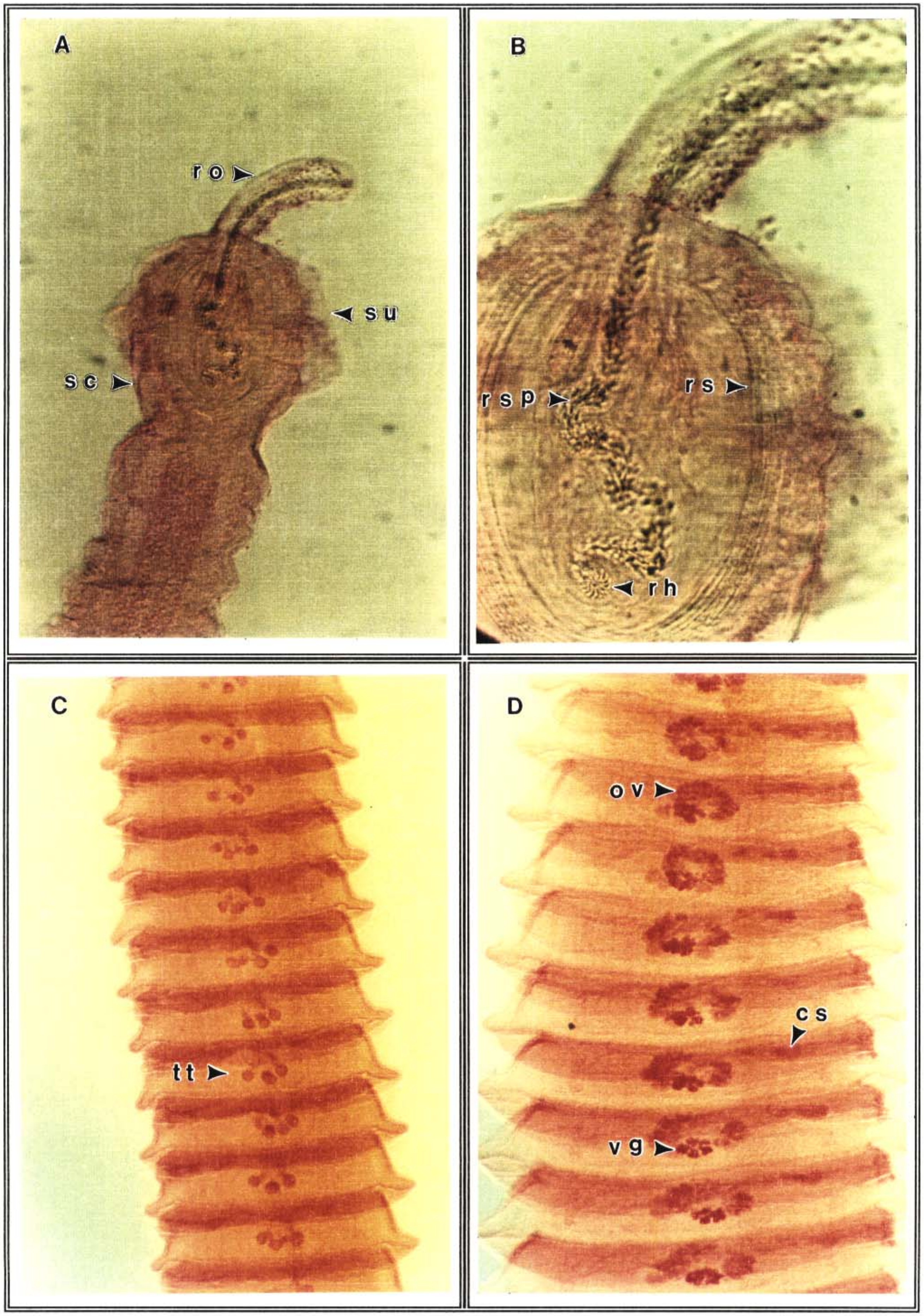

A
ro
su
sc
B
rsp
rs
rh
C
tt
D
ov
cs
vg

FIG. 78

ECHINORHYNCHOTAENIA TRITESTICULATA

(Scanning Electron Microscopy)

A. *Scolex with rostellum extended*

B. *Distal end of rostellum with rostellar hooks clearly visible*

C. *Rostellar spines covering the entire rostellum*

D. *Anterior part of the worm showing proglottids and the scolex*

Key:

pg. - proglottid

rh. - rostellar hooks

ro. - rostellum

rs. - rostellar sac

sc. - scolex

su. - sucker


A
7.0KV X60 100µm WD34
ro
su
B
1.1kx 4kv
rh
rs
C
0.97kx 6kv
ro
rs
D
7.0KV X70 100µm WD30
ro
sc
pg

FIG. 79

ECHINORHYNCHOTAENIA TRITESTICULATA AND HYMENOLEPIS CORMORANTI

(Light Microscopy)

A.	*Rostellar spines of E. tritesticulata enlarged*	*x*	*500*
B.	*Scolex of H. cormoranti with rostellum fully extended*	*x*	*250*
C.	*H. cormoranti - distal end of rostellum enlarged*	*x*	*500*
D.	*H. cormoranti - mature proglottids*	*x*	*250*

Key:

cs. - cirrus sac

ov. - ovary

rh. - rostellar hooks

ro. - rostellum

rs. - rostellar sac

sc. - scolex

su. - sucker

tt. - testes

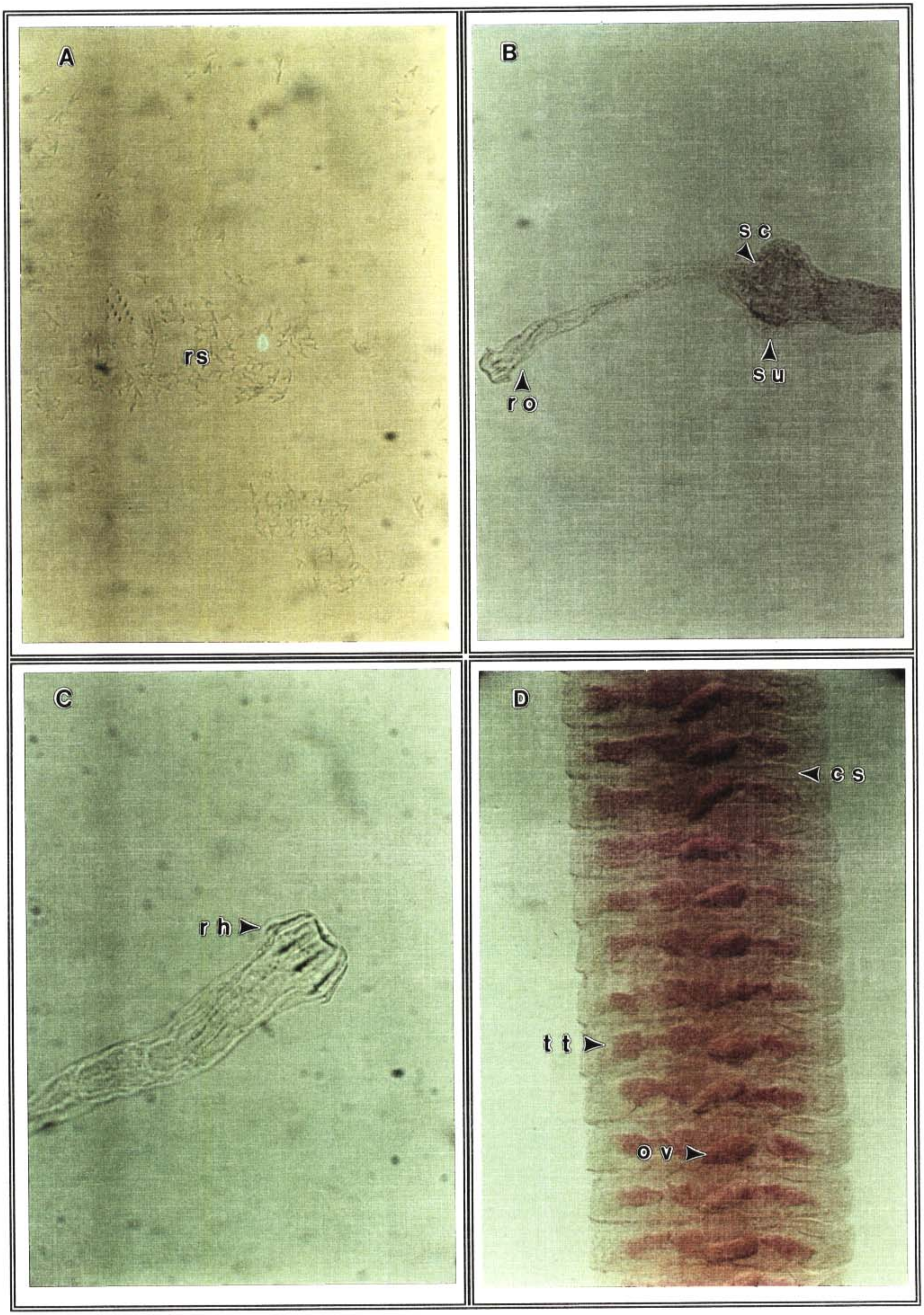

A
rs
B
sc
su
ro
C
rh
D
cs
tt
ov

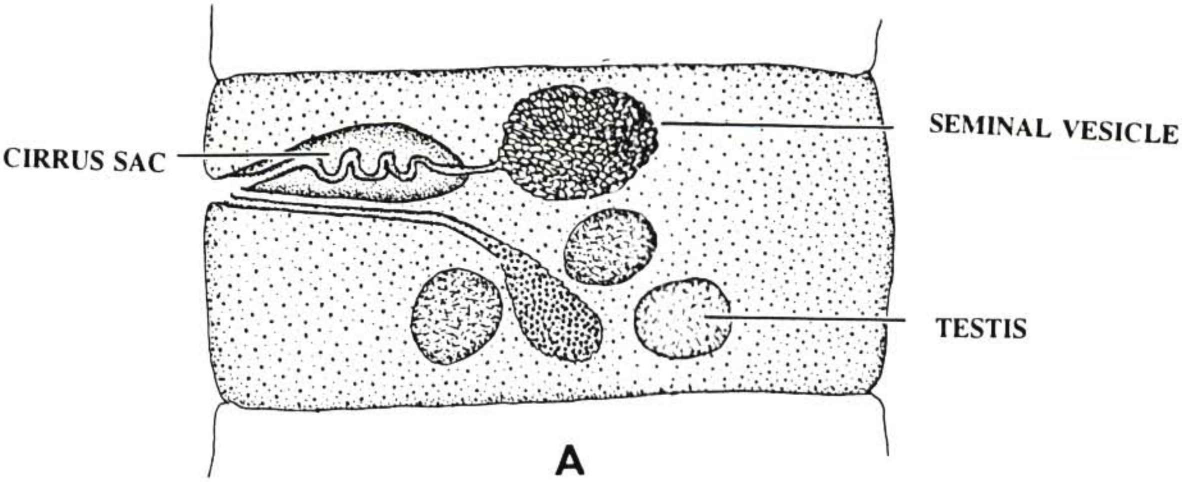
FIG. 80

HYMENOLEPIS CORMORANTI

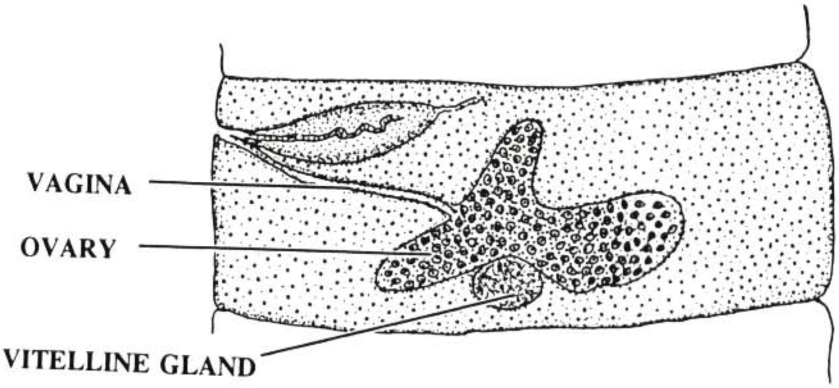
Diagrammatic representation of the reproductive organs
(After Ortlepp, 1938)

A. ***Proglottid with mature testes***

B. ***Proglottid with mature ovary***


SEMINAL VESICLE
CIRRUS SAC
TESTIS

A


VAGINA
OVARY
VITELLINE GLAND

B

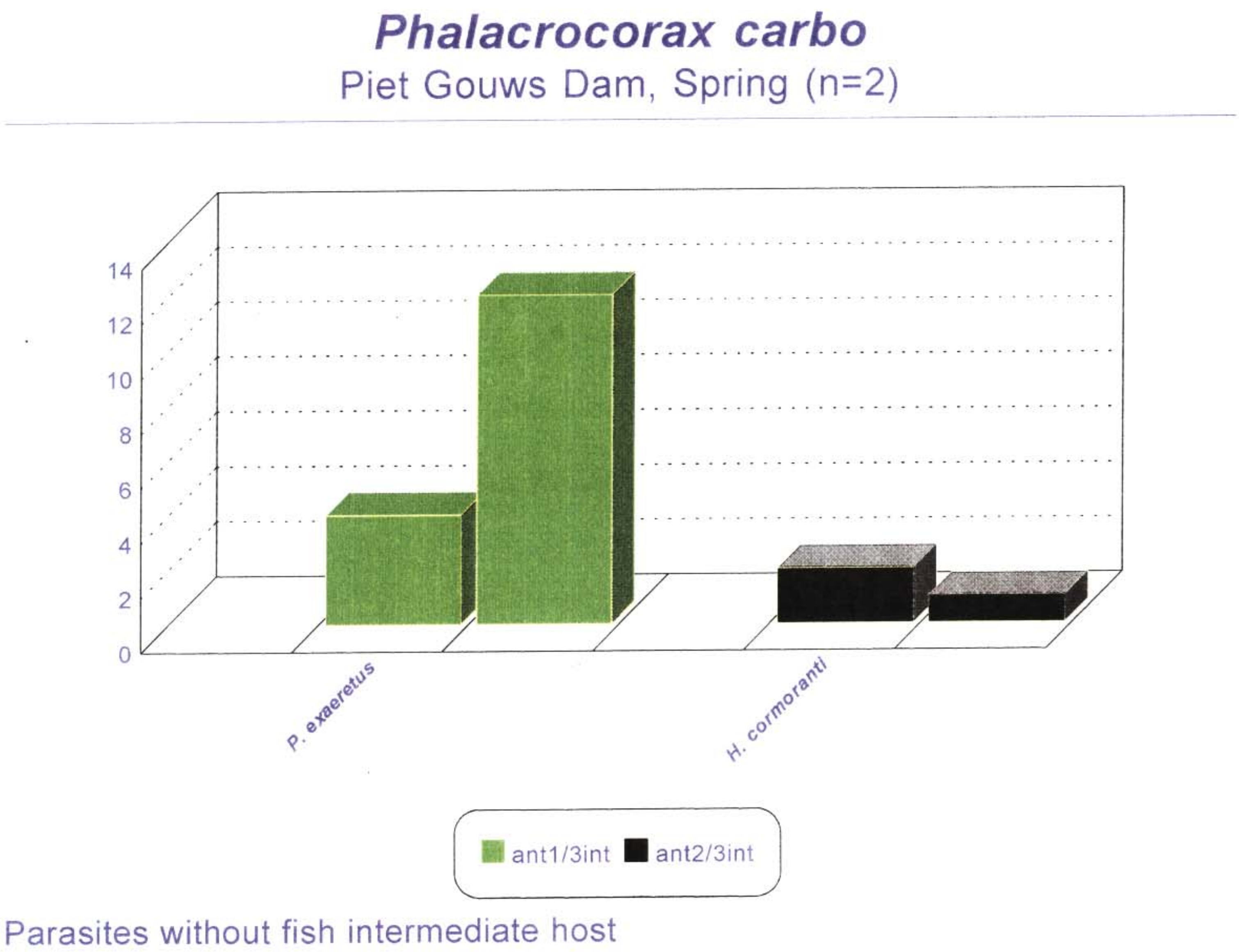
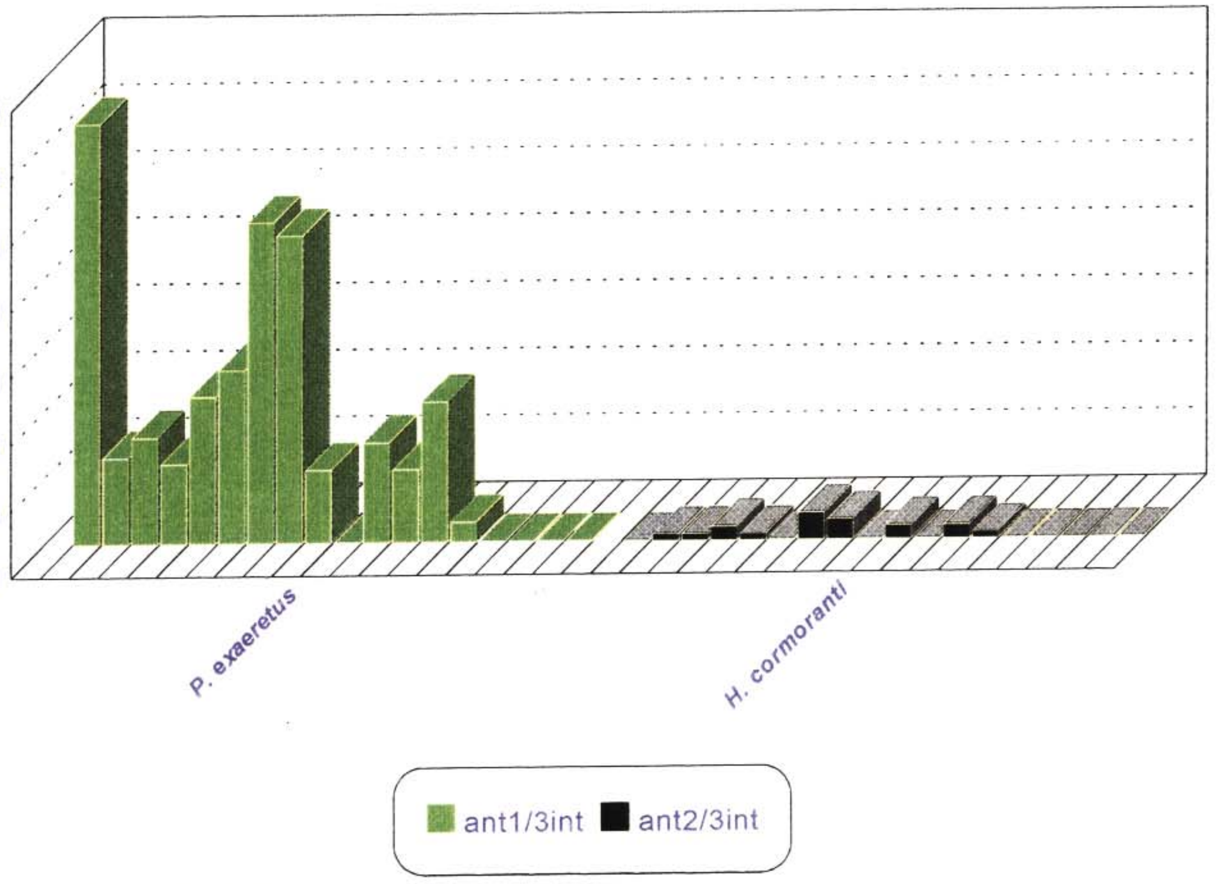

Phalacrocorax carbo
Piet Gouws Dam, Spring (n=2)
14
12
10
8
6
4
2
0
P. exaeretus
H. cormoranti
🟩 ant1/3int
■ ant2/3int
Parasites without fish intermediate host

Fig. 81

Phalacrocorax carbo

Seshego Dam, Winter (n=18)

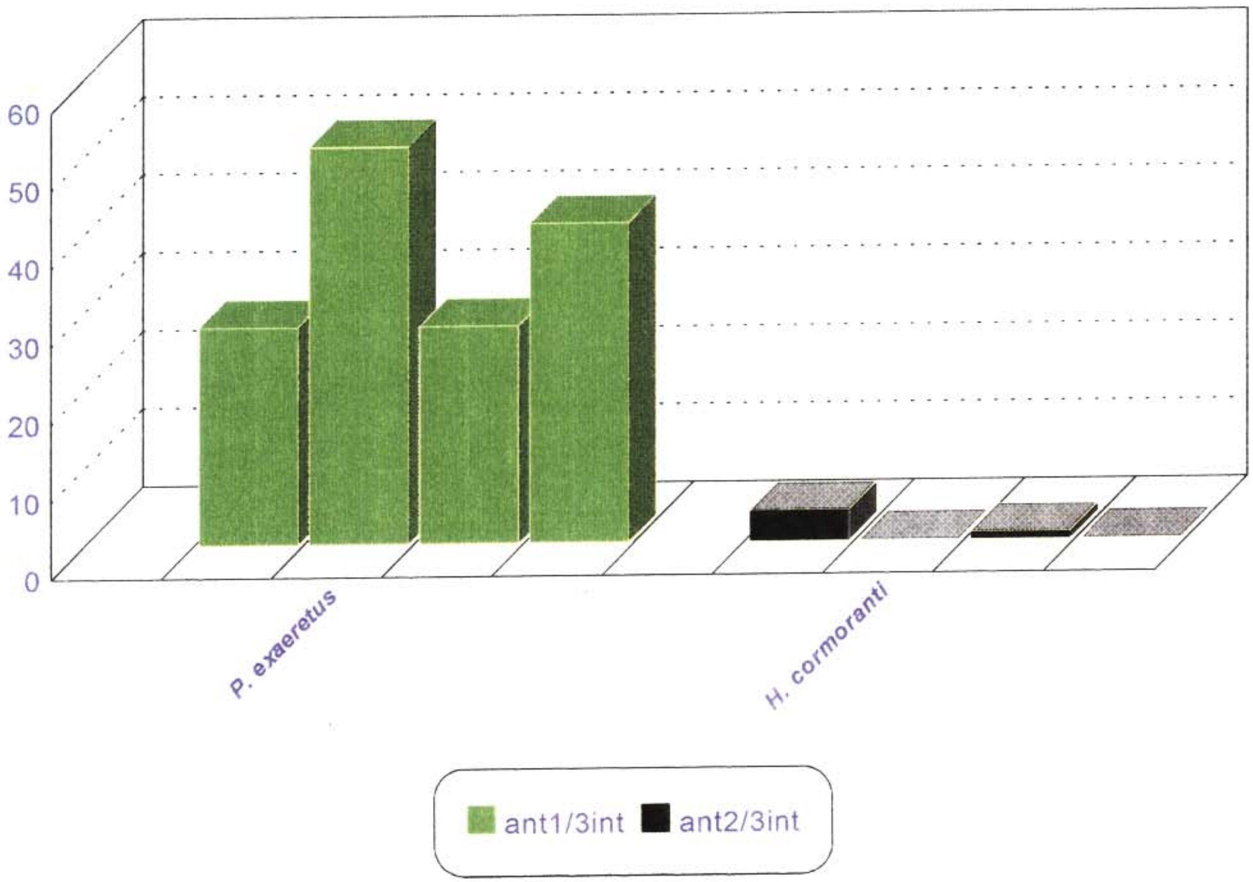


Parasites without fish intermediate host

Fig. 82

Phalacrocorax carbo

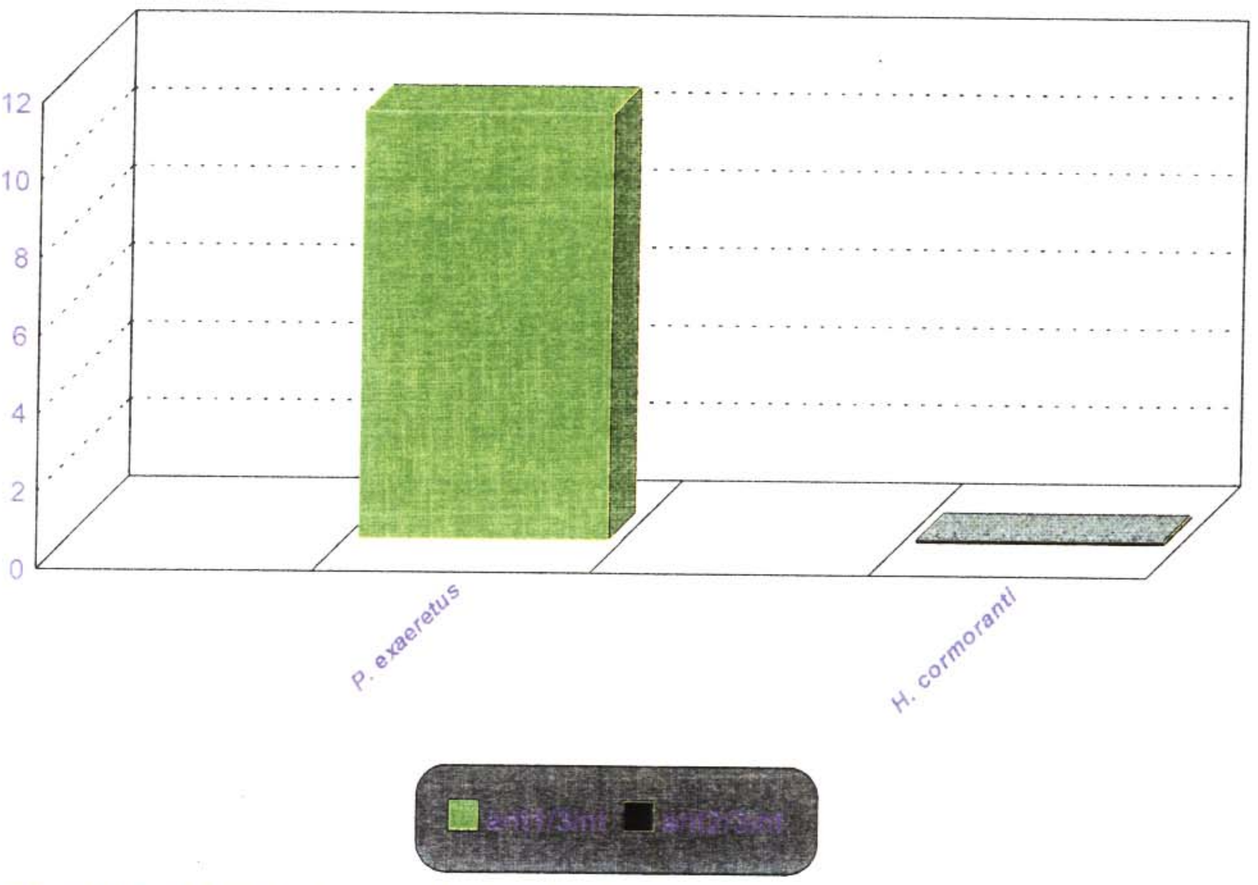
Seshego Dam, Spring (n=4)



Parasites without fish intermediate host

Fig. 83

Phalacrocorax carbo
Seshego Dam, summer (n=1)

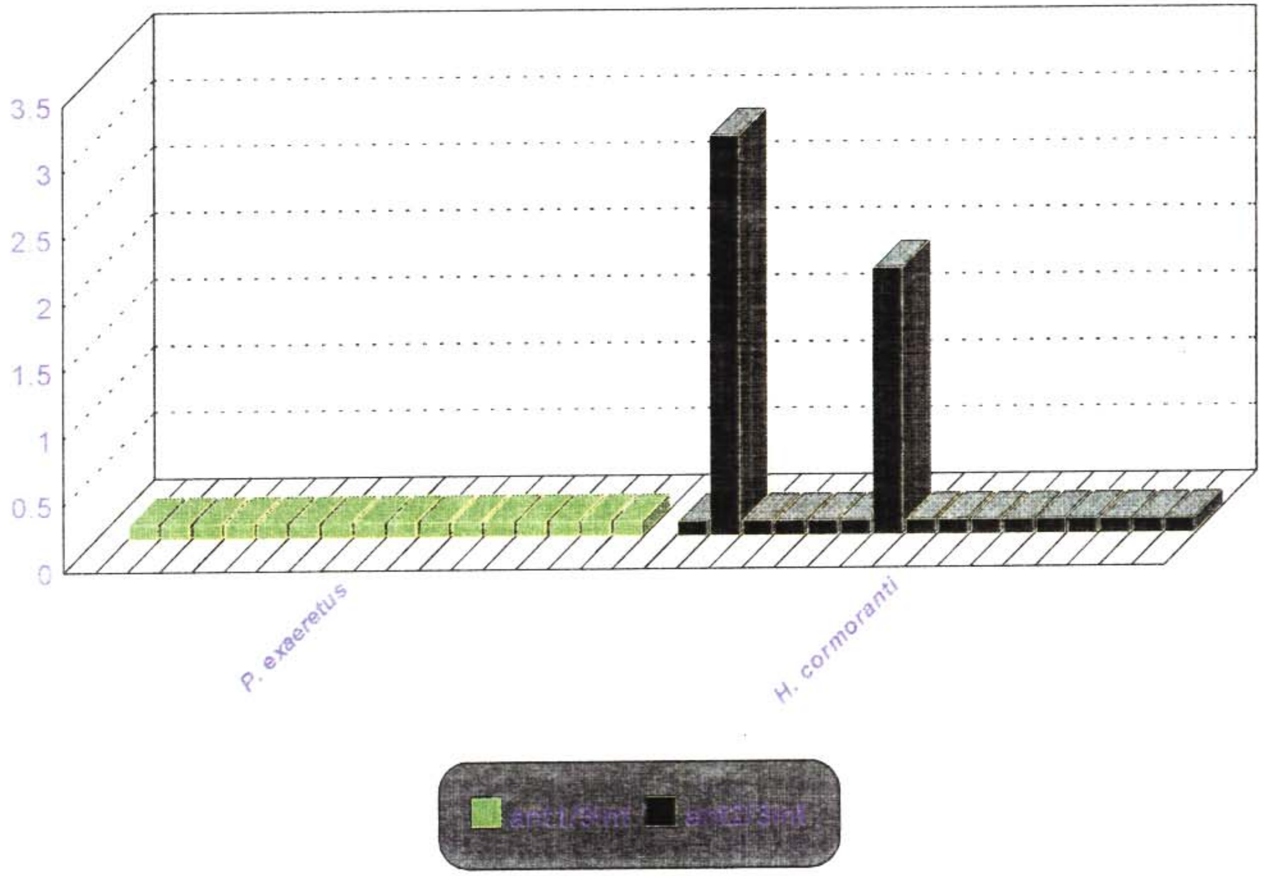


Parasites without fish intermediate host

Fig. 84

Phalacrocorax carbo

Seshego Dam, autumn (n=16)

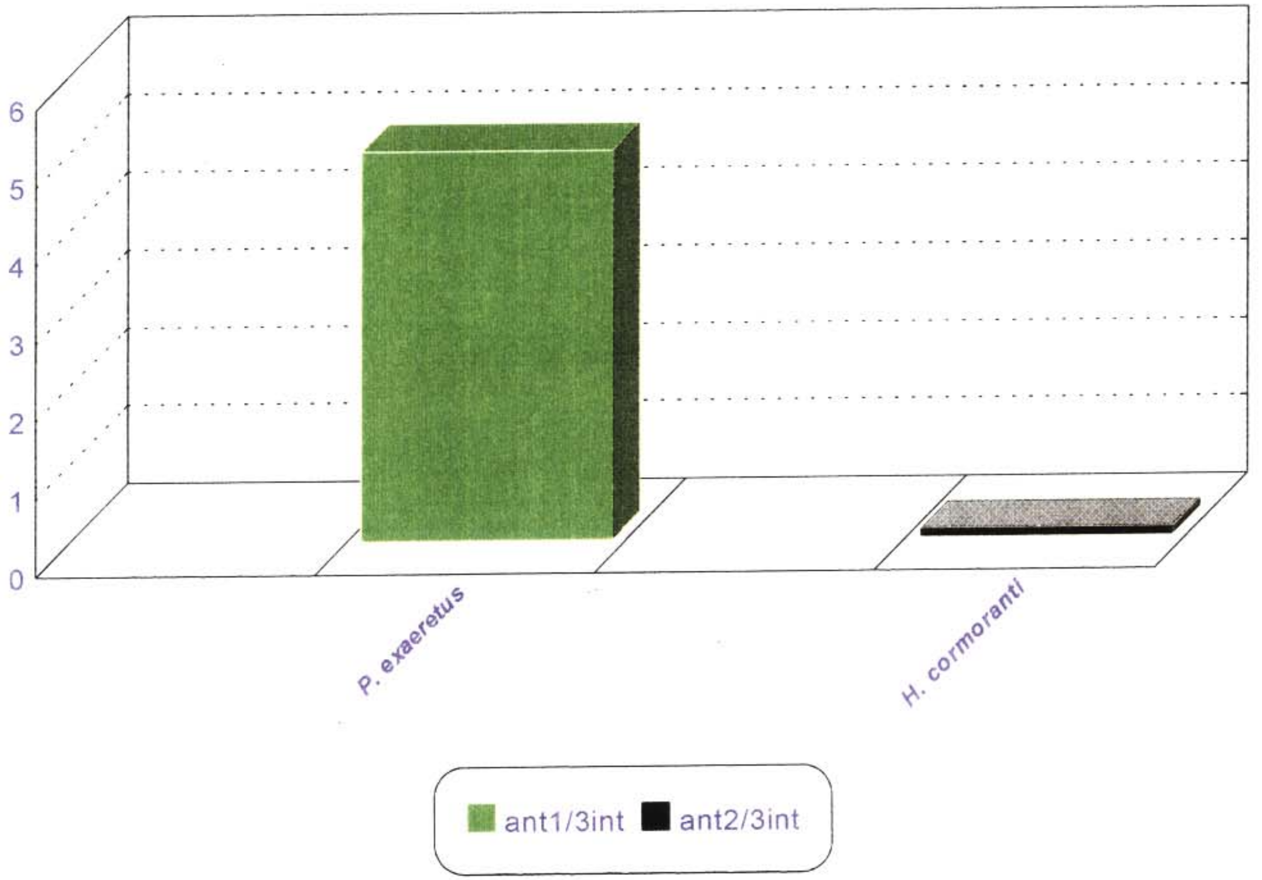


Parasites without fish intermediate host

Fig. 85

Phalacrocorax carbo

Middle Letaba Dam, Winter (n=1)

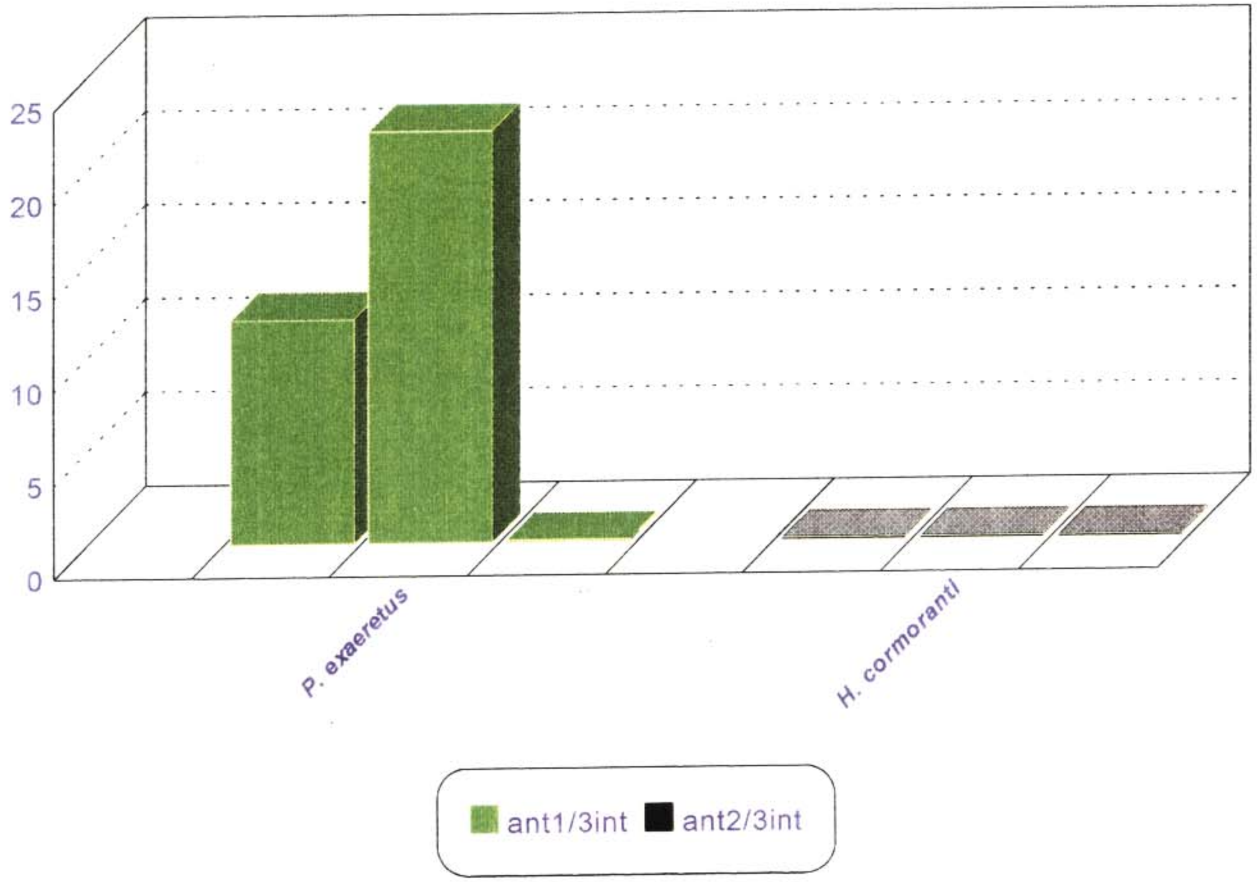


Parasites without fish intermediate host

Fig. 86

Phalacrocorax carbo

Middle Letaba Dam, Spring (n=3)

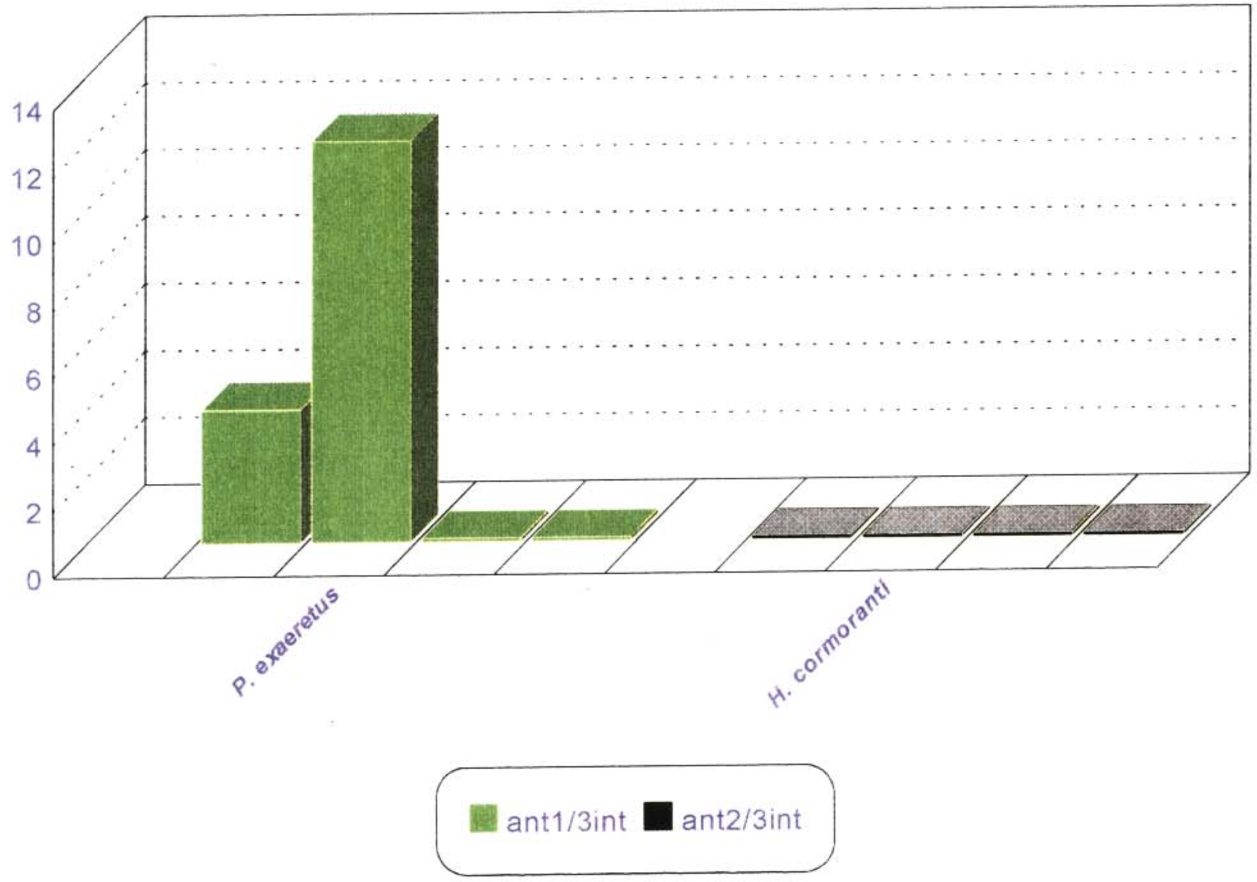


Parasites without fish intermediate host

Fig. 87

Phalacrocorax carbo

Middle Letaba Dam, Autumn (n=4)

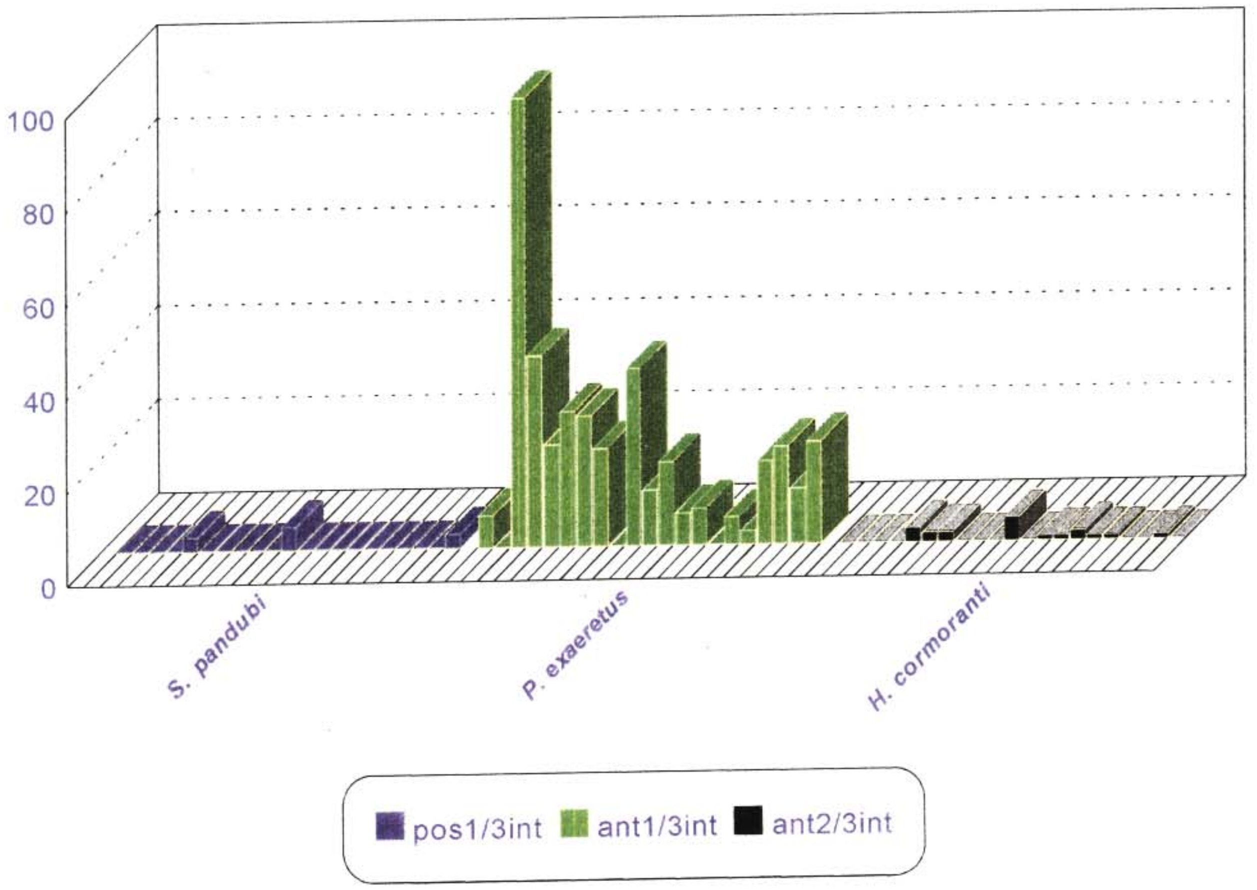


Parasites without fish intermediate host

Fig. 88

Phalacrocorax africanus

Seshego Dam, Winter (n=21)

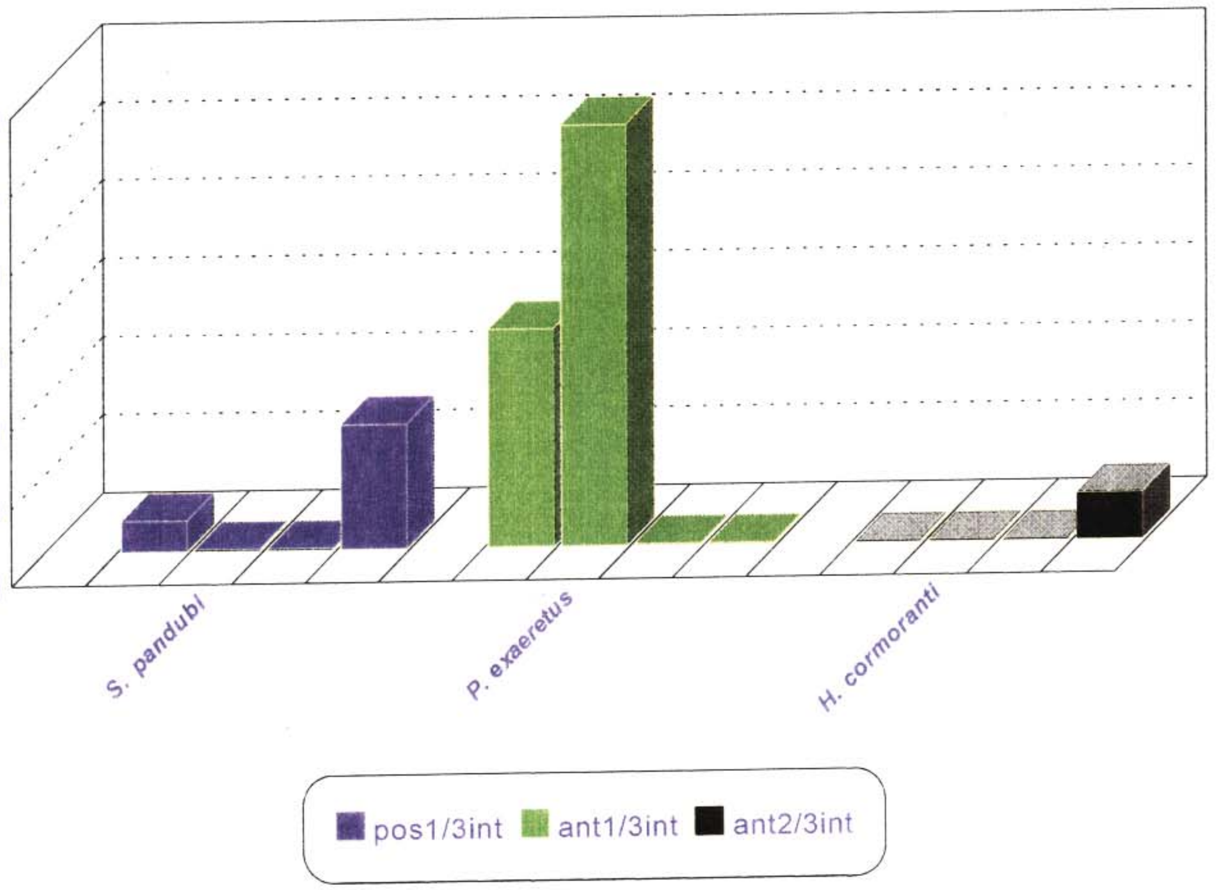


Parasites without fish intermediate host

Fig. 89

Phalacrocorax africanus

Seshego Dam, Summer (n=4)

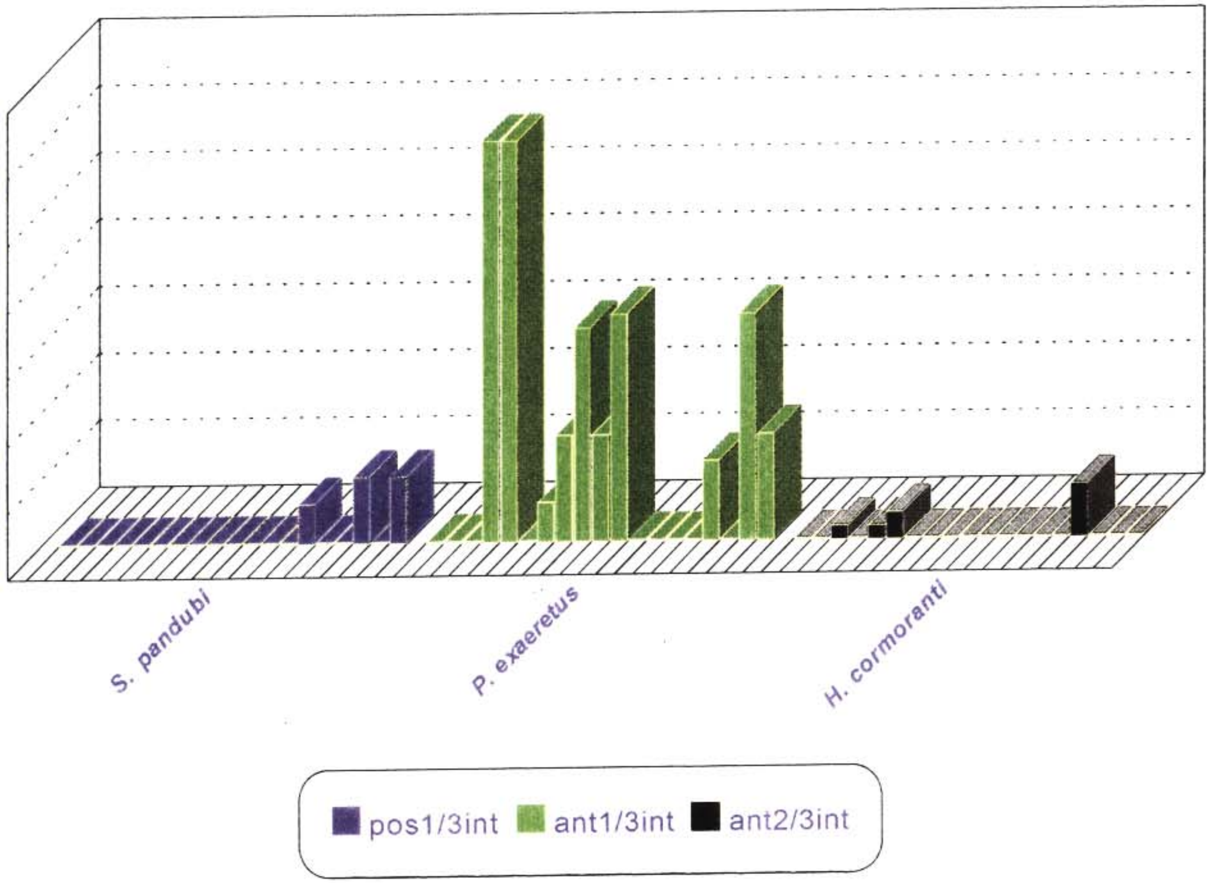


Parasites without fish intermediate host

Fig. 90

Phalacrocorax africanus

Seshego Dam, Autumn (n=19)



Parasites without fish intermediate host

Fig. 91

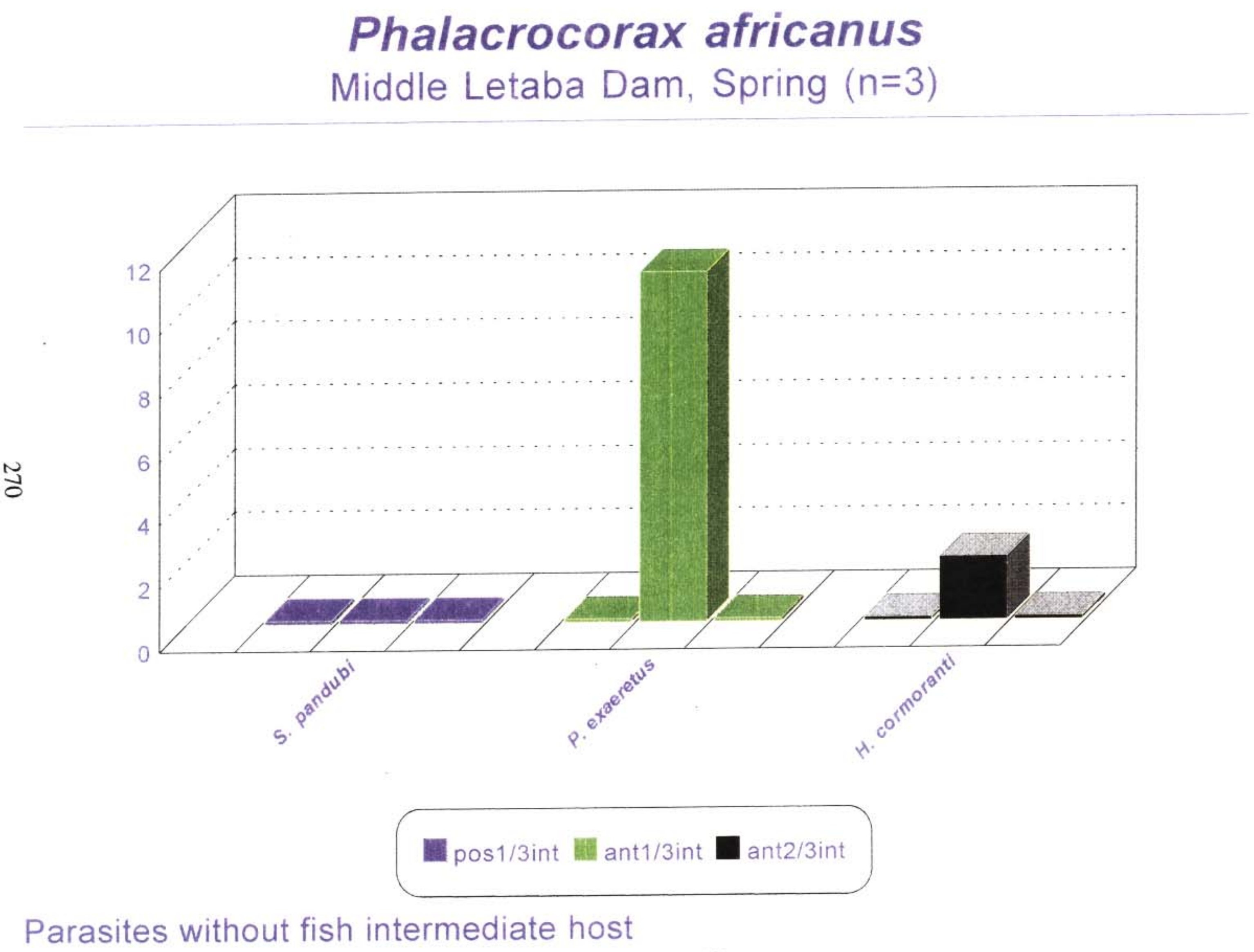
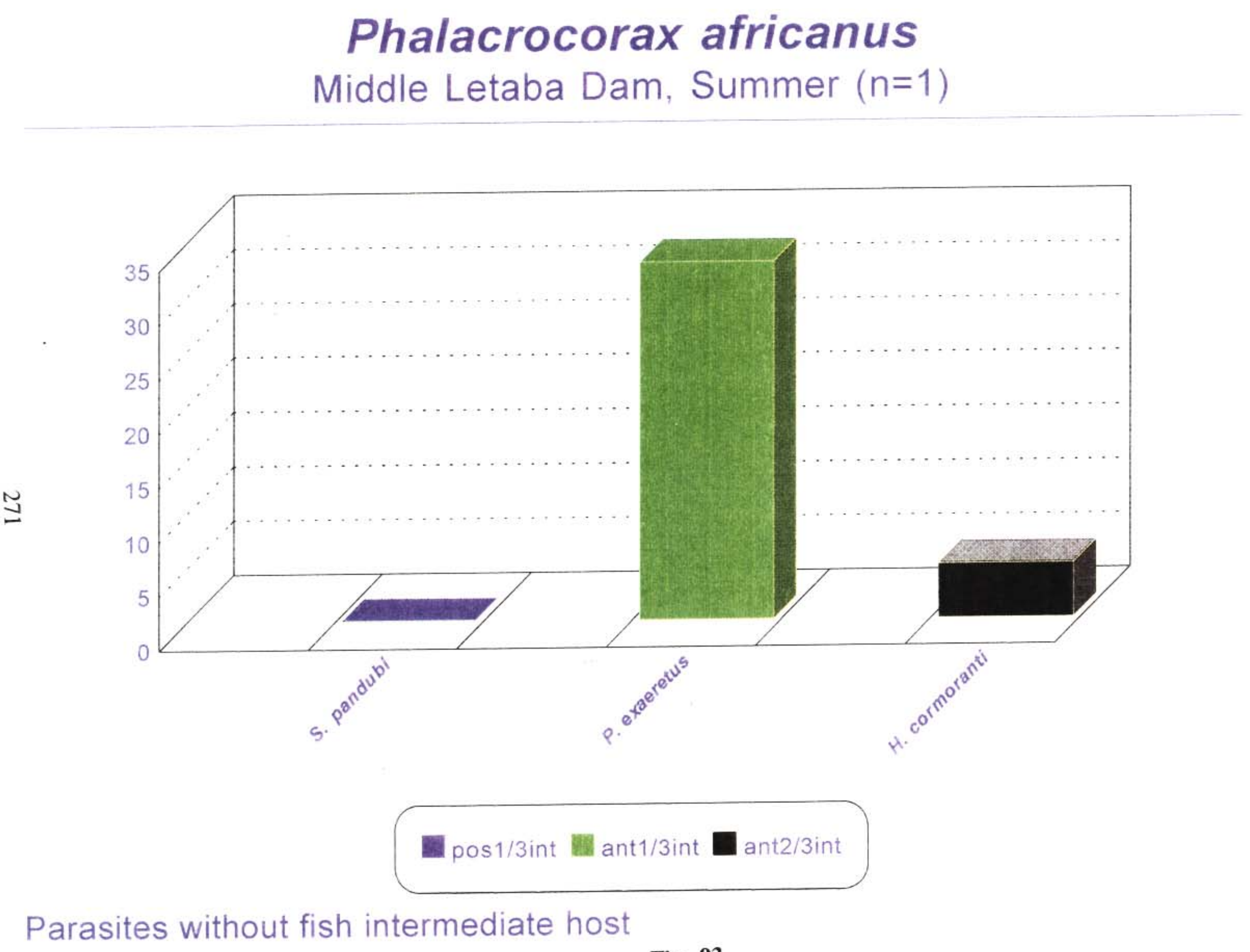

Phalacrocorax africanus
Middle Letaba Dam, Spring (n=3)
12
10
8
6
4
2
0
S. pandubi
P. exaeretus
H. cormoranti
pos1/3int
ant1/3int
ant2/3int
Parasites without fish intermediate host

Fig. 92



Phalacrocorax africanus

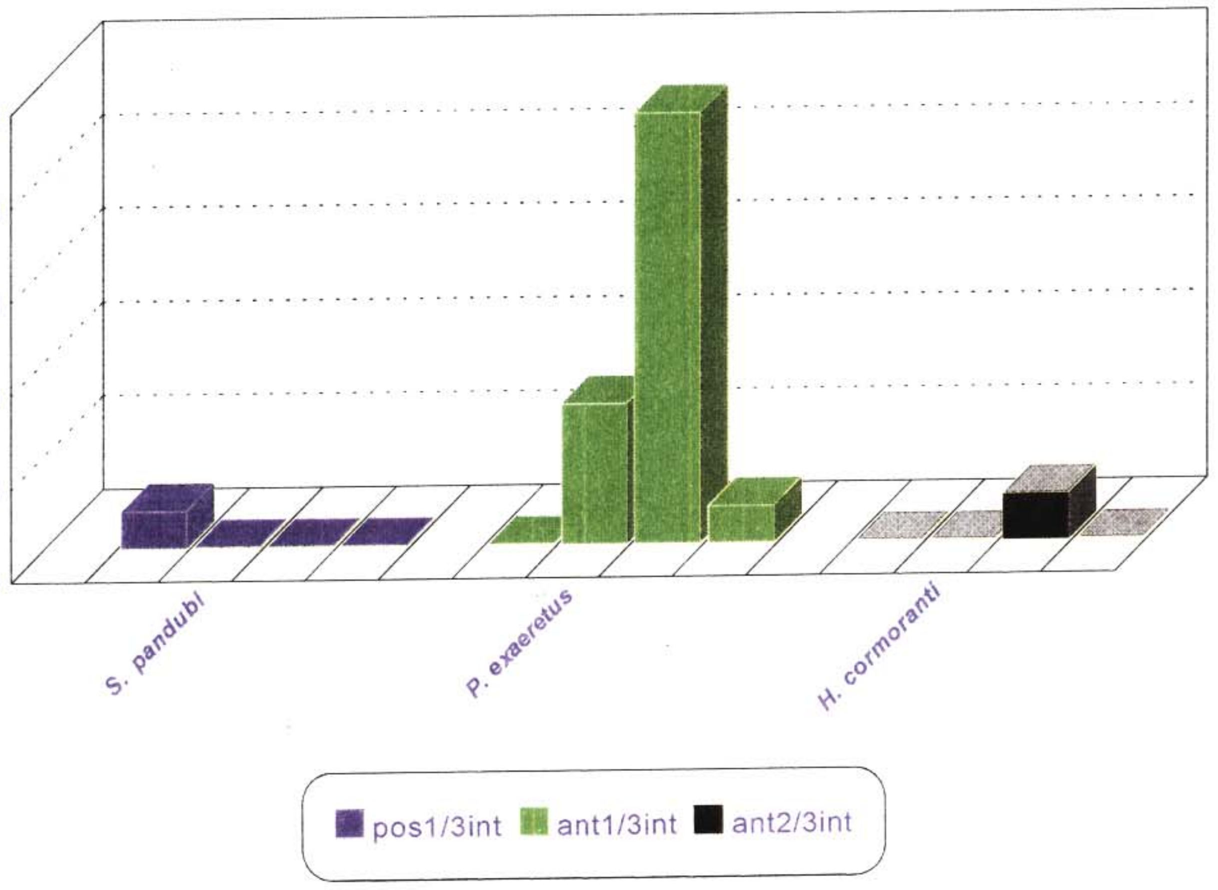
Middle Letaba Dam, Summer (n=1)

Parasites without fish intermediate host

Fig. 93

Phalacrocorax africanus

Middle Letaba Dam, Autumn (n=4)

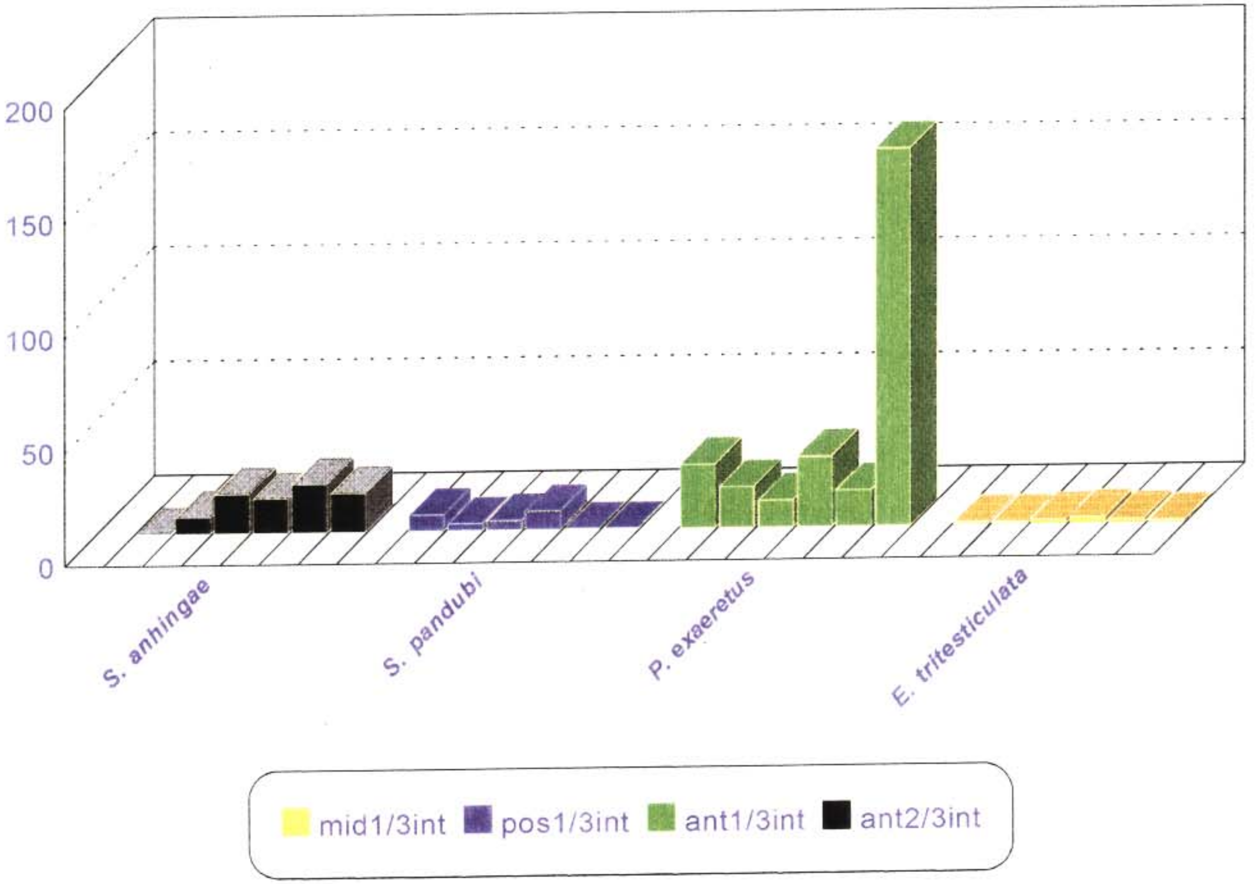


Parasites without fish intermediate host

Fig. 94

Anhinga melanogaster

Piet Gouws Dam, Spring (=6)

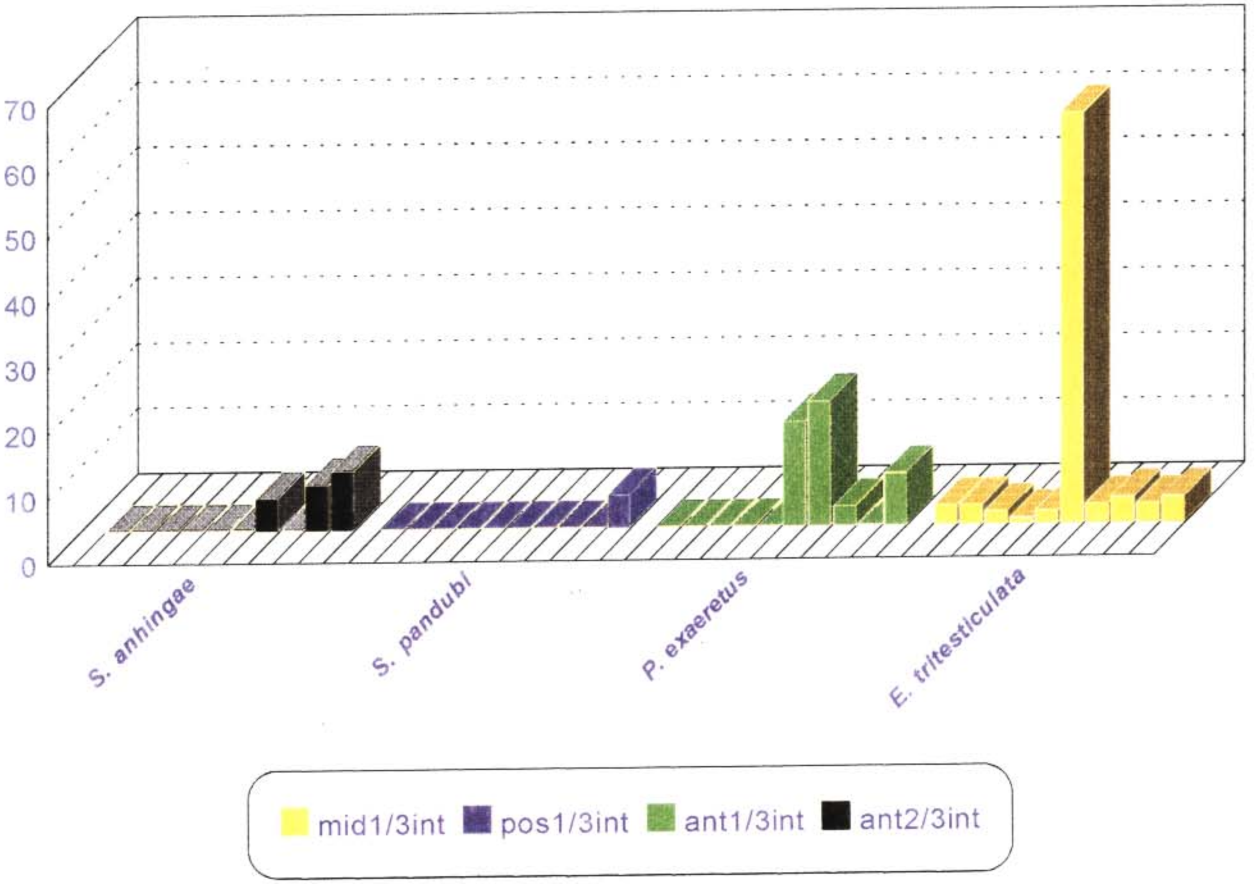


Parasites without fish intermediate host

Fig. 95

Anhinga melanogaster

Seshego Dam, Winter (n=10)

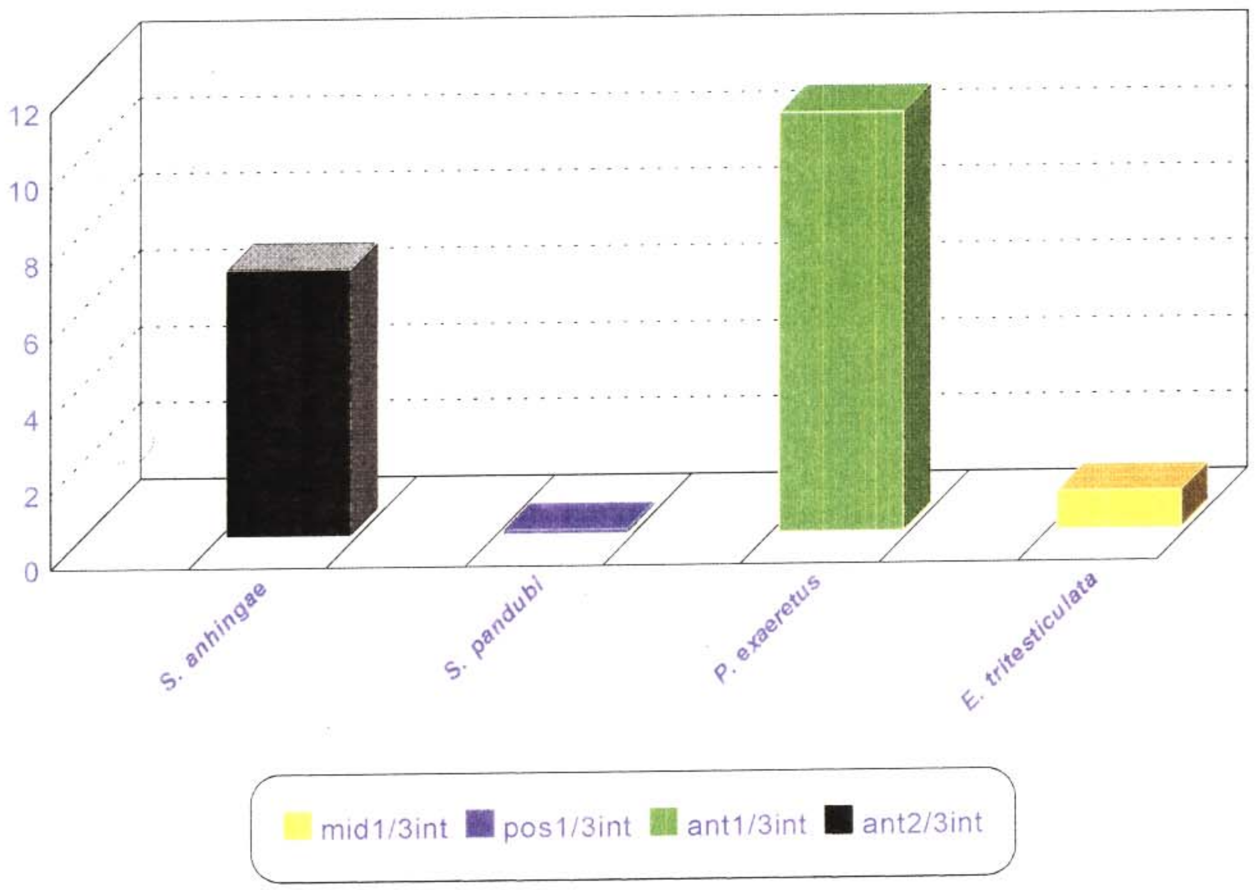


Parasites without fish intermediate host

Fig. 96

Anhinga melanogaster

Seshego Dam, Summer (n=1)

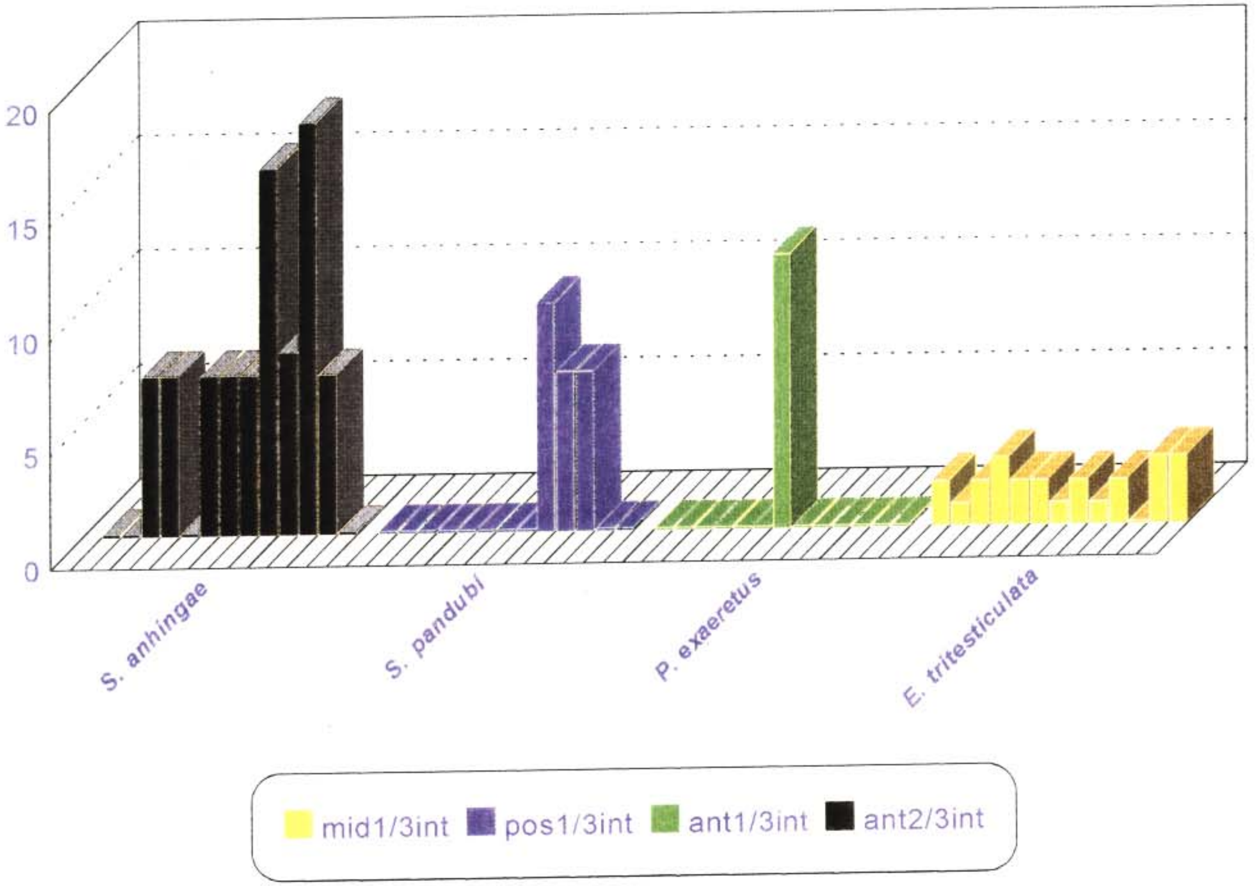


Parasites without fish intermediate host

Fig. 97

Anhinga melanogaster

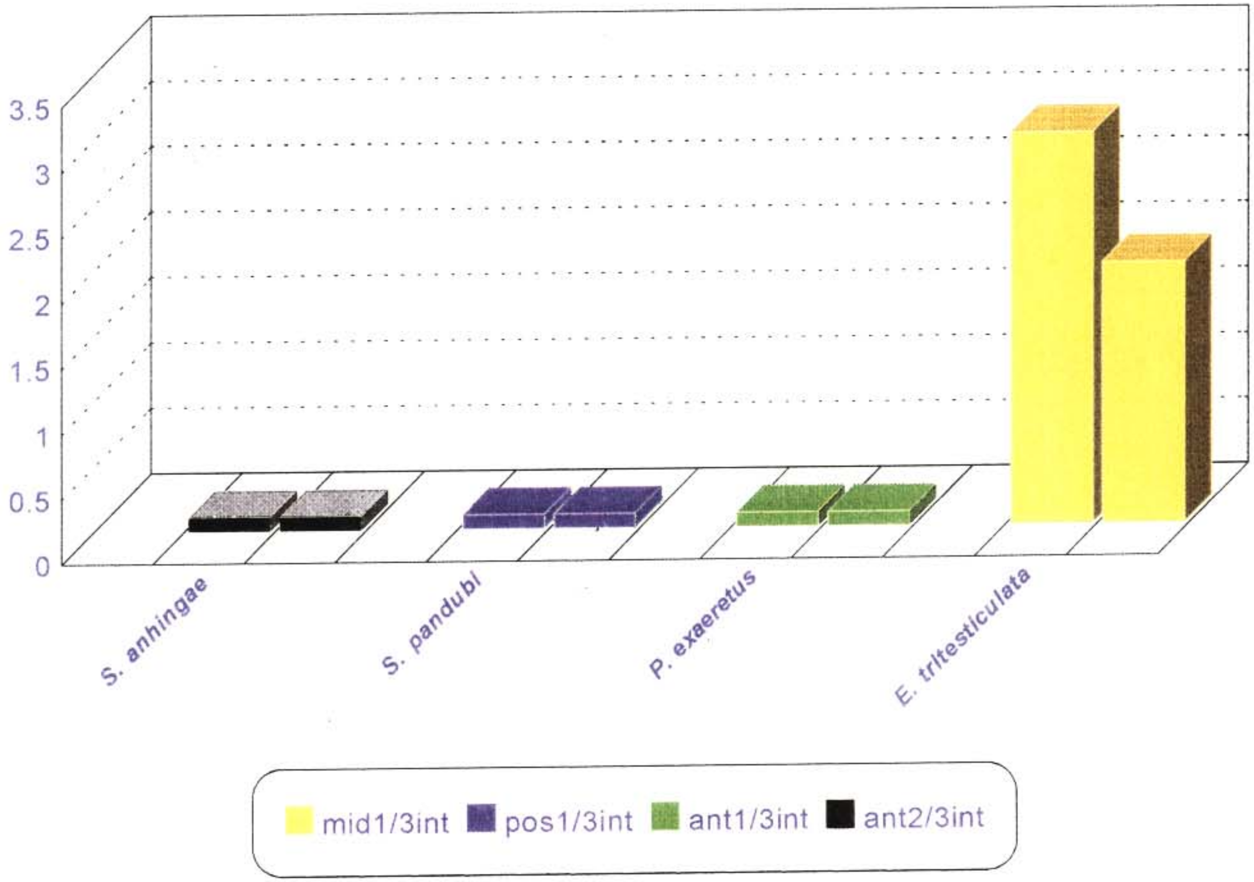
Seshego Dam, Autumn (n=13)



Parasites without fish intermediate host

Fig. 98

Anhinga melanogaster
Middle Letaba Dam, Spring (n=2)

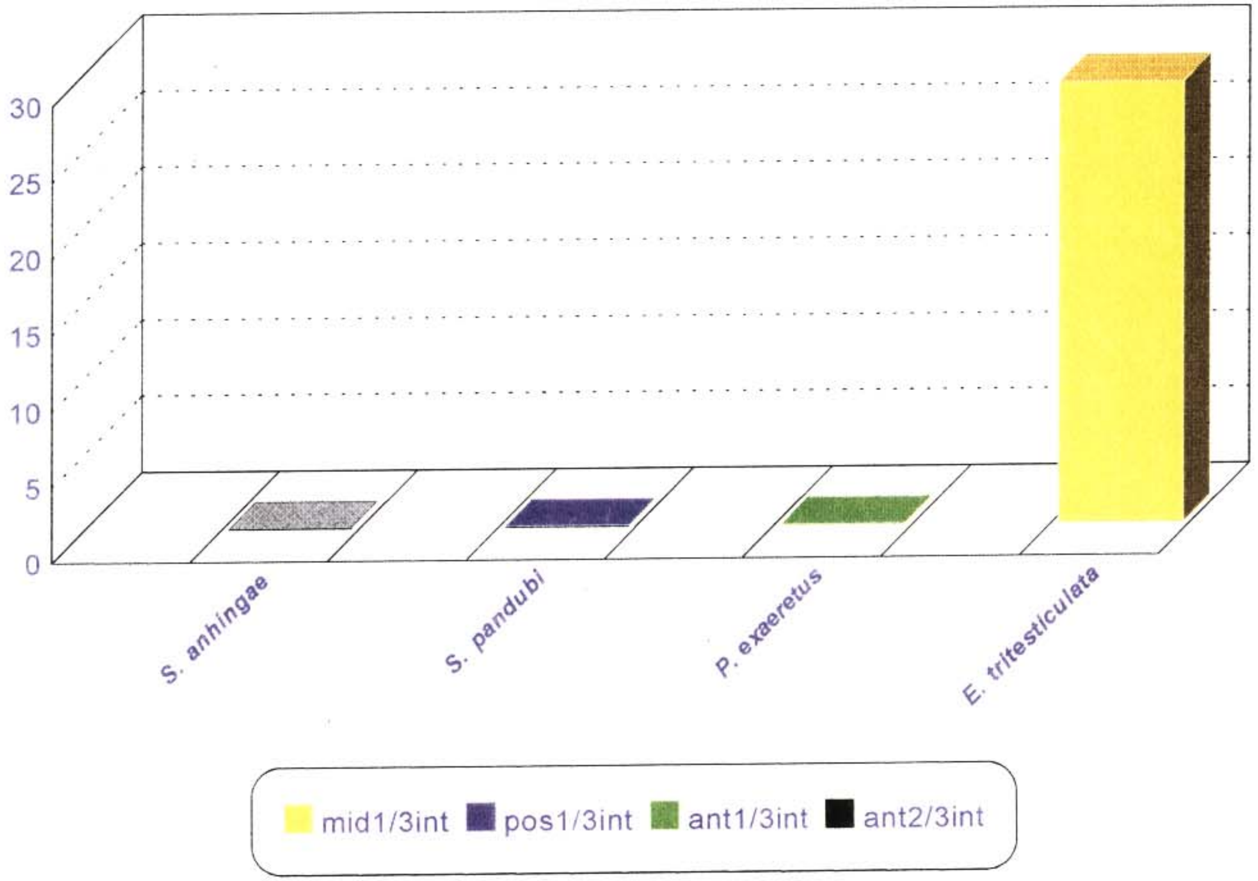


Parasites without fish intermediate host

Fig. 99

Anhinga melanogaster

Middle Letaba Dam, Summer (n=1)

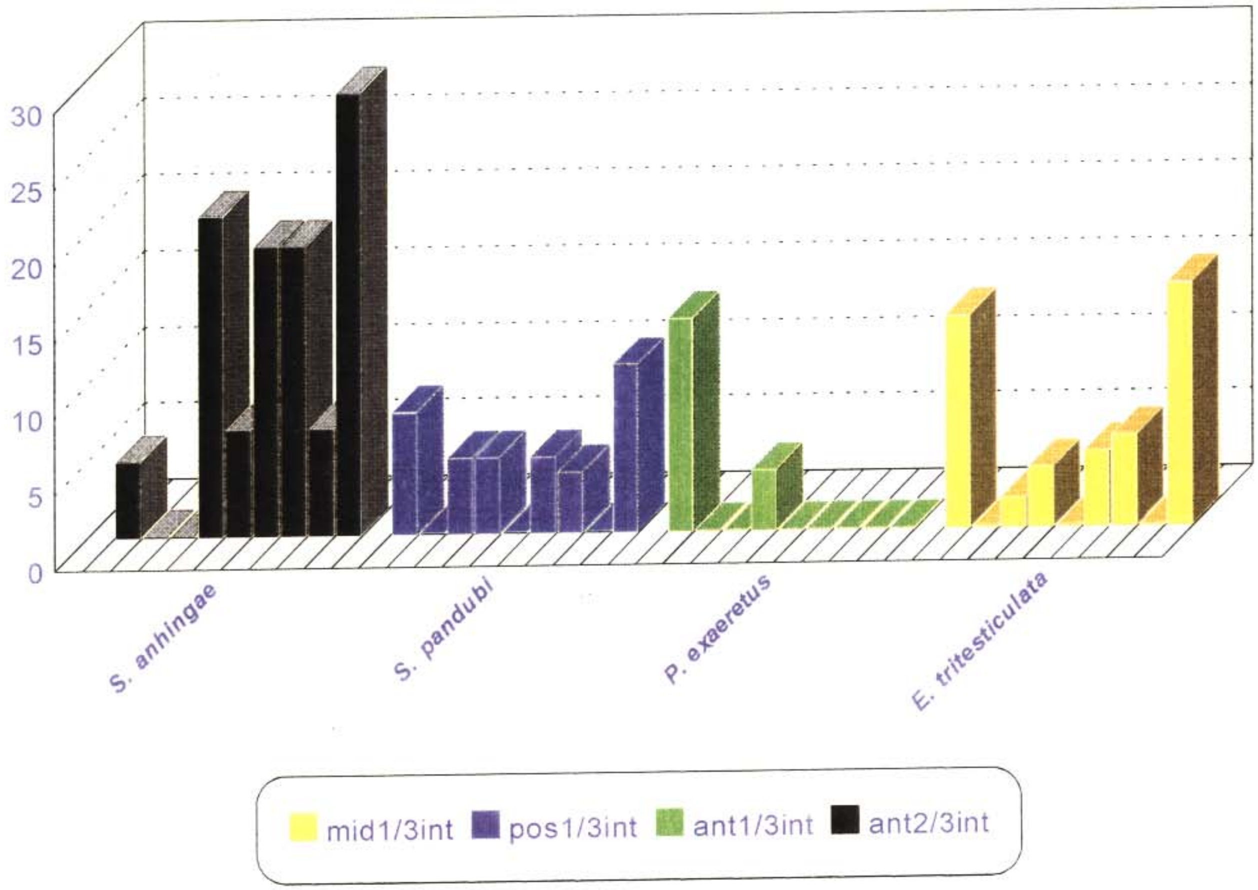


Parasites without fish intermediate host

Fig. 100

Anhinga melanogaster

Middle Letaba Dam, Autumn (n=9)



Parasites without fish intermediate host

Fig. 101

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7

SHORTCOMINGS AND FUTURE RESEARCH

7

SHORTCOMINGS AND FUTURE RESEARCH:

Over the last two decades considerable progress was registered concerning the parasitofauna of South African freshwater fish species (see also p.4). The greatest volume of research on South African freshwater ichthyoparasitology was carried out on the more subtropical aquatic ecosystems of the Olifants- and Limpopo River Drainage Systems. In contrast to earlier research efforts, which were purely of a taxonomic nature, the research of the last two decades, especially research on the helminth parasitofauna of indigenous fish species, also ventured into ecoparasitological aspects. This particular approach was specifically aimed at providing scientific background information on fish parasites to the growing Aquaculture enterprises in the Northern regions of South Africa. This approach was therefore in line with more applied limnological research as suggested by Noble and Hemens (1978) and Safriel and Bruton (1984).

The ecoparasitological research approach, remarked on in the preceding paragraph, with regard to freshwater fish helminths, was, however, not followed beyond the strict fish model. The present study on the gastrointestinal helminth fauna of three of the most common and widespread piscivorous birds at aquatic ecosystems in the Northern regions of South Africa, is the first in-depth study aimed at establishing fish-avian parasitic linkages. (see also aims and objectives, pp.5 and 6). In agreement with these aims and objectives the following were established:

- *Phalacrocorax carbo, P. africanus* and *Anhinga melanogaster* are infected with no less than 24 species of helminth parasites;
- No less than 19 of these helminth species involve a fish intermediate host in the life history;

The present study could draw on a comprehensive data bank on helminth infection statistics of the indigenous freshwater fish fauna of the aquatic ecosystems of the major drainage systems of the study area. This allowed for the fact that 18 of the 19 helminth species mentioned above could provisionally be linked to particular larval stages in fish intermediate hosts. Although this linkage is provisional, it should, however, be pointed out that the linkage is based on sound scientific bases, such as:-

- morphological similarities;
- a wide range of ecological data;
- numerical distributional records of fish intermediate hosts and avian final hosts for helminths in the major aquatic ecosystems of the study area;
- a limited number of experimental infections of avian hosts with larval helminths from fish intermediate hosts.

As was mentioned on p.4 the present study also formed part of a multi-disciplinary Departmental limnological investigation at one of the largest freshwater ecosystems in the study area. This provided an additional opportunity to examine a number of other aquatic birds for gastrointestinal helminths. These are:

Family Ardeidae		
Ardea cinerea	-	Grey Heron
A. melanocephala	-	Blackheaded Heron
A. purpurea	-	Purple Heron
Egretta garzetta	-	Little Egret
Bubulcus ibis	-	Cattle Egret
Butorides striatus	-	Greenbacked Heron
Nycticorax nycticorax	-	Blackcrowned Night Heron
Ixobrychus minutes	-	Little Bittern
Family Plataleidae		
Platalea alba	-	African Spoonbill
Family Jacanidae		
Actophilornis africanus	-	African Jacana
Family Alcedinidae		
Ceryle rudis	-	Pied Kingfisher
C. maxima	-	Giant Kingfisher
Alcedo cristata	-	Malachite Kingfisher

Eleven of the preceding thirteen aquatic avian species harboured gastrointestinal helminths. Some of these helminths such as clinostomatid spp., diplostomatid spp. and *Contracaecum* spp. are definitely fish related.

The numbers of hosts examined from the avian families mentioned in the preceding table, were relatively low, and although these hosts were not included in the original research protocol, their identified helminth parasites are listed in Table 47 below. This is done for two obvious reasons:

- To supplement the lack of information regarding the helminth parasites of the South African inland aquatic avifauna;

- to indicate that some of these birds can, and do play, a role in maintaining the life cycles of some of the most prevalent helminth parasites of indigenous freshwater fish fauna. As such they are, therefore, also potential agents for the translocation of helminth parasites from one water body to other aquatic systems, even fish production ponds of intensive aquacultural enterprises.

Table 47: Prevalence, intensity and mean intensity values for helminth infections of hosts other than members of the Phalacrocoracidae and Anhingidae at Middle Letaba Impoundment, Northern Province, South Africa.

AVIAN HOST	N.	PARASITE	PREVALENCE %	INTENSITY	MEAN INTENSITY
Ardea cinerea	3	**Trematoda** *Clinostomum complanatum*	66	1 - 3	2
		Euclinostomum heterostomum	100	4 - 6	5
		Nematoda *Contracaecum microcephalum*	33	6	6
A. melanocephala	5	**Trematoda** *E. heterostomum*	100	1 - 8	5
		Diplostomum tregenna	20	4	4
		Nematoda *C. microcephalum*			
A. purpurea	2	**Trematoda** *E. heterostomum*	50	1	1
Egretta garzetta	2	**Trematoda** *Apharyngostrigea simplex*	50	4	4
		Cestoda *Anomotaenia megascolecina*	100	2 - 2	2
Bubulcus ibis	7	**Trematoda** *A. simplex*	100	9 - 31	21
		Nephrostomum ramosum	100	2 - 7	4
		Nematoda *Microtetrameres spiralis*	50	5 - 9	8

Table 47: continued

AVIAN HOST	N.	PARASITE	PREVALENCE %	INTENSITY	MEAN INTENSITY
Butorides striatus	2	**Cestoda** *Hymenolepis ardeae*	50	1	1
		Anomotaenia sp.	50	6	6
Nycticorax nycticorax	3	**Trematoda** *Neutraclinostomum intermedialis*	66	2 - 4	3
		Cestoda *Dendrouterina* sp.	33	1	1
Ixobrychus minutes	1	**Trematoda** *Eurycephalus aspinocollaris*	100	1	1
Platalea alba		**Cestoda** *Paradilepis urceus*	100	436-658	545
Actiphilornis africanus	4	**Trematoda** *Cyclocoelum gendrei*	50	2 - 4	3
Ceryle rudis	3	-	-	-	-
C. maxima	2	**Trematoda** *Uvulifer microcephallus*	100	4.5	4.5
Alcedo cristata	2	-	-	-	-

Some of the parasites mentioned in the preceding table have previously been recorded from South Africa. These are:

Clinostomum complanatum	-	Ortlepp (1935) from *A. cinerea*
Neutraclinostomum intermedialis	-	Britz, Saayman & Van As (1984) from *A. cinerea*
Euclinostomum heterostomum	-	Prudhoe & Hussey (1977) from *A. cinerea* Britz, Saayman & Van As (1984) experimentally in *A. cinerea*
Nephrostomum rumosum	-	Mji (1951) from *A. melanocephala* Saayman (1966) from *B. ibis*; Raseroka (1970) from *Bostrychia hagedash* Prudhoe & Hussey (1977) from *A. cinerea*
Contracaecum microcephalum	-	Whitfield and Heeg (1977) from *Pelecanus onocrotalus*

The following helminths are recorded for the first time from South African aquatic ecosystems:

PARASITE	HOST
Trematoda	
Diplostomum tregenna	*Ardea melanocephala*
Apharyngostrigea simplex	*Egretta garzetta* and *Bubulcus ibis*
Eurycephalus aspinocollaris	*Ixobrychus minutus*
Cyclocoelum gendrei	*Actiphilornis africanus*
Uvulifer microcephallus	*Ceryle maxima*
Cestoda	
Anomotaenia megascolecina	*E. garzetta*
Hymenolepis ardeae	*Butorides striatus*
Dendrouterina sp.	*Nycticorax nycticorax*
Paradilepis urceus	*Platalea alba*
Nematoda	
Microtetrameres spiralis	*B. ibis*

Bisseru (1955, 1957) did not record any of the helminths mentioned in the preceding list from the Zambian birds he studied. *C. gendrei, E. aspinocollaris, U. microcephallus* (Trematoda: Digenea) and *A. megascolecina, Dendrouterina* sp., *H. ardeae* (Cestoda: Cyclophyllidea) were recorded by Ukoli (1968a, b,c,d and 1969) from aquatic birds from Accra, Ghana.

The foregoing synoptic account of the helminth parasites of South African non-phalacrocoracid and anhingid aquatic/semi-aquatic birds clearly underlines the necessity for further studies on the parasitofauna of this avian component. It is intended to further the preliminary surveys on the helminth fauna of the hosts mentioned in Table 47 on pp. 283 and 284, as well as to describe these helminths at the hand of the same procedures followed for the helminth parasites of the Phalacrocoracidae and Anhingidae mentioned earlier in this thesis.

A fairly extensive data bank is available on the nature and extent of the helminth parasites of the indigenous fish populations of the aquatic ecosystems of the Northern Province of South Africa. (Literature References, p.20). This body of information is enhanced by numerous studies on the ecology of freshwater fish species of the region (Du Plessis and Groenewald, 1953; Le Roux, 1956, 1961; Gaigher, 1969, 1973; Göldner, 1969; Schoonbee and Vermeulen, 1972; Schoonbee, Vermeulen and Du Toit, 1972; Gaigher and McPott, 1973; Batchelor, 1974, 1978 a and b; Potgieter, 1974; Brandt, 1975; Göldner, Van der Waal and Schoonbee, 1975; Hecht, 1980b; Hecht and Mashego, 1981; Hecht, Polling and

Mokgalong, 1981; Hecht and Saayman, 1981; Mabitsela, 1981; Hecht and Scholtz, 1983; Kleynhans, 1984, 1986; Saayman, 1986; Van Senus, 1989; Saayman and Schoonbee, et. al., 1991; Schoonbee, Hecht, Saayman and Polling, 1995). Aquacultural research and related enterprises have also reached an advanced stage of development in the Province (Taylor and Van der Walt, 1985; Van Senus, 1989; Saayman and Schoonbee et. al., 1991; Prinsloo, Hoffman and Theron, 1994a & b).

The preceding paragraph clearly indicates that the Northern Province of South Africa provides ideal opportunities for the study of the aetiology and ecology of aquatic helminth parasites. These aspects of parasitology have often been neglected in parasitological studies around the world (Kennedy, 1975; Anderson, 1976; Sinderman, 1987; Breev, 1980 and Bauer, 1984), but particularly so for aquaparasitology in Africa (Okorie, 1973; Paperna, 1980 and Saayman, 1986).

In addressing a symposium on the role of resource evaluation in the development and management of inland fisheries held in Chad under the auspices of the Committee for Inland Fisheries of Africa (CIFA) of the F.A.O., Okorie (1973) remarked as follows:

> *Parasitism is considered to be an important factor in the management of African fisheries and more work on the identification of parasites, incidence and intensity of infection, pathology and biology, with a view to control, is called for.*

Paperna (1980) also called for more comprehensive parasitological surveys in African freshwater bodies and stated:

> *Documented information on fish diseases in Africa is predominantly made of taxonomic studies. Most of such information consists of taxonomic descriptions of individual parasitic species from occasional collections and from museum material. Faunistic regional surveys were carried out only in a limited number of water systems, and all these surveys were not comprehensive but rather restricted to one or a few taxa of parasitic organisms.*
>
> *Long-term quantitative studies on infection cycles in fish populations in reference to ecological- environmental parameters, as well as studies on the biology of the parasites of African fish are scarce and almost non-existing.*

The last sentence of the preceding quotation from Paperna (1980) holds equally - if not more seriously - for the situation with respect to helminth parasites of African piscivorous birds, as well as the role of these hosts in the maintenance of fish helminth life histories and the translocation of parasites between geographically isolated aquatic systems.

The present study on the gastrointestinal helminths of the Phalacrocoracidae and Anhingidae in the Northern Province of South Africa must be regarded as the most comprehensive investigation of its kind ever to be undertaken on the African Continent. Despite this, several shortcomings became evident during the course of the investigation.

It is hoped that this study, as well as the ideal logistical circumstances that prevail in the present study area, will act as a stimulus towards further research on the epistemology of aquatic parasites of fish and piscivorous birds of the Southern African Subcontinent. Specific shortcomings that became evident during the present investigation are:

- An almost total lack of information on the molluscan phases of the life histories of fish and piscivorous avian parasites of the southern African region;
- Despite a considerable knowledge on the helminth parasites of indigenous fish species in the study area, supplemented by infection statistics of fish related helminths of the Phalacrocoracidae and Anhingidae as well as other aquatic birds, circumstances did not allow for a complete range of experimental infections in order to establish direct fish-avian parasitic linkages. It is intended to verify preliminary chain linkages established during the present investigation with follow-up experimental studies;
- During the present study 16 aquatic/semi-aquatic avian hosts were investigated for potential helminthic infections. Three hosts were studied on a comprehensive scale, namely, *Phalacrocorax carbo, P. africanus* and *Anhinga melanogaster*. These 16 hosts yielded 34 different helminth parasites, 21 of which definitely utilise freshwater fish as secondary intermediate hosts. Various other piscivorous/semi-piscivorous birds frequent aquatic ecosystems in the present study area. The helminth parasites of these birds also require investigation before a check list of fish-avian helminthic interrelationships for the region can be compiled;
- The complete life histories of the thirteen helminths mentioned in the preceding paragraph, and which do not require freshwater gastropods and fish as intermediate hosts, are not known in absolute detail. This aspect provides an area for future research;
- The present study came to the conclusion that research has, as yet, not even skimmed the surface of avian helminthology and/or fish-avian helminthological interrelationships. In chapter four (p.163) it has been pointed out that the southern African coastal waters are inhabited by no less than 39 species of piscivorous marine birds. This, together with a marine fish population consisting of some 2 200 species, and coupled with an almost non-existing literature on South African marine fish- piscivorous bird parasitic interlinkage, calls for urgent research in this particular field.

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