BRANCHIAL MONOGENEAN PARASITES (MONOGENEA: DACTYLOGYRIDAE) OF FISHES FROM THE OKAVANGO RIVER AND DELTA, BOTSWANA

By

Kevin William Christison

Thesis submitted in fulfilment of the requirements for the degree
Philosophiae Doctorae in the Faculty of Natural and Agricultural Sciences
Department of Zoology and Entomology
University of the Free State

Promotor Prof J G van AS
Co-promotor Prof Linda Basson

June 2002

Genesis 2:19

So out of the ground the LORD God formed every beast of the field and every bird of the air, and brought them to the man to see what he would call them; and whatever the man called every living creature, that was its name.

TABLE OF CONTENTS

CHAPTER 1

Introduction

The Okavango Delta is an internationally acclaimed natural heritage site and is one of Africa's last remaining wetland wilderness areas. It is a unique system presently being the only large river in the world to form an inland delta and has recently been listed as a wetland of international importance according to the Ramsar Convention. Many animals are drawn across hundreds of kilometres of arid Kalahari Desert annually in search of the life giving waters of this vast oasis, which is situated in Northwest Botswana. The water of the Okavango originates as two tributaries, the Cuito and the Cubango, from its catchment in the Angolan highlands, from where they flow together to form the Okavango River. After crossing Namibia's Caprivi Strip and flowing over the Popa Falls, the river flows into Botswana at Mohembo (figure 1.1). For approximately 100 km the river flows predominantly as a single mainstream within a broad riverine floodplain, winding its way through an area colloquially known as the Panhandle (figure 1.1). Approximately 11 billion cubic metres flow through the Panhandle each year, reaching its peak toward the end of summer (February – March), months after the rains have fallen in Angola.

Two geographical fault lines confine the Delta (figure 1.1), the Gumare Fault in the north and the Kunyere Fault in the south. In the vicinity of Seronga Village, the river flows over the Gumare Fault which causes the mainstream to split into three main distributary systems, the Thaoge, the Nqoga and the Jao-Boro System, changing the nature of the river drastically. This forms the northern border of the permanent swamp, a 6000 m^2 wetland of channels, lagoons, floodplains and islands which give the Okavango the character for which it is famed. The southern seasonal swamp covers about one third of the area of the Delta and is seasonally inundated with water, which varies markedly in surface area, depending on the magnitude of the annual flood from Angola and the amount of local rainfall.

Annual flooding of the Delta is primarily dependant on the rainfall patterns in the Okavango catchment in Angola which according to McCarthy and Ellery (1998), receives approximately 1000 mm per annum, with local rainfall having far less impact on the magnitude of the flood. Although most of the water entering the Delta at Mohembo is lost to evapotranspiration, a minimal 2% eventually reaches the Thamalakane River in Maun, approximately six months later (Merron 1991). The rise and fall of the annual floodwaters is considered one of the major driving forces in the Delta. The floodplains resulting from the inundation of low lying regions create vast shallow areas that are suitable for breeding and feeding by many fish species and cause large amounts of detritus from other sources, to enter the food chain.

It has also been reported that the arrival of the floods are responsible for supplying the stimulus for spawning and/or migration of certain fish species, and also provide a means of distributing the fish throughout the system (Welcomme 1979 and Merron 1991). According to Welcomme (1979), the timing and duration of flooding in general determines to a large extent the recruitment, growth and survival rates of wetland fish stocks which, according to Skelton, Bruton, Merron and Van Der Waal (1985), is likely to be the case in the Okavango Swamps as well.

The Okavango Delta houses a rich diversity of fish species which, up until the early 1980's, were only exploited by traditional subsistence fishermen and recreational anglers based at several fishing camps (Alonso, Ashton and Nordin, 2000 and Bills, 1996). According to Skelton (1993), traditional subsistence fishing involves both active and passive methods using fences, traps, hook and line and small lengths of gill nets. These fishing activities also rely on both individual and communal efforts, individuals use rod and line and woven grass or reed baskets, whereas communal efforts include groups of men and women combining to drive fish into bays and backwaters where they are more easily trapped in baskets. Other communal fish exploits occur as the water level in the Okavango floodplains is receding and fish are concentrated in the remaining pools, small groups of 10-20 women, using thrust baskets, form lines to drive and catch fish. A large variety of fish is usually caught by traditional fisheries, including both large and small species, all of which are consumed. According to Balfour (1996), the local Batswana's fishing exploits were always of secondary importance to them as they were primarily agriculturalists relying heavily on cattle and other livestock as their main source of income and protein. The recent outbreak of Contagious Bovine Pleuro Pneumonia, a cattle lung disease, resulted in the slaughter of all the cattle in the Ngamiland district, placing increasing pressure on the river resources to supplement the losses incurred from this large scale cattle cull (Shaw 1998). Although restocking of cattle is underway, the interim years have seen a lack of protein for the poorer rural dwellers throughout the region. In addition Shaw (1998) reports that former cattle owners in the Shakawe region, in particular, are opting for a cash reimbursement rather than replacing their livestock.

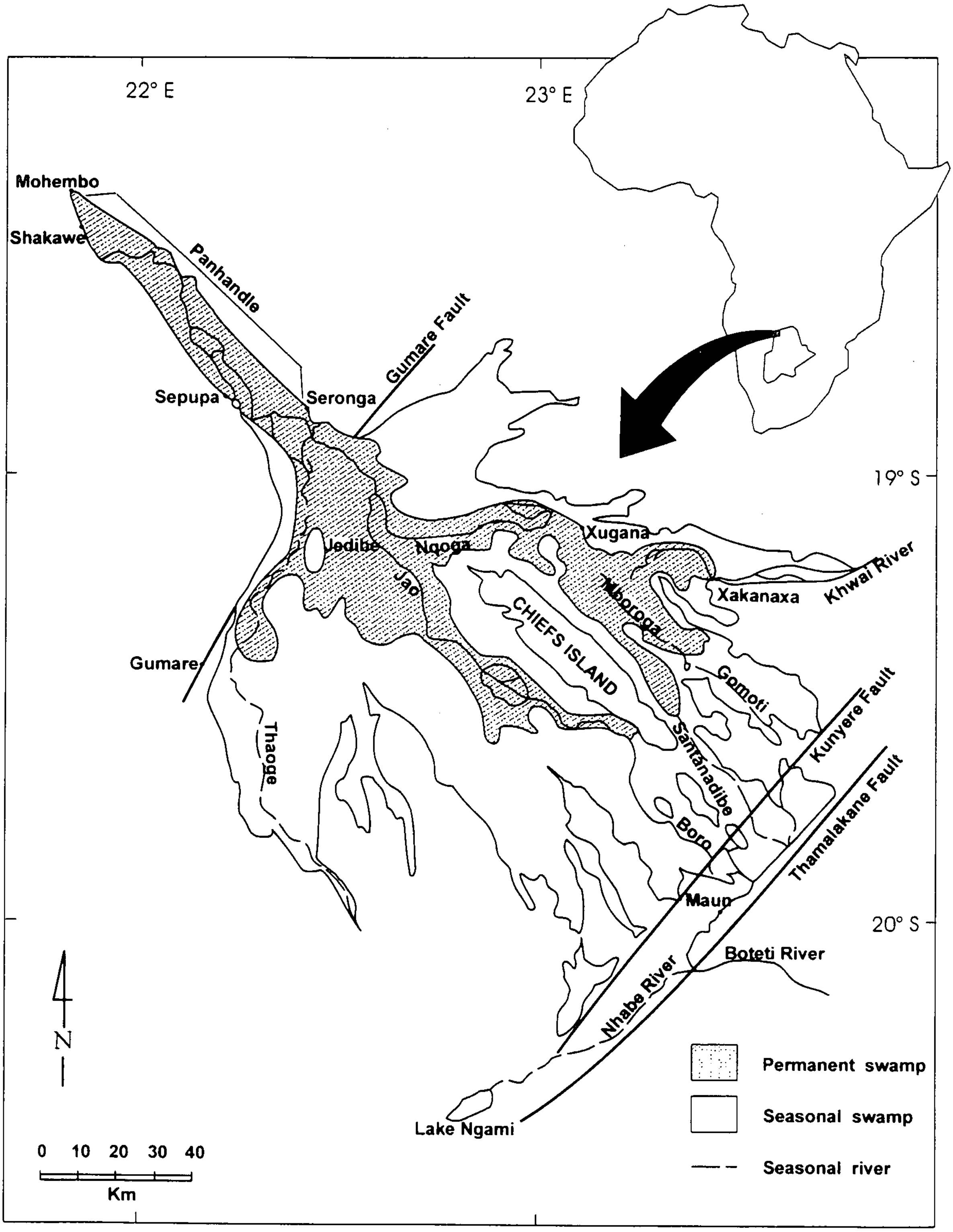

Figure 1.1: Generalised map of the Okavango Delta showing its location, major ecotones, rivers, drainage systems, villages and fault lines.

According to Shaw (1998), Botswana's Department of Agriculture has been interested in developing the fishery resources of the Okavango River. The implementation thereof has been made possible largely through the efforts of the Norwegian Agency for Development Co-operation (NORAD), a foreign aid agency active in Botswana. In 1993 NORAD supplied grants to fishermen to supply them with modern fishing implements like gill nets, seine nets and wire mesh fish traps, which resulted in an increased production efficiency, hence the beginnings of the commercial fishery. According to Alonso *et al.* (2000) the activities of the commercial fishermen are concentrated mainly in the Panhandle region with the rest of the Delta being relatively unexploited by the commercial fishery. Botswana's commercial fishing industry yields on average about 100 metric tonnes per annum and is centred on the distribution of the fish as a protein source to needy villages (Mosepele 2000). This yield is significantly lower than the potential yield of 1200 metric tonnes as estimated by Merron and Bruton (1986). However, the actual yield is biased as not all potential species are equally exploited with the tigerfish (*Hydrocynus vittatus*), various large cichlids (eg. *Oreochromis andersonii, Oreochromis macrochir, Serranochromis macrocephalus* and *Tilapia rendallii*) and some siluriforms (eg. *Clarias gariepinus*) being primarily harvested. According to Alonso *et al.* (2000) efforts to develop a viable fishery for other fish species like the relatively unexploited silver catfish (*Schilbe intermedius*), striped robber (*Brycinus lateralis*) and various other small species have failed as a result of their low market value and local consumer resistance.

Merron and Bruton (1986) report that since the late 1970's the size and numbers of particularly the tigerfish and various cichlid species have decreased. This observation has been confirmed by numerous individuals involved with the fishing industry in the Delta on a daily basis. Merron and Bruton (1986) highlighted a few of the external pressures that may hamper a successful life-cycle of a fish from the Okavango Delta. These pressures included insecticide spraying, recreational and commercial fishing, periods of prolonged drought and natural population oscillations. Although each of these pressures has the capacity to regulate the population numbers of fish, their effects are greatly magnified when acting simultaneously with one another (Merron and Bruton 1986).

Another pressure not noted by Merron and Bruton (1986), which may have an impact on the fish populations of the Okavango, is the prevalence and intensity of ichthyoparasites and or other potential pathogens. Although it is generally accepted that fish parasites do not significantly alter the population size of a particular fish species under natural conditions, their potential threat is exacerbated when one or more of the stresses, highlighted by Merron and Bruton (1986), impairs the resistance of the fish population to a potential pathogen significantly. In view of this, fish parasites may be regarded as secondary contributors to the declining fish stocks of the Okavango Delta. Professor J.G. Van As from the University of the Free State, Bloemfontein, South Africa, submitted a project proposal to the Ministry of Agriculture in Botswana to address this concern regarding the health status of the fish populations in the Okavango River and Delta.

In August 1997, the Ministry of Agriculture of Botswana approved the Okavango Fish Parasite Project (OFPP) as an official project within this Ministry, to be carried out under the auspices of the Kalahari Conservation Society. Permits to conduct this research were issued by the office of the President of Botswana. A comprehensive grant to finance this research, was obtained from the donations fund of Debswana Diamond Company in Botswana and further support was provided by Land Rover South Africa. Additional financial assistance was provided by the National Research Foundation South Africa, under the Inland Resources programme with the emphasis on inland biodiversity and conservation.

The aims of the Okavango Fish Parasite Project are to:

1. Determine the health status of the fish populations of the Okavango River and Delta in Botswana.
2. To compile a data base on the occurrence and distribution of fish parasites in the Okavango Delta.
3. To determine whether any parasite could become a potential threat to any species of fish or to the fish community as a whole.
4. To determine if potential pathogenic organisms could impact on the population density of any fish species.
5. To determine whether any parasite could be a potential threat to aquaculture in Botswana.
6. To determine whether any parasite could be a potential threat to human consumers.
7. To determine if the Okavango System harbours any alien or translocated fish parasites.
8. To elucidate the systematics and life cycles of new parasite species.
9. To expand the knowledge on the ichthyoparasite fauna of African inland waters.
10. To develop local expertise in fish health management programmes.

Since the inception of the OFPP in 1997, 59 of the 68 fish species recorded for the Delta have been collected and examined for parasites. A high diversity of parasite taxa have been recorded including several protozoan genera, a number of crustaceans including copepods and representatives of the Branchiura and numerous helminths including nematodes, acanthocephalans, cestodes, trematodes and monogeneans. Of the metazoan parasites the monogenans were the most prevalent among the fish species collected. The results of the

Okavango Fish Parasite Project thus far have been presented as follows: Various contributions have been made including four poster contributions and 17 papers presented at both national and international conferences. All the abstracts were published in the conference proceedings. Five full length articles have been published in international journals and three masters dissertations have also ensued from the OFPP. The present study and the potential publications ensuing from this study form an integral part of the findings of the OFPP. Although the results presented here are primarily of taxonomic importance, the application of the information gained herein would be of utmost importance when used for fisheries management or for fish health management in the growing aquaculture industry in Botswana.

CHAPTER 2

The class Monogenea

2.1 Introduction

The representative of the class Monogenea (Van Beneden, 1858) are hermaphroditic flatworms that according to Bychowsky (1957), are parasitic on elasmobranch and teleost fish in addition to amphibians, reptiles and parasitic crustaceans and are even known to exist on cephalopod molluscs. A single species is also known from an aquatic mammal, *Occulotrema hippopotami* from the eye of the hippopotamus. Most monogeneans are ectoparasites on the skin and gills of fishes (Llewellyn 1965, Schmidt and Roberts 1989, Euzet and Combes 1998 and Bush, Fernandez, Esch and Seed 2001) and their locations on their hosts are very diversified. Some species, however, are found internally in the diverticula of the stomoderm or proctoderm and also in the ureters of fishes (Schmidt and Roberts 1989).

Monogeneans are believed to be among the most host specific of parasites, suggesting that the diversity of monogeneans worldwide should closely equate the diversity of their hosts. Despite the presence of monogeneans on some amphibians, reptiles, crustaceans, molluscs and mammals, they have their greatest diversity on fish (Lim 1998). Llewellyn (1965) proposed that general speciation among the monogeneans has taken place in correspondence with that of their fish hosts. However, according to Rohde (1996), the number of fish hosts alone cannot be the cause of this great diversity, as there is a distinct latitudinal gradient in relative species diversity for the monogeneans. In other words the number of available hosts is not a limiting factor for species radiation as more than one species of monogeneans are found on a particular host in the tropics. In addition to this, Rohde (1996) proposed that the presence of complex attachment sclerites and complex copulatory sclerites might be important for great species diversity. Both the attachment and copulatory sclerites are possibly a direct consequence of an ectoparasitic way of life that requires a more robust attachment and copulatory mechanisms. The response of the monogeneans to maintaining their ecological position on their host has been the evolution of more efficient, complex attachment apparatus, which, in conjunction with host-specificity may have diverged in the kinds of opisthaptor they have evolved (Llewellyn 1965). Complex attachment sclerites are a contributing factor to strict microhabitat specificity of many monogeneans, and interspecific differences in copulatory sclerites, reproductively isolate species from one another, hence facilitating the coexistence of several monogenean species in the same microhabitat on the same fish species. Another factor contributing to mongenean diversity, according to Rohde (1996), may be the existence of infection mechanisms in the monogeneans that restrict infection to one host species, thereby contributing to host-specificity much greater than in other parasites.

Despite their great diversity, remarkable morphology and considerable economic significance with respect to losses caused in aquaculture, this group has received relatively little attention from parasitologists in the past, particularly in Africa. Schmidt and Roberts (1989) conservatively estimated that less than half of the existing species have been described worldwide, whereas Whittington (1998) suggests that possibly considerably less than 20 % of the total monogenean fauna that may exist are known.

2.2 Systematics of the class Monogenea (Van Beneden, 1858)

The phylum Platyhelminthes includes perhaps the largest clade of obligate parasites, the Monogenea, Cestoda, Digenea and Aspidogastrea, which according to Littlewood, Rohde and Clough (1999), are seen to occupy a pivotal position in early metazoan evolution. Whether in a cladistic or phenetic framework, and from both morphological and molecular perspectives it is the platyhelminths, or the taxon including the representatives of the Platyhelminthes and the Gnathostomulida (the Platyhelminthomorpha) respectively, that have been widely regarded as the earliest divergent bilaterian group and sister group to all other triploblasts (Littlewood *et al.* 1999).

The first author to recognise the monogeneans as a separate group was Van Beneden (1858), who divided the class Trematoda into two divisions, namely the digénèses and the monogénèses (Wheeler and Chisholm 1995). The French term monogénèses was thought to be vernacular and according to Wheeler and Chisholm (1995) was changed to Monogenea by Carus (1863) who was the first author to refer to the group by this name. However, the change from monogénèses to Monogenea is simply an emendation from the original French to a latinised suffix, in accordance with standard nomenclatural practice. Such a minor orthographic change does not justify attributing authorship of the name to Carus (Bychowsky 1957). Van Beneden established the group as a distinct taxon and gave it the scientific name still used today, albeit without a latinised suffix, authorship of the class Monogenea should still be attributed to Van Beneden (1858).

The classification system used by Price (1937) was based on the idea that all monogeneans are divided into two large groups, those having a true vagina, but do not have a genito-intestinal canal and those having a ductus vaginalis and a genito–intestinal canal as proposed by Odhner (1912). Odhner (1912) gave these groups sub-ordinal taxonomic status and named them Monopisthocotylea Odhner, 1912 and Polyopisthocotylea Odhner, 1912 respectively.

Based on the monogenean opisthaptor, which possesses hooks, and the cercomer in the ontogeny of the cestodes, amphilinideans and gyrocotylideans, Bychowsky (1937, 1957) suggested that these four groups were more closely related to each other than to the digeneans. Using this, Bychowsky (1937) elevated the taxon Monogenea from the rank of order to that of class and changed the name to Monogenoidea, although he still credited the authorship to Van Beneden and dismissed the objections of Price (1937) and other workers who still attributed the authorship to Carus. According to Wheeler and Chisholm (1995), most specialists in the former Soviet Union and some workers in other countries adopted Bychowsky's nomenclature for the group, although most specialists in the West continued to use the name Monogenea. Bychowsky's (1957) hypothesis on monogenean evolution was based on comprehensive ontogenetical and anatomical results taking into account the possible co-evolution between the hosts and their monogeneans. The monogenean classification of Bychowsky (1937) has been one of the main systems proposed. It was developed in the mid-thirties and was based on features of larval development and the structure of the hooks in the various groups of monogeneans. The class was hence divided into two sub-classes, namely Polyonchoinea (Bychowsky, 1937) and Oligonchoinea (Bychowsky, 1937).

According to Yamaguti (1963) most of the authors before him based their classification on the external morphology, particularly the cuticularised or sclerotised parts of the body, such as the haptoral anchors, clamp sclerites, copulatory apparatus, etc. Although the hard parts are of taxonomic importance, Yamaguti (1963) also included the internal morphology, particularly that of the genitalia, to represent what he described as a more natural classification of the representatives of the class Monogenea. This classification system, which was merely an elaboration of the scheme proposed by Odhner (1912) and Price (1937) was used as a standard in the literature for many years.

In 1988, Lebedev put forward a classification system based on a development of Bychowsky's approach with regard to other authors views and new faunistic additions. The main difference of this classification system from the others is the addition of an independent subclass Polystomatoinea, which was placed by the previous authors amongst either the lower Monogenea (Polyonchoinea, or Monopisthocotylea), or the higher Monogenea (Oligonchoinea, or Polyopistocotylea). Another significant difference was the introduction of orders within the Monogenea for the first time.

Malmberg (1990) proposed a classification scheme based on the ontogeny of the opisthaptor in which he suggested that the main trend in monogenean evolution is progressive, meaning that there is an increase of marginal hooks during evolution. He further suggested that the earlier theories assumed a reduction of the number of marginal hooklets during evolution, i.e. a regressive evolution.

According to Malmberg (1990), Justine, Lambert and Mattei (1985) also suggested that monogenean evolution was progressive using evolutionary trends in monogenean spermatozoon patterns. Justine (1991) stated that the results of comparative spermatology show disagreement with Malmberg's classification as sperm pattern is indicated for each family, but is not used for the erection of higher ranking taxa used in his classification.

Prior to Justine (1991) the cladistic review of platyhelminth phylogeny and classification was based primarily on ultrastructural characters. Spermatozoal ultrastructure was used by several authors for analysing phylogenetic relationships within the class Monogenea, but until Justine (1991) not with cladistic methods. Within the cercomerideans, which display a rather homogenous spermatozoal structure, the monogeneans are conspicuous because of the great diversity of their sperm structure, which allows recognition of numerous synapomorphies, hence allowing parsimony analysis. In their cladistic studies of the spermatozoan ultrustructure and spermiogenisis of monogeneans, Justine *et al.* (1985) and Justine (1991) found interesting similarities in terms of phylogenetic relationships amongst the monogeneans with Lebedev's (1988) classification, which was based on morphology such as the separation of the representatives of the Monopisthocotylea from that of the Polyopisthocotylea. No synapomorphy could be defined on spermatozoal characters for the entire taxon, hence the suggestion of a polyphyletic lineage of the monogeneans. The problem with these studies is that they proposed a potential phylogeny of the monogeneans based on the characters of a single structure or organ. As suggested by Justine (1991), it is not recommended to define the phylogeny of a group only on the basis of the characters of a single organ or structure such as spermatozoal stucture, hence these results should be tested against data coming from the analysis of other monogenean characters.

A common factor between the above mentioned systems is that they all make use of a single or a few sets of characters, paying less attention to other potentially useful homologies within the group. Boeger and Kritsky (1993) presented a phylogenetic hypothesis for 50 families of monogeneans based on a cladistic study of 47 character series representing both anatomical and ultrastructural features. Their analysis suggested two primary clades, the subclass Polyonchoinea representing 18 families and a second clade comprising two subclasses, the Polystomatoinea (with two families) and the Oligonchoinea (with 30 families). Lebedev (1995) proposed an emended version of his 1988 classification system, which is more or less congruent with Boeger and Kritsky (1993). There are, however, a few minor differences, which Lebedev (1995) attributes to the definition of homologous character series or the choice of pleisomorphies and apomorphies and agrees that both his, as well as the Boeger and Kritsky's (1993) hypothesis still need to be tested. In 1997, Boeger and Kritsky proposed a revised hypothesis of monogenean phylogeny, specifically the representatives of the subclass Polyonchoinea, based on new ultrastructural and anatomical data. This coevolutionary analysis suggested that the monogeneans underwent sympatric speciation on ancestral Gnathostomata resulting in the same two primary clades derived by Boeger and Kritsky (1993). These two clades apparently co-speciated independantly with the divergence of the Chondrichthys and Osteichthys. According to Boeger and Kritsky (1997), the monogenean subclasses Oligonchoinea and Polystomatoinea developed upon the divergence of the Chondrichthys and Osteichthys, with the subclass Oligonchoinea associated with the chondrichthyans and the polystomatoineans with the osteichthyans. Subsequent host switching (dispersal) or extinction events occurred in these parasite clades.

According to Justine (1998), there is currently no congruence between phylogenies based on morphology, in which the monogeneans are considered a monophylum, and the molecular phylogenies based on 18S or 28S rDNA, in which the Monogenea are never considered monophyletic. All analyses based on morphology and spermatozoal characters or molecular data constantly found the two subgroups composing the class Monogenea to be independantly monophyletic. This conflict concerns not only the monophyly of the Monogenea, but also the relationships of the monopisthocotyleans and polyopisthocotyleans with the trematodes and cestodes, and therefore the phylogeny of the parasitic platyhelminths as a whole.

Littlewood *et al.* (1999) used a data matrix of 65 morphological characters from 25 ingroup and six outgroup taxa, and an alignment comprising complete 18S rDNA sequences from 82 species of parasitic and free-living platyhelminths, and from 19 species of lower invertebrates to analyse the phylogenetic relationships of the various platyhelminth taxa. These data supported many of the findings in earlier studies. It supports the monophyly of the neodermatans and of the trematodes, monogeneans and cestodes within them. Concerning the monophyly of the Monogenea, the tree based purely on DNA differed in respect from the tree using combined morphological and DNA data. In the DNA trees, the Polyopisthocotylea are basal to the Monopisthocotylea and the latter to the cestodes, in other words, the two monogenean groups are closely related but paraphyletic (having evolved from a single ancestral form but not including all the decendants).

Boeger and Kritsky (2001) included the homologous series of Boeger and Kritsky (1993, 1997) and combined them with series containing information on sperm morphology and development. In the resulting hypothesis for monogenean classification, the clades containing the subclass Polystomatoinea and the subclass Oligonchoinea were reduced to Infra-subclass level with a new subclass, the Heteronchoinea being proposed to incorporate both the representatives of the Polystomatoinea and Oligonchoinea.

The classification of the class Monogenea (table 2.1) for the rest of this dissertation will be according to Boeger and Kritsky (2001), as this system is the most recent and most representative in terms of the phylogenetic relationships within the group.

Table 2.1. Classification of the class Monogenea (Van Beneden, 1858) adapted from Boeger and Kritsky (2001)

SUBCLASS	INFRA SUBCLASS	ORDER	SUBORDER	INFRA ORDER	SUPER FAMILY	FAMILY
Polyonchoinea (Bychowsky, 1937)		Monocotylidea				Monocotylidae
						Loimoidae
		Capsalidea				Dionchidae
						Capsalidae
		Lagarocotylidea				Lagarocotylidae
		Motchadskyellidea				Montchadskyellidae
		Gyrodactylidea				Tetraonchoididae
						Bothitrematidae
						Anoplodiscidae
						Udonellidae
						Gyrodactylidae
						Acanthocotylidae
		Dactylogyridea	Calceostomatinea			Calceostomatidae
			Neodactylodiscinea			Neodactylodiscidae
			Amphibdellatinea			Amphibdellatidae
			Tetraonchinea			Sundanonchidae
						Tetraonchidae
						Neotetraonchidae
			Dactylogyrinea			Dactylogyridae
						Diplectanidae
						Psuedomurraytrematidae
Heteronchoinea, (Boeger & Kritsky, 2001)	Polystomatoinea (Lebedev, 1986)	Polystomatidea				Polystomatidae
						Sphyranuridae
	Oligonchoinea (Bychowsky, 1937)	Chimaericolidea				Chimaericolidae
		Diclybothriidea				Diclybothriidae
						Hexabothriidae
		Mazocraeidea	Mazocraeinea			Plectanocotylidae
						Mazoplectidae
						Mazocraeidae
			Gastrocoltylinea	Anthocotylinea		Anthocotylidae
				Gastrocotylinea		Psuedodiclidophoridae
					Protomicrocotyloidea	Allodiscocotylidae
						Psuedomazocraeidae
						Chauhaneidae
					Gastrocotyloidea	Bychowskycotylidae
						Gastrocotylidae
						Neothoracocotylidae
						Gotocotylidae
			Discocotylinea			Discocotylidae
						Diplozoidae
						Octomacridae
			Hexostomatinea			Hexostomatidae
			Microcotylinea		Microcotyloidea	Axinidae
						Diplasiocotylidae
						Heteraxinidae
						Microcotylidae
					Allopyragraphoroidea	Allopyragraphoridae
					Diclidophoroidea	Diclidophoridae
					Pyragraphoroidea	Pterinotrematidae
						Rhinecotylidae
						Pyragraphoridae
						Heteromicrocotylidae

2.3 Monogenean research in Africa

Of the five families of the class Monogenea that infest African freshwater fishes, three are representatives of the subclass Polyonchoinea, namely Gyrodactylidae Cobbold, 1864, Dactylogyridae Bychowsky, 1933 and Diplectanidae Bychowsky, 1957. Only two families of the subclass Oligonchoinea, namely Diplozoidae Tripathi, 1959 and Diclidophoridae Cerfontaine, 1859, have been found infesting African freshwater fishes (Khalil and Polling, 1997).

The first record of monogeneans from African freshwater fish was by Wedl (1861) who described a dactylogyrid, *Dactylogyrus gracilis* Wedl, 1861 from *Hydrocynus forskalii* (Cuvier, 1819). This monogenean was later placed in the genus *Neodactylogyrus* Price, 1938. The generic diagnosis of this monogenean was again emended by Paperna (1973) who placed it in the genus *Annulotrema* Paperna and Thurston, 1969, based on the tegumental annulation and opisthaptoral hook arrangement. Monogenean research in Africa has relied chiefly on the works of a few scientists who have conducted studies in north and west Africa.

Since the late sixties to early eighties, Paperna laid the foundation for monogenean research in Africa. In this time he described numerous species and also created 11 genera. Paperna concentrated his work to Uganda and Ghana and also did some work in Tanzania and Kenya.

Apart from Paperna, many French scientists like Birgi, Euzet, Guegan, Lambert and their co-workers made meaningful contributions from the late seventies to the present. These contributions are, however, concentrated to the West African countries, which were previously colonised by the French.

The monogenean research conducted in southern Africa, which includes countries like Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe, is very sparse. According to Khalil and Polling (1997) there are no monogenean records for Angola, Botswana, Lesotho, Mozambique, Namibia and Swaziland. The rest of the southern African countries do have monogenean records, which are represented by one off studies and hence do not represent many species. Zimbabwe has the most records (25 species) of monogeneans in southern Africa due to the work of Douëllou in the early nineties, followed by South Africa (16 species), Zambia (3 species) and Malawi (2 species).

2.4 Monogeneans from Botswana

Genera of African dactylogyrids are either endemic to Africa or belong to genera with wider geographical ranges. In general dactylogyrids are highly host specific parasites and their zoogeographical affinities are therefore linked to the faunistic origin of their host fishes. The distribution pattern of dactylogyrid species within Africa is determined by the distribution pattern of their hosts.

Fishes of the Okavango Delta are diverse and represent 12 families. Various monogeneans were collected from the Okavango Delta and monogenean genera were found to be specific to the respective fish families they infested. The following genera were collected from their representative hosts from the Okavango Delta in a series of surveys spanning four years.

Class: Monogenea (Van Beneden, 1858)
Subclass: Polyonchoinea Bychowsky, 1937
Order: Dactylogyridea Bychowsky, 1937
Suborder: Dactylogyrinea Bychowsky, 1937
Family: Dactylogyridae Bychowsky, 1933
Subfamily: Dactylogyrinae Bychowsky, 1933

Genus: *Characidotrema* Paperna and Thurston, 1968

Species of the genus *Characidotrema* Paperna and Thurston, 1968 are parasites of characiform fish in Africa. This genus is represented by 10 species (appendix 1), only infesting fishes in the family Characidae. These species share many common characteristics with the closely related Neotropical genus, *Jainus* Mizelle, Kritsky and Crane, 1968, but is now considered as a separate genus (Kritsky, Kulo and Boeger 1987). The generic diagnosis of this genus is summarised in table 2.2.

Table 2.2 Generic diagnosis of the genus *Charcidotrema* Paperna and Thurston, 1968 according to Kritsky, Kulo and Boeger (1987).

	Characidotrema Paperna and Thurston, 1968
BODY	• Cuticle usually thick, spinous, ciliated, papiliated or gently annulated • Long strips of muscles extend along two sides of body, from prohaptor to opisthaptor
HAPTOR	• Opisthaptor is fully merged with posterior end of body • Both opisthaptor and anchors reduced in size • Outer root of ventral anchors far larger than inner root • Marginal hooklets arranged in two groups of seven hooklets
DIGESTIVE TRACT	• Intestine consists of two caeca which do not unite posteriorly
FEMALE REPRODUCTIVE SYSTEM	• Vagina opens on left of body • Vaginal wall is muscular • Seminal receptacle present • Vitelline follicles massed on both sides of ovary-testis zone
MALE REPRODUCTIVE SYSTEM	• Testis located dorsoposterior to ovary • Copulatory organ consists of rounded funnel, tubular cirrus and accessory piece • Prostatic glands and seminal vesicle present
GENERAL	• Cephalic region and organs well delimited from rest of body • Four eyes present • Pharynx present, usually muscular • Type species: *Characidotrema elongata* Paperna and Thurston, 1968

Genus: *Dactylogyrus* Diesing, 1850

Species of the genus *Dactylogyrus* Diesing, 1850 are parasites of cyprinid fish. In Africa, this genus is represented by 94 species (appendix 1), only infesting fishes in the family Cyprinidae. The generic diagnosis of this genus is summarised in table 2.3.

Table 2.3 Generic diagnosis of the genus *Dactylogyrus* Diesing, 1850, according to Price (1967)

	Dactylogyrus Diesing, 1850
HAPTOR	• Opisthaptor usually terminal • Single pair of anchors supported by a connecting bar • Ventral bar may or may not be present • Marginal hooklets arranged in two groups of seven hooklets
FEMALE REPRODUCTIVE SYSTEM	• Vagina present or absent and position is variable
MALE REPRODUCTIVE SYSTEM	• Copulatory organ consists of tubular cirrus articulated to accessory piece basally • Vas deferens usually looped around intestinal limb • Seminal vesicle is a simple dilation of the vas deferens • One or two prostatic reservoirs may be present
GENERAL	• Four eyes present • Type species: *Dactylogyrus auriculatus* Diesing, 1850

Genus: *Quadriacanthus* Paperna, 1961

The genus *Quadriacanthus* Paperna, 1961 is represented by 25 species most of which have been recovered from siluriform fish (appendix 1). A single species *Q. tilapiae* Paperna, 1973 was recorded from the cichlid *Tilapia esculenta* Graham, 1928 but this record seems doubtful. According to Paperna (1979), this genus shares some common characteristics with *Bychowskyella* Akhmerov, 1952 which is found on Palearctic Bagridae. The generic diagnosis of this genus is summarised in table 2.4.

Table 2.4 Generic diagnosis of the genus *Quadriacanthus* Paperna, 1961 according to Kritsky and Kulo (1988)

	Quadriacanthus Paperna, 1961
BODY	• Can be divided into cephalic region, trunk, peduncle and haptor • Tegument is thin and smooth
HAPTOR	• Dorsal and ventral anchor pairs • Anchors with basal accessory sclerite • Ventral and dorsal bars present • Posterior muscular pad between bars • 7 pairs of hooklets with ancyrocephaline distribution
DIGESTIVE TRACT	• Mouth subterminal, oesophagus short • 2 intestinal caeca
FEMALE REPRODUCTIVE SYSTEM	• Oviduct short • Vitellaria well developed • Common vitelline duct anterior to seminal receptacle
MALE REPRODUCTIVE SYSTEM	• Testis dorsal to ovary • Vas deferens looping left of intestinal caecum • Seminal vesicle dilation of vas deferens • 2 prostatic reservoirs • Copulatory complex comprising basally articulated cirrus, accessory piece
GENERAL	• Eyes present or absent, granules usually scattered in cephalic area • Pharynx muscular, glandular • Type species: *Quadriacanthus clariadis* Paperna, 1961

Genus: *Schilbetrema* Paperna and Thurston, 1968

The genus *Schilbetrema* Paperna and Thurston, 1968 is represented by 15 species (appendix 1). The generic diagnosis of this genus is summarised in table 2.5.

Table 2.5 Generic diagnosis of the genus *Schilbetrema* Paperna and Thurston, 1968 according to Kritsky and Kulo (1992)

	Schilbetrema Paperna and Thurston, 1968
BODY	• Divided into cephalic region, trunk, peduncle and haptor • Tegument thin and smooth
HAPTOR	• Dorsal and ventral anchor pairs • Dorsal and ventral connecting bars • 7 pairs of marginal hooklets
DIGESTIVE TRACT	• Mouth subterminal, midventral • Oesophagus present • 2 intestinal caeca, confluent posterior to gonads
FEMALE REPRODUCTIVE SYSTEM	• Oviduct short • Uterus delicate • Vagina dextral • Vitellaria dense
MALE REPRODUCTIVE SYSTEM	• Testes dorsal to ovary • Vas deferens looping left of intestinal caecum, with constriction at union with seminal vesicle • Seminal vesicle fusiform • Prostatic reservoir close to cirral base • Copulatory organ comprising cirrus, accessory piece articulating to dorsal surface of cirral base
GENERAL	• Eyes generally compact, granules large, sub-spherical • Type species: *Schilbetrema quadricornis* Paperna and Thurston, 1968

Subfamily: Ancyrocephalinae

Genus: *Annulotrema* Paperna and Thurston, 1969

The genus *Annulotrema* Paperna and Thurston, 1969, are parasites of characiform fish, particularly of the representatives of the families Hepsetidae and Characidae. This genus is represented by 46 species, which have all been described from Africa (appendix 1). The genus *Annulotrema* is closely related to the Neotropical genus *Annulotrematoides* Kritsky and Boeger, 1995, which has similar host preferences and morphological characters. The generic diagnosis of this genus is summarised in table 2.6.

Table 2.6 Generic diagnosis of the genus *Annulotrema* Paperna and Thurston, 1969 according to Paperna and Thurston (1969a)

	Annulotrema Paperna and Thurston, 1969
BODY	• Posterior half covered by thick annulated cuticle
HAPTOR	• Well delineated from body and divided into 2 zones • Proximal zone has 2 lateral bunches of large hooklets, 7 in each bunch • Posterior zone has 2 pairs of anchors and 2 bars • Anchor shaft usually elongated and delicate, while spike is very small • Roots of anchors very solid and well delineated from anchor shaft • An additional small process located between inner and outer roots may develop into additional root in some species
DIGESTIVE TRACT	• Intestinal caeca united posteriorly
FEMALE REPRODUCTIVE SYSTEM	• Vagina opening sinistral • Seminal receptacle and 2 lateral vitelline vesicles present
MALE REPRODUCTIVE SYSTEM	• Copulatory organ consists of cirrus, an accessory piece, seminal vesicle and a prostate gland • Testis located ventral or slightly posterior-ventral to the ovary
GENERAL	• 4 eyes • Parasites of the fish of the family Characidae • Type species: *Annulotrema gravis* Paperna and Thurston, 1969

Genus: *Bouixella* Euzet and Dossou, 1976

The genus *Bouixella* Euzet and Dossou, 1976 was created to include a unique group of ancyrocephaline monogeneans which have only been encountered on fish representatives of the family Mormyridae. To date only eight species (appendix 1) have been described including *Bouixella mormyrus* (Paperna, 1973), which was originally described as *Ancyrocephalus mormyrus* from *Mormyrus niloticus* Bloch and Steindachner, 1801 from Tanzania. The generic diagnosis of this genus is summarised in table 2.7.

Table 2.7 Generic diagnosis of the genus *Bouixella* Euzet and Dossou, 1976 according to Euzet and Dossou (1976).

	Bouixella Euzet and Dossou, 1976
BODY	• Divided into cephalic region, body and haptor
HAPTOR	• Dorsal and ventral anchor pairs • Dorsal and ventral connecting bars • 7 pairs of marginal hooklets
DIGESTIVE TRACT	• Intestinal caeca unite posteriorly
FEMALE REPRODUCTIVE SYSTEM	• Vagina sclerotised
MALE REPRODUCTIVE SYSTEM	• Copulatory organ present, articulates with accessory piece at its base • Seminal vesicle and prostatic reservoir present
GENERAL	• 4 pairs of eyes present • Type species: *Bouixella mormyrume* Euzet and Dossou, 1976

Genus: *Cichlidogyrus* Paperna, 1960

The genus *Cichlidogyrus* Paperna, 1960 are parasites of cichlid fish. This genus is represented by 65 species, which have all been described from Africa (appendix 1). The generic diagnosis of this genus is summarised in table 2.8.

Table 2.8 Generic diagnosis of the genus *Cichlidogyrus Paperna,* 1960 according to Paperna (1979).

	Cichlidogyrus Paperna, 1960
BODY	• Can be divided into cephalic region, trunk, peduncle and haptor • Tegument is thin and smooth
HAPTOR	• Dorsal and ventral anchor pairs • Dorsal and ventral connecting bars • 7 pairs of marginal hooklets
DIGESTIVE TRACT	• Mouth sub-terminal, oesophagus short • 2 intestinal caeca
FEMALE REPRODUCTIVE SYSTEM	• Oviduct short • Vitellaria well developed • Common vitelline duct anterior to seminal receptacle
MALE REPRODUCTIVE SYSTEM	• Testis dorsal to ovary • Seminal vesicle and prostatic reservoirs present • Copulatory complex comprising basally articulated cirrus and accessory piece
GENERAL	• 4 pairs of eyes present • Type species: *Cichlidogyrus tilapiae* Paperna, 1960

CHAPTER 3

Materials and methods

3.1 Fieldwork

The Okavango Delta is approximately 2000 km from Bloemfontein, a journey that usually takes two to three days. Due to the vast distance that has to be travelled, field trips are usually no shorter than one month and usually continue for two to three months. The implication of such extensive field trips is that all equipment and luggage has to be transported there.

The accommodation for the duration of these trips is either in the tented camps provided by the various tourist lodges on the banks of the river (e.g. Drodsky's Cabins, Shakawe Fishing Camp, Xaro Lodge and Guma Lagoon), or in two-man tents. Working from the tented camps limits the diversity of the sampling localities. In order to sample a diversity of habitats, sampling is frequently done from remote sites, where there are no facilities and which are unreachable by road. These sites are reached by boat, which is limited for space. On trips like these, a reduced field laboratory is used and an electricity generator is used as a power supply for the microscopes.

As most processing of the material takes place in the field, fixation and preservation methods are kept as simple as possible. The fieldwork is conducted by the Aquatic Parasitology study group from the Department of Zoology and Entomology, University of the Free State, Bloemfontein, South Africa. Each member of the group concentrates on a different group of parasites and hence each fish that is collected is optimally utilised.

3.2 Study area

The Okavango Delta (figure 3.1) is situated in northwestern Botswana and is an extension of the East African Rift Valley System. It is a large, low gradient, alluvial fan located in a depression of the earth's crust between two parallel geological faults. This fan has formed in response to geological processes, especially the presence of an internal drainage system, as well as rifting (Mc Carthy and Ellery, 1998).

The affluent Okavango River originates on the southern slopes of the Angolan highlands. After crossing Namibia's Caprivi Strip, it enters Botswana at Mohembo. On flowing into Botswana, the Okavango River flows in a series of exaggerated S-bends amid two banks of Kalahari sand set about a kilometre apart. This region is colloquially known as the Panhandle. Just south of the village of Seronga, the Okavango River flows over a geographical fault line (the Gumare Fault) giving the Delta the nature for which it is famed. Here the mainstream channel divides into three distributary channels; the Thaoge Channel, the Nqoga Channel and the Jao

Channel; which act as the arteries of the Delta, providing the life sustaining water to the numerous channels, pathways and inundated swamps.

The area of the Delta fluctuates from 15000 km^2 in the flood season to 6000 – 8000 km^2 in the dry season. Flooding is seasonal and water levels usually start to rise, at the Panhandle of the Delta, in January with peak flow occurring between March and May. The water slowly percolates through the perennial and seasonal swamps, reaching the drainage rivers in the south about five to six months later. Southern water levels at Maun usually peak between June and September (Merron, 1991 and Booth and McKinlay, 2001) depending on the timing and magnitude of the flood. Changes with respect to water quality, temperature and oxygen content, brought about annually by the flood, impact directly on the animals dependant on the Delta (Merron, 1991). According to Skelton *et al.* (1985), the floods create vast shallow areas that are suitable for breeding and feeding by many species.

The nature of the Okavango environment has been radically shaped by its biota and hence the character of the fan is as much the product of biological processes as it is of its geographical and geological environment (McCarthy and Ellery 1998). Merron (1991) divided the Okavango Delta into five ecological regions, namely the riverine floodplain, the permanent swamp, the seasonal swamp, drainage rivers and the sump lakes. The regions described by Merron (1991) are regarded as habitat types within two larger ecotones or ecological regions rather than as separate isolated regions. Due to the diverse nature of the Okavango Delta, two ecotones can be determined which represent various habitat types. The ecotones of the Panhandle region and swamps south of the Gumare Fault to Maun, are clearly segregated with respect to both their physical natures of the habitats represented by the regions as well as the biota inhabiting these habitats.

Alonso *et al.* (2000) further divided the two ecotones into four focal areas. They divided the Panhandle region into the upper Panhandle and the lower Panhandle. According to Alonso *et al.* (2000), the upper Panhandle is characterised by high fish diversity with a different composition of species to that of the lower Delta. Plant diversity here was low and aquatic bird diversity good. Aquatic invertebrate diversity was low in the upper Panhandle due to the high water levels and flow rates. The lower Panhandle had moderate fish diversity, which was lowest and isolated in Guma Lagoon. This focal area exhibited a high diversity in plant species and like the upper Panhandle had good aquatic bird diversity and low aquatic invertebrate diversity, probably due to low oxygen levels. The Moremi Reserve focal area was characterised by good fish diversity, the highest plant diversity and higher diversity of aquatic invertebrates than recorded in the Panhandle region. The Chiefs Island focal area had moderate fish diversity, but had species unique to this region and a relatively high diversity of bream species. Alonso *et al.*

(2000) recorded high plant diversity in this region with a lack of dominance by any species. Once again a higher aquatic invertebrate diversity was recorded in this region than in the Panhandle region.

Within the primary ecological regions various habitat types were identified based on physical properties characteristic to these habitats. At each sampling locality, all the available habitats available were sampled. The various habitat types include Okavango mainstream, river channels, floodplains, backswamps (backwaters), lagoons, perennial swamp (permanent swamp) and seasonal swamps (temporary swamp).

- **Mainstream** - This habitat is characterised by fast flowing water with a sandy substrate. This habitat is found in the Panhandle or in the major distributary rivers where the river is deep and fast flowing.
- **Channels** - This habitat type is very similar to that of the mainstream. It differs from the mainstream in being narrower and shallower. These channels are open-ended and originate from a mainstream habitat and terminate in the same habitat further downstream. The channels are also characterised by flowing water. These habitats are frequently blocked by papyrus rafts and are cleared either manually or by flooding.
- **Backwaters** - The backwaters are also mainly associated with the mainstream habitats and are represented by adjacent channel-like water bodies in which there is no current or water flow and they are not open on both ends. These water bodies are distinguished from floodplains by being permanent.
- **Floodplains** - The floodplains are usually shallow temporary water masses on the marginal land which are inundated during the floods in winter and recede progressively during the hot summer.
- **Lagoons** - These are large, deep, open water masses and are usually associated with channels or the mainstream habitats. In some cases, the channel leading to and from the lagoons block up, isolating the lagoon.
- **Permanents swamps** - These are found in the southern Delta and are characterised by shallow stationary waters. These swamps are littered with islands and are always inundated with water and form the low water mark at the end of summer before the floods.
- **Temporary swamps** - Temporary swamps are found at the margin of the permanent swamps and are also characterised by shallow, stationary water. These swamps vary in size according to the magnitude of the flood. When in flood they represent the high water mark of the flood and recede gradually throughout the following year.

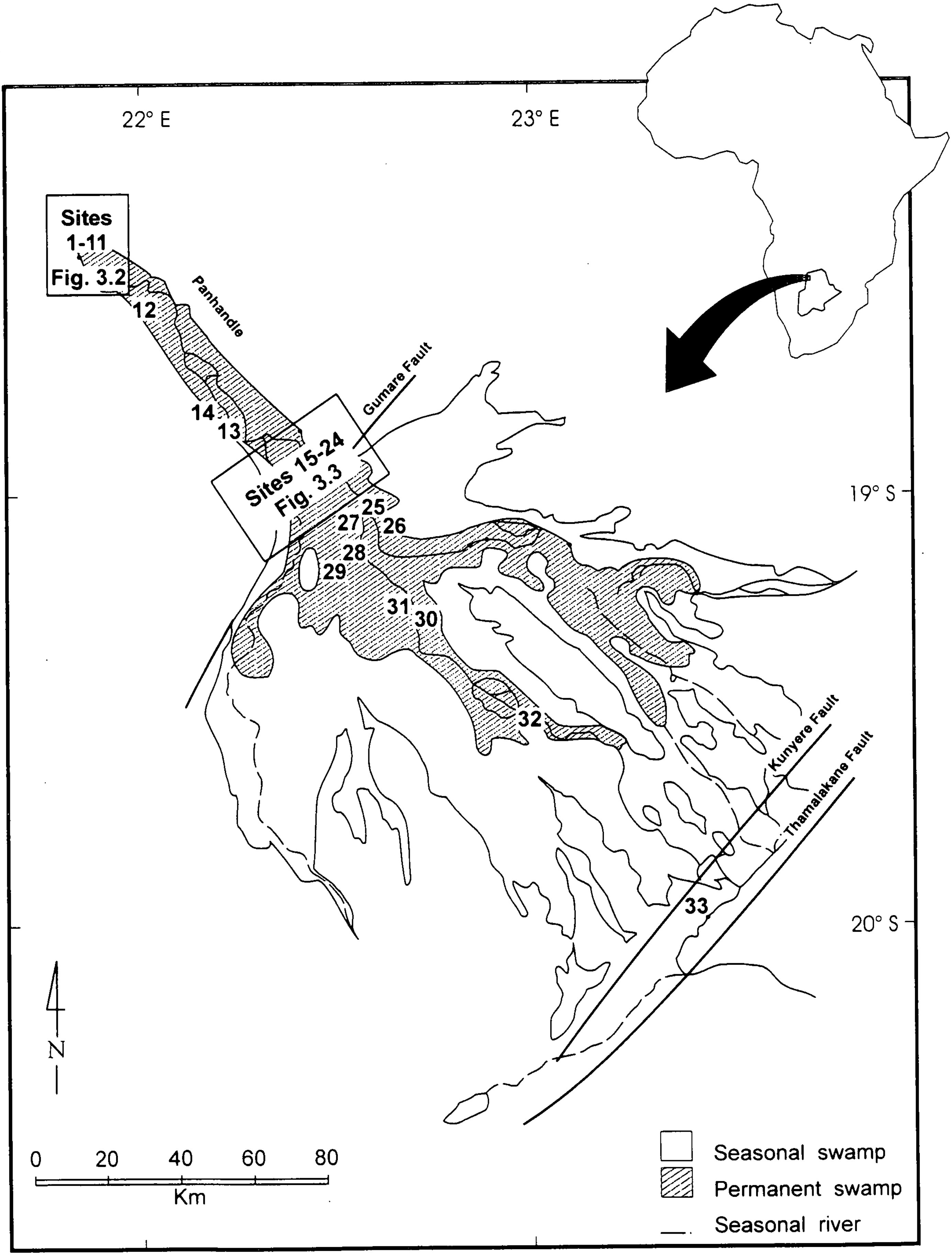

Figure 3.1 Map of the Okavango Delta showing the specific locations of all sampling localities.

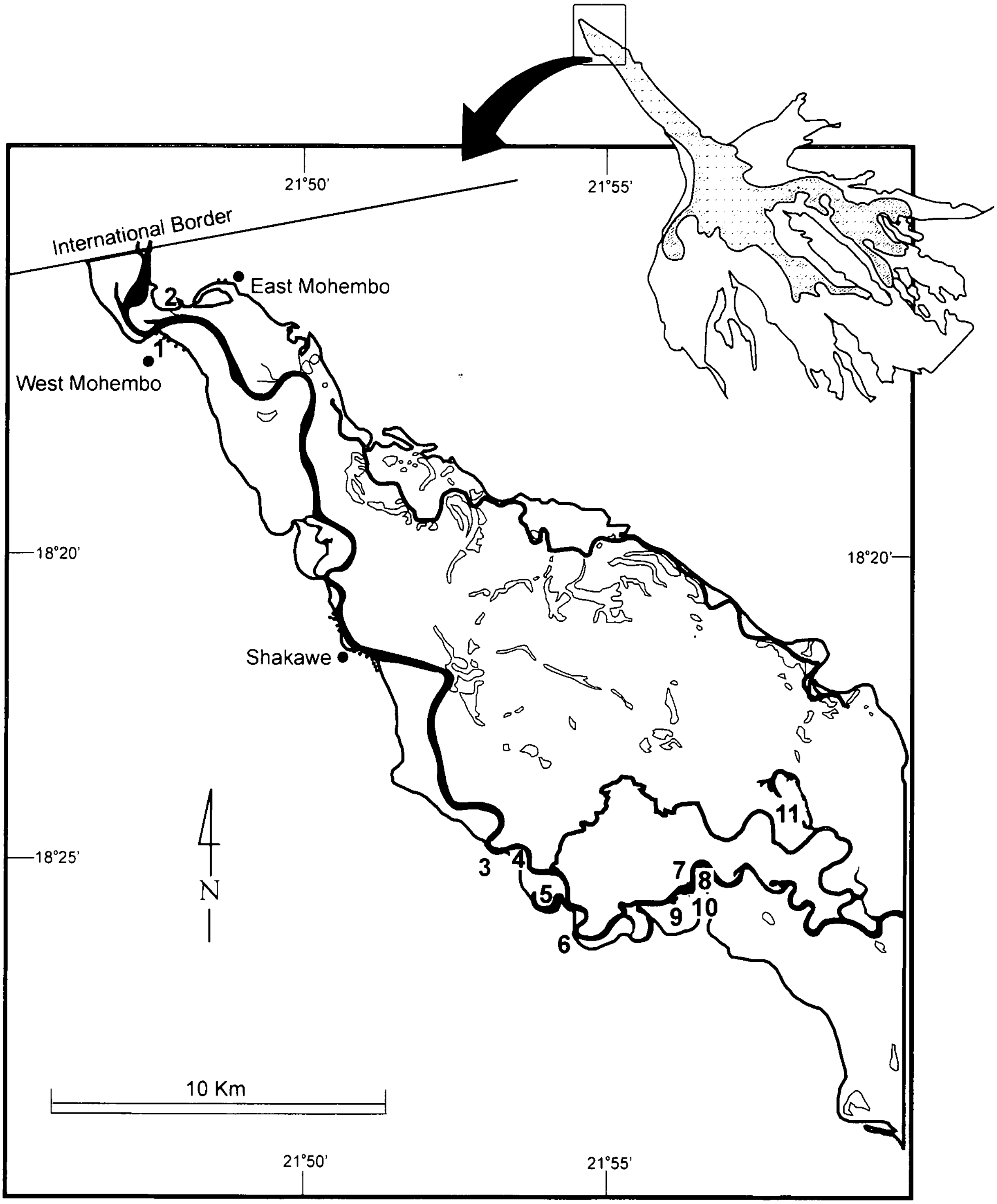

Figure 3.2 Map of the upper Panhandle region of the Okavango Delta showing specific locations of sampling localities 1-11.

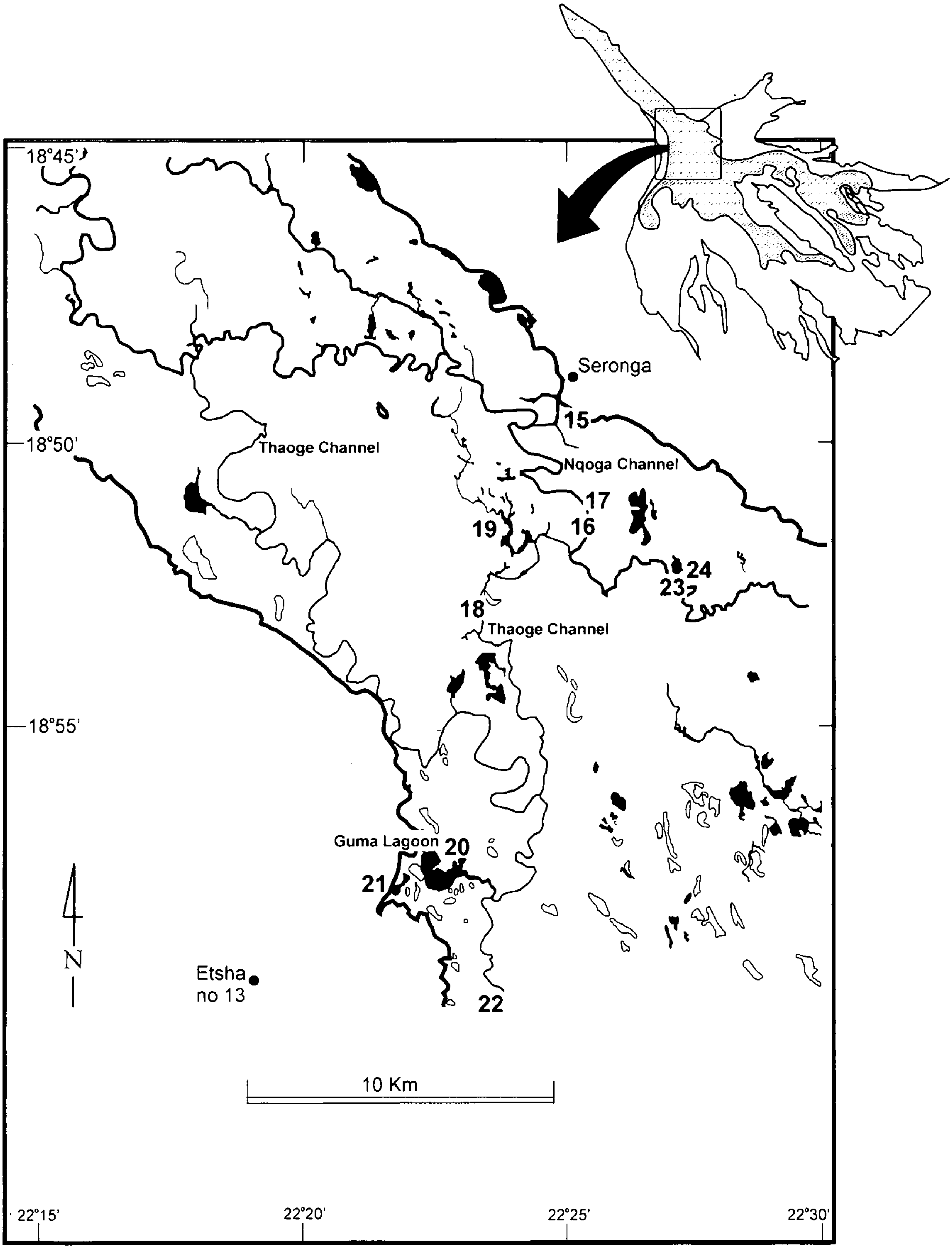

Figure 3.3 Map of lower Panhandle and upper swamp region of the Okavango Delta showing specific locations of sampling localities 15-24

3.3 Collection of fish

The collection methods for the fish varied according to their habitat preferences. When the water was very shallow and formed small pools as encountered in the floodplains and swampy areas, a variety of hand held scoop nets were used. In slightly deeper water, like that of the backwaters, lagoons, swamps and the margins of the main channel over sandbanks, cast nets were effective for the collection of a wide variety of fish hosts. Gill nets were also effective in deep lagoons, channels or backwaters. These nets consisted of a graded series of lengths, each 10 m long and each of a different mesh size. The minimum mesh size was 40 mm and the maximum of 140 mm (40 mm, 70 mm, 90 mm, 100 mm, 110 mm, 120 mm and 140 mm). These nets were set at dusk, left overnight and lifted the following morning at sunrise.

Other collection methods were also used with varying degrees of success. Seine nets were occasionally used in floodplain pools that were too large for the hand held nets to be effective. Using a fishing rod was particularly effective for collecting species like the tigerfish, which are found in the mainstream channel, where the current is too strong for nets to be effective. Electro-fishing apparatus was also used and was effective in the marginal areas of the mainstream and over sandbanks. This method, however, was not excessively used as the above-mentioned methods were far more effective and less labour and time consuming.

3.4 Examination of hosts

After collection, the fishes were taken to a field laboratory where they were examined. As far as possible the fish were kept live and were placed in a temporary holding tank for examination. Upon examination the fishes were anaesthetised and the gills were removed.

After the live observations and counting of the monogeneans, the gill arches were placed in a 1: 4 000 formalin solution for about half an hour. This solution is insufficient to fix the monogeneans, but will kill them in a relatively short time. After the monogeneans were dead, they were fixed in a 10 % neutral buffered formalin solution, still attached to the host tissue. This method of killing and fixing ensures that very few monogeneans contract on contact with the formalin and most of the specimens collected were relaxed.

In the laboratory in Bloemfontien the fixed material was re-examined and individual parasites were identified.

3.5 Light microscopy preparation

In preparation for compound light microscopy, the specimens were removed from the gill tissue individually and mounted either in a ammonium picrate glycerine solution similar to that used by Malmberg (1957), to study the opisthaptoral armature, or stained in Gomori's trichrome (Kritsky, pers. com.) and mounted in Canada Balsam mounting medium for the study of the internal organs. The latter method had limited success and hence the former was used almost exclusively as in some specimens, the internal structures were also visible and formalin fixed material often did not take up sufficient stain.

AMMONIUM PICRATE GLYCERINE

Neutral Buffered Formalin 10 %	1 part
Glycerine	9 parts
Picric acid	

Mix formalin and glycerine. Add 1 drop of the Picric acid for every 10 ml solution.

GOMORI'S TRICHROME

Chromotrope 2R (C. I. 16570)	0.6 g
Aniline blue WS (C. I. 42780)	0.6 g
Phosphomolybdic acid	1.0 g
Distilled water	100.0 ml
Hydrochloric acid	1.0 ml

Dissolve stains in distilled water, add hydrochloric acid, allow to stand for 24 hours, store in dark container, DO NOT filter. It is recommended that the stain be stored in a refrigerator.

3.6 Morphological measurements

With the exception of specimens from the genus *Cichlidogyrus* and *Quadriacanthus*, measurements of the sclerotised parts of all specimens were according to N'Douba, Pariselle and Euzet (1997). Six basic measurements, i.e. total length (A), base width (B), inner root (C), outer root (D), shaft (E) and the tip (F) were obtained from the opisthaptoral anchors (figure 3.4). The dorsal and ventral bars were measured in terms of their total length (G) and width (H) (figure 3.4). The marginal hooklets were numbered according to the system proposed by Malmberg (1990) and only their total length was measured (I) (figure 3.4). The total length of the cirrus (J) as well as the accessory piece (K) were measured and not only the length of their axis (figure 3.4).

Quadriacanthus specimens were measured according to N'Douba, Lambert and Euzet (1999). Three basic measurements were obtained from the anchors, total length (A), base width (B) and the tip (C). Both the dorsal and ventral anchors possessed an accessory sclerite, which was measured in length (D) and breadth (E), respectively. The half-length of the dorsal bar was measured (F) as well as the centrum height (G) and the median process length (H) (figure 3.5). Half of the ventral bar was measured (I) and its width was measured at its widest point (J) (figure 3.5). The marginal hooklets were numbered according to the system proposed by Malmberg

(1990) and only their total length was measured (K) (figure 3.5). The total length of the cirrus (L) as well as the accessory piece (M) were measured and not only the length of their axis (figure 3.5).

Specimens of the genus *Cichlidogyrus* were measured according to Pariselle and Euzet (1998). Six basic measurements, i.e. total length (A), base width (B), inner root (C), outer root (D), shaft (E) and the tip (F) were obtained from the opisthaptoral anchors (figure 3.6). Four basic measurements were obtained from the dorsal bar, total length (G), centrum width (H), centrum height (I) and auricle length (J) (figure 3.6). Half of the ventral bar was measured (K) and its width was measured at its widest point (L) (figure 3.6). The marginal hooklets were numbered according to the system proposed by Euzet and Prost (1981), for consistency with relevant literature, and only their total length was measured (M). The total length of the cirrus (N) as well as the accessory piece (O) were measured and not only the length of their axis (figure 3.6).

Digital images of the respective sclerites were taken using a Zeiss Axiophot compound microscope and a Nikon Coolpix 990 digital camera. These images were then analysed and the respective measurements were taken from them using the Scion Image software package.

3.7 Type and reference material

All type and reference material was deposited in the collection of the Aquatic Parasitology, Department of Zoology and Entomology, University of the Free State. The descriptions of 10 new species are contained in this thesis. These descriptions should only be regarded as valid once they have appeared in an accredited systematic journal.

3.8 Data analysis

Raw data was analysed to determine the fish distribution throughout the Delta, and the monogenean prevalence of the fish populations at the various collection sites. Only total prevalence data was collected due to fieldwork constraints and various researchers collecting the data, therefore no accurate intensity data or data regarding interspecific relationships concerning congeneric species were obtained. These data were collected in the field and were processed further in the laboratory. The results of this analysis are represented in chapter 7.

3.9 Format of thesis

This thesis has been written according to the guidelines set out for authors publishing in the journal SYSTEMATIC PARASITOLOGY.

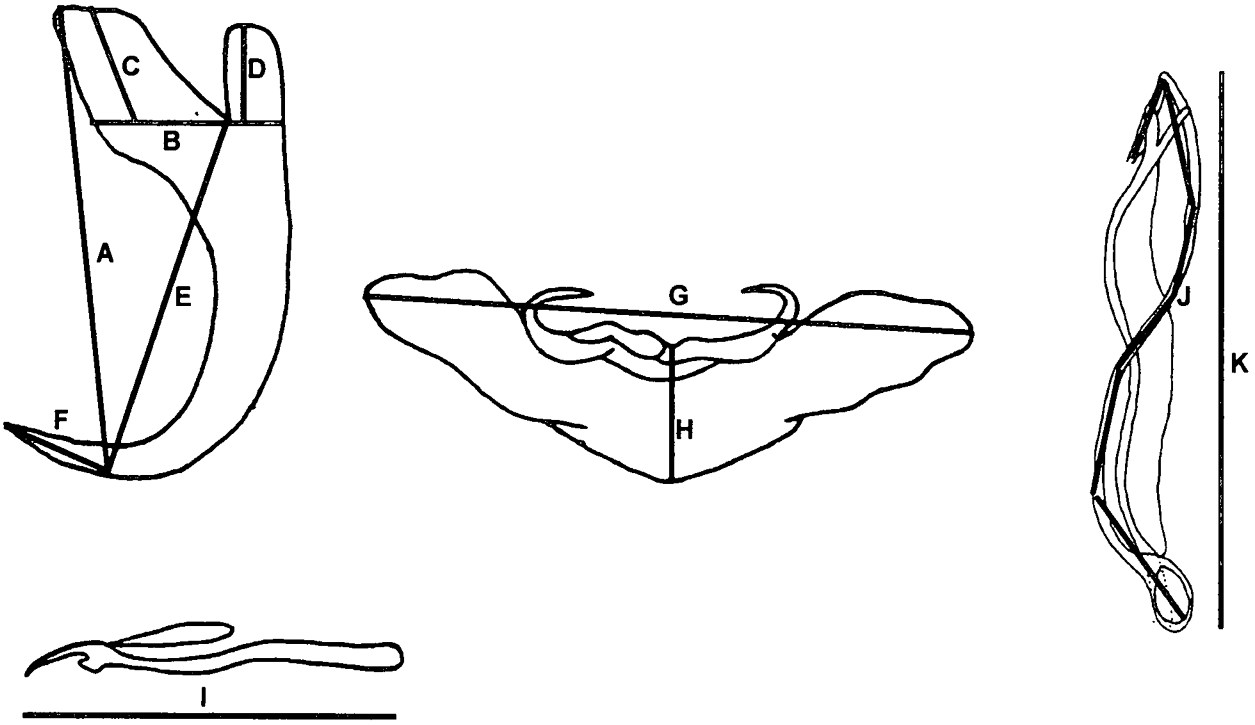

Figure 3.4 Illustration of the measurement of the sclerotised structure of Okavango monogeneans. Abbreviations: A – total length, B – base width, C - inner root, D – outer root, E – shaft, F – tip, G – connecting bar length, H – connecting bar width, I – marginal hooklets, J – cirrus length, K – accessory piece length.

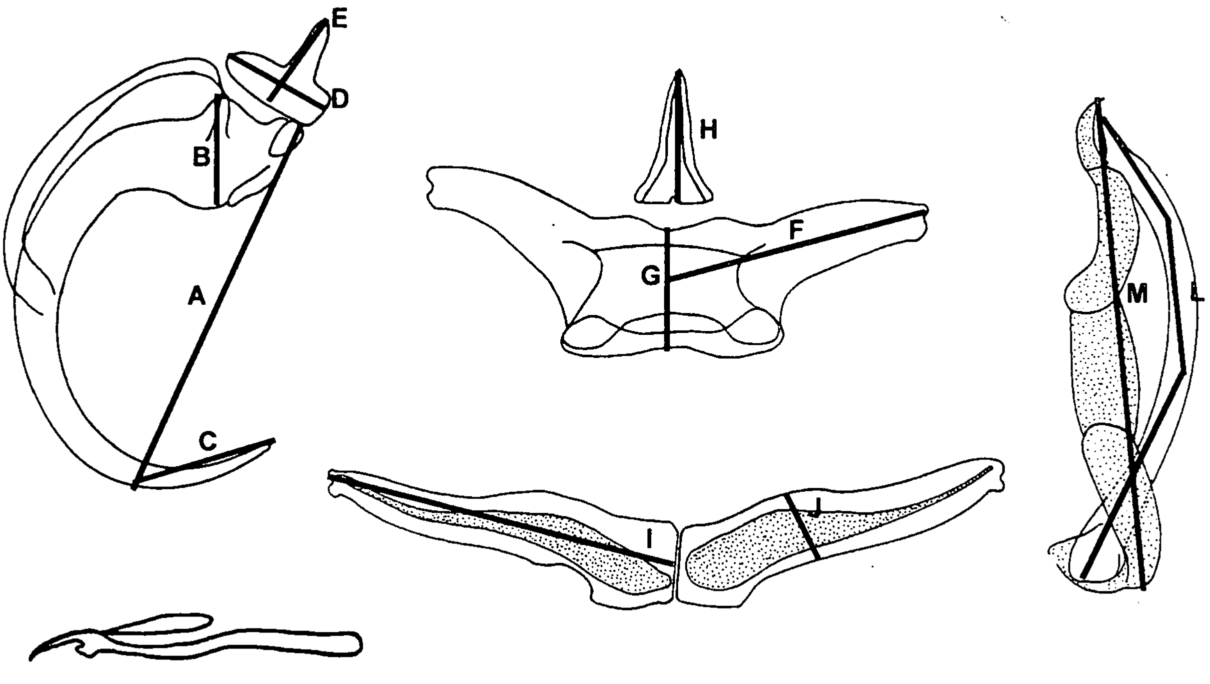

Figure 3.5 Illustration of the measurement of the sclerotised structure of Okavango monogeneans of the genus *Quadriacanthus*. Abbreviations: A – total length, B – base width, C - tip, D – accessory sclerite length, E – accessory sclerite width, F – dorsal bar half length, G – centrum height, H – median process length, I – ventral bar half length, J – ventral bar width, K– marginal hooklet, L – cirrus length, M – accessory piece length.

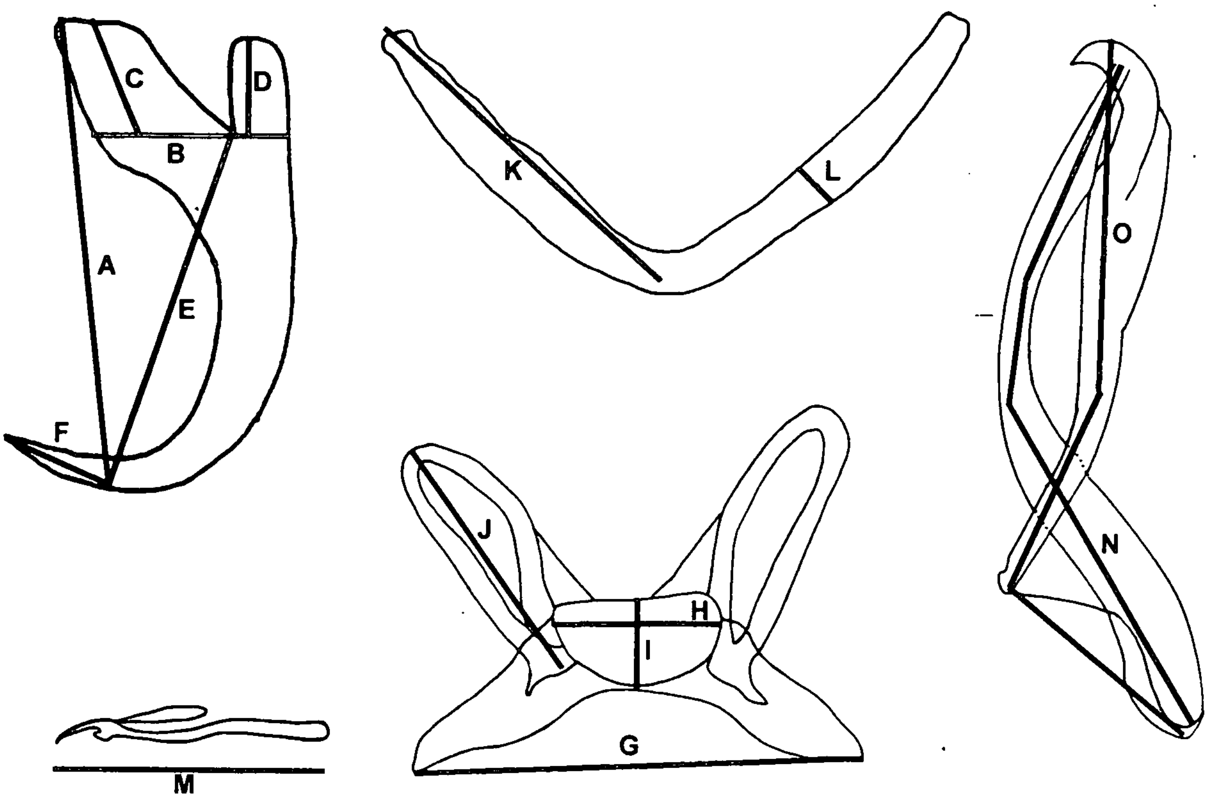

Figure 3.6 Illustration of the measurement of the sclerotised structure of Okavango monogeneans of the genus *Cichlidogyrus*. Abbreviations: A – total length, B – base width, C - inner root, D – outer root, E – shaft, F – tip, G – dorsal bar length, H – centrum width, I – centrum height, J – auricle length, K – ventral bar half length, L – ventral bar width, M – marginal hooklet length, N – cirrus length, O – accessory piece length.

CHAPTER 4

Some monogeneans infesting Okavango cyprinids

This chapter comprises the taxonomic diagnoses of some monogeneans of the family Dactylogyridae from fishes representative of the family Cyprinidae. The monogeneans infesting representatives of the family Cichlidae will be represented in the following chapter and that of the rest of the families will be represented in chapter 6. The following account does not represent all of the dactylogyrids that infest the Okavango cyprinids but only those with sufficient parasite prevalence and intensities.

Family: Dactylogyridae Bychowsky, 1933

Subfamily: Dactylogyrinae (Boeger and Kritsky, 1987)

Dactylogyrus dominici **Mashego, 1983**

Host: *Barbus paludinosus* Peters, 1852

Locality: Guma Lagoon (S18°57'44.94" E022°22'26.76")

Additional localities: Floodplain at Mohembo (S18°16'19.8" E021°47'38.7"), Nxamesere Floodplain (S18°36'03.2" E022°01'42.1"), Floodplains at Sepopa (S18°44'42.45" E022°11'50.4"), Okavango Mainstream at Etsatsa (S18°51'0.4" E022°25'12.0"), Thaoge Channel (S18°51'52.62" E022°25'8.1"), Thaoge Lagoons (S18°51'44.18" E022°24'22.29"), Nqoga Mainstream (S18°52'20.46" E022°28'34.5"), Perennial Swamp at Fly Camp (S19°01'35.4" E022°28'57.3").

Site of infestation: Gills

Reference material: 99 / 06 / 27 – 01 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (figure 4.1, table 4.1) were made using light microscopy from 10 specimens mounted in ammonium picrate glycerine.

Description and measurements:

Body length 220.2 ± 47.0 (134.2 – 290.2), greatest width 72.4 ± 22.3 (43.0 – 122.4) usually at level of ovary. Pharynx spherical, 16.6 ± 3.1 (12.7 – 20.5). Anchors length 40.5 ± 2.5 (37.1 – 44.3), base width 6.2 ± 2.0 (3.6 – 10.3), inner root 18.7 ± 2.4 (15.6 – 22.3), outer root 3.0 ± 1.0 (2.0 – 5.0), shaft 27.5 ± 6.2 (21.1 – 35.3), tip 13.5 ± 2.1 (10.4 – 16.6). Dorsal bar length 22.8 ±

4.2 (18.8 – 28.4), width 4.1 ± 0.4 (3.7 – 4.7). Marginal hooklets; I= 12.7 ± 2.6 (9.2 – 15.3), II= 14.4 ± 2.7 (10.5 – 17.5), III= 17.4 ± 1.8 (14.5 – 19.8), IV= 17.4 ± 1.4 (16.1 – 20.0), V= 17.4 ± 2.4 (14.7 – 21.5), VI= 16.4 ± 1.7 (14.0 – 18.6), VII= 16.3 ± 2.1 (12.2 – 18.1). Cirrus 49.0 ± 1.5 (47.9 – 50.0). Accessory piece 24.8 ± 2.7 (22.9 – 26.7). Vagina not observed.

Remarks:

On comparing *Dactylogyrus dominici* Mashego, 1983 from the Okavango Delta and the same species from Limpopo Province, South Africa (Mashego 1983), the Okavango population has much smaller sclerites than that of the Limpopo Province population (table 4.1). These two populations are considered as the same species based on the unique morphology of the dorsal bar, the morphology and distribution of the marginal hooklets and the general morphology and size of the copulatory organ (figure 4.1). Both the populations described by Mahego (1983) and the Okavango population were recorded from the same host, *Barbus paludinosus.*

Table 4.1 Measurements of *Dactylogyrus dominici* Mashego, 1983 from *Barbus paludinosus* Peters, 1852 from the Okavango Delta and its comparison with the published descriptions of similar species. All measurements are given in micrometers.

Monogenean **Host**	*Dactylogyrus dominici* (n=10) *Barbus paludinosus*		*Dactylogyrus dominici* *Barbus paludinosus*
	Mean ± SD	Range	Mashego (1983)
Anchor			
Total length	41 ± 2.5	37-44	58-80
Shaft	28 ± 6.2	21-35	40-54
Tip	14 ± 2.1	10-17	15-19
Dorsal Bar			
Length	23 ± 4.2	19-28	43-58
Width	4 ± 0.4	4-5	4-5
Copulatory organ			
Cirrus	49 ± 1.5	48-50	25-45
Accessory piece	25 ± 2.7	23-27	15-19

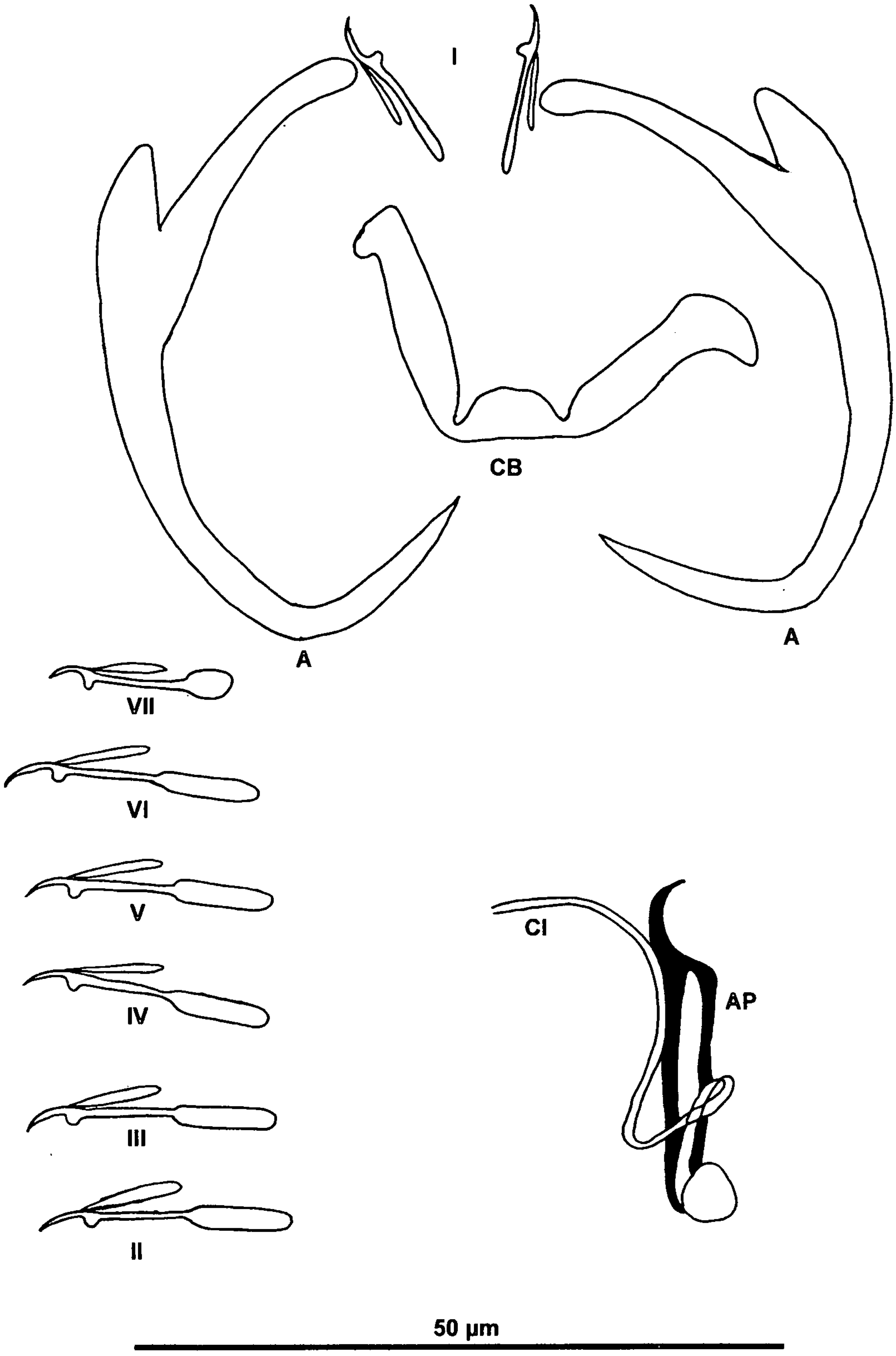

Figure 4.1 Microscope projection drawings of *Dactylogyrus dominici* Mashego, 1983 from the gills of *Barbus paludinosus* Peters, 1852 Abbreviations: **A** – anchor, **AP** – accessory piece, **CB** – dorsal bar, **CI** – Cirrus, **I** to **VII** – marginal hooklets.

Dactylogyrus myersi Price, McClellan, Druckenmiller and Jacobs, 1969

Host: *Barbus poechii* Steindachner, 1911

Locality: Okavango Mainstream at Drodsky's Cabins (S18°24'48.66" E021°53'9.6")

Additional localities: Channel off mainstream near Drodsky's Cabins (S18°25'01.00" E021°53'34.29"), Okavango Mainstream at Xaro Lodge (S18°25'23.6"; E21°56'18.2"), Kalatog Channel and Lagoons (S18°23'58.3" E021°58'16.0"), Backwaters at Xaro Lodge (S18°25'23.58" E021°56'18.18"), Backwaters at Seronga (S18°49'48.96" E022°24'22.74"), Samochima Lagoon (S18°25'26.08" E021°54'09.26"), Lagoon 1 near Xaro (S18°25'29.34" E021°56'24.48"), Floodplains at Mohembo (S18°16'19.8" E021°47'38.7"), Guma Lagoon (S18°57'44.94" E022°22'26.76"), Seasonal Swamp at Nxabega (S19°26'30.02" E022°49'12.33"), Perennial Swamp at Film Camp (S19°26'32.88" E022°49'10.32").

Site of infestation: Gills

Reference material: 98 / 08/ 03 –05 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (figure 4.2, table 4.2) were made using light microscopy from 12 specimens mounted in ammonium picrate glycerine.

Description and measurements:

Body length 252.1 ± 62.1 (137.2 – 359.3), greatest width 82.8 ± 22.6 (51.9 – 122.8) usually at level of ovary. Pharynx spherical, 22.8 ± 2.2 (20.4 – 24.7). Anchors length 108.7 ± 5.2 (101.0 – 118.5), base width 13.2 ± 2.1 (10.2 – 16.4), inner root 35.2 ± 2.5 (29.1 – 37.4), outer root 3.5 ± 0.5 (2.6 – 4.1), shaft 80.9 ± 5.0 (70.5 – 87.1), tip 33.2 ± 1.7 (31.4 – 37.0). Dorsal bar length 39.5 ± 3.5 (35.3 – 45.3), width 6.4 ± 1.9 (4.0 – 10.1). Marginal hooklets; I= 12.5 ± 2.1 (9.9 – 15.6), II= 17.2 ± 2.3 (13.9 – 22.6), III= 20.5 ± 2.1 (16.3 – 23.4), IV= 22.1 ± 3.0 (17.9 – 25.8), V= 21.8 ± 3.2 (17.6 – 26.5), VI= 17.6 ± 2.6 (15.3 – 18.4), VII= 16.4 ± 1.3 (15.3 – 18.4). Cirrus 55.3 ± 2.9 (53.3 – 57.4), Accessory piece 23.8 ± 1.2 (23.2 – 24.6). Vagina not observed.

Remarks:

Dactylogyrus myersi Price, McClellan, Druckenmiller and Jacobs, 1969 is characterised by its massive hamuli, which are about a third or more of the entire body length. This is consistent with the Okavango population collected from *Barbus poechii*. The Okavango population shows remarkable consistency with respect to copulatory organ size and morphology, similarity in size and shape of the dorsal bar and hamuli and the marginal hooklets, with that of *D. myersi* (Price, McClellan, Druckenmiller and Jacobs 1969 and Paperna 1979) (table 4.2 and figure 4.2). Hence the Okavango specimens are regarded as *D. myersi*. The Okavango population of *D. myersi* represents the record of this species from *Barbus poechii*.

Table 4.2 Measurements of *Dactylogyrus myersi* Price, McClellan, Druckenmiller and Jacobs, 1969 from *Barbus poechii* Steindachner, 1911 from the Okavango Delta and its comparison with the published descriptions of similar species. All measurements are given in micrometers.

Monogenean **Host**	*Dactylogyrus myersi* (n=12) *Barbus poechii*		*D. myersi* (n=3) *Barbus perice*	*D. myersi* (n=12) *Barbus trimaculatus*
	Mean ± SD	Range	Paperna (1979)	Price *et al.* (1969)
Anchor				
Total length	108 ± 5.2	101-119	103-114	100-112
Inner root	35 ± 2.5	29-37	31-40	
Outer root	4 ± 0.5	3-4	3-4	
Shaft	81 ± 5.0	71-87	80-82	
Tip	33 ± 1.7	31 - 37	30-33	
Dorsal Bar				
Length	40 ± 3.5	35 - 45	39-41	43-52
Width	6 ± 1.9	4-10		
Copulatory organ				
Cirrus	55 ± 2.9	53 - 57	28-32	22-28
Accessory piece	24 ± 1.2	23-25	17-22	25-31

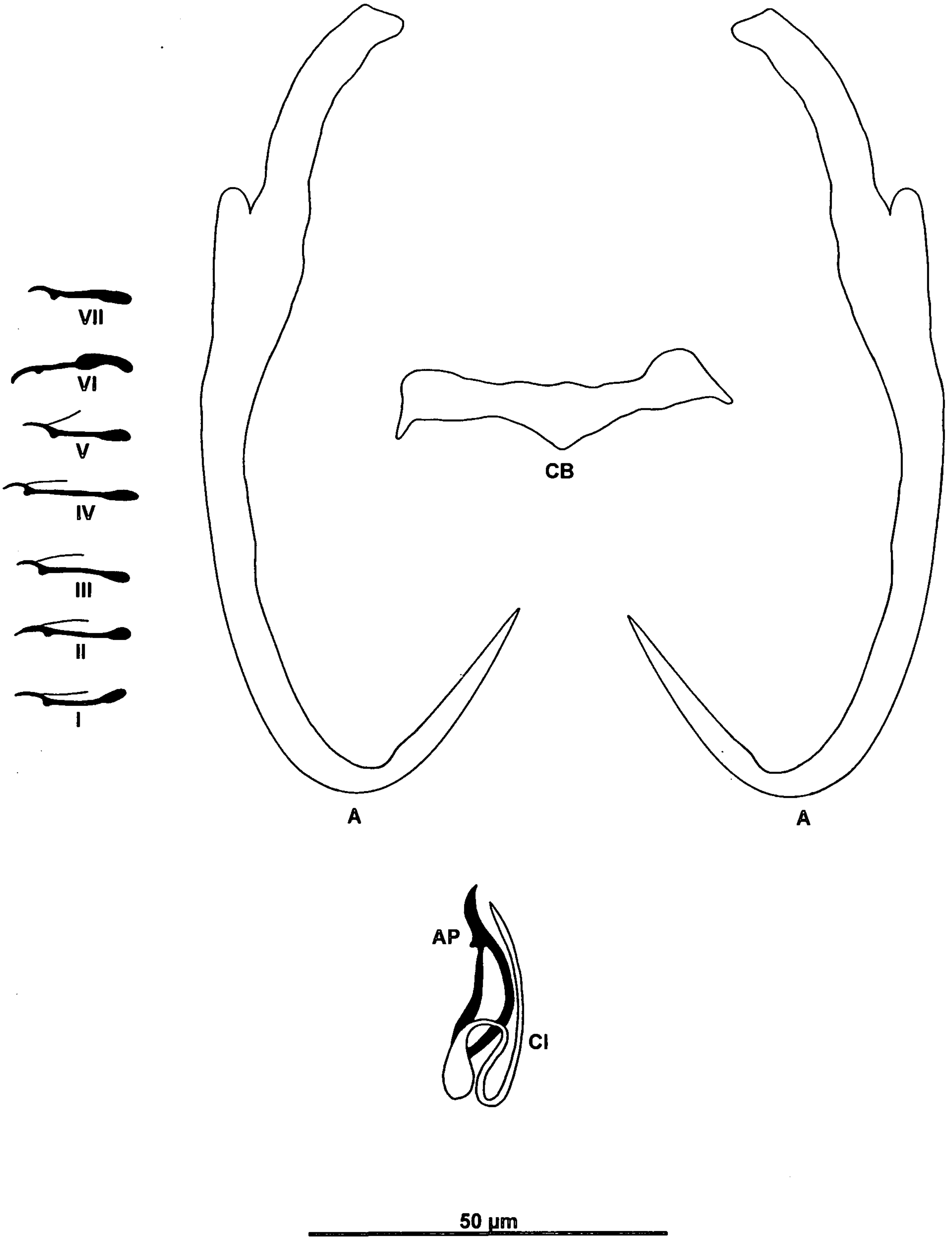

Figure 4.2 Microscope projection drawings of *Dactylogyrus myersi* Price, McCllelan, Druckenmiller and Jacobs, 1969 from the gills of *Barbus poechii* Steindachner, 1911. Abbreviations: **A** – anchor, **AP** – accessory piece, **CB** – dorsal bar, **CI** – cirrus, **I** to **VII** – marginal hooklets.

***Dactylogyrus barrilus* n. sp.**

Type host: *Barbus radiatus* Peters, 1853

Type locality: Backwaters at Shakawe Fishing Camp (S18°26'09.9" E021°54'20.3")

Site of infestation: Gills

Type material: Holotype: 2000 / 06 / 30-01 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Paratype: 2000 / 06 / 30-02 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (figure 4.3, table 4.3) were made using light microscopy from 2 specimens mounted in ammonium picrate glycerine.

Etymology: This species is named after Mr. Barry Pryce, owner of Shakawe Fishing Camp where the type specimens were collected.

Description and measurements:

Body length 311.5 ± 54.4 (273.0 – 350.0), greatest width 53.5 ± 4.9 (50.0 – 56.9) usually at level of ovary. Anchors length 34.8 ± 0.4 (34.5 – 35.0), base width 9.0 ± 1.4 (8.0 – 10.0), inner root 5.9 ± 0.1 (5.8 – 6.0), outer root 2.5 ± 0.7 (2.0 – 3.0), shaft 26.6 ± 0.6 (26.1 – 27.0), tip 10.0 ± 2.8 (8.0 – 12.0). Dorsal bar length 31.8 ± 2.5 (30.0 – 33.6), width 11.2 ± 1.1 (10.4 – 12.0). Marginal hooklets; I= 14.6 ± 1.8 (13.3 – 15.8), II= 14.4 ± 0.6 (14.0 – 14.8), III= 22.3 ± 3.5 (19.8 – 24.7), IV= 17.6 ± 0.8 (17.0 – 18.1), V= 20.9 ± 5.4 (17.0 – 24.7), VI= 32.3 ± 0.4 (32.0 – 32.5), VII= 23.8 ± 0.4 (23.5 – 24.0). Copulatory organ cirrus 31.5 ± 2.1 (30.0 – 33.0). Accessory piece 23.8 ± 4.0 (21.0 – 26.6).

Remarks:

Dactylogyrus barrilus n. sp. from the Okavango most closely resembles *D. aspili* Birgi and Lambert, 1987, not illustrated here, with respect to the general morphology of the opisthaptoral sclerites and the copulatory organ (figure 4.3). The dorsal bar of both species is A-shaped which distinguishes these two species from the other species of the genus *Dactylogyrus* from the Ethiopian Zoogeographical region. The Okavango population is distinguished from *D. aspili* with respect to the general size of the sclerites (table 4.3). The Okavango specimens appear smaller than those of *D. aspili*. The anchors of the Okavango population are also less complex than those of *D. aspili* in that they lack the lateral indentations that are clearly illustrated by Birgi and Lambert (1987).

Based on these differences, *Dactylogyrus barrilus* is considered a new species and also represents the first monogenean record from its host.

Table 4.3 Measurements of *Dactylogyrus barrilus* n. sp. from *Barbus radiatus* Peters, 1853 from the Okavango Delta and its comparison with the published descriptions of similar species. All measurements are given in micrometers.

Monogenean	*Dactylogyrus barrilus*		*Dactylogyrus aspili*
Host	*Barbus radiatus*		*Barbus aspilus*
	Mean ± SD	Range	Birgi & Lambert (1987)
Anchor			
Total length	35 ± 0.4	34-35	40-50
Shaft	27 ± 0.6	26–27	30-32
Tip	10 ± 2.8	8-12	11-13
Dorsal Bar			
Length	32± 2.5	30-34	50-62
Width	11 ± 1.1	10-12	5-10

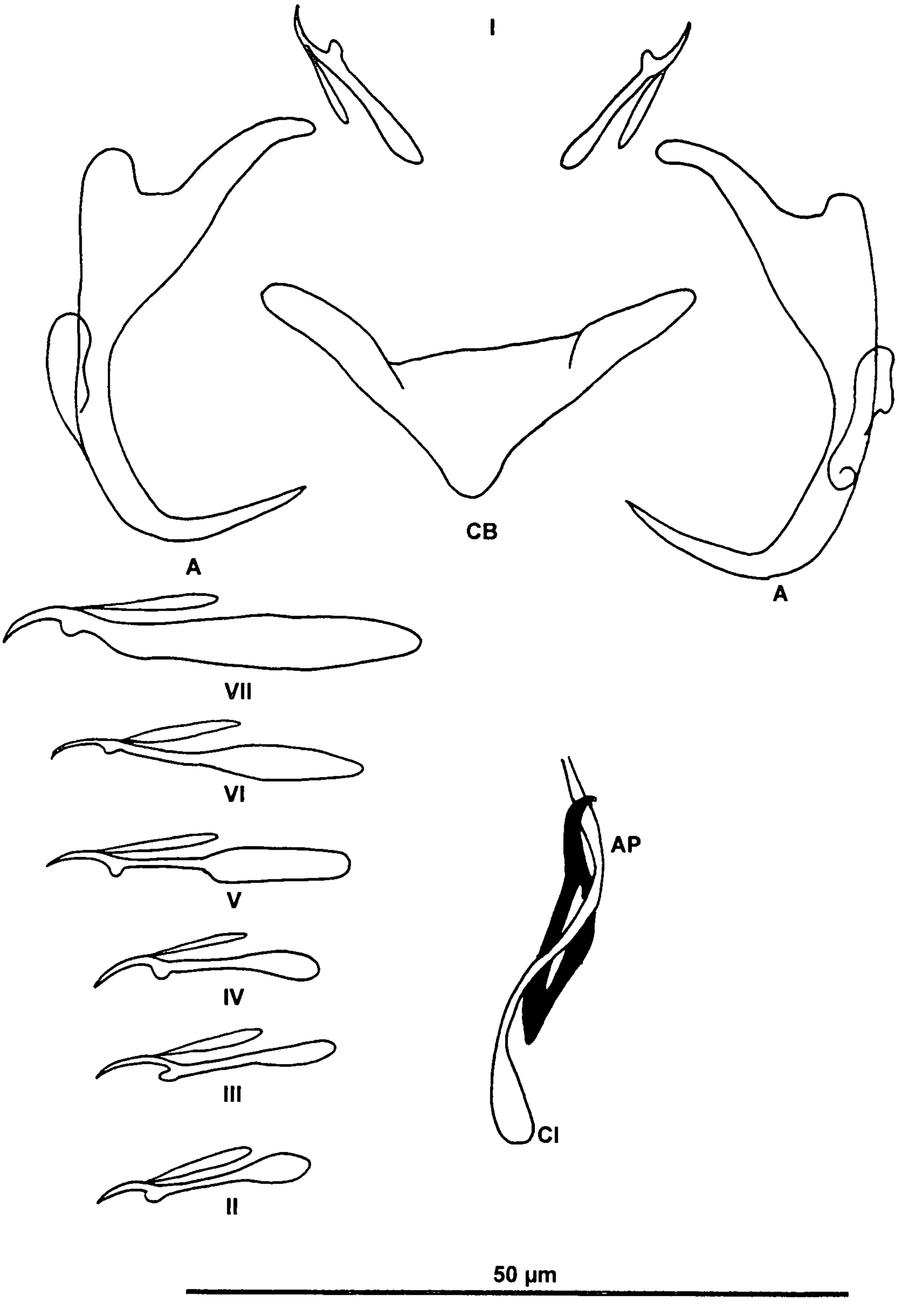

Figure 4.3 Microscope projection drawings of *Dactylogyrus barrilus* n. sp from the gills of *Barbus radiatus* Peters 1853 Abbreviations: **A** – anchor, **AP** – accessory piece, **CB** – dorsal bar, **CI** – Cirrus, **I** to **VII** – marginal hooklets.

Dactylogyrus viviersii n. sp.

Type host: *Barbus multilineatus* Worthington, 1933

Additional host: *Barbus barnardi* Jubb, 1965

Type locality: Backwaters at Seronga (S18°49'48.96" E022°24'22.74")

Additional localities: Okavango Mainstream at Drodsky's Cabins (S18°24'48.66" E021°53'9.6"), Backwaters at Shakawe Fishing Camp (S18°26'09.9" E021°54'20.3"), Backwaters at Xaro Lodge (S18°25'23.58" E021°56'18.18"), Floodplain at Mohembo (S18°16"19.8" E021°47'38.7"), Floodplain at Nxameseri (S18°36'03.2" E022°01'42.1"), Floodplains at Sepopa (S18°44'42.45" E022°11'50.4"), Nqoga Mainstream (S18°52'20.46" E022°28'34.5"), Thoage Lagoons (S18°51'44.18" E022°24'22.29"), Perennial Swamp at Fly Camp (S19°01'35.4" E022°28'57.3").

Site of infestation: Gills

Type material: Holotype: 1999 / 07 / 02 / 09-01 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Paratype: 1999 / 07 / 02 / 09-02 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (figure 4.4, table 4.4) were made using light microscopy from 10 specimens mounted in ammonium picrate glycerine.

Etymology: This species is named after the Vivier family for all their help, inspiration, hospitality and support during my study.

Description and measurements:

Body length 219 ± 46.7 (153.2 – 317.0), greatest width 68.3 ± 25.7 (43.8 – 128.4) usually at level of ovary. Pharynx spherical, 17.9 ± 3.9 (13.4 – 22.2). Anchors length 46.2 ± 4.9 (41.7 – 57.5), base width 6.0 ± 1.4 (4.8 – 9.0), inner root 20.1 ± 3.5 (16.5 - 27.6), outer root 5.8 ± 3.2 (2.5 – 11.6), shaft 28.6 ± 7.6 (23.6 – 46.2), tip 14.4 ± 1.5 (12.2 – 17.2). Dorsal bar length 32.7 ± 1.2 (31.0 – 34.4), width 2.4 ± 0.5 (1.5 – 2.9). Marginal hooklets; I= 12.9 ± 5.0 (7.7 – 22.4), II= 12.0 ± 2.7 (9.1 – 16.9), III= 15.9 ± 3.2 (12.4 – 21.6), IV= 15.0 ± 1.5 (12.6 – 17.6), V= 15.6 ± 2.4 (12.7 – 19.7), VI= 14.5 ± 0.9 (12.8 – 15.2), VII= 11.3 ± 1.7 (9.3 – 12.8). Cirrus 46.5 ± 2.7 (43.6 – 50.0). Accessory piece 21.9 ± 1.6 (20.2 – 23.9). Vagina not observed.

Remarks:

Based on the copulatory organ and haptoral sclerites (figure 4.4), *Dactylogyrus viviersii* n. sp. collected from both *Barbus multilineatus* and *Barbus barnardi* from the Okavango System, most closely resembles *Dactylogyrus enidae* Mashego, 1983, not illustrated here, and *Dactylogyrus myersi*, not illustrated here. *Dactylogyrus viviersii* differs from *D. enidae* and *D. myersi* in having smaller hamuli in the haptor (table 4.4). Furthermore, the dorsal bar of *D. viviersii* is not as simple as those of *D. enidae* and *D. myersi* in that its extremities are jointed and the plate like endings are supported by a narrow dorsal piece, which is not the case in both the other species (figure 4.4).

Dactylogyrus viviersii is thus considered as a new species, based on the consistent differences with similar species and due to the fact that this is the first monogenean record from both host species, *Barbus multilineatus* and *Barbus barnardi*.

Table 4.4 Measurements of *Dactylogyrus viviersii* n. sp. from *Barbus multilineatus* Worthington, 1933 and *Barbus barnardi* Jubb, 1965 from the Okavango Delta and its comparison with the published descriptions of similar species. All measurements are given in micrometers.

Monogenean	*Dactylogyrus viviersii* (n=10)		*Dactylogyrus viviersii* (n=7)	*D. enidae*	*D. myersi*
Host	*Barbus multilineatus*		*Barbus barnardi*	*Barbus neefi*	*Barbus trimaculatus*
	Mean ± SD	Range		Mashego (1983)	Price *et al.* (1969)
Anchor					
Total length	46 ± 4.9	42-58	40-47	68-81	100-112
Inner root	20 ± 3.5	17-28	17-22	21-31	
Outer root	6 ± 3.2	3-12	2-3	3-9	
Shaft	29 ± 7.6	24-46	24-28	50-56	
Tip	14 ± 1.5	12-17	11-16	19	
Dorsal Bar					
Length	33 ± 1.2	31-34	28-35	31-43	43-52
Width	2 ± 0.5	2-3	3-4	4-6	
Copulatory organ					
Cirrus	47 ± 2.7	44-50	33-43	21-25	22-28
Accessory piece	22 ± 1.6	20-24	19 - 28	19	25-31

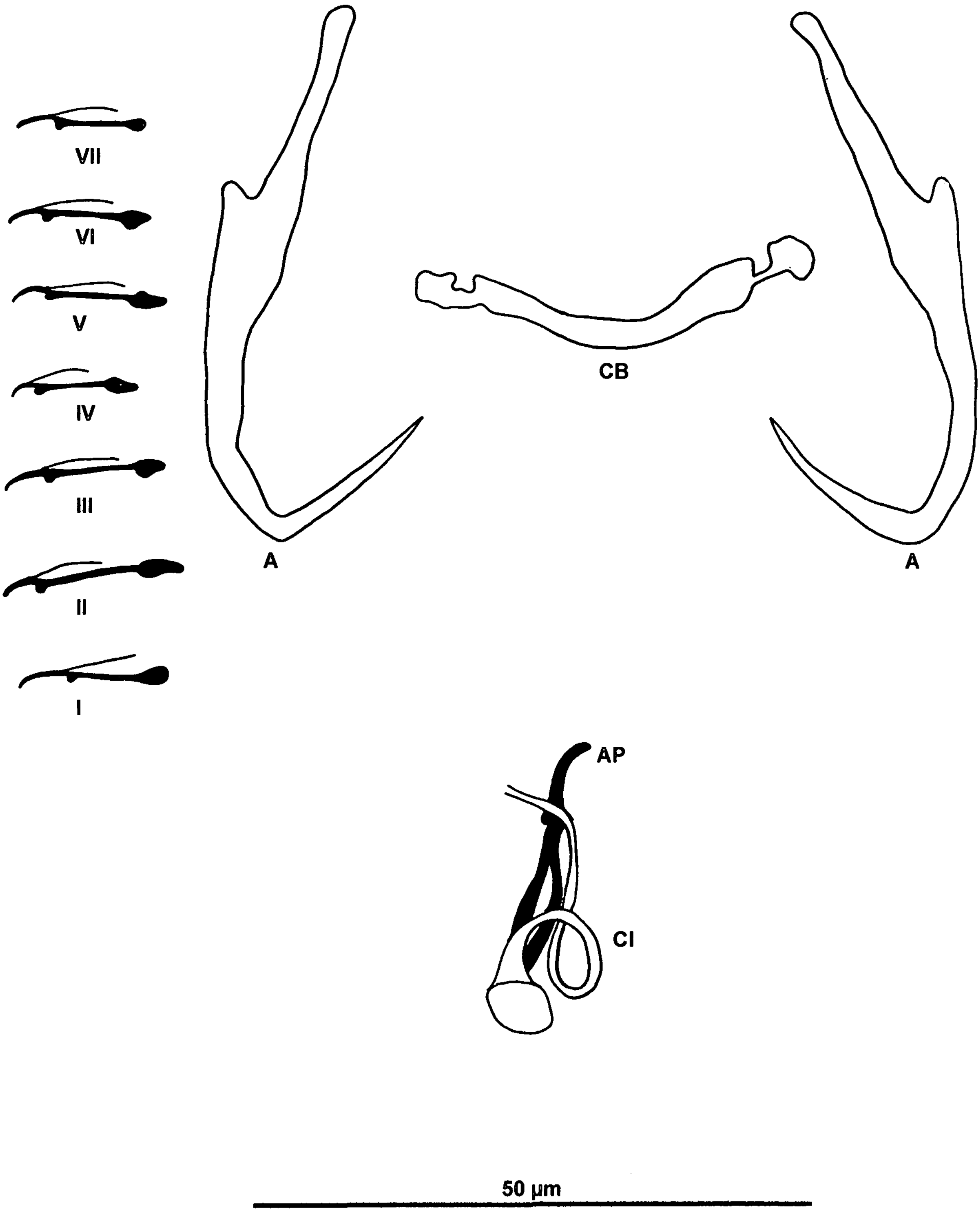

Figure 4.4 Microscope projection drawings of *Dactylogyrus viviersii* n. sp from the gills of *Barbus multilineatus* Worthington, 1933. Abbreviations: **A** – anchor, **AP** – accessory piece, **CB** – dorsal bar, **CI** – cirrus, **I** to **VII** – marginal hooklets

CHAPTER 5

Some monogeneans infesting Okavango cichlids

This chapter comprises the taxonomic diagnoses of some monogeneans of the family Dactylogyridae from fishes representative of the family Cichlidae. The monogeneans infesting the cyprinids have been represented in the previous chapter and that of the rest of the families will be represented in the following chapter. The following account does not represent all of the dactylogyrids that infest the Okavango cichlids but only those with sufficient parasite prevalence and intensities.

Family: Dactylogyridae Bychowsky, 1933
Subfamily: Ancyrocephalinae

***Cichlidogyrus halli* (Price and Kirk, 1967)**
Host: *Oreochromis andersonii* Weber, 1897
Locality: Samochima Lagoon (S18°25'26.08" E021°54'09.26")
Site of infestation: Gills
Reference material: 1998 / 08 / 07 / 07 - 04 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.
Material examined: Detailed morphometric measurements and drawings (figure 5.1, table 5.1) were made using light microscopy from eight specimens mounted in ammonium picrate glycerine. Measurements according to Pariselle and Euzet (1998).

Description and measurements:

Body fusiform, total length 1023.6 ± 100.1 (910.9 – 1150.0), greatest width 342.7 ± 48.8 (310.0 – 440.0). Haptor terminal and distinct. Dorsal anchors 52.6 ± 4.0 (47.1 – 57.0), base width 18.0 ± 0.6 (17.6 – 18.4), inner root 18.6 ± 2.0 (16.0 – 20.4), outer root 5.4 ± 1.2 (4.0 – 7.0), shaft 38.3 ± 2.4 (34.9 – 41.0), tip 9.3 ± 1.4 (7.0 – 10.6). Dorsal bar length 70.3 ± 7.6 (64.3 – 78.8), centrum height 9.2 ± 1.5 (7.2 – 12.2), centrum width 21.6 ± 2.4 (19.0 – 27.3), auricle height 28.8 ± 2.8 (25.0 – 33.3). Ventral anchors 58.1 ± 2.6 (53.2 – 61.1), base width 26.2 ± 1.6 (24.9 – 27.8), inner root 13.6 ± 1.7 (12.0 – 16.4), outer root 6.2 ± 2.2 (3.9 – 9.2), shaft 50.9 ± 2.1 (49.0 – 54.1), tip 14.5 ± 1.8 (12.3 – 16.9). Ventral bar half length 68.2 ± 4.5 (64.3 – 74.5), ventral bar width 11.0 ± 0.7 (9.6 – 11.8). Marginal hooklets; I= 19.3 ± 1.6 (16.2 – 22.0), II= 16.4 ± 2.0

(14.1 – 19.4), III= 32.0 ± 2.9 (26.2 – 35.3), IV= 31.2 ± 5.3 (26.0 – 39.2), V= 37.1 ± 1.9 (36.0 – 39.2), VI= 35.8 ± 2.1 (34.1 – 37.9), VII= 36.1 ± 5.3 (30.0 – 39.2). Cirrus tubular 92.6 ± 6.5 (86.2 – 103.0), accessory piece length 84.9 ± 4.5 (78.4 – 90.2), heel 10.5 ± 1.1 (9.0 – 11.8). Vagina not observed.

Remarks:

Cichlidogyrus halli (Price and Kirk, 1967) was first described as *Cleidodiscus halli* from Malawi in 1967 (Price and Kirk 1967). Since it's description, various authors have recorded it from a variety of hosts and a diversity of localities. Paperna (1979) synonymised *Cleidodiscus halli* with *Cichlidogyrus tubicirrus magnus* Paperna and Thurston, 1969 and proposed *Cichlidogyrus halli* as the new combination for this species. Paperna (1979) also differentiated two subspecies for this species, *C. halli typicus* Paperna, 1979 and *C. halli victorianus* Paperna, 1979 (Douëllou 1993).

The Okavango population of *C. halli* is characterised by their large size and sclerotised structures. The opisthaptor is armed with sturdy hamuli and large marginal hooklets. The first two pairs of marginal hooklets, are, however, smaller than the other five pairs. The copulatory organ consists of a thick tubular cirrus, which is associated with the accessory piece proximally. The accessory piece is robust and tapers to a point distally (figure 5.1).

The general features of the Okavango population closely resemble the type population as described by Price and Kirk (1967), and it also closely resembles the other recorded populations of this species morphometrically (Paperna and Thurston 1969b and Douëllou 1993)(table 5.1).

Characidotrema halli has been recorded from many different closely related hosts, but the Okavango population represents the first record of this species from *Oreochromis andersonii* and hence constitutes a new host and distribution record.

Table 5.1 Measurements of *Cichlidogyrus halli* (Price and Kirk, 1967) from *Oreochromis andersonii* Weber, 1897 from the Okavango Delta and its comparison with the published measurements of the same species from different localities. All measurements are given in micrometers.

Monogenean	*Cichlidogyrus halli* (n=8)		*Cichlidogyrus halli* (n=15)	*Cichlidogyrus halli*	*Cichlidogyrus halli* (n=15)
Host	*Oreochromis andersonii*		*Tilapia shirana shirana*	*Oreochromis niloticus*	*Oreochromis mortimeri*
	Mean ± SD	Range	Price & Kirk (1967)	Paperna & Thurston (1969)	Douëllou (1993)
Dorsal anchor					
Total length	53 ± 4.0	47-57	53-60	42-53	42-56
Dorsal bar					
Length	70 ± 7.6	64-79	68-79	72-79	51-73
Ventral anchor					
Total length	58 ± 2.6	53-61	54-62	42-56	49-60
Ventral bar					
Length	68 ± 4.5	64-75	52-61	55-63	52-72
Marginal hooklets					
I	19 ± 1.6	16-22	20-22	13-15	17-20
II	16 ± 2.0	14-19	20-22	13-20	16-18
III	34 ± 4.2	26-34	35-44	33-37	29-43
Copulatory organ					
Cirrus	93 ± 7.3	86-103	82-86	66-79	66-96
Accessory piece	85 ± 3.3	83-90	61-67	59-76	54-66

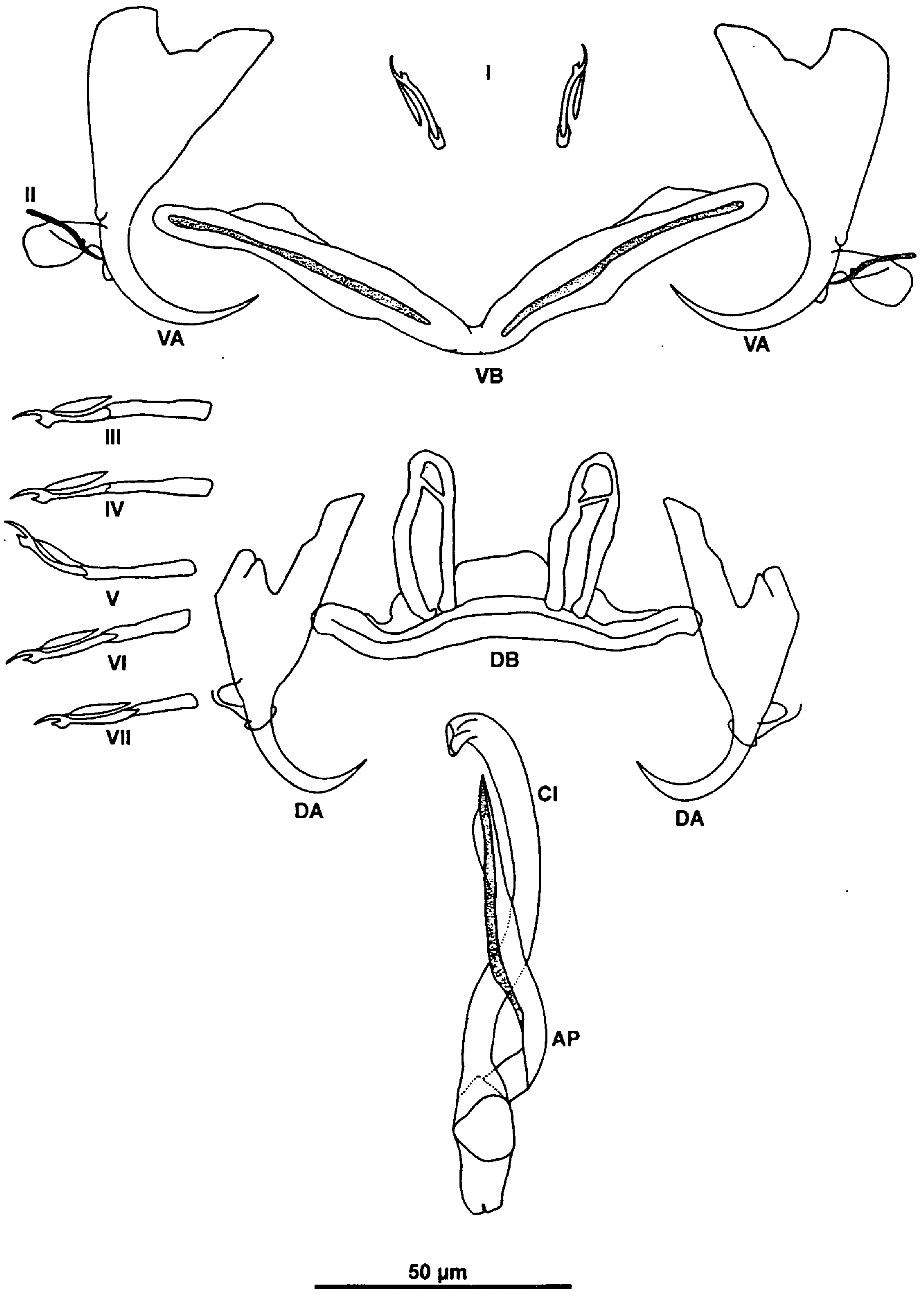

Figure 5.1 Microscope projection drawings of *Cichlidogyrus halli* (Price and Kirk, 1967) from the gills of *Oreochromis andersonii* Weber, 1897. Abbreviations: **AP** – accessory piece, **CI** – Cirrus, **DA** – dorsal anchor, **DB** – dorsal bar, **VA** – ventral anchor, **VB** – ventral bar, **I** to **VII** – marginal hooklets.

***Cichlidogyrus karibae* Douëllou, 1993**

Host: *Serranochromis macrocephalus* (Boulenger, 1899).

Locality: Lagoon 1 near Xaro Lodge (S18°25'29.34" E021°56'24.48").

Additional hosts: *Serranochromis robustus* (Günther, 1864) *Sargochromis codringtonii* (Boulenger, 1908), *Sargochromis giardi* (Pellegrin, 1903).

Additional localities: Okavango Mainstream at Drodsky's Cabins (S18°24'48.66" E021°53'9.6"), Channel off mainstream near Drodsky's Cabins (S18°25'01.00" E021°53'34.29"), Kalatog Channel and Lagoons (S18°23'58.3" E021°58'16.0"), Backwaters at Mohembo (S18°16'18.9" E021°47'40.1"), Samochima Lagoon (S18°25'26.08" E021°54'09.26"), Floodplains at Nxamasere (S18°36'03.2" E022°01'42.1"), Floodplains at Sepopa (S18°44'42.45" E022°11"50.4'), Pepere Lagoon (S18°54'57.42" E022°32'17.70"), Duba Lagoon (S18°58'27.78" E022°33'44.22").

Site of infestation: Gills.

Reference material: 2000 / 07 / 02 - 06 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (figure 5.2, table 5.2) were made using light microscopy from 10 specimens mounted in ammonium picrate glycerine. Measurements according to Pariselle and Euzet (1998).

Description and measurements:

Body total length 927.5 ± 83.5 (842.4 – 1048.2), greatest width 145.9 ± 14.5 (131.3 – 165.2). Haptor terminal and distinct. Dorsal anchors 43.8 ± 2.9 (37.7 – 46.5), base width 12.8 ± 1.0 (11.2 – 14.3), inner root 12.4 ± 1.8 (10.3 – 15.2), outer root 4.3 ± 0.6 (3.8 – 5.6), shaft 32.4 ± 2.8 (26.2 – 35.1), tip 11.2 ± 1.4 (8.3 – 12.2). Dorsal bar length 41.0 ± 2.2 (37.2 – 44.0), centrum height 8.3 ± 0.8 (7.3 – 9.3), centrum width 13.9 ± 0.9 (12.5 – 15.3), auricle height 23.4 ± 1.7 (21.2 – 25.5). Ventral anchors 38.4 ± 1.5 (36.2 – 40.0), base width 16.7 ± 1.4 (13.8 – 18.6), inner root 6.3 ± 1.5 (3.7 – 8.1), outer root 4.0 ± 0.9 (2.8 – 5.3), shaft 34.8 ± 1.5 (32.1 – 36.4), tip 12.0 ± 1.5 (9.6 – 14.4). Ventral bar half length 41.9 ± 1.8 (39.7 – 44.7), ventral bar width 6.6 ± 0.7 (5.9 – 7.9). Marginal hooklets; I= 18.2 ± 1.0 (17.2 – 20.2), II= 12.3 ± 0.7 (10.8 - 13.2), III= 22.5 ± 2.2 (18.7 – 25.7), IV= 21.0 ± 3.3 (17.5 – 24.7), V= 22.8 ± 1.7 (20.3 – 24.8), VI= 22.6 ± 2.3 (18.6 – 25.1), VII= 23.6 ± 1.6 (20.5 – 25.0). Cirrus tubular 63.4 ± 1.7 (60.3 – 65.2), accessory piece length 56.5 ± 3.0 (53.3 – 60.4), width 6.5 ± 1.0 (5.4 – 8.1). Vagina not sclerotised.

Remarks:

Cichlidogyrus karibae Douëllou, 1993 from the Okavango System is characterised by its unique copulatory organ structure. The copulatory organ consists of an accessory piece, which is more or less S-shaped and broadens along its length distally. The accessory piece is associated with the cirrus at its base proximally and terminates in a single well-defined hook distally. No perforated heel was observed at the base of the accessory piece, as has been the case in other *Cichlidogyrus* species. The cirrus is a hollow, robust tube, which tapers distally.

This species shares many close affinities with *C. zambezensis* Douëllou, 1993 especially with regard to the opisthaptoral sclerites, which are similar in size and shape (table 5.2). These two species are only distinguished through observation of the copulatory organs (Douëllou 1993). The copulatory organs of *C. karibae* and *C. zambezensis* are morphologically very similar and according to Douëllou (1993), the difference is that the accessory piece of *C. karibae* is associated with the cirrus proximally (figure 5.2) whereas the accessory piece of *C. zambezensis* is articulated with the cirral tube.

Cichlidogyrus karibae from the Okavango Delta was recorded from three host species, namely *Serranochromis macrocephalus, Sargochromis codringtonii* and *Sargochromis giardi.* No morphometric variability was observed between *C. karibae* specimens from any of the above mentioned hosts and hence these results are not presented here. Douëllou (1993) recorded *C. karibae* from *Serranochromis codringtonii* and *Oreochromis mortimeri.* The record of this species from the Okavango System thus represents a second record from the type host *Sargochromis codringtonii,* which is the valid synonym of *Serranochromis codringtonii* (Skelton 2001), and the first record from *Serranochromis macrocephalus* and *Sargochromis giardi.*

Table 5.2 Measurements of *Cichlidogyrus karibae* Douëllou, 1993 from *Serranochromis macrocephalus* (Boulenger, 1899) from the Okavango Delta and its comparison with the published descriptions of similar species. All measurements are given in micrometers.

Monogenean	*Cichlidogyrus karibae* (n=10)		*Cichlidogyrus karibae* (n=15)	*Cichlidogyrus zambezensis* (n=15)
Host	*Serranochromis macrocephalus*		*Sargochromis codringtonii*	*Serranochromis macrocephalus*
	Mean ± SD	Range	Douëllou (1993)	Douëllou (1993)
Dorsal anchor				
Total length	44 ± 2.9	38-47	42-49	41-45
Inner root	12 ± 1.8	10-15	12-22	13-18
Outer root	4 ± 0.6	4-6	3-11	3-8
Shaft	32 ± 2.8	26-35	30-36	29-35
Tip	11 ± 1.4	8-12	10-15	10-14
Dorsal bar				
Length	41 ± 2.2	37-44	37-49	32-38
Centrum width	14 ± 0.9	13-15	12-18	11-15
Centrum height	8 ± 0.8	7-9	8-9	8-10
Ventral anchor				
Total length	38 ± 1.5	36-40	37-45	37-42
Inner root	6 ± 1.5	4-8	8-15	9-13
Outer root	4 ± 0.9	3-5	4-10	4-7
Shaft	35 ± 1.5	32-36	32-38	32-36
Tip	12 ± 1.5	10-14	9-16	13-17
Ventral bar				
Length	42 ± 1.8	40-45	41-48	34-41
Width	7 ± 0.7	6-8	6-8	4-7
Marginal hooklets				
I	18 ± 1.0	17-20	16-19	18-20
II	12 ± 0.7	11-13	11-13	12-13
III	23 ± 2.2	19-26	18-22	18-20
IV	21 ± 3.3	18-25	22-25	23-25
V	23 ± 1.7	20-25	24-27	23-27
VI	23 ± 2.3	19-25	22-26	23-26
VII	24 ± 1.6	21-25	18-25	19-23
Copulatory organ				
Cirrus	63 ± 1.7	60-65	57-65	60-65
Accessory piece	57 ± 3.0	53-60	51-63	46-50

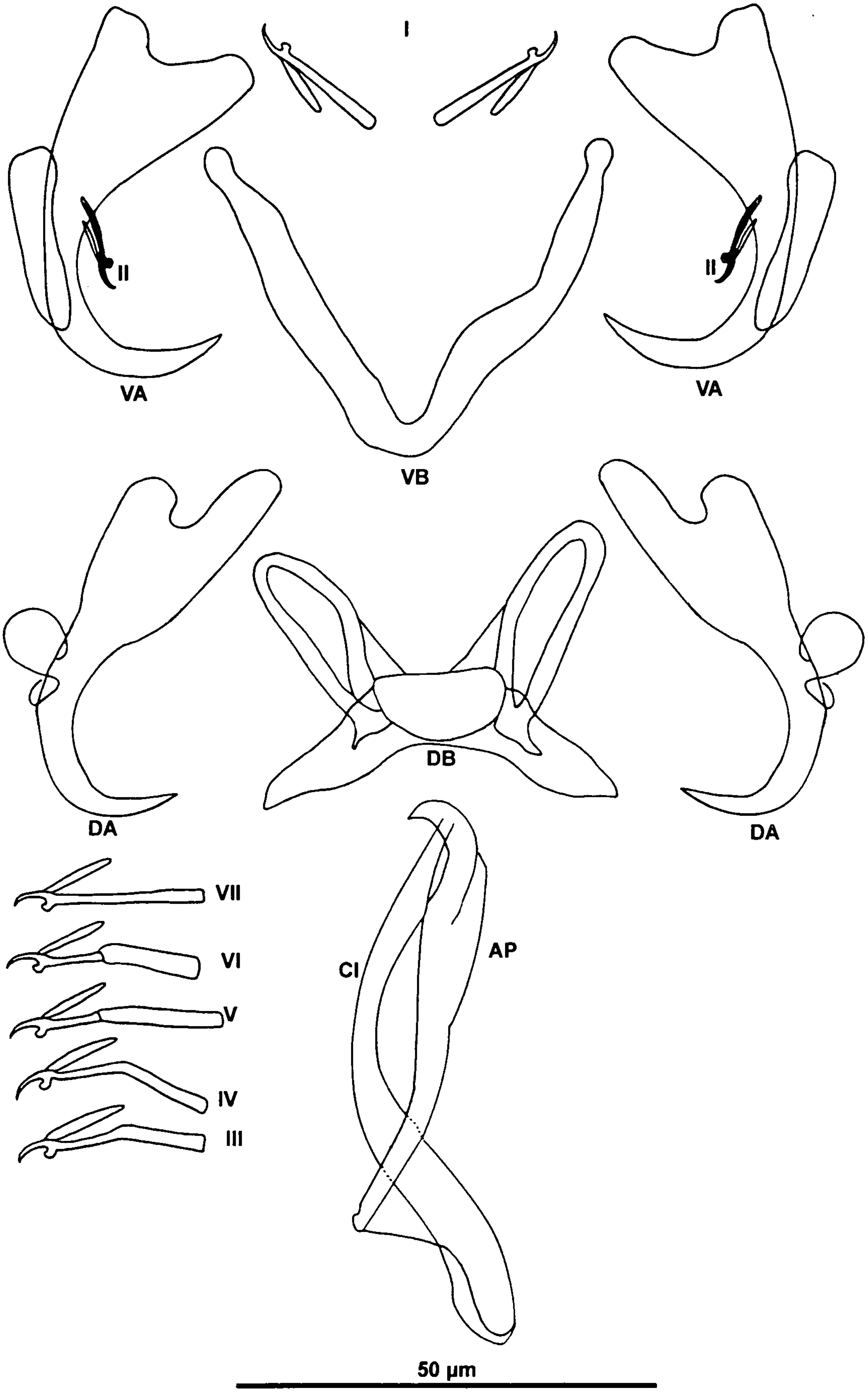

Figure 5.2 Microscope projection drawings of *Cichlidogyrus karibae* Douëllou, 1993 from the gills of *Serranochromis macrocephalus* (Boulenger, 1899). Abbreviations: **AP** – accessory piece, **CI** – Cirrus, **DA** – dorsal anchor, **DB** – dorsal bar, **VA** – ventral anchor, **VB** – ventral bar, **I** to **VII** – marginal hooklets.

Cichlidogyrus philander Douëllou, 1993

Host: *Pseudocrenilabrus philander* (Weber, 1897).

Locality: Backwater at Shakawe Fishing Camp (S18°26’09.9” E021°54’20.3”).

Additional localities: Backwaters at Mohembo (S18°16’18.9” E021°47’40.1”), Okavango Mainstream at Drodsky’s Cabins (S18°24’48.66” E021°53’9.6”), Samochima Lagoon (S18°25’26.08” E021°54”09.26’), Lagoon 1 near Xaro Lodge (S18°25’29.34” E021°56’24.48”), Lagoon 2 near Xaro Lodge (S18°25’26.08” E021°56’27.93”), Backwaters at Xaro Lodge (S18°25’23.58” E021°56’18.18”), Nxamesere Floodplains (S18°36’03.2” E022°01’42.1”), Sepopa Lagoon (S18°44’42.24” E022°11’49.2”), Backwaters at Seronga (S18°49’48.96” E022°24’22.74”), Okavango Mainstream at Etsatsa (S18°51’0.4” E022°25’12.0”), Thaoge Channel (S18°51’52.62” E022°25’8.1”), Nqoga Mainstream (S18°52’20.46” E022°28’34.5”), Thaoge Lagoons (S18°51’44.18” E022°24’22,29”), Guma Lagoon (S18°57’44.94” E022°22’26.76”), Duba Lagoon (S18°58’27.78” E022°33’44.22”), Perennial Swamp at Fly Camp (S19°01’35.4” E022°28’57.3”), Perennial Swamp at Film Camp (S19°26’32.88” E022°49’10.32”).

Site of infestation: Gills.

Reference material: 2000 / 07 / 05 - 04 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (figure 5.3, table 5.3) were made using light microscopy from 10 specimens mounted in ammonium picrate glycerine. Measurements according to Pariselle and Euzet (1998).

Description and measurements:

Body total length 417.9 ± 91.0 (335.2 – 591.5), greatest width 71.7 ± 15.8 (51.8 – 106.9). Haptor terminal and distinct. Dorsal anchors 33.2 ± 1.6 (31.7 – 35.5), base width 7.9 ± 0.8 (7.0 – 9.3), inner root 12.6 ± 1.4 (10.7 – 14.4), outer root 4.8 ± 1.2 (3.0– 6.4), shaft 22.0 ± 2.3 (19.3 – 26.8), tip 7.0 ± 0.3 (6.4 – 7.3). Dorsal bar length 25.6 ± 1.7 (23.9 – 28.3), centrum height 4.8 ± 0.7 (4.0 – 5.6), centrum width 9.8 ± 0.8 (8.8 – 10.7), auricle height 12.0 ± 1.7 (9.1 – 14.2). Ventral anchors 31.6 ± 1.2 (29.7 – 32.8), base width 10.8 ± 0.6 (10.0 – 11.7), inner root 7.5 ± 1.3 (5.2 – 9.1), outer root 4.7 ± 0.7 (3.8 – 5.9), shaft 26.3 ± 1.3 (24.2 – 27.6), tip 9.9 ± 0.8 (9.0 – 11.1). Ventral bar half length 25.7 ± 1.7 (23.8 – 28.1), ventral bar width 3.8 ± 0.2 (3.4 – 4.1). Marginal hooklets; I= 22.0 ± 1.1 (20.9 – 24.2), II= 10.3 ± 0.3 (9.9 – 10.8), III= 16.1 ± 1.6 (13.8

– 19.1), IV= 20.9 ± 2.3 (18.6 – 24.1), V= 23.6 ± 1.9 (20.6 – 25.6), VI= 20.9 ± 0.9 (19.9 – 22.4), VII= 18.7 ± 0.4 (18.0 – 19.3). Cirrus tubular, 42.5 ± 1.9 (38.6 – 44.3), accessory piece length 45.7 ± 1.9 (42.4 – 48.0), accessory piece width 4.6 ± 0.6 (3.8 – 5.1), heel 3.7 ± 0.6 (3.1 – 4.8). Vagina not sclerotised.

Remarks

Cichlidogyrus philander Douëllou, 1993 is characterised by its very robust first pair of marginal hooklets and by having dissimilar dorsal and ventral anchors (figure 5.3). These characters are shared by a group of *Cichlidogyrus* species including *C. albareti* Pariselle and Euzet, 1998; *C. arfii* Pariselle and Euzet, 1995; *C. brevicirrus* Paperna and Thurston, 1969; *C. digitatus* Dossou, 1982; *C. euzeti* Birgi and Lambert, 1986; *C. halinus* Paperna, 1969; *C. kothiasi* Pariselle and Euzet, 1994; *C. nandidae* Birgi and Lambert, 1986; *C. nunienzi* Pariselle and Euzet, 1998; *C. quaestio* Douëllou, 1993 and *C. yanni* Pariselle and Euzet, 1996. Of these *C. philander*, *C. quaestio* and *C. yanni* can be distinguished from the rest by having a copulatory organ with an accessory piece which is elongate, terminating in a single hook and almost equal in length to the robust tubular cirrus.

Cichlidogyrus philander can be distinguished from both *C. quaestio* and *C. yanni* by having generally smaller opisthaptoral armature (table 5.3), particularly the ventral bar. The copulatory organ of *C. philander* is also generally larger than that of the other two species.

The Okavango population of *C. philander* was the only monogenean collected from the gills of its host *Pseudocrenilabrus philander*, which is consistent with the Lake Kariba population (Douëllou 1993).

Table 5.3 Measurements of *Cichlidogyrus philander* Douëllou, 1993 from *Pseudocrenilabrus philander* (Weber, 1897) from the Okavango Delta and its comparison with the published descriptions of similar species. All measurements are given in micrometers.

Monogenean	*Cichlidogyrus philander* (n=10)		*Cichlidogyrus philander* (n=15)	*Cichlidogyrus quaestio* (n=15)	*Cichlidogyrus yanni* (n=30)
Host	*Pseudocrenilabrus philander*		*Pseudocrenilabrus philander*	*Tilapia rendalli*	*Tilapia zilli*
	Mean ± SD	Range	Douëllou (1993)	Douëllou (1993)	Pariselle & Euzet (1996)
Dorsal anchor					
Total length	33 ± 1.6	32-36	29-36	33-34	33-43
Inner root	13 ± 1.4	11-14	12-16	13-21	11-17
Outer root	5 ± 1.2	3-6	3-7	4-10	2-6
Shaft	22 ± 2.3	19-27	18-23	21-32	23-32
Tip	7 ± 0.3	6-7	6-9	7-14	9-14
Dorsal bar					
Length	26 ± 1.7	24-28	24-31	28-35	26-36
Centrum width	10 ± 0.8	9-11	7-12	9-14	9-20
Centrum height	5 ± 0.7	4-6	4-6	5-7	6-11
Ventral anchor					
Total length	32 ± 1.2	30-33	28-32	28-39	29-39
Inner root	8 ± 1.3	5-9	8-12	8-12	6-13
Outer root	5 ± 0.7	4-6	4-7	3-7	2-5
Shaft	26 ± 1.3	24-28	23-27	24-38	27-36
Tip	10 ± 0.8	9-11	8-11	10-17	12-18
Ventral bar					
Length	25 ± 1.7	24-28	25-29	31-39	31-45
Width	4 ± 0.2	3-4	3-5	2-5	4-7
Marginal hooklets					
I	22 ± 1.1	21-24	22-24	23-31	20-28
II	10 ± 0.3	10-11	10-11	10-12	10-13
III	16 ± 1.6	14-19	15-17	16-20	15-21
IV	21 ± 2.3	19-24	19-20	18-22	17-25
V	24 ± 1.9	21-26	22-25	21-25	18-26
VI	21 ± 0.9	20-22	20-22	21-26	18-25
VII	19 ± 0.4	18-19	18-20	18-22	15-24
Copulatory organ					
Cirrus	43 ± 1.9	39-44	44-50	27-32	29-37
Accessory piece	46 ± 1.9	42-48	27-35	22-27	23-33

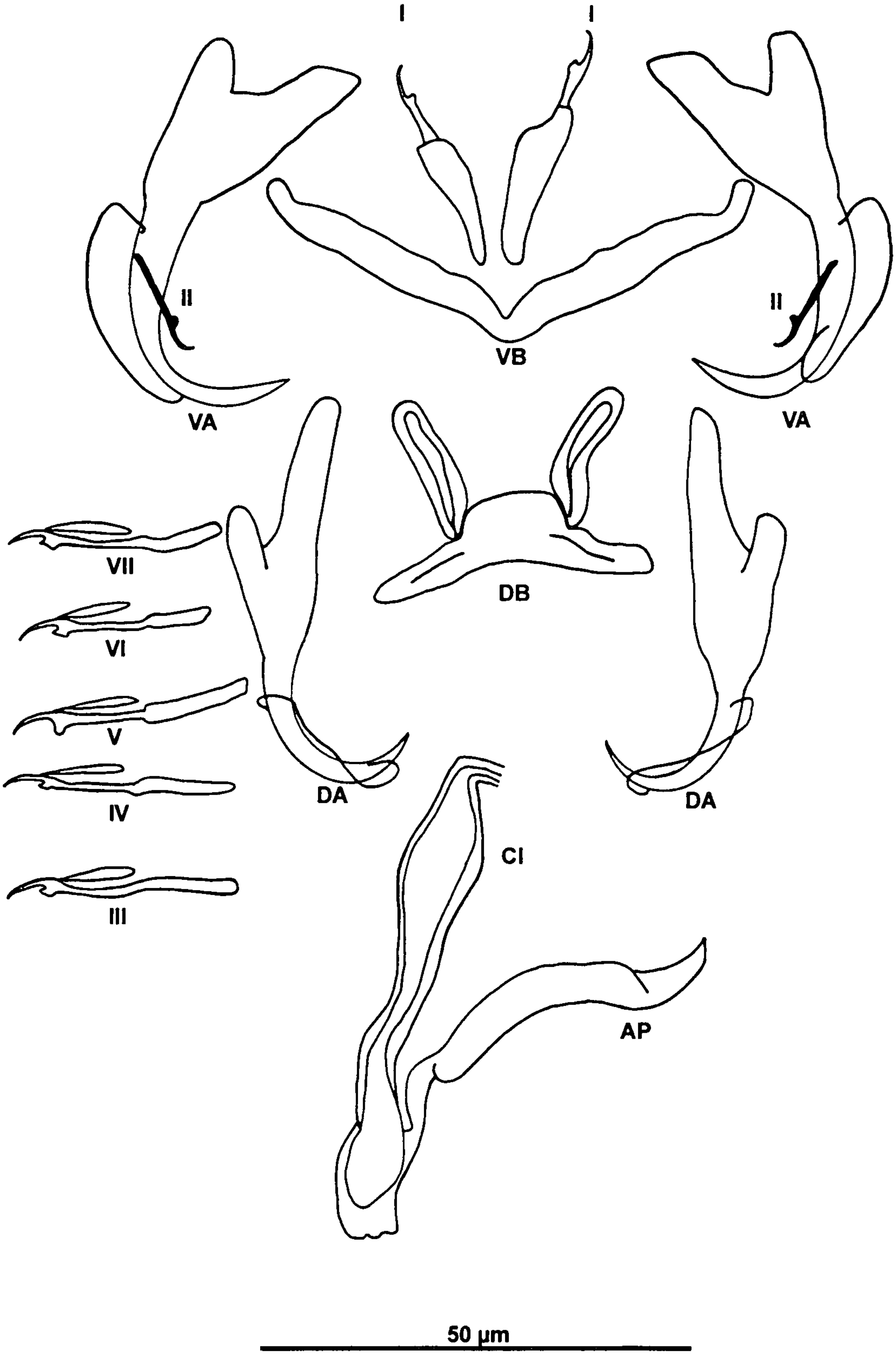

Figure 5.3 Microscope projection drawings of *Cichlidogyrus philander* Douëllou, 1993 from the gills of *Pseudocrenilabrus philander* (Weber,1897). Abbreviations: **AP** – accessory piece, **CI** – Cirrus, **DA** – dorsal anchor, **DB** – dorsal bar, **VA** – ventral anchor, **VB** – ventral bar, **I** to **VII** – marginal hooklets.

Cichlidogyrus sclerosus **Paperna and Thurston, 1969**

Host: *Oreochromis andersonii* Weber, 1897.

Locality: Floodplain at Mohembo (S18°16'19.8" E021°47'38.7").

Additional localities: Okavango Mainstream at Drodsky's Cabins (S18°24'48.66" E021°53'9.6"), Kalatog Channel and Lagoons (S18°23'58.3" E021°58'16.0"), Samochima Lagoon (S18°25'26.08" E021°54'09.26"), Lagoon 2 at Xaro Lodge (S18°25'26.08" E021°56'27.93"), Floodplains at Nxamasere (S18°36'03.2" E022°01'42.1"), Backwaters at Seronga (S18°49'48.96" E022°24'22.74"), Okavango Mainstream at Etsatsa (S18°51'0.4" E022°25'12.0"), Duba Lagoon (S18°58'27.78" E022°33'44.22").

Site of infestation: Gills.

Reference material: 1997 / 10 / 23 / 09 - 28 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (figure 5.4, table 5.4) were made using light microscopy from 15 specimens mounted in ammonium picrate glycerine. Measurements according to Pariselle and Euzet (1998).

Description and measurements:

Body total length 359.6 ± 39.6 (285.4 – 424.2), greatest width 173.6 ± 21.2 (135.9 – 204.5). Haptor terminal and distinct. Dorsal anchors 29.6 ± 2.2 (26.8 – 34.4), base width 16.7 ± 1.0 (15.6 – 18.8), inner root 6.0 ± 1.1 (5.0 – 8.4), outer root 3.1 ± 0.9 (1.4 – 4.4), shaft 28.6 ± 1.0 (26.5 – 30.3), tip 9.2 ± 1.1 (7.6 – 11.5). Dorsal bar length 31.8 ± 2.2 (29.1 – 33.5), centrum height 7.6 ± 1.5 (5.6 – 10.2), centrum width 11.2 ± 1.3 (9.6 – 13.1), auricle height 16.5 ± 1.1 (13.9 – 18.8). Ventral anchors 29.8 ± 2.2 (26.8 – 32.8), base width 16.0 ± 1.3 (14.1 – 17.7), inner root 5.7 ± 1.4 (3.7 – 8.3), outer root 2.3 ± 0.5 (1.6 – 3.1), shaft 30.1 ± 2.0 (27.4 – 33.0), tip 11.5 ± 1.8 (9.3 – 15.2). Ventral bar half length 28.6 ± 4.0 (21.6 – 34.4), ventral bar width 7.6 ± 0.8 (6.2 – 9.0). Marginal hooklets; I= 14.3 ± 1.8 (10.5 – 16.3), II= 11.0 ± 1.2 (9.5 – 12.8), III= 16.1 ± 1.1 (14.5 – 17.7), IV= 15.8 ± 1.2 (13.6 – 17.7), V= 16.7 ± 1.5 (14.5 - 18.0), VI= 16.2 ± 1.1 (14.7 – 17.8), VII= 16.4 ± 0.7 (15.0 – 17.7). Cirrus tubular, 51.5 ± 4.0 (49.4 – 57.6), accessory piece length 50.3 ± 6.9 (40.8 – 65.6), accessory piece width 11.9 ± 1.3 (9.2 – 13.4), heel 11.8 ± 2.1 (9.0 – 15.7). Vagina not sclerotised.

Remarks:

Cichlidogyrus sclerosus Paperna and Thurston, 1969 collected from *Oreochromis andersonii* from the Okavango Delta is distinguished by its anchors, which possess poorly developed roots. Although this character is not evident in the original description by Paperna and Thurston (1969b), it is consistent with both the findings of Kritsky and Thatcher (1974) and Douëllou (1993). This species is further characterised by the shape of the accessory piece of the copulatory organ. Paperna and Thurston (1969b), provided two illustrations of the accessory piece one possessing a perforated heel and one without. The accessory piece of the Okavango population has a perforated heel, which is consistent with both Kritsky and Thatcher (1974) and Douëllou (1993). From the heel, the accessory piece of the Okavango population extends in the form of a robust bar, which tapers proximally and terminates in a well developed hook (figure 5.4). This terminal hook is not clearly illustrated by Douëllou (1993), but is consistent with Paperna and Thurston (1969b). Morphometrically the Okavango population of *C. sclerosus* is consistent to that of both the type population (Paperna and Thurston 1969) and the population from Lake Kariba, Zimbabwe (Douëllou 1993), and shares close affinities to that of *C. amphoratus* Pariselle and Euzet, 1996 and *C. flexicolpos* Pariselle and Euzet, 1995 (table 5.4).

The opisthaptoral sclerites of *C. sclerosus* closely resemble those of *C. amphoratus*. Both species possess anchors of similar size with poorly developed roots. Similarity between these two species is also evident when considering the relative sizes of both connecting bars and the corresponding marginal hooklets. The copulatory organ of *C. amphoratus* also resembles that of *C. sclerosus* morphologically, however, both the cirrus and accessory piece of *C. amphoratus* are generally smaller than that of *C. sclerosus*. Furthermore the cirrus of *C. amphoratus* possesses a well marked swollen portion (Pariselle and Euzet 1996), which is not present in *C. sclerosus* and hence these two species can easily be distinguished.

Morphologically the copulatory organs of *C. sclerosus* and *C. flexicolpos* are similar in that the accessory piece of both possess a perforated heel and the shaft of both terminate in a well developed hook. The accessory piece of the respective copulatory organs also resembles each other in size (table 5.4). These two species are, however, distinguished by their opisthaptoral sclerites. The anchors of *C. flexicolpos* have well developed roots as opposed to that of *C. sclerosus* and *C. amphoratus*. The marginal hooklets of *C. flexicolpos* are generally much larger than those of *C. sclerosus* and hence these two species can be distinguished.

This represents the first record of *Ciclidogyrus sclerosus* from *Oreochromis andersonii* and is consistent with the previous host range of this parasite, which has been recorded from various species all belonging to the subfamily Pseudocrenilabrinae.

Table 5.4 Measurements of *Cichlidogyrus sclerosus* Paperna and Thurston, 1969 from *Oreochromis andersonii* Weber, 1897 from the Okavango Delta and its comparison with the published descriptions of similar species. All measurements are given in micrometers.

Monogenean	*Cichlidogyrus sclerosus* (n=15)		*Cichlidogyrus sclerosus* (n=15)	*Cichlidogyrus amphoratus* (n=29)	*Cichlidogyrus flexicolpos* (n=24)
Host	*Oreochromis andersonii*		*Serranochromis macrocephalus*	*Tilapia louka*	*Tilapia guineensis*
	Mean ± SD	Range	Douëllou (1993)	Pariselle & Euzet (1996)	Pariselle & Euzet (1995)
Dorsal anchor					
Total length	30 ± 2.2	27-34	32-35	26-32	23-26
Inner root	6 ± 1.1	5-8	9-13	7-12	8-12
Outer root	3 ± 0.9	1-4	4-9	1-5	3-6
Shaft	29 ± 1.0	27-30	31-34	20-28	18-21
Tip	9 ± 1.1	8-12	9-13	8-12	7-11
Dorsal bar					
Length	32 ± 2.2	29-34	31-44	24-34	29-46
Centrum width	11 ± 1.3	10-13	10-13	9-13	12-21
Centrum height	8 ± 1.5	6-10	7-10	4-7	3-5
Ventral anchor					
Total length	30 ± 2.2	27-33	33-36	39-34	28-32
Inner root	6 ± 1.4	4-8	9-14	7-11	8-13
Outer root	2 ± 0.5	2-3	3-8	1-5	4-6
Shaft	30 ± 2.0	27-33	32-36	25-31	23-26
Tip	11.5 ± 1.8	9-15	12-15	10-13	9-13
Ventral bar					
Length	29 ± 4.0	22-34	31-35	24-30	30-37
Width	8 ± 0.8	6-9	3-8	2-5	3-6
Marginal hooklets					
I	14 ± 1.8	11-16	13-17	11-14	14-16
II	11 ± 1.2	10-13	12-14	8-13	11-13
III	16 ± 1.1	15-18	17-20	16-19	32-40
IV	16 ± 1.2	14-18	15-19	13-18	30-36
V	17 ± 1.5	15-18	16-20	12-18	35-40
VI	16 ± 1.1	15-18	14-18	12-17	33-37
VII	16 ± 0.7	15-18	14-18	13-16	31-36
Copulatory organ					
Cirrus	52 ± 4.0	49-58	66-83	43-48	87-101
Accessory piece	50 ± 6.9	41-66	49-62	23-32	32-42

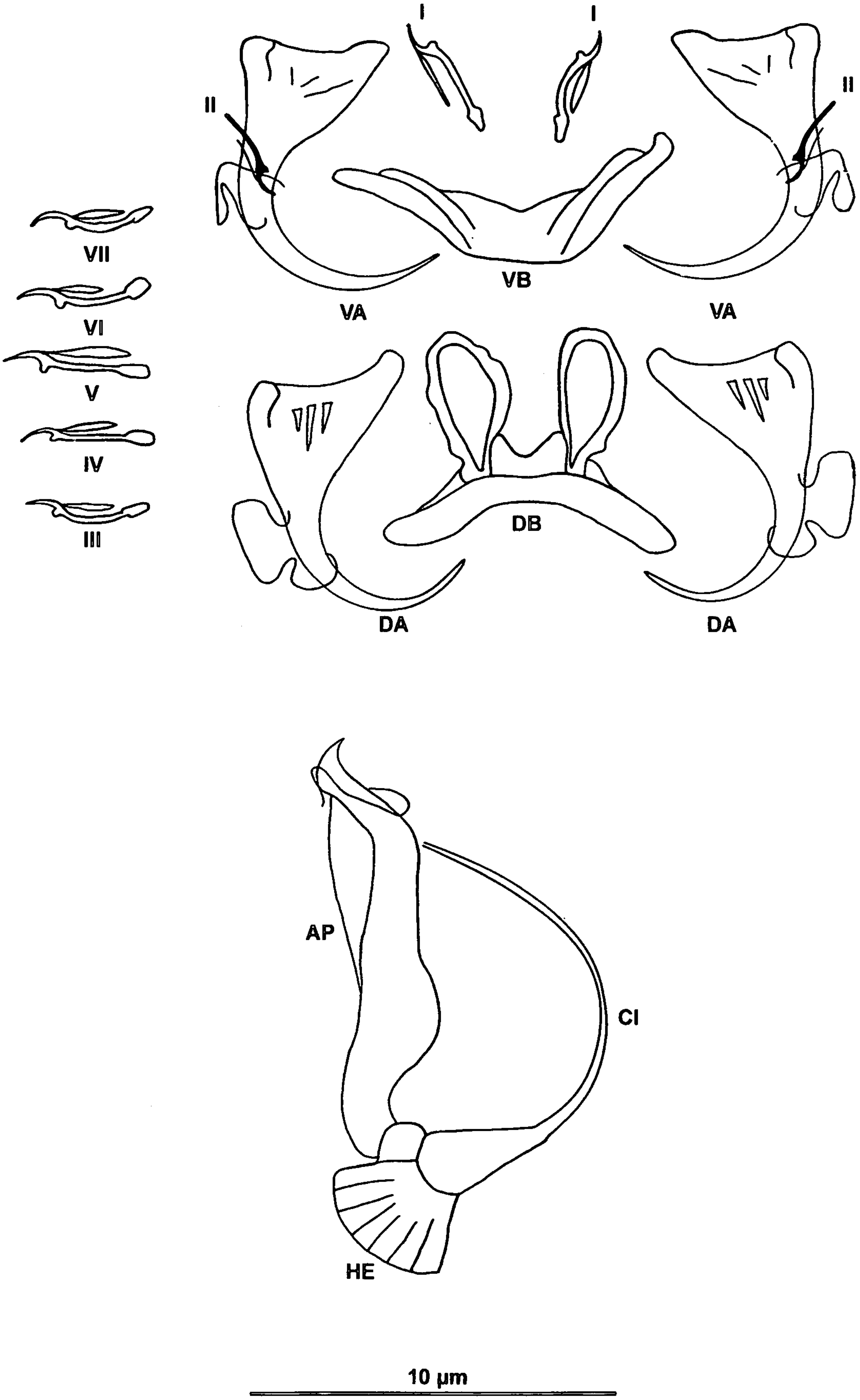

Figure 5.4 Microscope projection drawings of *Cichlidogyrus sclerosus* Paperna and Thurston, 1969 from the gills of *Oreochromis andersonii* Weber, 1987. Abbreviations: **AP** – accessory piece, **CI** – cirrus, **DA** – dorsal anchor, **DB** – dorsal bar, **HE** – heel, **VA** – ventral anchor, **VB** – ventral bar, **I** to **VII** – marginal hooklets.

***Cichlidogyrus botswanensis* n. sp.**

Type host: *Sargochromis codringtonii* (Boulenger, 1908).

Type locality: Lagoon 1 near Xaro Lodge (S18°25'29.34" E021°56'24.48").

Additional hosts: *Sargochromis giardi* (Pellegrin, 1903), *Serranochromis macrocephalus* (Boulenger, 1899).

Additional localities: Okavango Mainstream at Drodsky's Cabins (S18°24'48.66" E021°53'9.6"), Channel off mainstream near Drodsky's Cabins (S18°25'01.00" E021°53'34.29"), Kalatog Channel and Lagoons (S18°23'58.3" E021°58'16.0"), Backwaters at Mohembo (S18°16'18.9" E021°47'40.1"), Samochima Lagoon (S18°25'26.08" E021°54'09.26"), Floodplains at Nxamasere (S18°36'03.2" E022°01'42.1"), Floodplains at Sepopa (S18°44'42.24" E022°11'49.2"), Pepere Lagoon (S18°54'57.42" E022°32'17.70"), Duba Lagoon (S18°58'27.78" E022°33'44.22").

Site of infestation: Gills.

Type material: Holotype: 2000 / 07 / 02 - 17 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Paratype: 2000 / 07/ 02 – 18 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (figure 5.5, table 5.5) were made using light microscopy from seven specimens mounted in ammonium picrate glycerine. Measurements according to Pariselle and Euzet (1998).

Etymology: Name derived from Botswana, the country in which specimens were collected.

Description and measurements:

Body total length 972.5 ± 130.5 (876.3 – 1121.1), greatest width 104.0 ± 13.7 (86.7 – 128.3). Haptor terminal and distinct. Dorsal anchors 42.9 ± 2.5 (38.6 – 44.7), base width 14.0 ± 2.1 (11.2 – 16.4), inner root 11.6 ± 3.6 (6.3 – 16.3), outer root 4.2 ± 0.8 (3.2 – 5.0), shaft 32.4 ± 2.7 (29.6 – 36.1), tip 11.7 ± 1.0 (10.4 – 12.8). Dorsal bar length 39.2 ± 2.7 (36.2 – 43.2), centrum height 8.0 ± 1.1 (6.8 – 9.8), centrum width 13.3 ± 1.4 (11.5 – 15.6), auricle height 23.1 ± 1.8 (20.8 – 26.6). Ventral anchors 40.8 ± 1.9 (37.7 – 42.6), base width 15.8 ± 1.8 (12.8 – 17.9), inner root 9.9 ± 2.1 (7.8 – 13.3), outer root 5.8 ± 1.0 (4.5 – 6.6), shaft 34.5 ± 2.3 (31.8 – 38.2), tip 12.4 ± 2.3 (10.1 – 15.2). Ventral bar half length 41.9 ± 3.5 (38.3 – 48.2), ventral bar width 6.0 ± 0.8 (5.2 – 7.3). Marginal hooklets; I= 16.3 ± 2.1 (13.6 – 19.9), II= 12.7 ± 0.8 (11.7 – 13.7), III= 23.3 ± 2.9 (20.9 – 28.3), IV= 20.9 ± 1.9 (19.3 – 23.8), V= 23.3 ± 2.8 (19.7 – 28.0), VI= 23.6 ± 0.8 (22.4 – 24.5), VII= 23.0 ± 2.8 (18.1 – 26.6). Cirrus tubular, 95.5 ± 12.5 (77.9 – 107.2), accessory piece length 78.9 ± 8.8 (70.9 – 91.2). Vagina not sclerotised.

Remarks:

Cichlidogyrus botswanensis n. sp. is clearly distinguished from all existing species in the genus by possessing a unique copulatory organ which resembles no other species currently represented by this genus. The copulatory organ is very long and thin compared to most other *Cichlidogyrus* species and consists of a long, thin accessory piece which terminates in a hook, and is associated with the cirrus proximally at the basal cirral bulb (figure 5.5). The cirrus runs the length of the accessory piece and extends beyond it. The main distinguishing character of the cirrus is that it possesses a second bulb approximately a quarter of the way along its length, this feature has not been seen in any other species from this genus to date. Pariselle and Euzet (1996) noted a swollen portion of the cirrus near the sub-spherical basal bulb of *C. amphoratus*, but this is just a thickened portion of the cirrus, not a well defined bulb as is present in *C. botswanensis.*

Cichlidogyrus albareti is also characterised by a long slender copulatory organ. Apart from the second cirral bulb, *C. botswanensis* can be distinguished from *C. albareti* by having smaller haptoral sclerites, particularly the dorsal anchors (table 5.5). The copulatory organs of these two species are similar in length with reference to their respective parts, but the accessory piece of *C. albareti* possesses a distinct heel as opposed to that of *C. botswanensis*, and the accessory piece of *C. albareti* does not terminate in a hook as is the case for *C. botswanensis*.

Table 5.5 Measurements of *Cichlidogyrus botswanensis* n. sp. from *Sargochromis codringtonii* (Boulenger, 1908) from the Okavango Delta and its comparison with the published descriptions of *Cichlidogyrus albareti* Pariselle and Euzet, 1998. All measurements are given in micrometers.

Monogenean	*Cichlidogyrus botswanensis* (n=7)		*Cichlidogyrus albareti* (n=18)
Host	*Sargochromis codringtonii*		*Tilapia brevimanus*
	Mean ± SD	Range	Pariselle & Euzet (1998)
Dorsal anchor			
Total length	43 ±2.5	39-45	50-62
Inner root	12 ± 3.6	6-16	20-30
Outer root	4 ± 0.8	3-5	3-8
Shaft	32 ± 2.7	30-36	30-40
Tip	12 ± 1.0	10-13	12-17
Dorsal bar			
Length	39 ± 2.7	36-43	57-68
Centrum width	13 ± 1.4	12-16	20-32
Centrum height	8 ± 1.1	7-10	11-17
Ventral anchor			
Total length	41 ± 1.9	38-43	40-53
Inner root	10 ± 2.1	8-13	10-19
Outer root	6 ± 1.0	5-7	4-11
Shaft	35 ± 2.3	32-38	35-47
Tip	12 ± 2.3	10-15	11-18
Ventral bar			
Length	42 ± 3.5	38-48	30-67
Width	6 ± 0.8	5-7	6-10
Marginal hooklets			
I	16 ± 2.1	14-20	27-39
II	13 ± 0.8	12-14	11-15
III	23 ± 2.9	21-28	18-28
IV	21 ± 1.9	19-24	22-33
V	23 ± 2.8	20-28	26-34
VI	24 ± 0.8	22-25	24-30
VII	23 ± 2.8	18-27	20-29
Copulatory organ			
Cirrus	96 ± 12.5	78-107	98-121
Accessory piece	79 ± 8.8	71-91	53-93

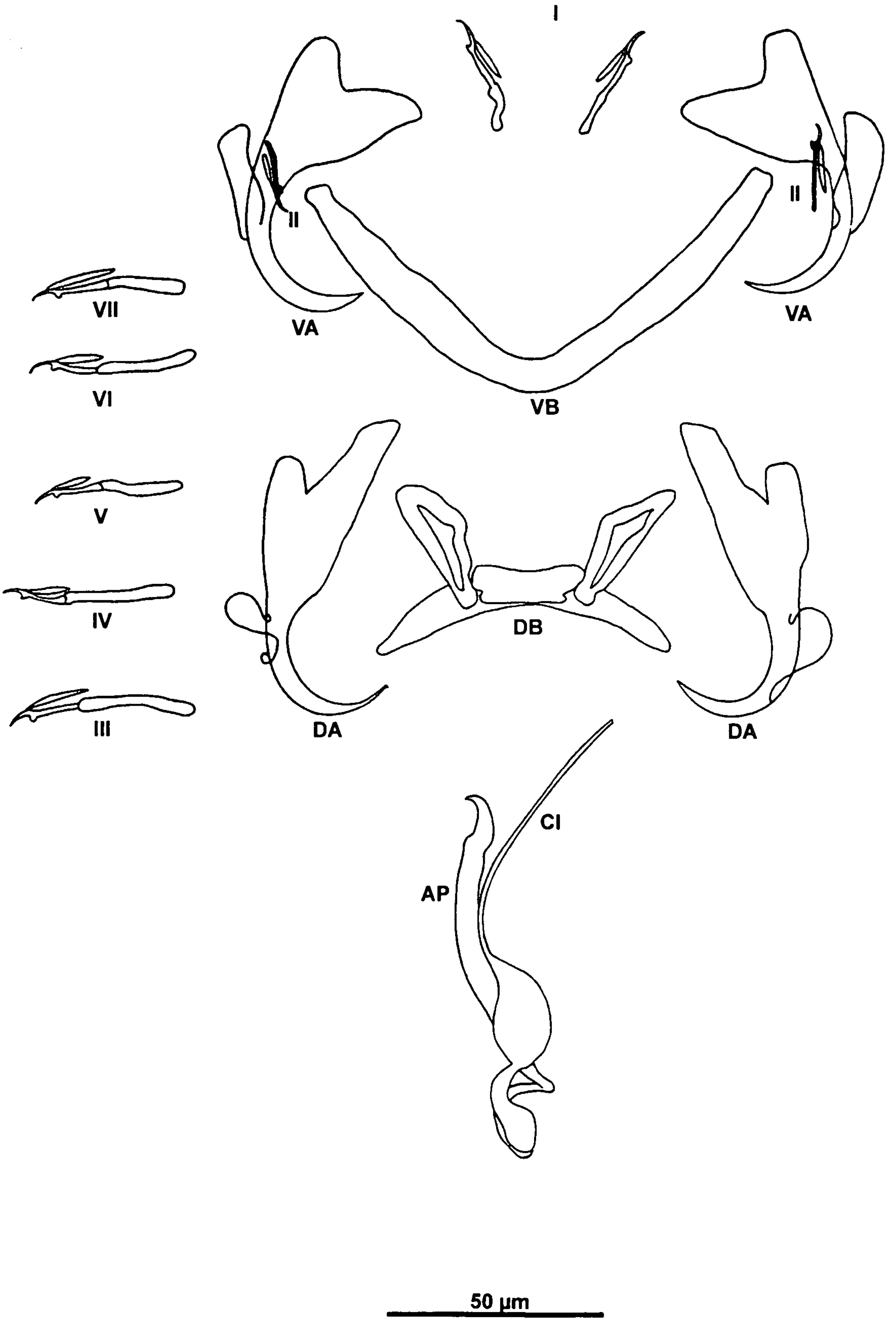

Figure 5.5 Microscope projection drawings of *Cichlidogyrus botswanensis* n. sp. from the gills of *Sargochromis codringtonii* (Boulenger, 1908). Abbreviations: **AP** – accessory piece, **CI** – Cirrus, **DA** – dorsal anchor, **DB** – dorsal bar, **VA** – ventral anchor, **VB** – ventral bar, **I** to **VII** – marginal hooklets.

***Cichlidogyrus mohemboensis* n.sp**

Type host: *Oreochromis andersonii* Weber, 1897.

Type locality: Floodplain at Mohembo (S18°16'19.8" E021°47'38.7").

Site of infestation: Gills.

Type material: Holotype: 1997 / 10 / 23 / 09 - 38 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Paratype: 1997 / 10 / 23 / 09 – 39 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (figure 5.6, table 5.6) were made using light microscopy from four specimens mounted in ammonium picrate glycerine. Measurements according to Pariselle and Euzet (1998).

Etymology: Name derived from the sampling locality at Mohembo from where these parasites were collected.

Description and measurements:

Body fusiform, 320.0 ± 28.3 (300.0 – 340.0), greatest width 125.0 ± 7.1 (120.0 – 130.0). Haptor terminal and distinct. Dorsal anchors 25.8 ± 3.3 (22.0 – 28.0), base width 10.2 ± 0.7 (9.7 – 10.7), inner root 5.1 ± 1.7 (3.0 – 7.2), outer root 5.8 ± 0.6 (4.9 – 6.3), shaft 17.9 ± 2.0 (15.6 – 20.0), tip 7.1 ± 2.0 (5.0 – 9.4). Dorsal bar length 28.6 ± 0.7 (28.2 – 29.1), centrum height 4.1 ± 0.8 (3.4 – 5.0), centrum width 9.6 ± 1.4 (8.0 – 11.0), auricle height 19.6 ± 1.0 (19.0 – 20.7). Ventral anchors 35.1 ± 2.6 (32.0 – 38.1), base width 12.9 ± 2.4 (10.3 – 15.1), inner root 8.8 ± 1.4 (7.0 – 10.2), outer root 5.2 ± 1.4 (3.1 – 6.6), shaft 30.2 ± 3.0 (28.2 – 34.7), tip 9.1 ± 2.1(7.0 – 12.0). Ventral bar half length 30.5 ± 3.4 (28.0 – 34.4), ventral bar width 5.0 ± 0.9 (4.3 – 6.3). Marginal hooklets; I= 15.4 ± 2.7 (11.4 – 17.0), II= 13.1 ± 1.8 (10.6 – 14.6), III= 35.7 ± 3.0 (33.1 – 39.0), IV= 32.6 ± 2.4 (29.3 – 35.0), V= 32.5 ± 1.3 (30.6 – 33.5), VI= 35.5 ± 3.7 (30.0 – 38.0), VII= 35.4 ± 3.6 (30.0 – 37.4). Cirrus tubular 52.3 ± 3.0 (48.9 – 54.5), accessory piece length 48.3 ± 1.8 (46.7 – 50.3), heel 13.8 ± 0.6 (13.2 – 14.3). Vagina not sclerotised.

Remarks:

This *Cichlidogyrus* species is characterised by a small marginal hooklet I, long marginal hooklets III – VII and no auxiliary plate associated with the male copulatory organ (figure 5.6). It shares these characters with *C. bouvii* Pariselle and Euzet, 1997; *C. ouedraogoi* Pariselle and Euzet 1996; *C. dossoui* Douëllou, 1993; *C. tiberianus* Paperna, 1960 and *C. vexus* Pariselle and

Euzet, 1995. The Okavango population is regarded as a new species, *Cichlidogyrus mohemboensis* n.sp, and shares close affinities with *C. bouvii, C. dousoui* and *C. tiberianus* with respect to opisthaptoral sclerite morphology and size (table 5.6), all these species share a common general accessory piece morphology as well. *Cichlidogyrus mohemboensis* can be distinguished from all of the closely related species besides *C. tiberianus* by possessing an accessory piece that terminates in two well defined, closely associated hooks and is distinguished from *C. tiberianus* in the general size of the copulatory organ and general shape of the opisthaptoral sclerites, specifically the dorsal anchor and the ventral anchor which possess well defined roots which are not evident in *C. tiberianus.*

Table 5.6 Measurements of *Cichlidogyrus mohemboensis* n. sp. from *Oreochromis andersonii* Weber, 1897 from the Okavango Delta and its comparison with the published descriptions of similar species. All measurements are given in micrometers.

Monogenean	*Cichlidogyrus mohemboensis* (n=4)		*C. tiberianus* (n=15)	*C. dossoui* (n=15)	*C. bouvii* (n=29)
Host	*Oreochromis andersonii*		*Tilapia rendalli*	*Tilapia rendalli*	*Sarotherodon occidentalis*
	Mean ± SD	Range	Douëllou (1993)	Douëllou (1993)	Pariselle & Euzet (1997)
Dorsal anchor					
Total Length	26 ± 3.3	22-28	22-27	27-32	27-31
Inner root	5 ±1.7	3-7	7-12	9-13	8-13
Outer root	6 ± 0.6	5-6	3-6	5-9	6-11
Shaft	18 ± 2.0	16-20	17-22	21-25	21-25
Tip	7 ± 2.0	5-9	5-10	8-12	6-9
Dorsal bar					
Length	29 ± 0.7	28-29	24-31	30-46	30-42
Centrum width	10 ± 1.4	8-11	7-10	10-15	9-13
Centrum height	4 ± 0.8	3-5	3-5	4-8	3-8
Ventral anchor					
Total length	35 ± 2.6	32-38	30-37	34-37	30-37
Inner root	9 ± 1.4	7-10	6-10	12-15	8-13
Outer root	5 ± 1.4	3-7	2-5	6-9	7-11
Shaft	30 ±3.0	28-35	30-36	29-32	26-31
Tip	9 ± 2.1	7-12	9-13	10-14	8-11
Ventral bar					
Length	31 ± 3.4	28-34	24-29	32-40	27-35
Width	5 ± 0.9	4-6	3-4	2-5	4-7
Marginal hooklets					
I	15 ± 2.7	11-17	12-15	17-20	14-20
II	13 ± 1.8	11-15	11-14	12-15	10-12
III	36 ± 3.0	33-39	25-31	36-45	31-39
IV	33 ± 2.4	29-35	27-34	38-46	31-39
V	33 ± 1.3	31-34	27-32	41-49	31-39
VI	36 ± 3.7	30-38	26-32	40-48	31-39
VII	35 ± 3.6	30-37	25-31	36-42	31-39
Copulatory organ					
Cirrus	52 ± 3.0	49-55	50-65	54-68	48-61
Accessory piece	48 ± 1.8	47-50	30-43	42-50	31-39

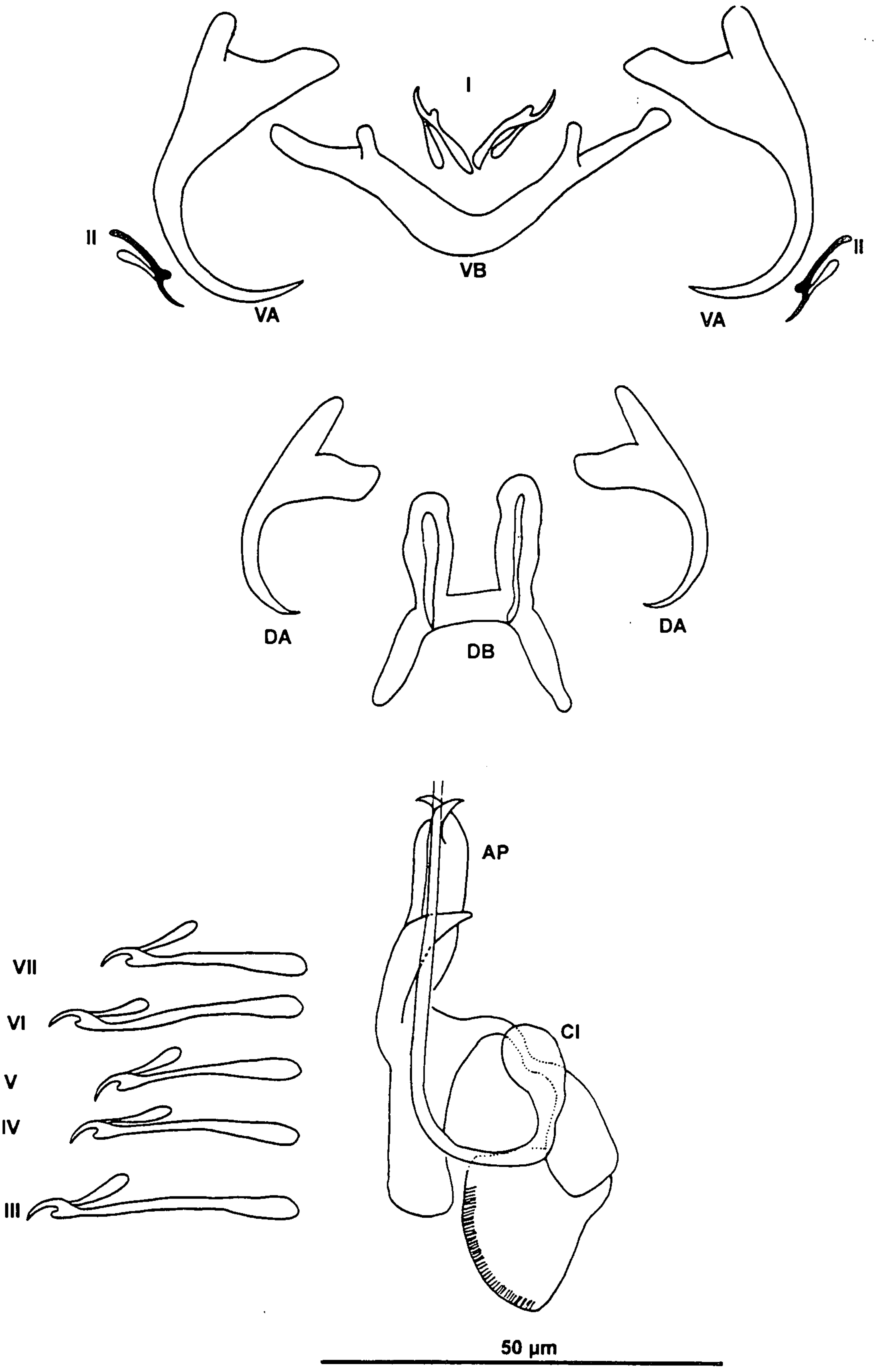

Figure 5.6 Microscope projection drawings of *Cichlidogyrus mohemboensis* n. sp. from the gills of *Oreochromis andersonii* Weber, 1987. Abbreviations: **AP** – accessory piece, **CI** – Cirrus, **DA** – dorsal anchor, **DB** – dorsal bar, **VA** – ventral anchor, **VB** – ventral bar, **I** to **VII** – marginal hooklets.

CHAPTER 6

The monogeneans of the other fish families of the Okavango Delta

This chapter comprises the taxonomic diagnoses of some monogeneans of the family Dactylogyridae from fishes representative of families other than the Cyprinidae and Cichlidae from the Okavango River and Delta. These families collected from the Okavango System for the purposes of this study include the Mormyridae, Distichodontidae, Characidae, Hepsetidae, Schilbeidae, Clariidae, Mochokidae, Cyprinodontidae and Anabantidae. The monogeneans infesting the fishes of the Cyprinidae and Cichlidae have been discussed in previous chapters (Chapter 4 and Chapter 5). This chapter does not represent all of the Dactylogyridae species that infest the above mentioned fishes in the Okavango System, but only those with sufficient parasite prevalence and intensities.

Family: Dactylogyridae Bychowsky, 1933

Subfamily: Dactylogyrinae (Boeger and Kritsky, 1987)

***Characidotrema nursei* Ergens, 1973**

Host: *Brycinus lateralis* (Boulenger, 1900).

Locality: Lagoon 1 off the Okavango Mainstream near Xaro (S18°25'29.34" E021°56'24.48"), *Additional localities*: Lagoon 2 near Xaro (S18°25'26.08" E021°56'27.93"), Sepopa Lagoon (S18°44'42.24" E022°11'49.2"), Thoage Lagoons (S18°51'44.18" E022°24'22,29"), Guma Lagoon (S18°57'44.94" E022°22'26.76"), Pepere Lagoon (S18°54'57.42" E022°32'17.70").

Site of infestation: Gills.

Reference material: 98/06/23–11 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings were made using light microscopy (table 6.1, figure 6.1) from 15 specimens mounted in ammonium picrate glycerine.

Description and measurements:

Body spindle-shaped, Total length 345.0 ± 50.4 (290.0 - 470.0), width 132.0 ± 35.9 (95.0 - 190.0). Prohaptor with two poorly developed cephalic lobes. Eyes equidistant, anterior pair smaller than posterior pair. Pharynx spherical, 15.0 ± 2.8 (10.0 - 19.0) in diameter. Opisthaptor sub-terminal and indistinct, appearing as extension of body trunk. Dorsal anchors 15.0 ± 2.4

(13.0 - 21.0), inner root 3.0 ± 0.9 (2.0 - 4.0), outer root 2.0 ± 0.8 (1.0 - 4.0), shaft 12.0 ± 1.8 (9.0 - 15.0), tip 2.0 ± 1.0 (1.0 - 4.0). Dorsal bar length 14.0 ± 2.6 (10.0 - 19.0), dorsal bar width 2.0 ± 0.7 (1.0 - 3.0). Ventral anchors 11.0 ± 1.3 (8.0 - 12.0), inner root 4.0 ± 1.1 (2.0 - 6.0), outer root 2.0 ± 0.7 (2.0 - 4.0), shaft 8.0 ± 1.1 (6.0 - 10.0), tip 2.0 ± 0.5 (1.0 - 2.0). Ventral bar length 15.0 ± 4.9 (7.0 - 22.0), ventral bar width 2.0 ± 0.4 (1.0 - 2.0), sinistral lateral arm 8.0 ± 1.9 (6.0 - 11.0), dextral lateral arm 8.0 ± 1.1 (6.0 - 9.0). Marginal hooklets; I= 8.0 ± 2.9 (5.0 - 13.0), II= 9.0 ± 2.5 (6.0 - 14.0), III= 8.0 ± 3.8 (4.0 - 15.0), IV= 8.0 ± 3.6 (5.0 - 14.0), V= 8.0 ± 2.5 (5.0 - 11.0), VI= 7.0 ± 1.7 (5.0 - 9.0), VII= 7.0 ± 1.7 (5.0 - 9.0). Cirrus, long curved shaft, 16.0 ± 2.3 (13.0 - 20.0). Accessory piece, elongated, associated with cirrus distally 9.0 ± 2.3 (8.0 - 10.0). Vagina opens dextrally, slightly sclerotised with spiralled tubular opening.

Remarks:

Characidotrema specimens collected from the Okavango are compared to the specimens collected by Ergens (1973a) from *Alestes nurse*, Nile River, Cairo, Egypt and by Paperna (1979) from *A. nurse*, Lake Albert, Uganda and *A. leuciscus*, Volta Lake and Mawli River, Ghana. The Okavango population is included as *C. nursei* based on the similarity both in size and morphology of the haptoral sclerites (table 6.1, figure 6.1). The tubular vagina characteristic of *C. nursei* was observed in the Okavango population and was proximally sclerotised.

According to Kritsky *et al.* (1987), Ergens (1973a) described *C. nursei* and Paperna (1973) proposed *Jainus longipenis* independently and without knowledge of each other. Upon examination of the holotypes of each of these species, Kritsky *et al.* (1987) confirmed their conspecificity and considered *J. longipenis* a junior subjective synonym of *C. nursei* based on priority. The Okavango population was recorded from *Brycinus lateralis*, which represents the first record of *C. nursei* from this host.

Table 6.1 Measurements of *Characidotrema nursei* Ergens, 1973 from *Brycinus lateralis* (Boulenger, 1900) from the Okavango Delta and its comparison with the published descriptions of the same species from *Alestes nurse* (Rüppel, 1832). All measurements are given in micrometers.

Monogenean	*Characidotrema nursei* (n=15)		*C. nursei* (n=3)
Host	*Brycinus lateralis*		*Alestes nurse*
	Mean ± S.D	Range	Paperna (1973)
Dorsal anchor			
Total length	15 ± 2.4	13-21	19-24
Inner root	3 ± 0.9	2-4	5-10
Outer root	2 ± 0.8	1-4	1-2
Shaft	12 ± 1.8	9-15	14-15
Tip	2 ± 1.0	1-4	3-5
Dorsal bar			
Total length	14 ± 2.6	10-19	15-17
Width	2 ± 0.7	1-3	1-2
Ventral anchor			
Total length	11 ± 1.3	8-12	13-17
Inner root	4 ± 1.1	2-6	4-6
Outer root	2 ± 0.7	2-4	4-7
Shaft	8 ± 1.1	6-10	9-12
Tip	2 ± 0.5	1-2	3-3
Ventral bar			
Total length	15 ± 4.9	7-22	9-12
Width	2 ± 0.4	1-2	2-3
Lateral processes	8 ± 1.9	6-11	9-10
Marginal hooklet	8 ± 3.8	4-15	7-18

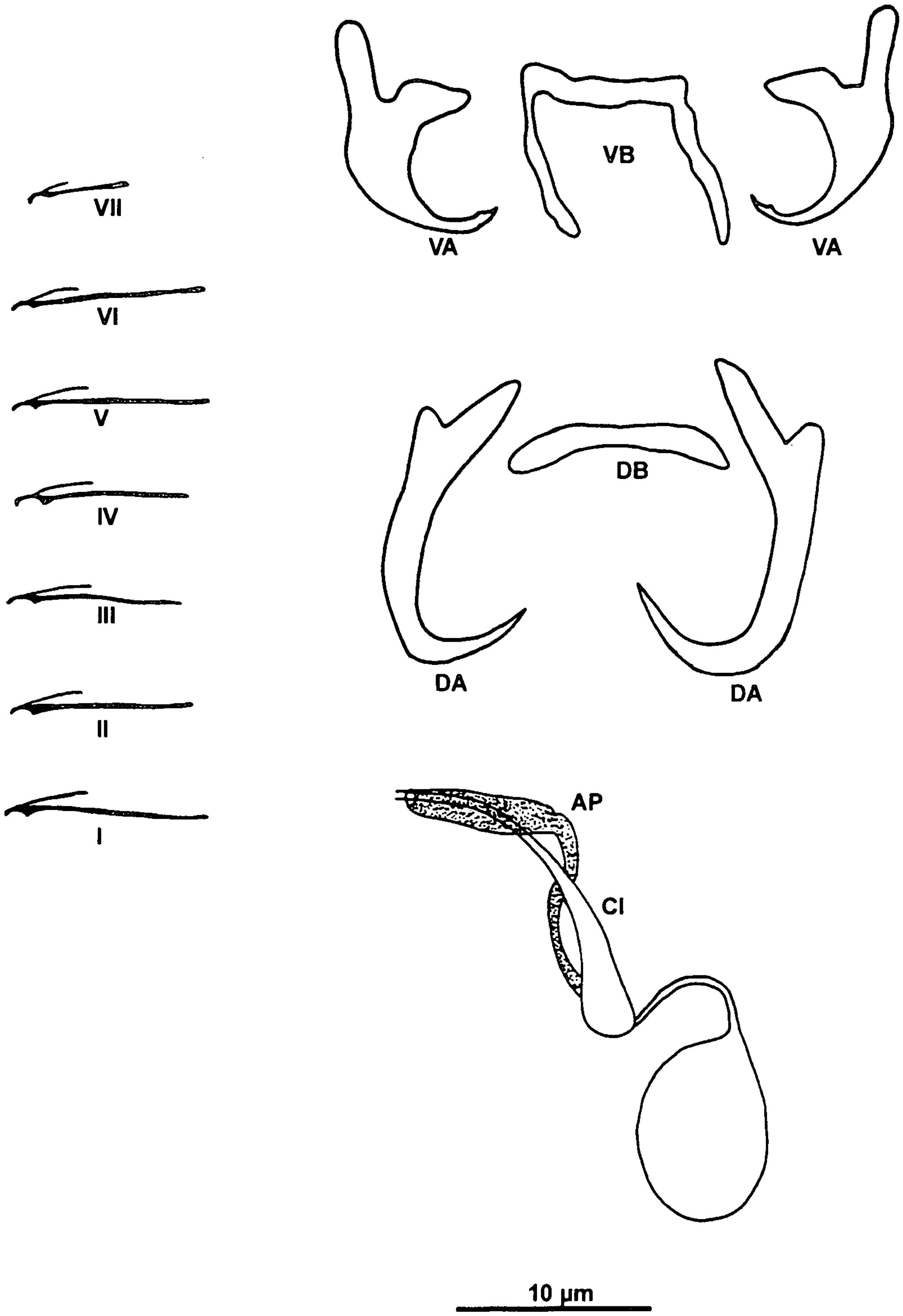

Figure 6.1 Microscope projection drawings of *Characidotrema nursei* Ergens, 1973 from the gills of *Brycinus lateralis* (Boulenger, 1900). Abbreviations: **AP** – accessory piece, **CI** – cirrus, **DA** – dorsal anchor, **DB** – dorsal bar, **VA** – ventral anchor, **VB** – ventral bar, **I** to **VII** – marginal hooklets.

***Quadriacanthus kalatensis* n. sp.**

Host: *Clarias gariepinus* (Burchell, 1822)

Type locality: Kalatog Lagoon (S18°23'58.3" E021°58'16.0")

Additional localities: Okavango Mainstream at Drodsky's Cabins (S18°24'48.66" E021°53'9.6"), Okavango Mainstream at Xaro Lodge (S18°25'23.6"; E021°56'18.2"), Samochima Lagoon (S18°25'26.08" E021°54'09.26"), Lagoon 1 near Xaro (S18°25'29.34" E021°56'24.48"), Sepopa Lagoon (S18°44'42.24" E022°11'49.2"), Floodplains at Mohembo (S18°16'19.8" E021°47'38.7"), Okavango Mainstream at Etsatsa (S18°51'0.4" E022°25'12.0"), Thaoge Lagoons (S18°51'44.18" E022°24'22,29"), Guma Lagoons (S18°57'44.94' E022°22'26.76"), Pepere Lagoons (S18°54'57.42" E022°32'17.70"), Duba Lagoon (S18°58'27.78" E022°33'44.22"), Perennial Swamp at Film Camp (S19°26'32.88" E022°49'10.32").

Site of infestation: Gills.

Type material: Holotype: 2001 / 10 / 04 / 09 – 07 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Paratypes: 2001 / 10 / 04 / 09 – 08 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (table 6.2 and figure 6.2) were made using light microscopy from 10 specimens mounted in ammonium picrate glycerine. Measurements according to N'Douba *et al.* (1999).

Etymology: Name derived from the sampling locality, Kalatog channel and lagoons, from where these parasites were found.

Description and measurements:

Body fusiform, total length 184.1 ± 45.6 (113.9-244.0), greatest width at level of ovaries 66.8 ± 9.7 (52.5-82.4). Two terminal cephalic lobes; four pairs of head organs. Eyes absent, pigment granules variable in size, spherical to ovate, scattered in cephalic region. Pharynx spherical. Haptor terminal and distinct. Dorsal anchors 41.4 ± 6.4 (33.4-53.9), base width 11.5 ± 2.6 (7.9-15.2), accessory sclerite length 15.6 ± 3.3 (10.8-21.6), accessory sclerite width 6.4 ± 2.0 (3.9-10.0), tip 4.8 ± 1.2 (2.6-6.6). Dorsal bar length 35.2 ± 4.7 (28.7-41.1), dorsal bar width 16.2 ± 5.0 (9.7 -27.1), median process 13.7 ± 1.5 (12.1-15.4). Ventral anchors 32.4 ± 3.5 (27.0-38.1) base width 8.9 ± 2.2 (5.7-12.5), accessory sclerite length 9.8 ± 1.8 (6.8-12.2), tip 11.0 ± 3.1 (6.5-14.4). Ventral bar length 48.4 ± 5.9 (43.2-59.0), ventral bar width 9.9 ± 1.9 (8.3-14.6). Marginal hooklets; I= 12.6 ± 0.2 (12.4-12.8), II= 14.0 ± 1.4 (12.6-15.8), III= 13.8 ± 1.4 (12.1-15.7), IV= 13.5 ± 0.9 (12.4-15.2), V= 34.1 ± 5.2 (26.1-43.9), VI= 19.5 ± 2.5 (16.18-23.5), VII= 15.3 ± 1.9 (12.8-17.5). Cirrus straight and tubular, 52.2 ± 11.7 (43.9-60.5), accessory piece 53.7 ± 5.8 (49.6-57.8) terminates distally in well defined hook. Vagina not sclerotised.

Remarks:

Quadriacanthus kalatensis n. sp. specimens collected from the Okavango System from *Clarias gariepinus* can be distinguished from similar species by possessing a ventral anchor which has a slightly elongated shaft and a large copulatory organ with a robust accessory piece which terminates in a definite hook (figure 6.2). The accessory piece consists of three sections and is closely associated with the cirrus, which is almost as long as the accessory piece.

Morphometrically the opisthaptoral sclerites of *Q. kalatensis* resembles that of *Q. aegypticus* El-Naggar and Serag, 1986 from Egypt (Kritsky and Kulo 1988) and the population from Lake Kariba, Zimbabwe (Douëllou and Chishawa 1995) (table 6.2). The size and shape of the copulatory organ of *Q. kalatensis*, however, distinguish it from both populations of *Q. aegypticus* (table 6.2).

N'Douba *et al.* (1999) described seven new *Quadriacanthus* species, including some that have close affinities to *Q. kalatensis*, *Q. clariadis* Paperna, 1961 and *Q. aegypticus*. Of these seven, *Q. agnebiensis* N'Douba, Lambert and Euzet, 1999 and *Q. longifilisi,* N'Douba, Lambert and Euzet, 1999 are also compared to *Quadriacanthus kalatensis* recorded from the Okavango Delta (figure 6.2). *Quadriacanthus kalatensis* can be distinguished from both *Q. agnebiensis* and *Q. longifilisi* in having a generally larger cirrus and accessory piece.

Table 6.2 Measurements of *Quadriacanthus kalatensis* n. sp from *Clarias gariepinus* (Burchell, 1822) from the Okavango Delta and its comparison with the published descriptions of similar species. All measurements are given in micrometers.

Monogenean	*Quadriacanthus kalatensis* (n=10)		*Q. aegypticus*	*Q. aegypticus*	*Q. longifilisi*
Host	*Clarias gariepinus*		*C. gariepinus*	*C. gariepinus*	*H. longifilis*
	Mean ± SD	Range	Douëllou & Chishawa (1995)	Kritsky & Kulo (1988)	N'Douba, Lambert & Euzet (1999)
Dorsal anchor					
Total length	41 ± 6.4	33-54	34-41	43-51	42-55
Base width	12 ± 2.6	8-15	11-13	13-18	13-17
Dorsal bar					
Length	35 ± 4.7	29-41	35-44	23-37	33-43
Ventral Anchor					
Total length	32 ± 3.5	27-38	29-34	36-44	33-41
Base width	9 ± 2.2	6-13	7-10	9-12	8-11
Ventral bar					
Length	48 ± 5.9	43-59	32-37	20-27	50-60
Marginal Hooklets					
I	13 ± 0.2	12-13	12-13	13-16	18-23
II	14 ± 1.4	13-16	12-13	13-16	13-17
III	14 ± 1.4	12-16	12-13	13-16	15-17
IV	14 ± 0.9	12-15	12-13	13-16	15-17
V	34 ± 5.2	26-43	24-27	31-36	33-41
VI	20 ± 2.5	16-24	13-17	16-22	14-17
VII	15 ± 1.9	13-18	13-17	20-21	24-29
Copulatory Organ					
Cirrus	52 ± 11.7	43-70	34-40	40-52	35-42
Accessory piece	54 ± 5.8	50-90	36-44	33-49	38-43

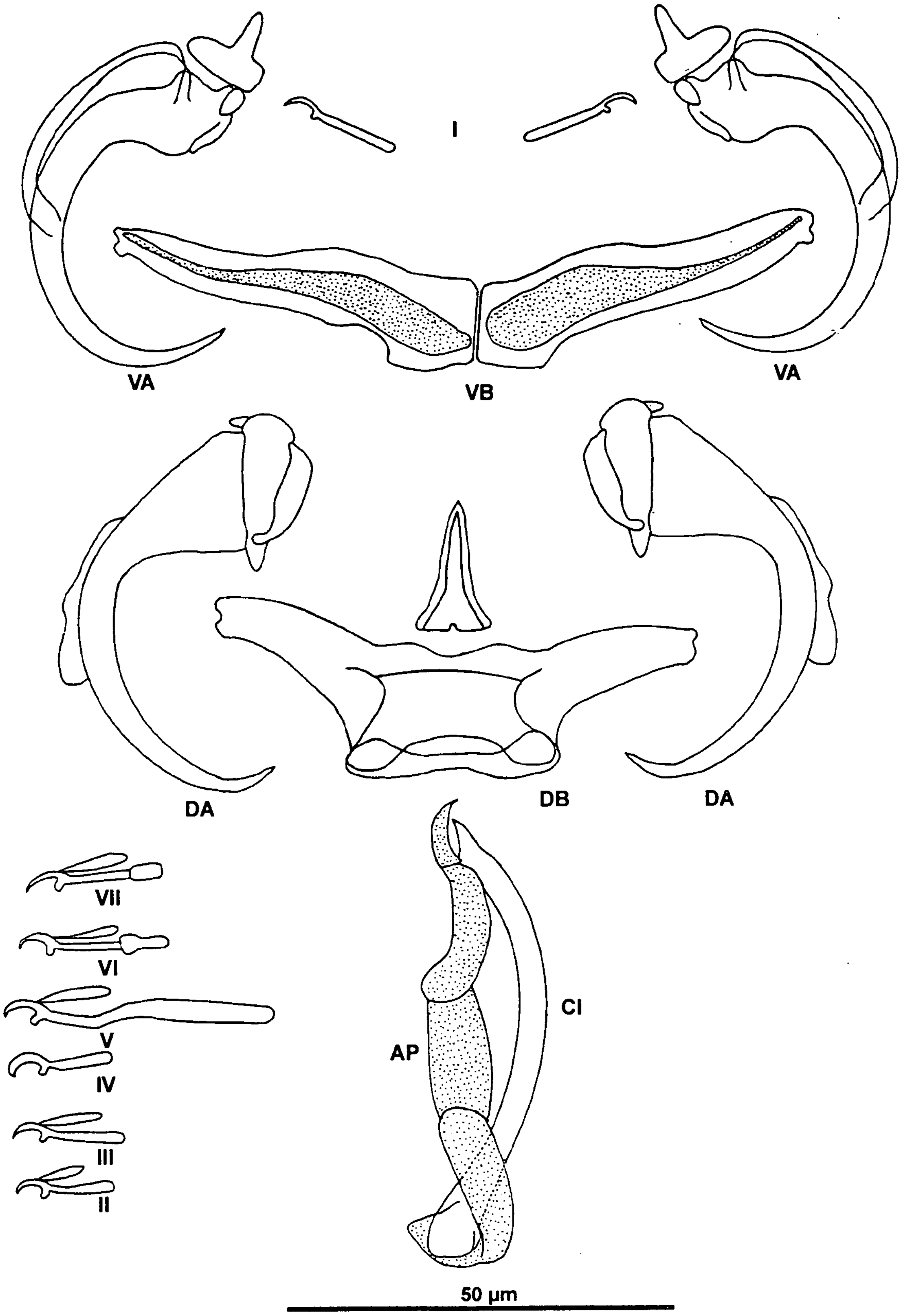

Figure 6.2 Microscope projection drawings of *Quadriacanthus kalatensis* n. sp. from the gills of *Clarias gariepinus* (Burchell, 1822). Abbreviations: **AP** – accessory piece, **CI** – cirrus, , **DA** – dorsal anchor, **DB** – dorsal bar, **VA** – ventral anchor, **VB** – ventral bar **I** to **VII** – marginal hooklets.

Quadriacanthus theodorae **n. sp.**

Host: *Clarias theodorae* Weber, 1897

Type locality: Nqoga Mainstream (S18°52'20.46" E022°28'34.5")

Additional localities: Backwaters at Xaro (S18°25'23.58" E021°56'18.18"), Sepopa Lagoon (S18°44'42.24" E022°11'49.2", Floodplains at Sepopa (S18°44'42.45" E022°11'50.4"), Floodplains at Mohembo (S18°16'19.8" E021°47'38.7"), Backwater at Etsatsa (S18°51'28.20" E022°25'33.6"), Floodplains at Jao Village (S19°02'36.48" E022°31'52.32")

Site of infestation: Gills.

Type material: Holotype 99 / 07 / 20 - 08 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Paratypes: 99 / 07 / 20 - 09 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (figure 6.3 and table 6.3) were made using light microscopy from 13 specimens mounted in ammonium picrate glycerine. Measurements according to N'Douba *et al.* 1999.

Etymology: Name derived from the host fish, *Clarias theodorae*, from where these parasites were found.

Description and measurements:

Body fusiform, total length 309.7 ± 50.4 (241.4 - 423.3), greatest width at level of ovaries 135.1 ± 36.6 (76.0 - 191.6). Two terminal cephalic lobes; four pairs of head organs. Eyes absent, granules variable in size, spherical to ovate, scattered in cephalic region. Pharynx spherical. Haptor terminal and distinct. Dorsal anchors 36.8 ± 3.1 (32.6 - 42.6), base width 11.0 ± 2.2 (6.7 - 14.9), accessory sclerite length 12.7 ± 1.0 (11.3 - 14.1), accessory sclerite width 4.5 ± 1.3 (2.9 - 7.8), tip 3.2 ± 0.8 (2.1 - 4.7). Dorsal bar length 25.9 ± 1.5 (23.5 - 27.7), dorsal bar width 11.3 ± 2.2 (8.1 - 14.9), median process 5.8 ± 2.2 (3.2 - 10.0). Ventral anchors 26.3 ± 3.6 (22.3 - 33.4) base width 7.6 ± 1.6 (5.3 - 10.8), accessory sclerite length 7.8 ± 1.5 (5.1 - 9.5), tip 3.9 ± 1.2 (1.9 - 5.9). Ventral bar length 36.0 ± 2.7 (33.6 - 42.9), ventral bar width 7.0 ± 0.8 (5.4 - 8.1). Marginal hooklets; I= 15.0 ± 1.2 (13.7 - 17.1), II= 11.9 ± 1.0 (10.0 - 13.2), III= 12.5 ± 1.7 (9.9 - 15.9), IV= 12.2 ± 0.9 (10.7 - 13.2), V= 12.4 ± 0.9 (11.4 - 14.1), VI= 24.3 ± 2.8 (18.7 - 26.5), VII= 14.9 ± 1.2 (13.2 - 16.8). Cirrus straight and tubular, 19.7 ± 3.8 (13.7 - 23.7), accessory piece 23.2 ± 4.8 (15.7 - 28.3). Vagina not sclerotised.

Remarks:

The *Quadriacanthus* sp. recorded from *Clarias theodorae* from the Okavango Delta closely resembles *Q. clariadis* with respect to its haptoral sclerites. This population is, however, distinguished from *Q. clariadis* by having generally smaller sclerites. Furthermore the accessory piece terminates in a definite hook, which is not the case for *Q. clariadis* (Kritsky and Kulo 1988). The Okavango population is distinguished from *Q. longifilisi* and *Q. agnebiensis* by having smaller haptoral sclerites, with the largest differences occurring between the connecting bars and the first, fifth and seventh marginal hooklets. The cirrus and accessory piece of the Okavango population are also smaller by comparison to *Q. longifilisi*.

The morphology and measurements of the opisthaptoral sclerites closely resembles *Q. aegypticus* particularly the Lake Kariba population (Douëllou and Chishawa 1995) (table 6.3). This species is, however, distinguished from the Lake Kariba population by having an accessory piece, which terminates in a single hook as opposed to two as reported by Douellou and Chishawa (1995). Furthermore this species differs from *Q. aegypticus* from Egypt (Kritsky and Kulo 1988) in having generally smaller haptoral sclerites and a significantly smaller copulatory complex (table 6.3). *Quadriacanthus theodorae* n. sp. from *Clarias theodorae* thus significantly different from the existing species and is hence regarded as a new species.

Table 6.3 Measurements of *Quadriacanthus theodorae* n. sp from *Clarias theodorae* Weber, 1897 from the Okavango Delta and its comparison with the published descriptions of similar species. All measurements are given in micrometers.

Monogenean	*Quadriacanthus theodorae* (n=13)		*Q. kalatensis* (n=10)	*Q. aegypticus*	*Q. aegypticus*
Host	*Clarias theodorae*		*Clarias gariepinus*	*Clarias gariepinus*	*Clarias gariepinus*
	Mean ± S.D.	Range	Current study	Douëllou & Chishawa (1995)	Kritsky & Kulo (1988)
Dorsal anchor					
Total length	36.8 ± 3.1	33-43	33-54	34-41	43-51
Dorsal bar					
Length	25.9 ± 1.5	23-28	29-41	35-44	45-74
Ventral anchor					
Total length	26.3 ± 3.6	22-33	27-38	29-34	36-44
Ventral bar					
Length	36.0 ± 2.7	34-43	43-59	32-37	39-53
Copulatory complex					
Cirrus	20 ± 3.8	14-24	44-70	34-40	40-52
Accessory piece	23 ± 4.8	16-28	50-90	36-44	33-49

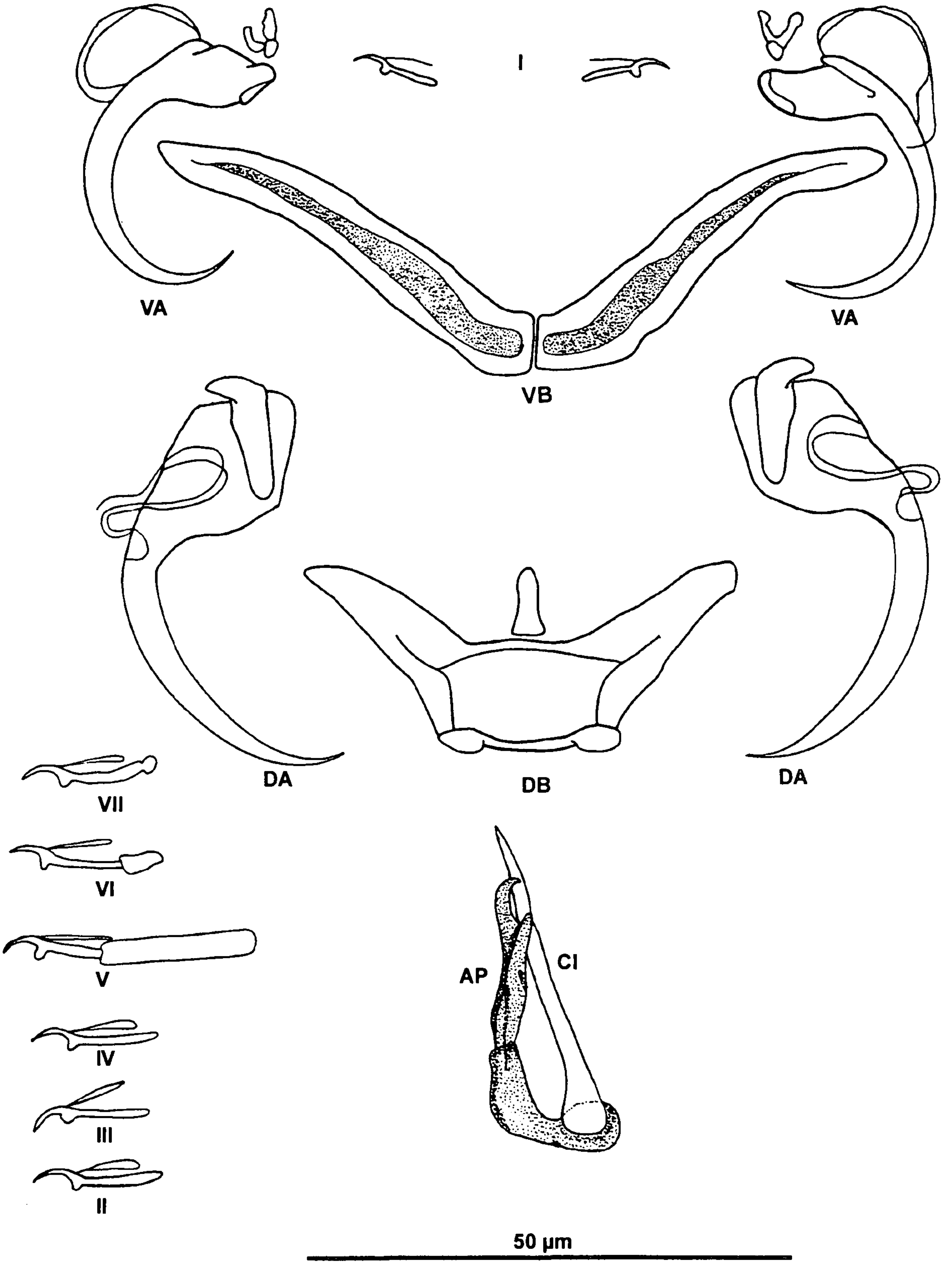

Figure 6.3 Microscope projection drawings of *Quadriacanthus theodorae* n. sp. from the gills of *Clarias theodorae* Weber, 1897. Abbreviations: **AP** – accessory piece, **CI** – cirrus, **DA** – dorsal anchor, **DB** – dorsal bar, **VA** – ventral anchor, **VB** – ventral bar, **I** to **VII** – marginal hooklets.

***Schilbetrema acornis* Paperna and Thurston, 1968**

Host: *Schilbe intermedius* Rüppell, 1832

Locality: Samochima Lagoon (S18°25'26.08" E021°54'09.26")

Site of infestation: Gills

Reference material: 2000 / 07 / 01 - 04 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morophometric measurements and drawings (figure 6.4 and table 6.4) were made using light microscopy from two specimens mounted in ammonium picrate glycerine.

Description and measurements:

Body total length 661.9 ± 71.0 (611.7 - 712.1), greatest width at level of ovaries 117.5 ± 1.6 (116.4 - 118.7). Haptor terminal and distinct. Dorsal anchors 34.2 ± 2.2 (32.6 - 35.7), base width 10.5 ± 0.3 (10.3 - 10.8), inner root 11.9 ± 1.5 (10.9 - 13.0), outer root 3.8 ± 0.1 (3.7 - 3.9), shaft 24.6 ± 1.0 (23.9 - 25.4), tip 15.7 ± 0.4 (15.4 - 16.0). Dorsal bar length 25.9 ± 2.0 (24.5 - 27.4), dorsal bar width 2.6 ± 0.9 (2.0 - 3.3). Ventral anchors 23.2 ± 1.2 (22.3 - 24.1) base width 9.6 ± 0.6 (9.1 - 10.0), inner root 6.5 ± 0.9 (5.9 - 7.2), median root 3.4 ± 0.5 (3.1 – 3.8), outer root 3.2 ± 1.1 (2.5 - 4.0), shaft 19.2 ± 0.1 (19.1 - 19.3), tip 11.4 ± 2.0 (10.0 - 12.9). Ventral bar length 23.7 ± 2.3 (22.1 - 25.3), medial process 21.4 ± 0.2 (21.2 - 21.5). Marginal hooklets; I= 17.0 ± 1.9 (15.7 - 18.3), II= 21.8 ± 3.5 (19.4 - 24.3), III= 23.3 ± 2.2 (21.8 - 24.8), IV= 23.1 ± 2.2 (21.6 - 24.7), V= 22.1 ± 0.3 (21.9 - 22.3), VI= 23.9 ± 1.0 (23.3 - 24.6), VII= 16.5 ± 5.2 (12.8 - 20.2). Cirrus coiled and tubular, 49.8 ± 2.3 (47.8 - 54.1), accessory piece 23.0 ± 1.8 (21.4 – 23.9) . Vagina not observed.

Remarks:

Schilbetrema acornis Paperna and Thurston, 1968 specimens from the Okavango System are characterised by large dorsal anchors, a simple dorsal transverse bar lacking any lateral or medial projections. The ventral anchors appear robust when compared to that of *S. quadricornis* Paperna and Thurston, 1968 and the roots are well differentiated. The shaft is bent near its midlength to form the tip. The ventral bar is simple, containing an elongated medial projection and does not appear to have any lateral horns or projections. Comparison of the specimens from the Okavango System, Botswana, with the original description by Paperna and Thurston (1968) and the population from Togo (Kritsky and Kulo 1992) clearly supports conspecificity of the

Okavango specimens with *Schilbetrema acornis* (table 6.4). According to Kritsky and Kulo (1992), *S. acornis* is easily confused with *S. undinula* Kritsky and Kulo, 1992 and *S. aegyptica* El-Naggar, 1985, but differs from these species by lacking lateral horns on the ventral bar which is also consistent with the Okavango population.

Table 6.4 Measurements of *Schilbetrema acornis* Paperna and Turston, 1968 from *Schilbe intermedius* Rüppel, 1832 from the Okavango Delta and its comparison with the published descriptions of the same and similar species. All measurements are given in micrometers. Marginal hooklet measurements are averaged across all hooklets.

Monogenean	*Schilbetrema acornis* (n=2)		*S. acornis* (n=3)	*S. acornis* Syntypes (n=2)	*S. acornis* Togo specimens
Host	*Schilbe intermedius*		*Schilbe intermedius*	*Schilbe intermedius*	*Schilbe intermedius*
	Mean ± S.D.	Range	Paperna & Thurston (1968)	Kritsky & Kulo (1992)	Kritsky & Kulo (1992)
Dorsal anchor					
Total length	34.2 ± 2.2	33-36	60-70	37-38	34-37 (n=5)
Dorsal Bar					
Length	25.9 ± 2.0	25-27	50		23-31 (n=6)
Ventral Anchor					
Total length	23.2 ±1.2	22-24	30-40	26-27	26-30 (n=4)
Ventral Bar					
Length	23.7 ± 2.3	22-25	30	20	18-22 (n=6)
Marginal hooklets	21.1 ± 1.6	16-25	20-30	23	20-27 (n=16)

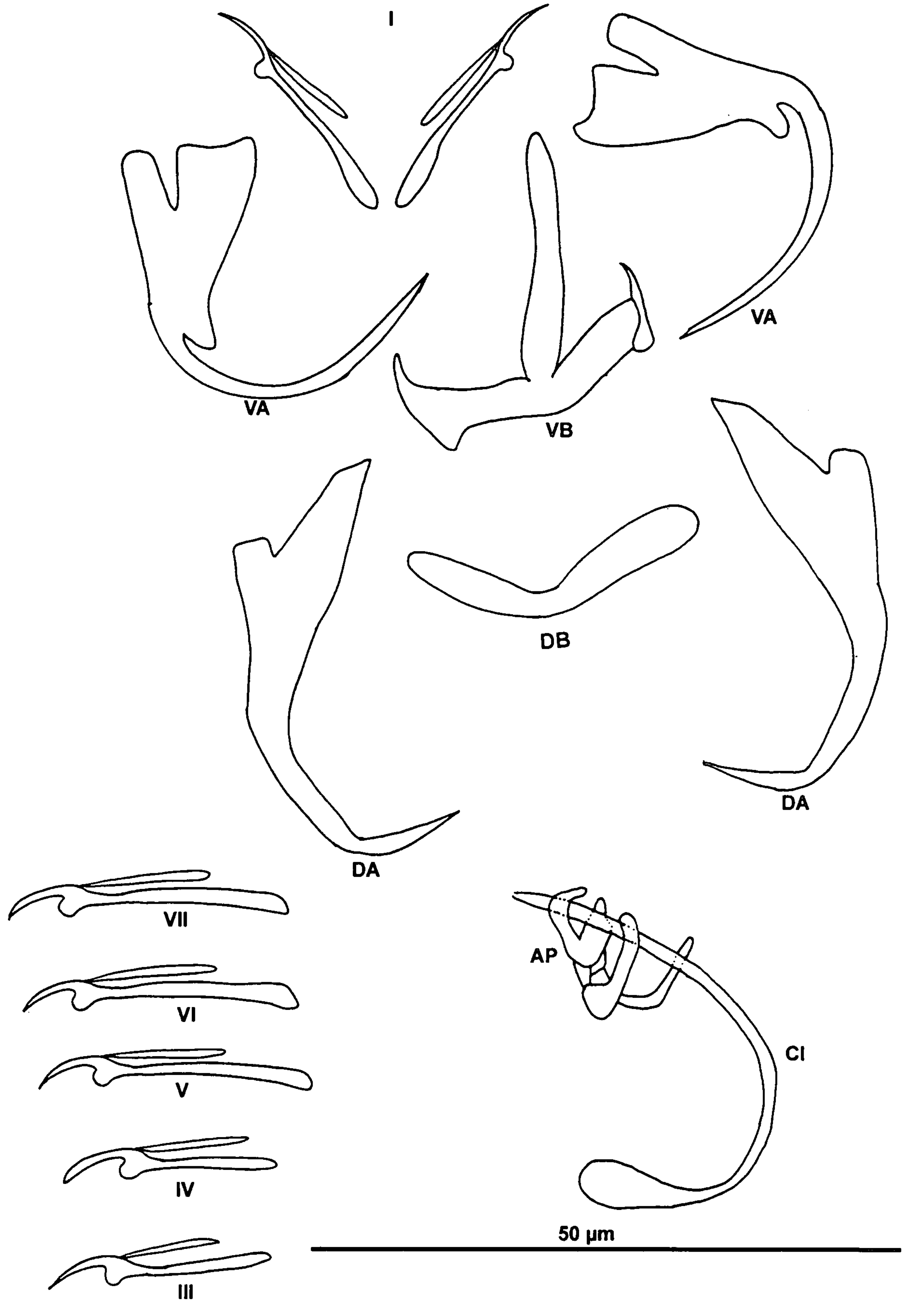

Figure 6.4 Microscope projection drawings of *Schilbetrema acornis* Paperna and Thurston, 1968 from the gills of *Schilbe intermedius* Rüppel, 1832. Abbreviations: **AP** – accessory piece, **CI** – cirrus, **DA** – dorsal anchor, **DB** – dorsal bar, **VA** – ventral anchor, **VB** – ventral bar, **I** to **VII** – marginal hooklets.

***Schilbetrema quadriacornis* Paperna and Thurston, 1968**

Host: *Schilbe intermedius* Rüppell, 1832

Locality: Lagoon 1 Near Xaro (S18°25'29.34" E021°56'24.48")

Additional localities: Channel off mainstream near Drodsky's Cabins (S18°25'01.00" E021°53'34.29"), Kalatog Channel and Lagoons (S18°23'58.3" E021°58'16.0"), Lagoon 2 Near Xaro (S18°25'26.08" E021°56'27.93"), Samochima Lagoon (S18°25'26.08" E021°54'09.26"), Floodplains at Mohembo (S18°16'19.8" E021°47'38.7"), Thaoge Channel (S18°51'52.62" E022°25'8.1"), Guma Lagoon (S18°57'44.94" E022°22'26.76"), Pepere Lagoon (S18°54'57.42" E022°32'17.70"), Nqoga Mainstream (S18°52'20.46" E022°28'34.5"), Duba Lagoons (S18°58'27.78" E022°33'44.22"), Jao Village (S19°02'36.48" E022°31'52.32"), Perennial Swamp at Film Camp (S19°26'32.88" E022°49'10.32").

Site of infestation: Gills

Reference material: 98 / 06 / 18 - 15 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (table 6.5 and figure 6.5) were made using light microscopy from 15 specimens mounted in ammonium picrate glycerine.

Description and measurements:

Body fusiform, total length 218.3 ± 19.6 (200.0 - 245.0), greatest width at level of ovaries 82.0 ± 11.7 (70.0 - 98.0). Haptor terminal and distinct. Dorsal anchors 61.5 ± 3.3 (55.0 - 64.2), base width 15.5 ± 2.2 (13.1 - 18.3), inner root 18.5 ± 4.7 (10.0 - 24.3), outer root 7.2 ± 2.8 (5.0 - 12.3), shaft 43.8 ± 2.8 (40.0 - 46.9), tip 15.4 ± 1.3 (12.5 - 16.5). Dorsal bar length 40.6± 1.0 (40.0 - 42.5), dorsal bar width 4.2 ± 1.0 (3.0 - 5.6). Ventral anchors 21.4 ± 2.0 (17.5 - 22.7) base width 5.3 ± 1.0 (4.2 - 6.6), inner root 13.9 ± 2.2 (10 - 16.3), median root 3.8 ± 1.7 (1.0 - 6.2), outer root 6.3 ± 1.7 (3.9 - 9.3), shaft 23.4 ± 1.9 (21.2 - 26.0), tip 31.8 ± 3.2 (27.0 - 35.9). Ventral bar length 65.2 ± 4.6 (60.0 - 71.5), ventral bar width 4.3 ± 0.6 (3.6 - 5.0), medial process 16.1 ± 2.5 (12.1 - 18.4). Marginal hooklets; I= 15.3 ± 0.5 (15.0 - 16.0), II= 12.7 ± 2.1 (10.0 - 15.0), III= 14.9 ± 4.7 (7.5 - 19.5), IV= 14.7 ± 2.8 (11.0 - 17.6), V= 14.5 ± 3.1 (10.0 - 18.8), VI= 14.9 ± 1.7 (12.5 - 17.7), VII= 13.2 ± 2.4 (10.0 - 16.3). Cirrus 49.3 ± 2.3 (37.9 – 56.0), accessory piece 22.5 ± 3.1 (17.8 – 30.4). Vagina not observed.

Remarks:

Schilbetrema quadricornis collected from the Okavango Delta have large dorsal anchors connected by a transverse dorsal bar, which possesses a pair of bilateral horns. The ventral anchors have a delicate, evenly curved hook with elongate variably bent roots (figure 6.5). Comparison of the specimens from the Okavango System, Botswana, with the original description by Paperna and Thurston (1968) and the population from Togo (Kritsky and Kulo, 1992) clearly supports conspecificity of the Okavango specimens with *Schilbetrema quadricornis* (table 6.5). Only minor differences in size of the haptoral sclerites could be detected. The only obvious difference in size of the ventral transverse bar (table 6.5) is as a result of including the bilateral horns in the length measurement according to N'Douba, Pariselle, Thys Van Den Audenaerde and Euzet (1997) of the Okavango population.

Table 6.5 Measurements of *Schilbetrema quadricornis* Paperna and Thurston, 1968 from *Schilbe intermedius* Rüppel, 1832 from the Okavango Delta and its comparison with the published descriptions of the same and similar species. All measurements are given in micrometers. The measurements for the marginal hooklets are averaged across all the hooklets.

Monogenean	*Schilbetrema quadricornis* (n=15)		*S. quadricornis* (n=5)	*S. quadricornis* Syntypes (n=3)	*S. quadricornis* Togo specimens
Host	*Schilbe intermedius*		*Schilbe intermedius*	*Schilbe intermedius*	*Schilbe intermedius*
	Mean ± S.D.	Range	Paperna & Thurston (1968)	Kritsky & Kulo (1992)	Kritsky & Kulo (1992)
Dorsal anchor					
Total length	61.5 ± 3.3	55-64	60-100	52-55	52-65 (n=40)
Dorsal Bar					
Length	40.6 ± 1.0	40-43	35-40	38-40	36-45 (n=16)
Ventral Anchor					
Total length	21.4 ± 2.0	18-23	45-50	22-25	21-28 (n=24)
Ventral Bar					
Length	65.2 ± 4.6	60-72	35-40	40	36-47 (n=16)
Marginal hooklets	14.5 ± 3.1	10-19	15-20	15-16	16-18 (n=48)

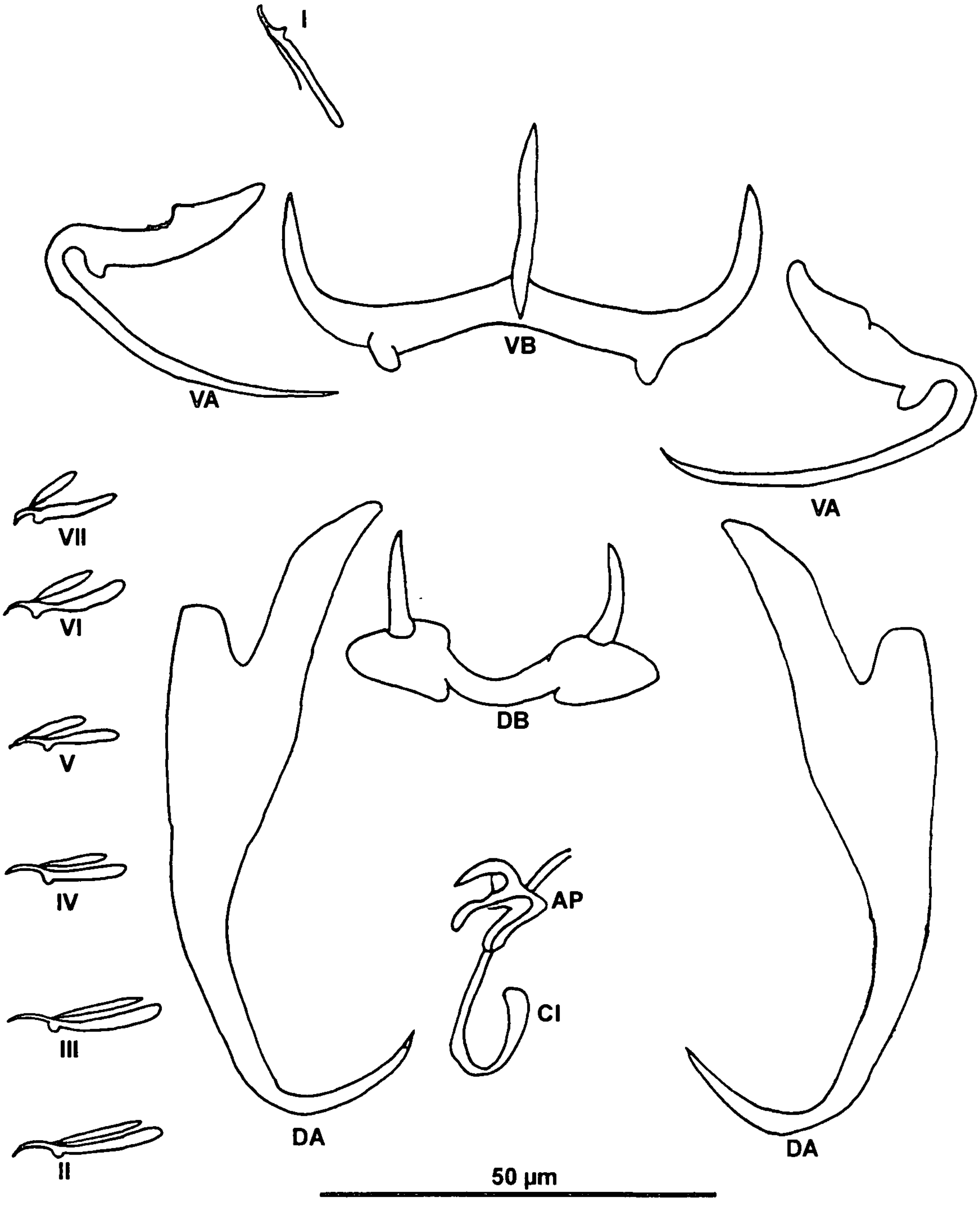

Figure 6.5 Microscope projection drawings of *Schilbetrema quadriacornis* Paperna and Thurston, 1968 from the gills of *Schilbe intermedius* Rüppel, 1832. Abbreviations: **AP** – accessory piece, **CI** – cirrus, **DA** – dorsal anchor, **DB** – dorsal bar, **VA** – ventral anchor, **VB** – ventral bar, **I** to **VII** – marginal hooklets.

SubFamily: Ancyrocephalinae Bychowsky, 1937

***Annulotrema curvipenis* Paperna, 1969**

Host: *Brycinus lateralis* Boulenger, 1900

Locality: Okavango River Mainstream at Xaro (S 18°25'23.6"; E 021°56'18.2")

Additional localities: Lagoon 2 near Xaro (S18°25'26.08" E021°56'27.93"), Sepopa Lagoon (S18°44'42.24" E022°11'49.2"), Thoage Lagoons (S18°51'44.18" E022°24'22,29"), Guma Lagoon (S18°57'44.94" E022°22'26.76"), Pepere Lagoon (S18°54'57.42" E022°32'17.70").

Site of infestation: Gills

Reference material: 98 / 07 / 03 – 01 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings were made using light microscopy from 10 specimens mounted in ammonium picrate glycerine (figure 6.6, table 6.6).

Description and measurements:

Small worms, total length 221.0 ± 25.0 (170.0 - 250.0), width 77.0 ± 10.6 (70.0 - 100.0). Tegument smooth, annulated in posterior half, annulations overlapping with wavy edges, annulations not too distinct. Prohaptor consists of four clearly defined cephalic lobes, sensory setae present on prohaptor, especially on cephalic lobes, prohaptor contains oral opening. Opisthaptor clearly separated from body trunk, dorsal anchors 37.0 ± 5.1 (31.0 - 45.0), inner root 8.0 ± 2.6 (5.0 - 12.0), outer root 4.0 ± 1.2 (3.0 - 6.0), shaft 29.0 ± 3.4 (22.0 - 32.0), tip 3.0 ± 1.2 (2.0-5.0). Dorsal bar length 23.0 ± 4.8 (18.0 - 32.0), dorsal bar width 3.0 ± 1.5 (2.0 - 6.0). Ventral anchors 39.0 ± 5.7 (32.0 - 48.0), inner root 8.0 ± 2.5 (4.0 - 10.0), outer root 3.0 ± 0.9 (2.0 - 5.0), shaft 32.0 ± 6.6 (25.0 - 44.0), tip 3.0 ± 0.7 (2.0 - 4.0). Ventral bar length 25.0 ± 4.1 (19.0 - 28.0), ventral bar width 5.0 ± 1.0 (4.0 - 6.0). Marginal hooklets; I= 12.0 ± 3.5 (8.0 - 17.0), II= 22.0 ± 5.6 (12.0 - 26.0), III= 24.0 ± 6.2 (16.0 - 31.0), IV= 22.0 ± 4.3 (16.0 - 27.0), V= 20.0 ± 5.1 (13.0 - 29.0), VI= 19.0 ± 4.7 (13.0 - 26.0), VII= 15.0 ± 5.7 (8.0 - 25.0). Copulatory organ opens ventrally, posterior to oral opening (figure 6.6), consists of curved cirrus and distally forked accessory piece, cirrus 39.0 ± 14.0 (26.0 - 65.0), accessory piece 15.0 ± 2.1 (12.0 - 18.0). Vagina not sclerotised, opening sinistral.

Remarks:

When comparing the Okavango population of *Annulotrema curvipenis* Paperna, 1969 with the population described from Uganda (Paperna 1969) (table 6.6), the greatest difference is the difference in body size, the Okavango specimens are smaller than those from Uganda. The sclerotised parts of the two populations, however, show a marked resemblance in shape and size. The ventral transverse bar of the Okavango population (figure 6.6) differs from that of the Uganda population in lacking the two anterio-lateral processes indicated by Paperna (1969a). As this is the only morphological difference between the specimens of these populations, the Okavango specimens are considered to be *A. curvipenis*. The specimens from the Okavango System were recovered from the gills of *Brycinus lateralis*, which represents a new host record for these parasites.

Table 6.6 Measurements of *Annulotrema curvipenis* Paperna, 1969 from *Brycinus lateralis* Boulenger, 1900 from the Okavango Delta and its comparison with the published descriptions of the same species from *Alestes baremoze*. All measurements are given in micrometers.

Monogenean **Host**	*A. curvipenis* (n=10) *Brycinus lateralis* Mean ± S.D	 Range	*A. curvipenis* (n=5) *Alestes baremoze* Paperna (1968)
Dorsal Anchor			
Total length	37 ± 5.1	31-45	50-55
Inner root	8 ± 2.6	5-12	15-20
Outer root	4 ± 1.2	3-6	5
Shaft	29 ± 3.4	22-32	20-25
Dorsal bar			
Total length	23 ± 4.8	18-32	30-35
Ventral anchor			
Total length	39 ± 5.7	32-48	40-50
Inner root	8 ± 2.5	4-10	10-12
Outer root	3 ± 0.9	2-5	8-10
Shaft	32 ± 6.6	25-44	25-30
Ventral bar			
Total length	25 ± 4.1	19-28	30-35
Marginal hooklet			
IV	24 ± 6.2	16-31	18-22
Copulatory organ			
Cirrus	39 ± 14	26-65	40-50
Accessory piece	15 ± 2.1	12-18	20
Vagina		Not sclerotised	Sclerotised
Tegumental annulation		Not too distinct	Not too distinct

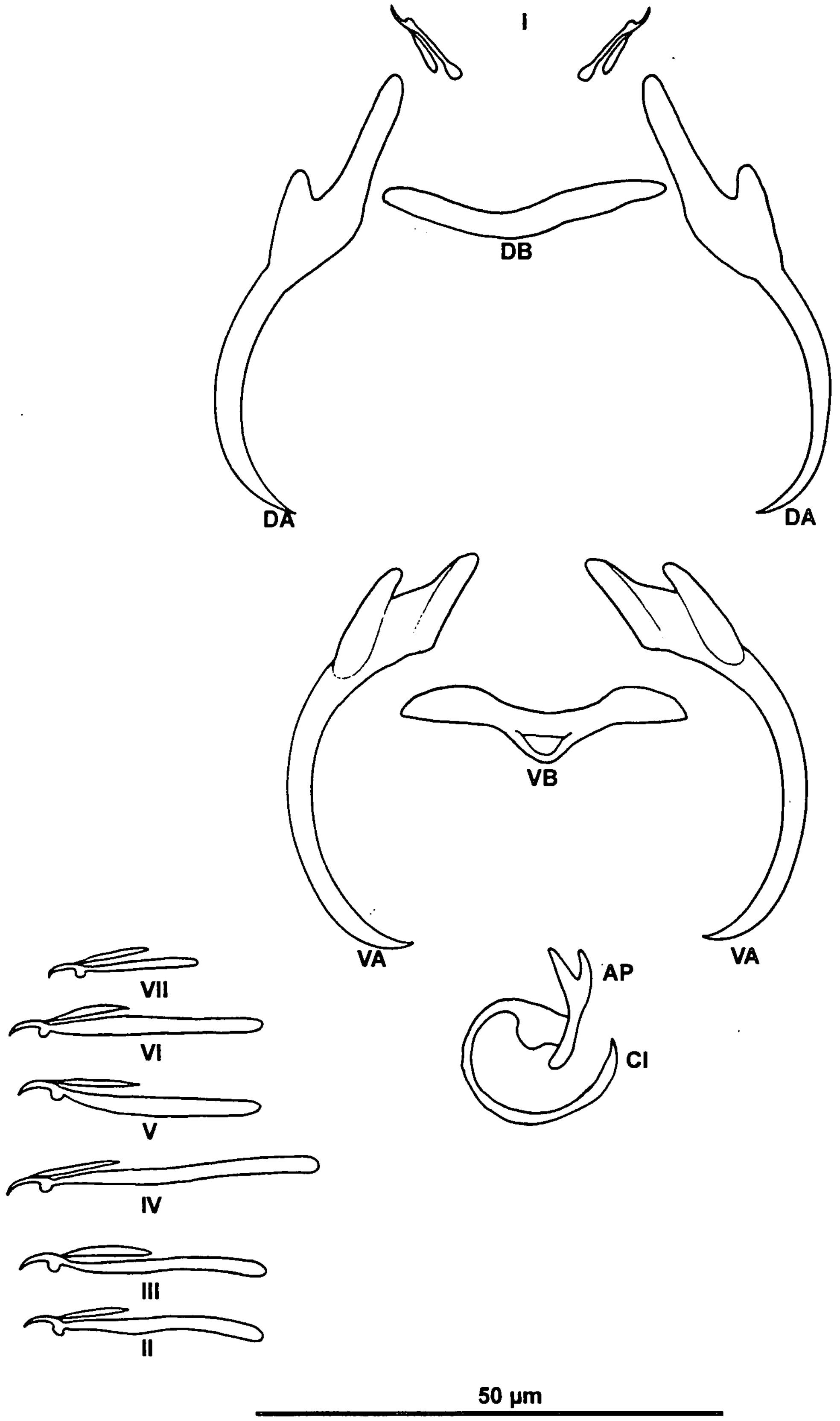

Figure 6.6 Microscope projection drawings of *Annulotrema curvipenis* Paperna, 1969 from the gills of *Brycinus lateralis* Boulenger, 1900. Abbreviations: **AP** – accessory piece, **CI** – cirrus, **DA** – dorsal anchor, **DB** – dorsal bar, **VA** – ventral anchor, **VB** – ventral bar, **I** to **VII** – marginal hooklets.

***Annulotrema hepseti* Paperna and Thurston, 1969**

Fish host: *Hepsetus odoe* (Bloch, 1794)

Locality: Lagoon 1 near Xaro Lodge (S 18°25'29.34"; E 021°56'24.48")

Additional localities: Channel off Mainstream near Drodsky's Cabins (S18°25'01.00" E021°53'34.29"), Kalatog Channel and Lagoons (S18°23'58.3" E021°58'16.0"), Samochima Lagoon (S18°25'26.08" E021°54'09.26"), Lagoon 2 near Xaro (S18°25'26.08" E021°56'27.93"), Thaoge Channel (S18°51'52.62" E022°25'8.1"), Thaoge Lagoons (S18°51'44.18" E022°24'22,29"), Guma Lagoon (S18°57'44.94" E022°22'26.76"), Duba Lagoons (S18°58'27.78" E022°33'44.22").

Site of infestation: Gills

Reference material: 97 / 10 / 21 – 05; 98 / 06 / 17 – 07 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (table 6.7 and figure 6.7) were made using light microscopy from 20 specimens mounted in ammonium picrate glycerine.

Description and measurements:

Medium to large worms, total length 462.0 ± 64.9 (310.0 - 560.0), width at level of copulatory organ 168.0 ± 37.1 (130.0 - 250.0). Tegument smooth, posterior half, annulated annulations distinct. Prohaptor consists of four indistinct cephalic lobes, contains oral opening, prohaptoral tegument contains sensory pits and setae. Oral opening sub-terminal. Pharynx 27.0 ± 3.5 (18.0 - 33.0). Opisthaptor triangular in shape with large anchors and marginal hooklets. Dorsal anchors 65.0 ± 5.8 (58.0 - 83.0), inner root 23.0 ± 1.9 (20.0 - 28.0), outer root 8.0 ± 1.6 (5.0 - 11.0), shaft 47.0 ± 6.7 (36.0 - 60.0), tip 6.0 ± 2.8 (2.0 - 12.0). Dorsal bar slightly concave, length 35.0 ± 3.0 (31.0 - 43.0), dorsal bar width 6.0 ± 0.9 (4.0 - 7.0). Ventral anchors 67.0 ± 5.3 (61.0 - 77.0), inner root 23.0 ± 2.9 (17.0 - 28.0), outer root 7.0 ± 2.1 (4.0 - 14.0), shaft 49.0 ± 3.8 (43.0 - 57.0), tip 4.0 ± 1.3 (3.0 - 7.0). Ventral bar length 38.0 ± 3.8 (30.0 - 44.0), ventral bar width 6.0 ± 1.1 (4.0 - 8.0). Marginal hooklets; I= 15.0 ± 1.1 (13.0 - 17.0), II= 46.0 ± 5.2 (33.0 - 55.0), III= 43.0 ± 6.4 (27.0 - 54.0), IV= 42.0 ± 4.5 (32.0 - 46.0), V= 43.0 ± 5.4 (27.0 - 52.0), VI= 41.0 ± 3.6 (37.0 - 51.0), VII= 36.0 ± 4.4 (26.0 - 44.0). Copulatory organ opens ventrally, posterior to oral opening, consists of long spiralled cirrus in thick muscular sheath or accessory piece, number of turns averages 25 and ranges from 21 - 29, cirrus length 58.0 ± 8.2 (43.0 - 78.0). Vagina not sclerotised, vaginal opening dextral.

Remarks: *Annulotrema hepseti* Paperna and Thurston, 1969 shares many common characteristics with *A. biaensis* N'Douba, Pariselle and Euzet, 1997 and *A. macropenis* N'Douba, Pariselle and Euzet, 1997, which have been described from the same host from the Ivory Coast. According to N'Douba *et al.* (1997) *A. hepseti* differs from *A. macropenis* in the form and size of the sclerotised parts of the opisthaptor and particularly the size of the cirrus. *Annulotrema biaensis* on the other hand is clearly distinguished from *A. macropenis* in the size of the cirrus. *Annulotrema biaensis* and *A. hepseti* are separated according to N'Douba, *et al.* (1997) by the size of the opisthaptoral sclerites especially the size of the third, fourth and seventh marginal hooklets (table 6.7).

The three populations of *A. hepseti* recorded from Ghana (Paperna and Thurston 1969a), Ivory Coast (N'Douba, *et al.* 1997) and the Okavango System differ considerably in the measurements of the various specimens (Table 6.7). The Ivory Coast population seems to be represented by specimens far larger than the other two populations. Very small specimens on the other hand, represent the population from Ivory Coast. The major recorded difference between the three populations is the morphology and location of the vagina. According to Paperna and Thurston (1969a) the specimens from Ghana have a vagina that opens sinistrally. No comment was made about whether or not the vagina was sclerotised. N'Douba, *et al.* (1997) noted that the vagina of the Ivory Coast specimens open laterally and are sclerotised. No sclerotisation of the vagina was noticeable in the Okavango specimens and with the aid of light and scanning electron microscopy (not presented here), it was determined that the vagina of the Okavango specimens open dextrally. A possible explanation for this contradiction could be due to the confusion of the dorsal ventral axis when using light microscopy hence confusing the dextral sinistral axis.

Table 6.7 Measurements of *Annulotrema hepseti* Paperna and Thurston, 1969 from *Hepsetus odoe* Bloch, 1794 from the Okavango Delta and its comparison with the published descriptions of similar species. All measurements are given in micrometers.

Monogenean	*Annulotrema hepseti* (n=20)		*A. hepseti*	*A. hepseti*	*A. macropenis*	*A. biaensis*
Host	*Hepsetus odoe*		*H. odoe*	*H. odoe*	*H. odoe*	*H. odoe*
	Mean ± SD	Range	Paperna & Thurston, (1969a)	N'Douba *et al.* (1997)	N'Douba *et al.* (1997)	N'Douba *et al.* (1997)
Dorsal anchor						
Total length	65 ± 5.8	58-83	70-100	45-66	27-36	39-55
Inner root	23 ± 1.9	20-28	12-15	13-24	10-17	14-25
Outer root	8 ± 1.6	5-11	4-9	4-8	4-9	2-8
Shaft	47 ± 6.7	36-60	50-70	38-49	20-25	28-37
Dorsal bar						
Length	35 ± 3.0	31-43	35-40	34-44	34-48	26-42
Width	6 ± 0.9	4-7		5-7	2-5	3-9
Ventral Anchor						
Total length	67 ± 5.3	61-77	60-75	55-74	26-38	38-52
Inner root	23 ± 2.9	17-28	18-20	15-26	8-20	14-23
Outer root	7 ± 2.1	4-14	4-6	4-9	4-10	3-8
Shaft	49 ± 3.8	43-57	40-55	43-66	21-28	34-45
Ventral bar						
Length	38 ± 3.8	30-44	38-42	36-52	34-50	32-48
Width	6 ± 1.1	4-8		5-7	2-5	4-6
Marginal Hooklets						
I	15 ± 1.1	13-17	30-40	14-19	12-22	14-22
II	46 ± 5.2	33-55	40-60	34-44	26-40	24-29
III	43 ± 6.4	27-54	40-60	38-46	23-31	22-28
IV	42 ± 4.5	32-46	40-60	46-58	19-29	18-25
V	43 ± 5.4	27-52	40-60	39-50	24-42	23-30
VI	41 ± 3.6	37-51	40-60	38-47	28-44	25-33
VII	36 ± 4.4	26-44	40-60	31-41	24-38	15-21
Copulatory Organ						
Cirrus	58 ± 8.2	43-78		65-82	107-127	61-90

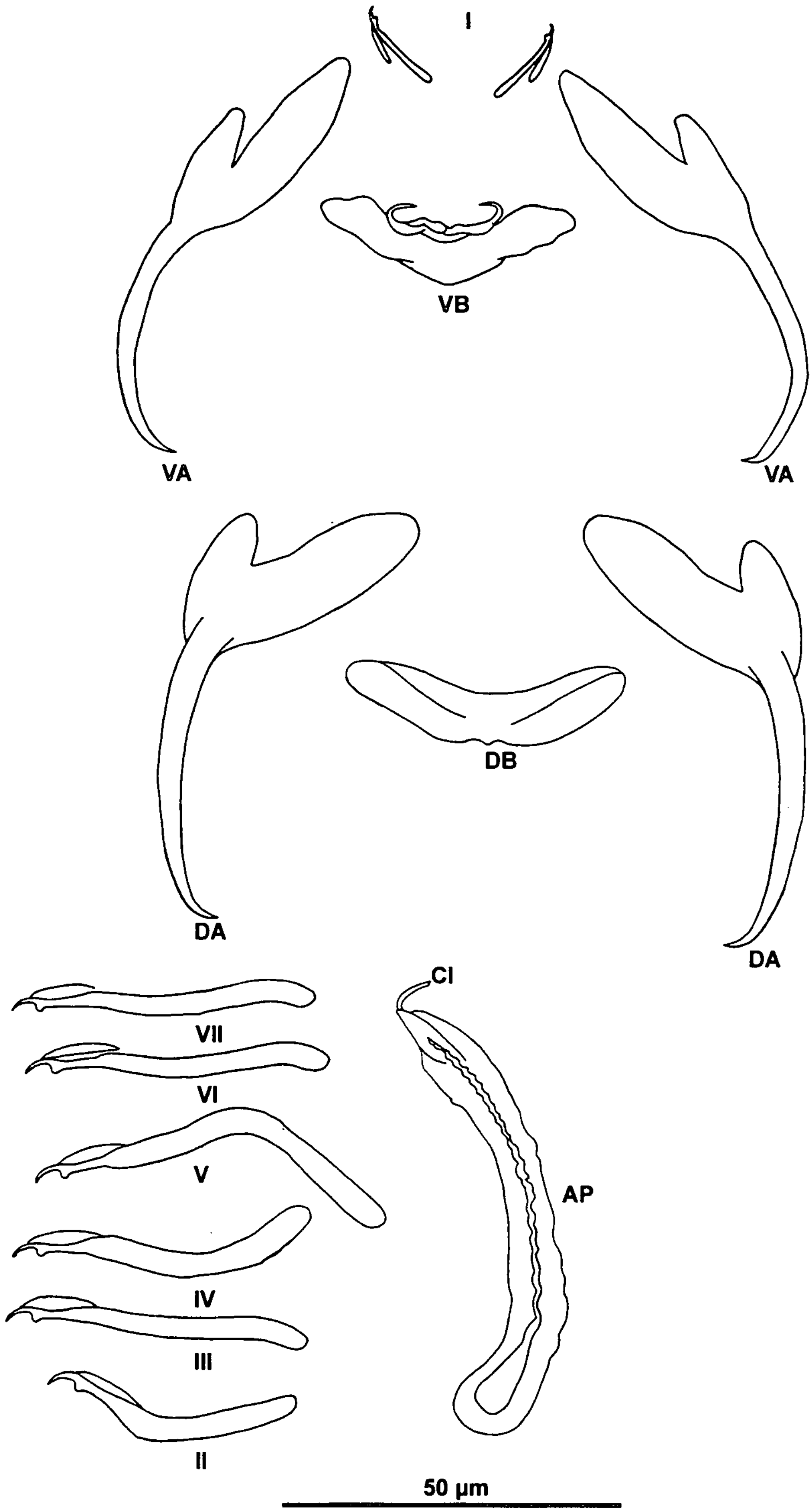

Figure 6.7 Microscope projection drawings of *Annulotrema hepseti* Paperna and Thurston, 1969 from the gills of *Hepsetus odoe* Bloch, 1794. Abbreviations: **AP** – accessory piece, **CI** – cirrus, **DA** – dorsal anchor, **DB** – dorsal bar, **VA** – ventral anchor, **VB** – ventral bar, **I** to **VII** – marginal hooklets.

***Annulotrema pikei* (Price, Peebles and Bamford, 1969)**

Host: *Hydrocynus vittatus* Castelnau, 1861

Locality: Okavango Mainstream at Xaro Lodge (S18°25'23.6"; E021°56'18.2")

Additional Localities: Okavango Mainstream at Drodsky's Cabins (S18°24'48.66" E021°53'9.6"), Channel off Mainstream near Drodsky's Cabins (S18°25'01.00" E021°53'34.29"), Kalatog Channel and Lagoons (S18°23'58.3" E021°58'16.0"), Samochima Lagoon (S18°25'26.08" E021°54'09.26"), Lagoon 1 near Xaro (S18°25'29.34" E021°56'24.48"), Okavango Mainstream at Etsatsa (S18°51'0.4" E022°25'12.0"), Nqoga Mainstream (S18°52'20.46" E022°28'34.5"), Pepere Lagoon (S18°54'57.42" E022°32'17.70").

Site of infestation: Gills

Reference material: 98 / 08 / 08 – 03; 97 / 10 / 27 – 03 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (table 6.8 and figure 6.8) were made using light microscopy from 20 specimens mounted in ammonium picrate glycerine.

Description and measurements:

Medium to large worms, total length 462.0 ± 68.9 (350.0 - 580.0), total width at level of cirrus 105.0 ± 24.2 (70.0 - 170.0). Tegument smooth, posterior half annulated, annulations distinct. Prohaptor, four well defined cephalic lobes with sensory pits and setae, oral opening ventral. Pharynx 21.0 ± 7.7 (9.0 - 29.0), intestinal caeca fused posteriorly. Opisthaptor with large anchors, dorsal anchor 52.0 ± 4.0 (44.0 - 58.0), inner root 13.0 ± 3.3 (8.0 - 18.0), outer root 5.0 ± 1.6 (2.0 - 9.0), shaft 40.0 ± 4.1 (33.0 - 50.0), tip 6.0 ± 1.7 (3.0 - 9.0). Dorsal bar length 39.0 ± 8.0 (22.0 - 53.0), dorsal bar width 9.0 ± 2.1 (5.0 - 14.0). Ventral anchor 53.0 ± 4.6 (44.0 - 62.0), inner root 14.0 ± 4.2 (6.0 - 21.0), outer root 5.0 ± 1.7 (3.0 - 9.0), shaft 40.0 ± 3.7 (34.0 - 48.0), tip 6.0 ± 1.5 (4.0 - 10.0). Ventral bar length 38.0 ± 4.6 (28.0 - 46.0), ventral bar width 7.0 ± 1.7 (5.0 - 12.0). Marginal hooklets I= 15.0 ± 4.2 (9.0 - 22.0), II= 29.0 ± 4.5 (21.0 - 36.0), III= 29.0 ± 5.1 (21.0 - 38.0), IV= 29.0 ± 8.3 (16.0 - 43.0), V= 29.0 ± 6.6 (20.0 - 43.0), VI= 26.0 ± 4.0 (21.0 - 33.0), VII= 20.0 ± 3.1 (16.0 - 25.0). Copulatory organ opens ventrally, posterior to oral opening, consists of elongated cirrus entwined with the accessory piece, cirrus 84.0 ± 25.4 (29.0 - 120.0), accessory piece 83.0 ± 18.0 (31.0 - 102.0). Vagina opens sinistrally and is not sclerotised, vitellaria are massed on both sides of the reproductive organs, not extending into opisthaptor.

Remarks:

The specimens of *Annulotrema pikei* (Price, Peebles and Bamford, 1969) collected from *Hydrocynus vittatus* from the Okavango System have close affinities with *Annulotrema pikei ruahae* Paperna, 1979 and *A. pikoides* Guegan, Lambert and Birgi, 1988 as described by Paperna (1979) and Guegan, Lambert and Birgi (1988) respectively. As these three species have very similar opisthaptoral hook arrangements and morphology, differential diagnosis depends on the morphology of the copulatory organ. The copulatory organ of *A. pikei* consists of an elongated tubular cirrus extending from the seminal vesicle intertwined with the accessory piece which is almost as long as the cirrus which is consistent with the population from the Okavango System.

The Okavango population of *Annulotrema pikei* is comparable to the populations from South Africa, Tanzania and Ghana respectively (table 6.8). The size range of the Okavango specimens fits well within the size ranges of the other populations. The anchors, both dorsal and ventral, appear larger than those of the other four populations. The population of *A. pikei* from the Okavango seems to be more closely associated with the population from the Volta Lake, Ghana, as these specimens are very similar in size and both populations exhibit distinct cuticular annulation. The other three populations on the other hand are smaller and do not have distinct cuticular annulation.

Table 6.8 Measurements of *Annulotrema pikei* (Price, Peebles and Bamford, 1969) from *Hydrocynus vittatus* Castelnau, 1861 from the Okavango Delta and its comparison with the published descriptions of the same or similar species. All measurements are given in micrometers.

Monogenea	*A. pikei (n=20)*		*A. pikei* (n=20)	*A. pikei*	*A. pikei*	*A. pikei ruahae*	*A. pikoides* (n=19)
Host	*Hydrocynus vittatus*		*H. vittatus*	*Hydrocynus* sp.	*H. forskalii*	*H. vittatus*	*H. vittatus*
	Mean ± S.D	Range	Price, *et al.* (1969)	Paperna (1979)	Paperna (1979)	Paperna (1979)	Guegan *et al.* (1988)
Dorsal anchor							
Total length	52 ± 3.99	44-58	35-43	43-47	37-40	43-47	41-47
Ventral anchor							
Total length	53 ± 4.63	44-62	36-43	40-42	38-42	42-43	40-48
Marginal hooklet							
IV	29 ± 8.26	16-43	27	30	25	34	33
Copulatory organ							
Cirrus	84 ± 25.43	29-120	47	40	57	52-57	72-96
Tegumental annulation	Distinct		Not distinct	Distinct	Not distinct	Not distinct	

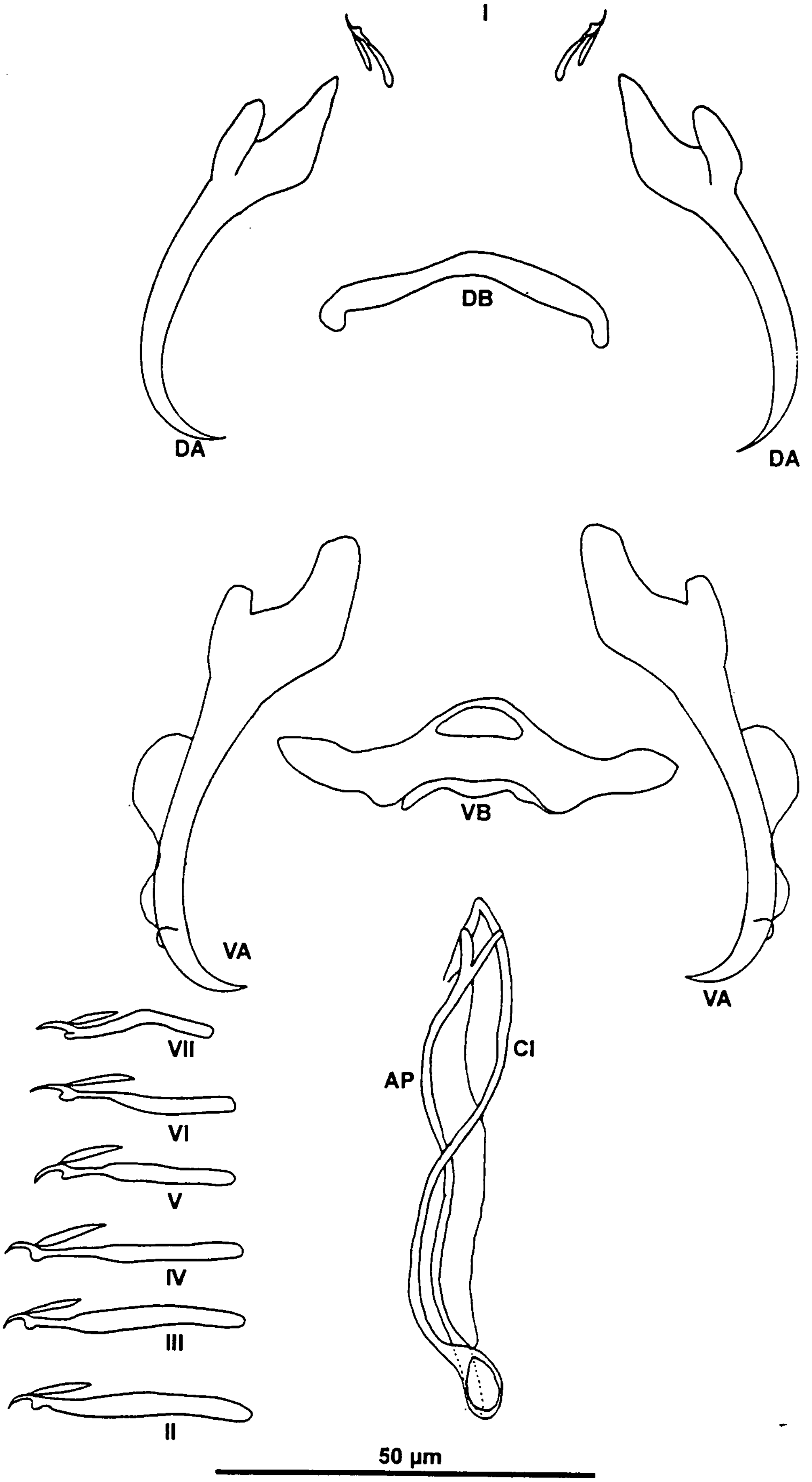

Figure 6.8 Microscope projection drawings of *Annulotrema pikei* (Price, Peebles and Bamford, 1969) from the gills of *Hydrocynus vittatus* Castelnau, 1861. Abbreviations: **AP** – accessory piece, **CI** – cirrus, **DA** – dorsal anchor, **DB** – dorsal bar, **VA** – ventral anchor, **VB** – ventral bar, **I** to **VII** – marginal hooklets.

***Annulotrema micralesti* sp. n.**

Host: *Micralestes acutidens* (Peters, 1852)

Type locality: Okavango Mainstream at Xaro Lodge (S 18°25'23.6"; E 021°56'18.2")

Additional localities: Okavango Mainstream at Drodsky's Cabins (S18°24'48.66" E021°53'9.6"), Kalatog Channel and Lagoons (S18°23'58.3 E021°58'16.0"), Lagoon 1 near Xaro (S18°25'29.34" E021°56'24.48"), Okavango Mainstream at Etsatsa (S18°51'0.4" E022°25'12.0"), Nqoga Mainstream (S18°52'20.46" E022°28'34.5), Jao Village (S19°02'36.48" E022°31'52.32"), Perennial Swamp at Fly Camp (S19°01'35.40" E022°28'57.3").

Site of infestation: Gills

Type material: Holotype: 98 / 06 / 24 / 03 - 01 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Paratypes: 98 / 06 / 24 / 04 - 02 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (table 6.9 and figure 6.9) were made using light microscopy from 20 specimens mounted in ammonium picrate glycerine.

Etymology: Name derived from the host fish, *Micralestes acutidens*, on which these parasites were found.

Description and measurements:

Small to medium sized worms, total length 299.0 ± 41.4 (240.0 - 350.0), width 94.0 ± 18.0 (60.0 - 120.0). Tegument smooth, posterior half annulated, annulations not too distinct. Prohaptor consists of four well defined cephalic lobes. Oral opening, sub-terminal opening ventrally, pharynx 23.0 ± 3.9 (18.0 - 26.0), intestinal caeca fused posteriorly. Opisthaptor terminal, dorsal anchors 28.0 ± 1.4 (25.0 - 30.0), inner root 9.0 ± 0.9 (7.0 - 10.0), outer root 5.0 ± 1.4 (3.0 - 7.0), shaft 19.0 ± 1.2 (18.0 - 22.0), tip 4.0 ± 0.8 (2.0 - 4.0). Dorsal bar length 26.0 ± 1.7 (24.0 - 29.0), dorsal bar width 5.0 ± 1.6 (3.0 - 7.0). Ventral anchors 34.0 ± 2.7 (32.0 - 39.0), inner root 8.0 ± 0.3 (4.0 - 14.0), outer root 6.0 ± 2.3 (4.0 - 10.0), shaft 27.0 ± 1.9 (24.0 - 28.0), tip 3.0 ± 0.7 (3.0 - 5.0). Ventral bar length 25.0 ± 3.2 (20.0 - 29.0), ventral bar width 9.0 ± 1.6 (7.0 - 12.0). Marginal hooklets; I= 7.0 ± 1.6 (5.0 – 8.0), II= 15.0 ± 4.0 (8.0 - 21.0), III= 20.0 ± 5.0 (14.0 - 26.0), IV= 18.0 ± 3.9 (13.0 - 24.0), V= 15.0 ± 2.7 (11.0 - 19.0), VI= 11.0 ± 3.5 (6.0 - 16.0), VII= 12.0 ± 2.2 (8.0 - 14.0). Copulatory organ opening ventrally posterior to oral opening, consists of curved tubular cirrus with distally bifurcated accessory piece, cirrus 54.0 ± 13.1 (30.0 - 65.0).

Accessory piece 23.0 ± 1.0 (22.0 - 24.0). Vagina opens sinistrally, not sclerotised. Vitellaria massed on either side of reproductive organs, not extending into opisthaptor.

Remarks:

Annulotrema micralesti n. sp. can be distinguished from the *Annulotrema* species collected in the Okavango in being a small monogenean and only being recorded from *Micralestes acutidens*. The anchors of this monogenean are prominent with the dorsal and ventral anchors being similar in shape. The dorsal bar is narrow and elongated and the ventral bar is A-shaped and does not resemble that of any of the existing species. The marginal hooklets of *A. micralesti* are also comparatively small. The copulatory organ consists of an elongated, curved cirrus, which is associated with the accessory piece both distally and proximally (figure 6.9). The accessory piece makes a smaller curve parallel to the cirrus. The accessory piece is bifid distally and is similar to that of *A. curvipenis*, which is bifid. The distal ends of the accessory piece curve away from each other whereas those of *A. curvipenis* curve toward each other. The copulatory organ of *A. micralesti* is also much larger than that of *A. curvipenis* from Uganda and the Okavango (see table 6.9). Due to the significant differences in opisthaptoral sclerite morphology and size (table 6.9), as well as the unique copulatory organ structure, this species is considered a new species.

Table 6.9 Measurements of *Annulotrema micralesti* n. sp. from *Micralestes acutidens* (Peters, 1852) from the Okavango Delta and its comparison with that of the *A. curvipenis* Paperna, 1969 from the Okavango System and Uganda. All measurements are given in micrometers.

Monogenean	*A. micralesti* (n=20)		*A. curvipenis* (n=10)	*A. curvipenis* (n=5)
Host	*Micralestes acutidens*		*Brycinus lateralis*	*Alestes baremoze*
	Mean ± S.D	Range	Okavango population	Paperna (1968)
Dorsal Anchor				
Total length	28 ± 1.4	25-30	31-45	50-55
Inner root	9 ± 0.9	7-10	5-12	15-20
Outer root	5 ± 1.4	3-7	3-6	5
Shaft	19 ± 1.2	18-22	22-32	20-25
Dorsal bar				
Total length	26 ± 1.7	24-29	18-32	30-35
Ventral anchor				
Total length	34 ± 2.7	32-39	32-48	40-50
Inner root	8 ± 0.3	4-14	4-10	10-12
Outer root	6 ± 2.3	4-10	2-5	8-10
Shaft	27 ± 1.9	24-28	25-44	25-30
Ventral bar				
Total length	25 ± 3.2	20-29	19-28	30-35
Marginal hooklet				
III	20 ± 5.0	14-26	16-31	18-22
Copulatory organ				
Cirrus	54 ± 13.1	30-65	26-65	40-50
Accessory piece	23 ± 1.0	22-24	12-18	20
Vagina		Not sclerotised	Not sclerotised	Sclerotised
Tegumental annulation		Not too distinct	Not too distinct	Not too distinct

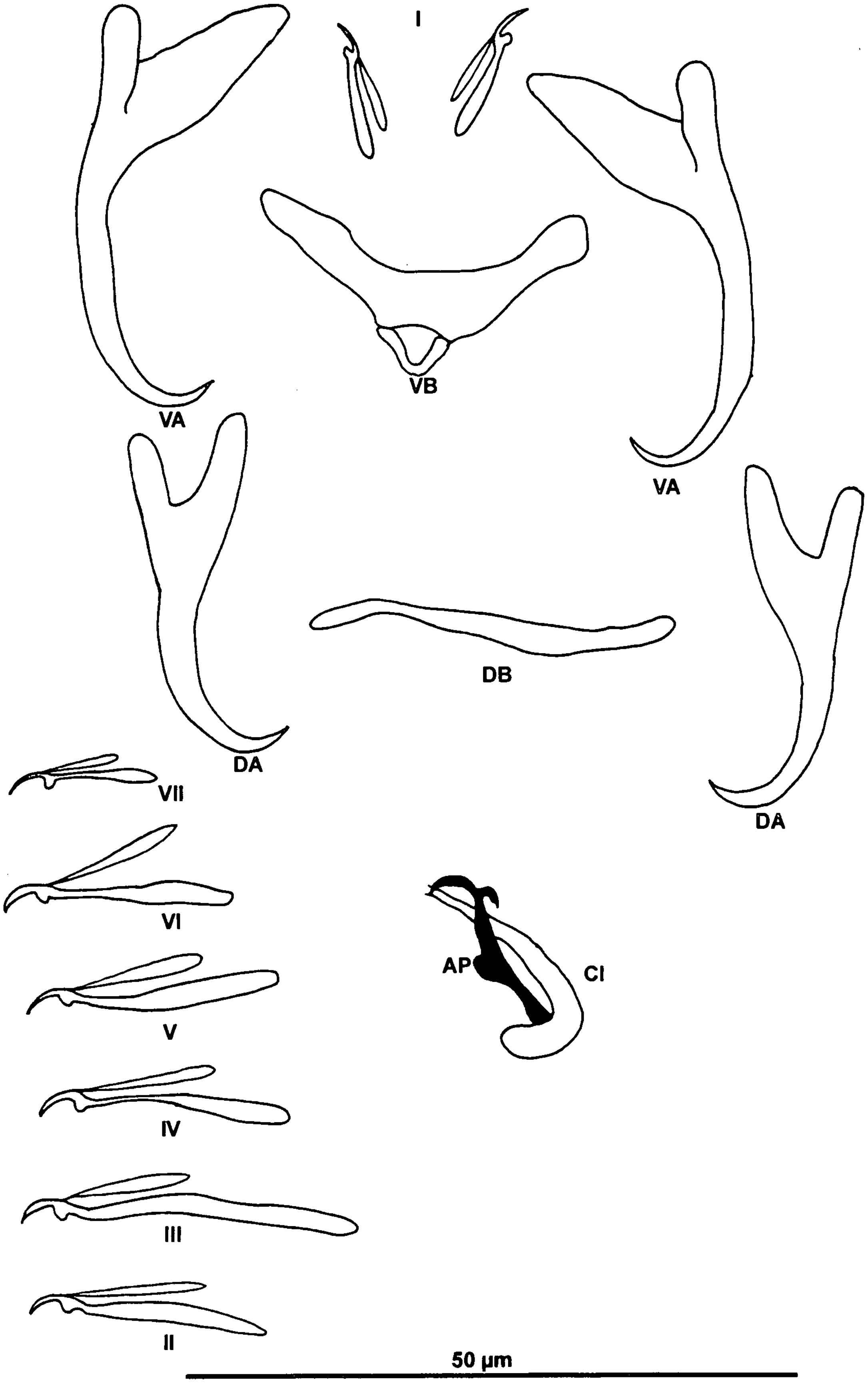

Figure 6.9 Microscope projection drawings of *Annulotrema micralesti* n. sp. from the gills of *Micralestes acutidens* (Peters, 1852). Abbreviations: **AP** – accessory piece, **CI** – cirrus, **DA** – dorsal anchor, **DB** – dorsal bar, **VA** – ventral anchor, **VB** – ventral bar, **I** to **VII** – marginal hooklets.

***Annulotrema rhabdalesti* sp. n.**

Host: *Rhabdalestes maunensis* (Fowler, 1935)

Type locality: Okavango Mainstream at Xaro Lodge (S18°25'23.6" E021°56'18.2")

Additional localities: Okavango Mainstream at Drodsky's Cabins (S18°24'48.66" E021°53'9.6"), Channel off Mainstream near Drodsky's Cabins (S18°25'01.00" E021°53'34.29"), Kalatog Channel and Lagoons (S18°23'58.3" E021°58'16.0"), Samochima Lagoon (S18°25'26.08" E021°54'09.26"), Floodplains at Nxamasere (S18°36'03.2" E022°01'42.1"), Backwaters at Seronga (S18°49'48.96" E022°24'22.74"), Okavango Mainstream at Etsatsa (S18°51'0.4" E022°25'12.0"), Thaoge Channel (S18°51'52.62" E022°25'8.1"), Thaoge Lagoons (S18°51'44.18" E022°24'22,29")

Site of infestation: Gills

Type material: Holotype: 98 / 06 / 23 / 06 - 01 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Paratypes: 98 / 06 / 23 / 07 -02 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (table 6.10 and figure 6.10) were made using light micreoscopy from 10 specimens mounted in ammonium picrate glycerine.

Etymology: Name derived from the host fish, *Rhabdalestes maunensis*, on which these parasites were found.

Description and measurements:

Medium sized worms, total length 305.0 ± 48.6 (240.0 - 360.0), width 94.0 ± 19.6 (70.0 - 130.0). Tegument annulated, annulations distinct. Prohaptor consists of four clearly defined cephalic lobes, oral opening ventral, sub-terminal. Pharynx 23.0 ± 3.6 (17.0 - 26.0), intestinal caeca fuse posteriorly. Opisthaptor terminal, clearly separated from body trunk, dorsal anchors 32.0 ± 4.0 (26.0 - 38.0), inner root 11.0 ± 3.0 (8.0 - 17.0), outer root 6.0 ± 1.8 (2.0 - 8.0), shaft 22.0 ± 3.0 (19.0 - 28.0), tip 4.0 ± 0.9 (3.0 - 6.0). Dorsal bar length 26.0 ± 2.7 (22.0 - 30.0), dorsal bar width 5.0 ± 1.3 (3.0 - 7.0). Ventral anchors 36.0 ± 3.9 (28.0 - 42.0), inner root 12.0 ± 1.8 (9.0 - 14.0), outer root 6.0 ± 1.4 (3.0 - 8.0), shaft 25.0 ± 3.0 (20.0 - 28.0), tip 4.0 ± 0.7 (3.0 - 5.0). Ventral bar length 29.0 ± 4.8 (20.0 - 38.0), ventral bar width 6.0 ± 1.2 (4.0 - 8.0). Marginal hooklets; I= 8.0 ± 2.4 (5.0 - 12.0), II= 17.0 ± 2.4 (14.0 - 22.0), III= 19.0 ± 3.4 (12.0 - 23.0), IV= 19.0 ± 4.7 (13.0 - 25.0.), V= 20.0 ± 4.0 (14.0 - 25.0), VI= 19.0 ± 3.0 (14.0 - 22.0), VII= 12.0 ± 2.3 (8.0 - 15.0).

Copulatory organ opens ventrally, posterior to prohaptor, cirrus elongated and tubular, cirrus 25.0 ± 6.1 (18.0 - 37.0), accessory piece 22.0 ± 5.2 (16.0 - 30.0). Vagina opening sinistral, not sclerotised.

Remarks:

Annulotrema rhabdalesti n. sp. from the Okavango Delta is distinguished from all existing species as it is the first monogenean record from *Rhabdalestes maunensis* and has a unique shaped copulatory organ differing from the existing species of the genus *Annulotrema*. The anchors are robust and prominent. The ventral anchors differ from the dorsal anchors in having a median root, which is vestigial. The dorsal bar is slightly concave and narrow. The ventral bar has an apron resembling that of *A. pikei* and *A. elongata* Paperna and Thurston, 1969. The marginal hooklets are uniformly shaped and are relatively small. Although the opisthaptoral sclerites of *Annulotrema rhabdalesti* resemble those of *Annulotrema pikei* and *A. elongata* morphologically, they differ in size (table 6.10). The copulatory organ consists of an elongated straight cirrus that runs parallel to the accessory piece, which is more or less as long as the cirrus and is bifid distally (figure 6.10).

Table 6.10 Measurements of *Annulotrema rhabdalesti* n. sp. from *Rhabdalestes maunensis* (Fowler, 1935) from the Okavango Delta and its comparison with the published descriptions of similar species. All measurements are given in micrometers.

Monogenean **Host**	*Annulotrema rhabdalesti* (n=10) *Rhabdalestes maunensis* Mean ± S.D.	 Range	*A. pikei* (n=20) *Hydrocynus vittatus* Current study	*A. elongata* (n=4) *Alestes baremoze* Paperna & Thurston (1969a)
Dorsal anchor				
Total length	32 ± 4.0	26-38	44-58	75-80
Inner root	11 ± 3.0	8-17	8-18	25-30
Outer root	6 ± 1.8	2-8	2-9	12-15
Shaft	22 ± 3.0	19-28	33-50	30-45
Dorsal bar				
Total length	26 ± 2.7	22-30	22-53	35-45
Ventral anchor				
Total length	36 ±3.9	28-42	44-62	65-80
Inner root	12 ± 1.8	9-14	6-21	20-30
Outer root	6 ± 1.4	3-8	3-9	10-20
Shaft	25 ± 3.0	20-28	34-48	40-60
Ventral bar				
Total length	29 ± 4.8	20-38	28-46	35-45

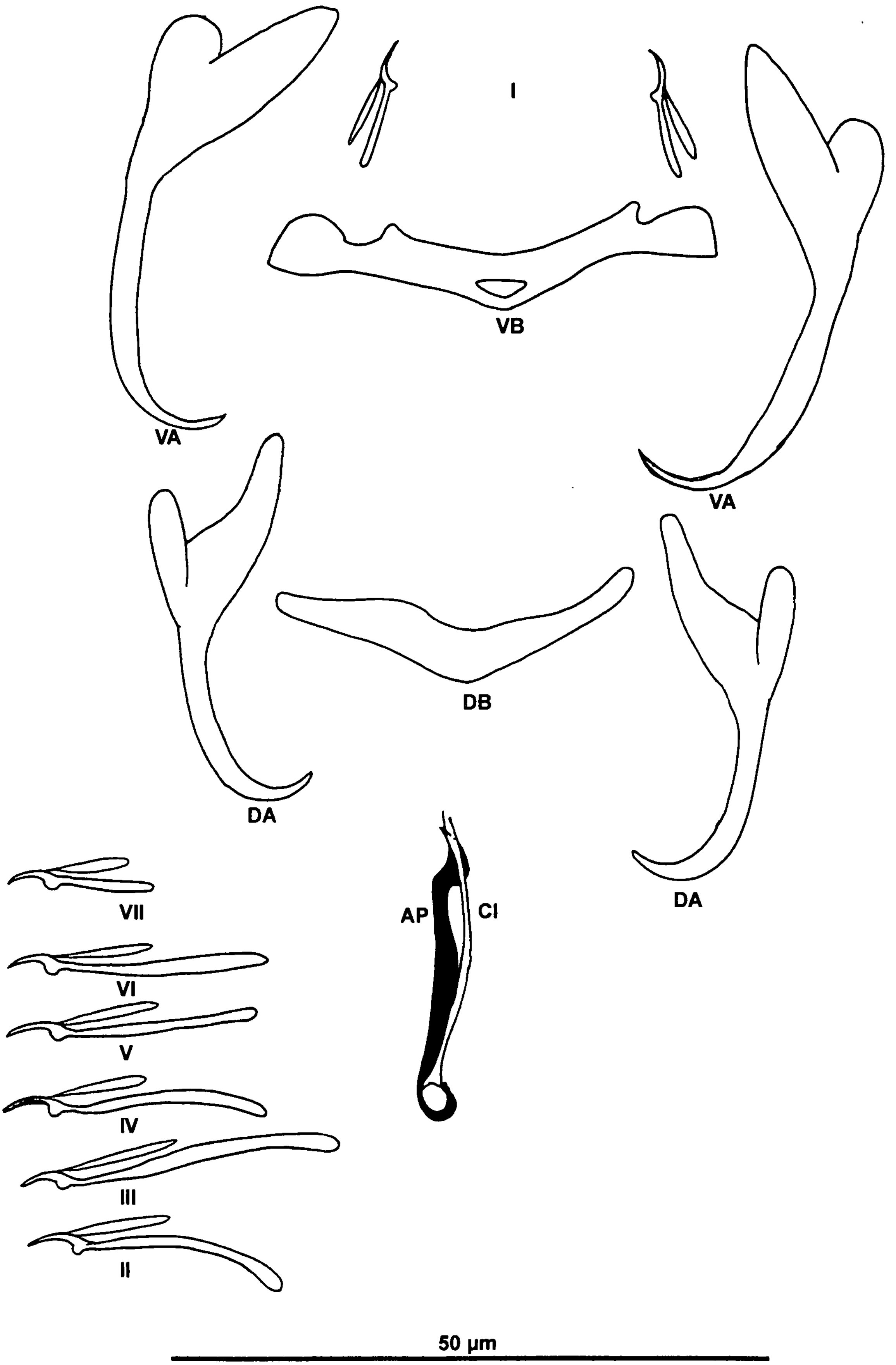

Figure 6.10 Microscope projection drawings of *Annulotrema rhabdalesti* n. sp. from the gills of *Rhabdalestes maunensis* (Fowler, 1935). Abbreviations: **AP** – accessory piece, **CI** – cirrus, **DA** – dorsal anchor, **DB** – dorsal bar, **VA** – ventral anchor, **VB** – ventral bar, **I** to **VII** – marginal hooklets.

Genus: *Bouixella* Euzet and Dossou, 1976

***Bouixella duba* n.sp**

Host: *Mormyrus lacerda* Castelnau, 1861

Type locality: Duba Lagoon (S18°58'27.78" E022°33'44.22")

Additional localities: Samochima Lagoon (S18°25'26.08" E021°54'09.26"), Perennial Swamp at Film Camp (S19°26'32.88" E022°49'10.32")

Site of infestation: Gills

Type material: Holotype: 99 / 07 / 08 / 01 - 01 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Paratype: 99 / 07 / 08 / 01 - 02 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (figure 6.11) were made using light microscopy from 11 specimens mounted in ammonium picrate glycerine.

Etymology: Name derived from the sampling locality Duba Island and Lagoons, from where these parasites were found.

Description and measurements:

Total length 364.4 ± 36.2 (308.0 - 440.3), greatest width 113.5 ± 24.7 (79.9 - 159.1). Four pairs of head organs; cephalic glands unicellular, comprising 2 bilateral groups lateral to pharynx. Eyes present, 2 pairs equidistant. Eye granules spherical to ovate. Haptor terminal well delineated from body, dorsal anchors 28.3 ± 2.5 (24.6 - 33.7), base width 9.8 ± 1.6 (5.5 - 11.6) inner root 9.5 ± 1.0 (8.2 - 11.5), outer root 5.2 ± 1.0 (3.2 - 7.1), shaft 25.1 ± 2.2 (23.0 - 30.6), tip 4.9 ± 1.2 (3.3 - 7.8). Dorsal bar length 26.0 ± 2.7 (20.4 - 29.5), dorsal bar width 4.3 ± 0.4 (3.6 - 5.0). Ventral anchors 27.9 ± 2.2 (24.1 - 31.0), base width 10.3 ± 1.0 (8.4 - 12.0), inner root 8.8 ± 0.9 (7.8 - 10.3), outer root 5.4 ± 0.7 (4.2 - 6.4), shaft 25.9 ± 1.6 (22.6 - 28.0), tip 5.2 ± 0.6 (4.3 - 6.3). Ventral bar length 27.6 ± 2.1 (23.4 - 30.8), ventral bar width 4.6 ± 0.5 (3.8 - 5.7). Marginal hooklets; I= 12.5 ± 2.0 (8.3 - 14.5), II= 18.1 ± 1.0 (16.3 - 19.6), III= 18.2 ± 1.8 (15.8 - 22.1), IV= 18.6 ± 1.6 (15.3 - 20.7), V= 18.7 ± 1.7 (15.2 - 21.7), VI= 16.6 ± 1.8 (14.9 - 21.7), VII= 13.9 ± 1.6 (12.3 - 17.2). Copulatory organ, cirrus 53.3 ± 10.1 (36.1 - 74.7) long, comprising curved tapered tube, accessory piece comprised of 2 sclerites associated medially; first sclerite 30.1 ± 2.3 (26.4 - 33.3) long, narrowing medially, terminating in well defined hook with muscle insertions along its length, second sclerite 34.7 ± 2.2 (30.4 - 36.5) long, narrowing medially. Vagina sclerotised opening sinistral.

Remarks:

Bouixella duba n. sp. is distinguished from the existing species by the nature of the copulatory complex. Both sclerites of the accessory piece are unique in size and shape when compared to the existing species. The haptoral sclerites of this species resemble the basic form of all the other species but are generally larger or more robust. No sclerite measurements have been given in the descriptions for any of the other species described in this genus for comparison purposes.

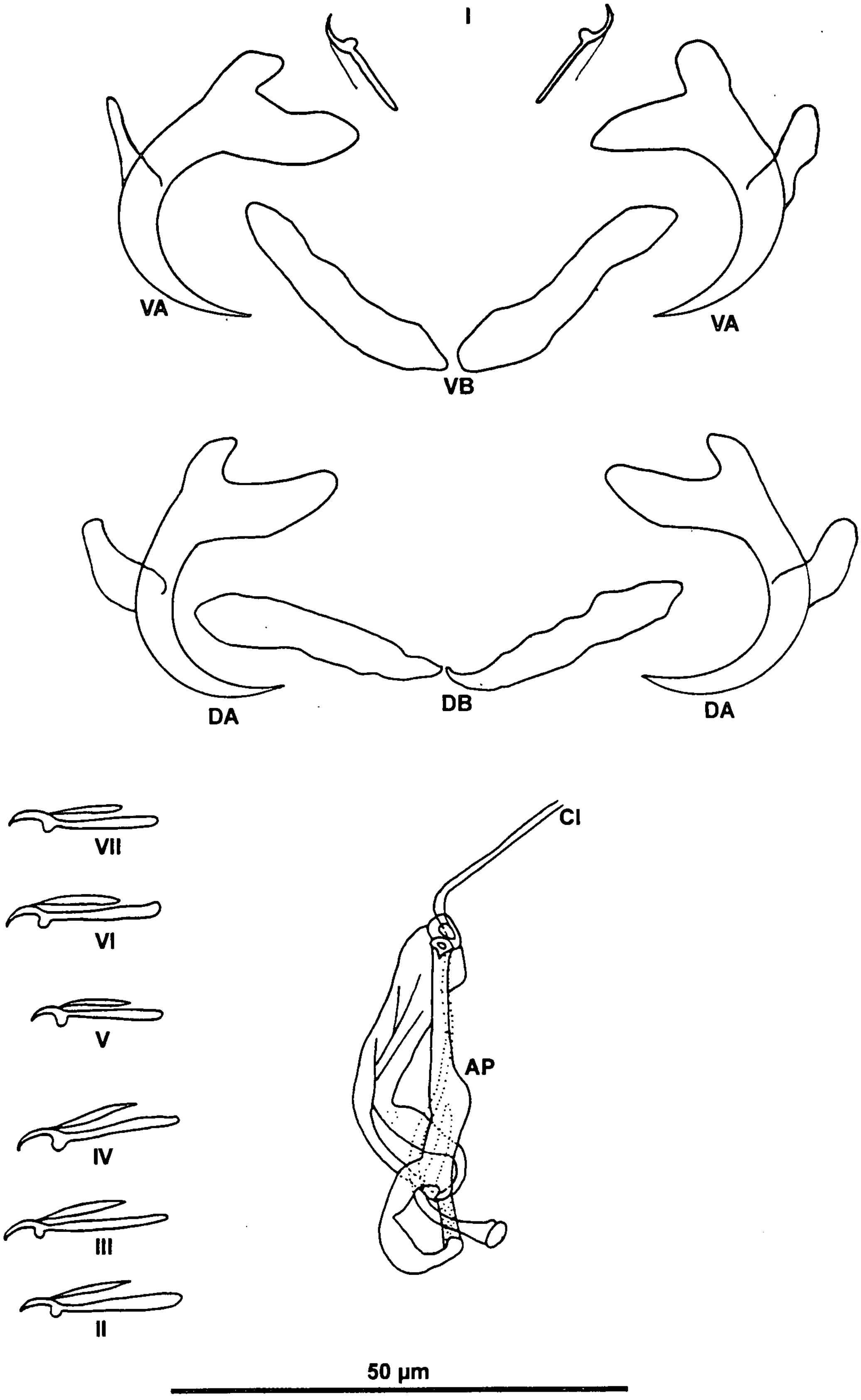

Figure 6.11 Microscope projection drawings of *Bouixella duba* n. sp. from the gills of *Mormyrus lacerda* Castelnau, 1861. Abbreviations: **AP** – accessory piece, **CI** – cirrus, **DA** – dorsal anchor, **DB** – dorsal bar, **VA** – ventral anchor, **VB** – ventral bar, **I** to **VII** – marginal hooklets.

Bouixella marcusenia **n.sp**

Fish host: *Marcusenius macrolepidotus* (Peters, 1852)

Type locality: Samochima Lagoon (S18°25'26.08" E021°54'09.26")

Additional localities: Kalatog Channel and Lagoons (S18°23'58.3" E021°58'16.0"), Lagoon 1 near Xaro (S18°25'29.34" E021°56'24.48"), Lagoon 2 near Xaro (S18°25'26.08" E021°56'27.93"), Floodplains at Mohembo (S18°16'19.8" E021°47'38.7"), Floodplains at Sepopa (S18°44'42.45" E022°11'50.4"), Thaoge Channel (S18°51'52.62" E022°25'8.1"), Backwaters at Pepere Lagoon (S18°54'57.42" E022°32'17.70"), Guma Lagoon (S18°57'44.94" E022°22'26.76"), Duba Lagoon (S18°58'27.78" E022°33'44.22"), Perennial Swamp at Film Camp (S19°26'32.88" E022°49'10.32").

Site of infestation: Gills

Type material: Holotype: 98 / 06 / 22 / 18 - 01 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Paratypes: 98 / 06 / 22 /18 - 02 in the collection of the Aquatic Parasitology group at the Department of Zoology and Entomology at the University of the Free State.

Material examined: Detailed morphometric measurements and drawings (figure 6.12) were made using light microscopy from 10 specimens mounted in ammonium picrate glycerine.

Etymology: Name derived from the genus of the host fish, *Marcusenius macrolepidotus*, on which these parasites were found.

Description and measurements:

Body fusiform, total length 250.3 ± 98.0 (180.2 - 474.4), width 84.4 ± 52.1 (55.4 - 211.0). Pharynx spherical, 16.2 ± 0.9 (15.6 - 17.3) in diameter. Four pairs of head organs; cephalic glands unicellular, comprising 2 bilateral groups lateral to pharynx. Eyes present, 2 pairs equidistant. Eye granules spherical to ovate. Haptor terminal well delineated from body, dorsal anchors 18.2 ± 1.1 (16.3 - 19.4) long, base width 5.6 ± 0.6 (4.9 - 6.4), inner root 6.6 ± 1.6 (4.3 - 8.8), outer root 3.8 ± 0.9 (2.9 - 5.1), shaft 15.0 ± 0.8 (14.2 - 16.4), tip 3.1 ± 0.5 (2.4 - 3.7). Dorsal bar half length 19.3 ± 0.9 (18.4 - 20.9), dorsal bar width 3.3 ± 0.4 (2.8 - 3.7). Ventral anchors 17.9 ± 1.4 (15.5 - 18.8), base width 5.9 ± 0.5 (5.3 - 6.6), inner root 5.7 ± 2.0 (2.6 - 7.2), outer root 3.9 ± 0.6 (3.1 - 4.4), shaft 14.5 ± 0.8 (13.3 - 15.2), tip 3.0 ± 0.6 (2.3 - 3.6). Ventral bar half length 17.3 ± 2.6 (13.1 - 19.6), ventral bar width 3.4 ± 0.5 (2.8 - 4.0). Marginal hooklets; I= 9.5 ± 2.9 (5.6 - 11.5), II= 13.6 ± 1.4 (11.6 - 15.0), III= 13.2 ± 1.9 (11.1 - 15.4), IV= 13.1 ± 1.4 (11.4 - 14.5), V= 13.8 ± 1.5 (13.1 - 16.1), VI= 13.4 ± 0.9 (12.8 - 14.8), VII= 10.6 ± 1.3 (8.6 -

12.2). Copulatory organ, cirrus 34.0 ± 16.5 (18.2 - 64.5) long comprising straight tapered tube, accessory piece comprised of two sclerites associated proximally; first sclerite 16.0 ± 2.6 (13.8 - 21.0) long terminating in curved point, second sclerite 21.4 ± 3.7 (17.1 - 26.2) long. Vagina sclerotised opening sinistral.

Remarks:

Bouixella marcusenia n. sp. is distinguished from the existing species by the nature of the copulatory complex. Both sclerites of the accessory piece are unique in size and shape when compared to the existing species. The haptoral sclerites are simple in form and are closely associated with *B. furcillata* Dossou and Euzet, 1984 and *B. torta* Dossou and Euzet, 1984 in general sclerite size. *Bouixella marcusenia* is distinguished from these two species by having accessory piece sclerites that are associated proximally as opposed to medially. *Bouixella marcusenia* shares its geographical distribution with *B. duba* and is distinguished from this species by being generally smaller, having smaller haptoral sclerites and smaller accessory piece sclerites which are clearly distinguishable morphologically.

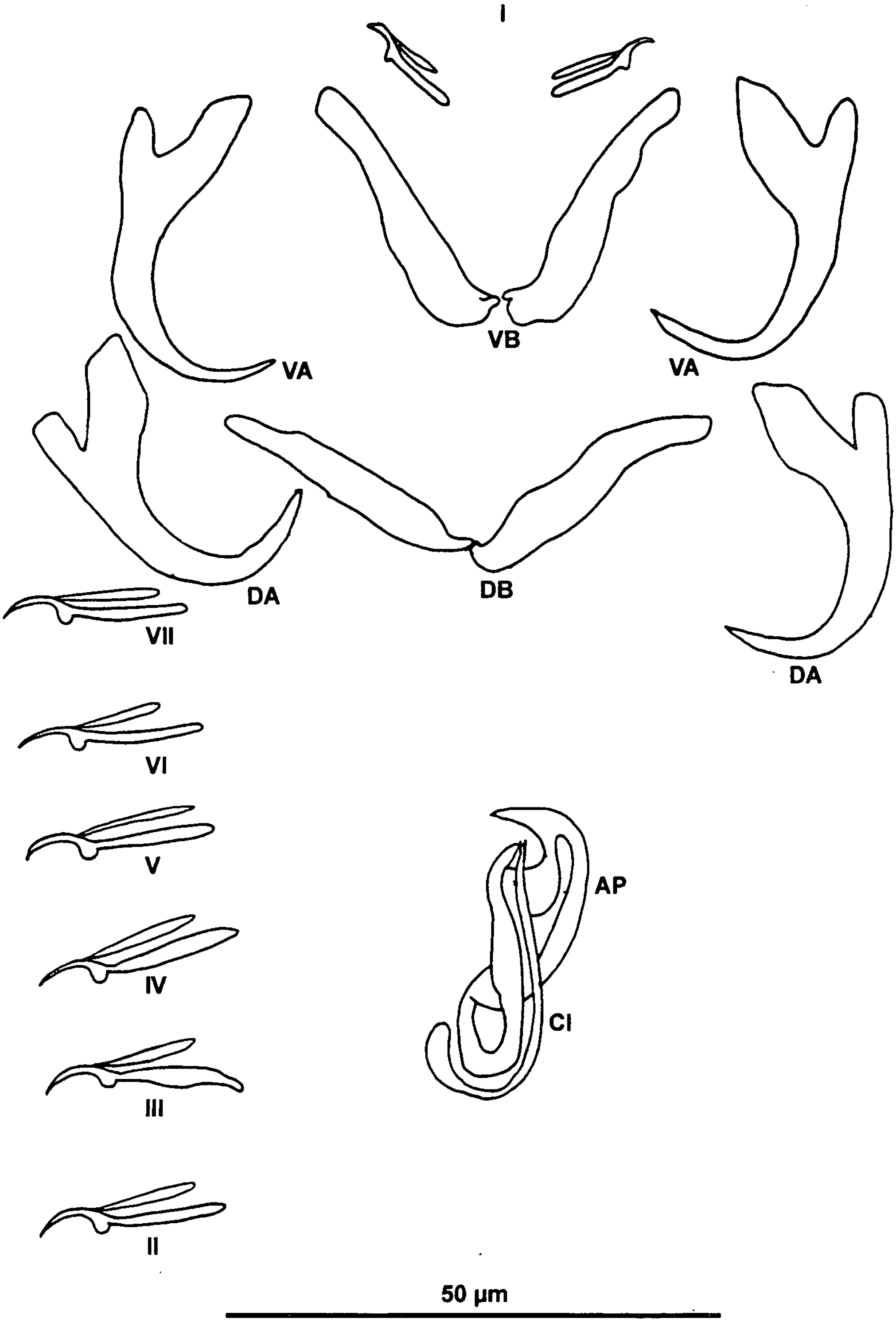

Figure 6.12 Microscope projection drawings of *Bouixella marcusenia* n. sp. from the gills of *Marcusenius macrolepidotus* (Peters, 1852). Abbreviations: **AP** – accessory piece, **CI** – cirrus, **DA** – dorsal anchor, **DB** – dorsal bar, **VA** – ventral anchor, **VB** – ventral bar, **I** to **VII** – marginal hooklets.

CHAPTER 7

Biodiversity and distribution of fish and parasites in the Okavango Delta

7.1 Fish diversity in the Okavango Delta

The ichthyofauna of the Okavango River and Delta is represented by at least 80 species of fish distributed throughout this system (Skelton, *et al.* 1985). Preliminary results of a rapid assessment of the Okavango Delta reflected only 61 species of fish including a new species of *Aplocheilichthys* Bleeker, 1863 collected from four localities (Alonso *et al* 2000). In the present study, 60 fish species were examined of which one species, *Aethiomastacembelus frenatus* (Boulenger, 1901), was recorded for its presence and distribution although it was collected from the stomach of a tigerfish, *Hydrocynus vittatus*. In the present study, fish were collected in the same season of the year for four consecutive years (June –September, shortly after the flood high water mark is reached in the lower parts of the Delta).

Of the 59 fish species collected during this study, two families dominated the ichthyofauna of the Okavango Delta, the Cichlidae, represented by 18 species or about 30 % of the fish species collected and the Cyprinidae, represented by 15 species or about 25% of the fish species collected (figure 7.1). Other fish families collected during this study include the Mochokidae (five species), Mormyridae (four species), Characidae (four species), Clariidae (three species), Cyprinidontidae (three species), Distichodontidae (two species), Anabantidae (two species), Hepsetidae (one species), Schilbeidae (one species) and Mastacembelidae (one species). The fish genus comprised of the most species was *Barbus* Cuvier and Cloquet, 1816 which, was represented by 12 of the 15 cyprinid species.

7.2 Fish distribution in the Okavango Delta

The major physical factor determining the distribution and abundance of fishes in the Delta appears to be habitat preferences, with the physical characteristics of the environment playing a major role. The permanence of the water and the nature of its flow are two of the most obvious ecological factors affecting community structure. These two factors affect other physical and chemical parameters such as substrate type, extent of emergent, submergent and floating macrophyte cover, dissolved oxygen levels and water temperatures, which in turn affect the distribution of the fishes (Merron 1993).

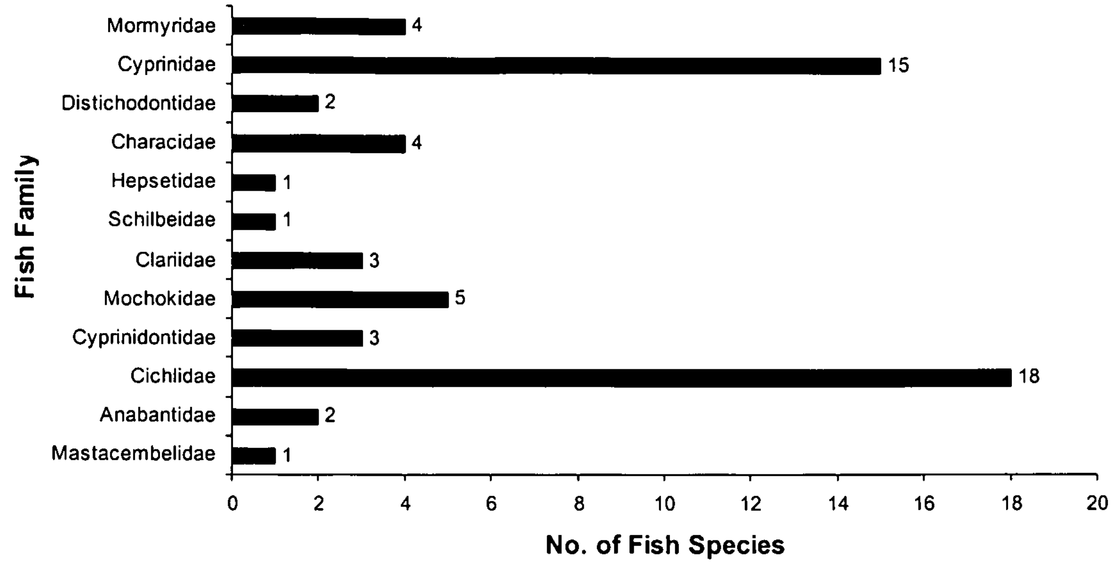

Figure 7.1 Graph illustrating the relative sizes of fish families collected from the Okavango Delta in the same season for four consecutive years from 1997 – 2000.

According to Skelton, *et al.* (1985) the rise and fall of the annual floodwaters is one of the major driving forces in the Delta. The floods create vast shallow areas that are suitable for breeding and feeding by many species and cause large amounts of detritus, from other sources, to enter the food chain. The arrival of the floods are also responsible for supplying the stimulus for spawning and or migration of certain fish species in the Delta (Merron, Holden and Bruton 1990, Skelton 1993 and Ross 1987), and also provide a means of distributing the fish throughout the system. Many of the sump lakes and drainage rivers rely on the floods for their water. Generally the timing and duration of the flooding determines to a large extent the recruitment, growth and survival rates of wetland fish stocks (Welcomme 1979) and according to Skelton *et al.* (1985), is likely to be the case in the Okavango Swamps as well.

The Okavango Delta can be classified as a river-associated wetland and as such has characteristic fish communities (Bruton and Jackson 1983). River associated wetlands have diverse fish fauna which can be divided into two groups: (1) those which avoid the severe conditions of the floodplain during the dry season and migrate into the main river channel and (2) those fish species which remain on the floodplain during the dry season and either withstand low oxygen levels by using air-breathing organs (e.g. *Clarias* sp. and *Ctenopoma* sp.) and desiccation by desiccation resistant eggs, or make short movements to the deeper edge of the river (e.g. some juvenile cichlids, cyprinidontids and cyprinids) (Bruton and Jackson 1983). An intermediate group also exists which can either remain sedentary or perform long migrations as the need arises (e.g. *Clarias gariepinus*). Furthermore, Bruton and Merron (1990) classify fish according to their etho-ecological section of reproductive guilds, distinguishing between non-guarders, guarders and bearers. Non-guarders are represented by fish species which produce bouyant or adhesive eggs, which may be hidden, but are not guarded. Guarders may spawn on the substrate or produce froth, gravel or sand nests and they actively guard their young. Bearers may bear their young either internally where they may receive some nutrition from the parent or externally where they carry the young in a cavity opening to the exterior to protect them.

The various collection sites were grouped into habitat types according to the physical properties of the ecological regions described in chapter 3. Fish hosts were collected using a variety of netting techniques (chapter 3) (appendix 2). According to Field, Clarke and Warwick (1982), accurate quantitative sampling of fish, which is equally representative of all the species in the community, is difficult. The sampling efficacy of nets, traps, etc. is often unknown, as are the differing abilities of the various fish species to evade capture or their susceptibility to be attracted to various baits. Due to the collection methods, the fish hosts are regarded as being collected qualitatively and not quantitatively, hence there is uncertainty regarding the community structure based on host abundance within each collection site. The original data was hence reduced to indicate only presence or absence of a particular species in a particular sample. According to Field *et al.* (1982), reduction to presence/absence may be thought of as the ultimate in severe transformations of counts. The data matrix (appendix 1) is replaced by 1 (presence) or 0 (absence), before a Bray-Curtis similarity was computed to determine the similarity of the fish communities from the various collection sites. This has the effect of giving equal weight to all species whether rare or abundant. Calculation of the similarity of species between sample sites in the Okavango System on the original abundance of fish species was over dominated by a small number of highly abundant species [e.g. *Schilbe intermedius* (n=97), *Aplocheilichthys hutereaui* (n=127), *Pseudocrenilabrus philander* (n=265) and *Tilapia sparrmanii* (n=160)] so that they failed to reflect the similarity of overall community composition (appendix 1). The reduction of the data to presence / absence scales the contribution of each species to adjust for this, but has the tendency to over compensate, i.e. rare species are given equal weight to common ones. Presence / Absence loses information about approximate prevalence of species (absent, rare, present in modest numbers, common, very abundant). To compensate for this Field *et al.* (1982) suggested the removal of all species that never constitute more than *p*% of the total abundance where *p* is arbitrarily chosen to retain the species with the highest abundance across all samples to obtain an interpretable cluster analysis. In this study, *p = 5%.*

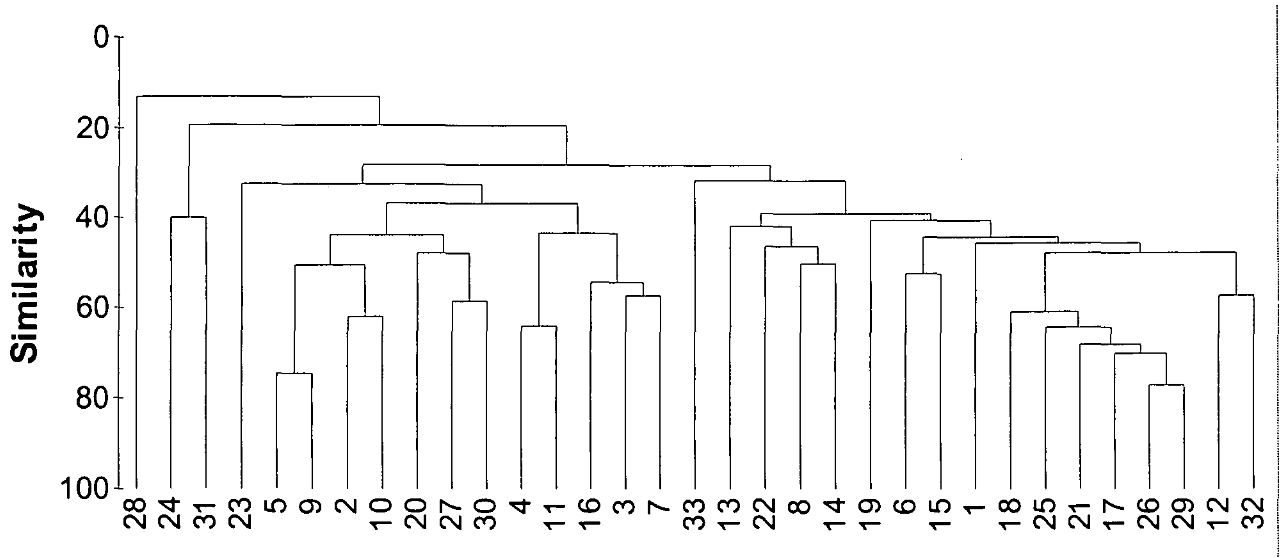

Figure 7.2 Dendrogram of similarity of fish species between different localities from the Okavango Delta, as provided in table 3.1 and table 7.1, using group average sorting based on Bray - Curtis Similarity.

The resulting dendrogram (figure 7.2) revealed several clusters of sampling sites exhibiting similar fish communities within each cluster (table 7.1). The collection site at Jao Village (28) exhibited very little similarity with respect to general fish community structure and the other collection sites. The collections at this site were characterised by low species diversity and were dominated by a single species *Micralestes acutidens* (14 individuals) with a few individuals of five other species being collected. The backwater habitats at Pepere Island (24) and the seasonal swamp at Nxabega (31) similarly show little similarity with the other habitats and also exhibit relatively low species diversity and numbers of individual fish.

The remaining collection sites formed two large clusters, which exhibited sufficiently different fish communities with respect to diversity and life history strategies. The first major cluster (table 7.1 and figure 7.2) mainly represents habitats, such as lagoons and mainstream habitats, which are regarded as generally stable with respect to physico-chemical properties, remaining almost unchanged throughout the year (Bruton and Jackson 1983). This cluster can again be further divided into three clusters showing closer similarity between the respective collection sites. These sub-clusters represent most of the lagoon localities and the Panhandle mainstream localities respectively, indicating that fish community structure at each respective collection locality is governed by the fish's tolerance to physico-chemical changes in that habitat and its respective reproductive or etho-ecological guild (Bruton and Merron 1990). These localities showed relatively high species diversity and are probably mostly dominated by fish species that avoid the severity of the floodplain as the waters recede. The Panhandle lagoons can also be distinguished from the other lagoon localities in this cluster and are represented by Samochima Lagoon (5), both lagoons 1 and 2 near Xaro (9 and 10 respectively) and Mohembo

Floodplain (2). These localities all represent comparatively high species diversity and numbers of individuals. The main sampling locality at the Mohembo Floodplain was an isolated pool which is inundated annually in the flood and slowly dries up as the year progresses. As this locality is in a slight depression, it maintains its water for longer periods than the surrounding floodplain and is able to support its high species diversity for longer periods and hence resembles a lagoon when only considering fish community structure. Other Panhandle lagoons like Sepopa Lagoon (13) show dissimilar fish community structure which may be as a result of the lagoon being at a different successional stage, hence exhibiting significantly different fish community structure than other Panhandle lagoons (McCarthy and Ellery 1998).

The second major cluster represents collection sites that are less stable with respect to physico-chemical properties. These sites are mainly floodplain and backwaters and are hence subject to vast changes throughout the year, they may change from inundated to dry within the space of a year and are totally reliant on the magnitude and timing of the annual flood. Fish species inhabiting these habitats would either be tolerant to these stresses or migrate short distances daily to overcome the severity of the extreme conditions that may be encountered there.

Species distribution and abundance appears stratified throughout the Delta depending on the physico-chemical stability of the habitats. It therefore follows that the Panhandle region exhibits higher fish diversity than the alluvial fan south of the Gumare Fault. The dominant habitat types in the Panhandle region are the mainstream and lagoon habitats with secondary floodplains and backwaters on the periphery. South of the Gumare Fault, the Okavango River splits into various distributary systems and its gradient decreases and hence flow rate slows and forms many channels and pathways, eventually leading to perrennial floodplains which in turn become seasonal floodplains. The dominant habitats here are floodplains and backwaters, which are much less stable than the dominant habitats in the Panhandle region. This is consistent with Alonso *et al.* (2000), who found the highest fish diversity in the Upper Panhandle, moderate fish diversity in the seasonal swamps, permanent swamps and small channels and moderate fish diversity in the region of Chiefs Island. A potential reason for this stratification according to Bruton and Merron (1990), is that the fish communities of river associated wetlands, like the Okavango Delta, are typically represented by a higher percentage of non-guarders due to less predictable physico-chemical regimes as a result of fluctuating water levels due to flooding and the unpredictability of the timing and magnitude of the flood. Furthermore, river associated wetlands have a greater variety of different reproductive guilds among their fishes than do other habitats (Bruton and Merron 1990).

Table 7.1 Table summarising the general results of a Bray - Curtis similarity comparing various collection sites from a presence / absence transformed data set.

Cluster	Site number	Description of collection site
I	28	Jao Village
II	24	Backwater at Pepere
	31	Seasonal Swamp at Nxabega
	23	Pepere Lagoon
III	5	Samochima Lagoon
	6	Lagoon 1 near Xaro
	2	Mohembo Floodplain
	10	Lagoon 2 near Xaro
	20	Guma Lagoon
	27	Duba Lagoon
	30	Perrennial Swamp at Film Camp
	4	Mainstream Channel near Drodsky's Cabins
	11	Kalatog Channel and Lagoons
	16	Okavango Mainstream at Etsatsa
	3	Okavango Mainstream at Drodsky's Cabins
	7	Okavango Mainstream at Xaro Lodge
	33	Island Safari Lodge Maun
IV	13	Sepopa Lagoon
	22	Lower Thaoge Channel near Makwena
	8	Backwaters at Xaro
	14	Sepopa Floodplain
	19	Thaoge Lagoons
	6	Shakawe Fishing Camp Backwaters
	15	Seronga Backwaters
	1	Mohembo Backwaters
	18	Thaoge Channel
	25	Nqoga Mainstream
	21	Guma Floodplains
	17	Etsatsa Backwater
	26	Nqoga Backwater
	29	Perrennial Swamp at Fly Camp
	12	Nxamesere Floodplains
	32	Boro River

7.3 Monogenean distribution

Prevalence of dactylogyridean monogeneans on the Okavango fishes seems uniformly distributed with 40 of the 59 fish species exhibiting a dactylogyrid infestation. Monogeneans of the genus *Dactylogyrus* were recorded from 10 of the 15 cyprinids collected from various localities in the Okavango Delta (figure 7.3A). Only three species showed an infestation prevalence of higher than 40%, namely *Barbus multilineatus, Barbus paludinosus* and *Barbus radiatus*.

Overall dactylogyrid prevalence was more generalised among the cichlids, 15 of the 18 species collected were found to be infested by at least one species of the genus *Cichlidogyrus* (figure 7.3B). General prevalence was found to be higher than in the cyprinids with eight fish species having an infestation prevalence of 50% or higher. Generalisation with respect to specific host selection was exhibited by some of the *Cichlidogyrus* species, which were found on more than one host species. Some fish hosts also hosted more than one species of *Cichlidogyrus* on its gills simultaneously. *Oreochromis andersonii* was found to be infested by *Cichlidogyrus halli*, *C. sclerosus* and *C. mohemboensis*.

The remaining fish families showed varying levels of dactylogyridean infestation (figure 7.3C). The mormyrids exhibited very specialised infestations with *Mormyrus lacerda* and *Marcusenius macrolepidotus* being infested by *Bouixella duba* and *B. marcusenia* respectively. The characins and hepsetid showed high prevalence of infestation by *Annulotrema* species with at least 40 % of each population being infested. Only *Brycinus lateralis* showed a mixed infestation of *Annulotrema curvipenis* and *Characidotrema nursei*. Of the three siluriform families, only the schilbeid and the clarids hosted significantly high infestations. Of the 97 specimens of the *Schilbe intermedius* collected, 59% were infested by *Schilbetrema quadriacornis* and only one individual was found to host two specimens of *S. acornis*. Both *Clarias gariepinus* and *C. theodorae* were infested by *Quadriacanthus kalatensis* and *Q. theodorae* respectively. The rest of the families had little or no significant dactylogyrid infestations.

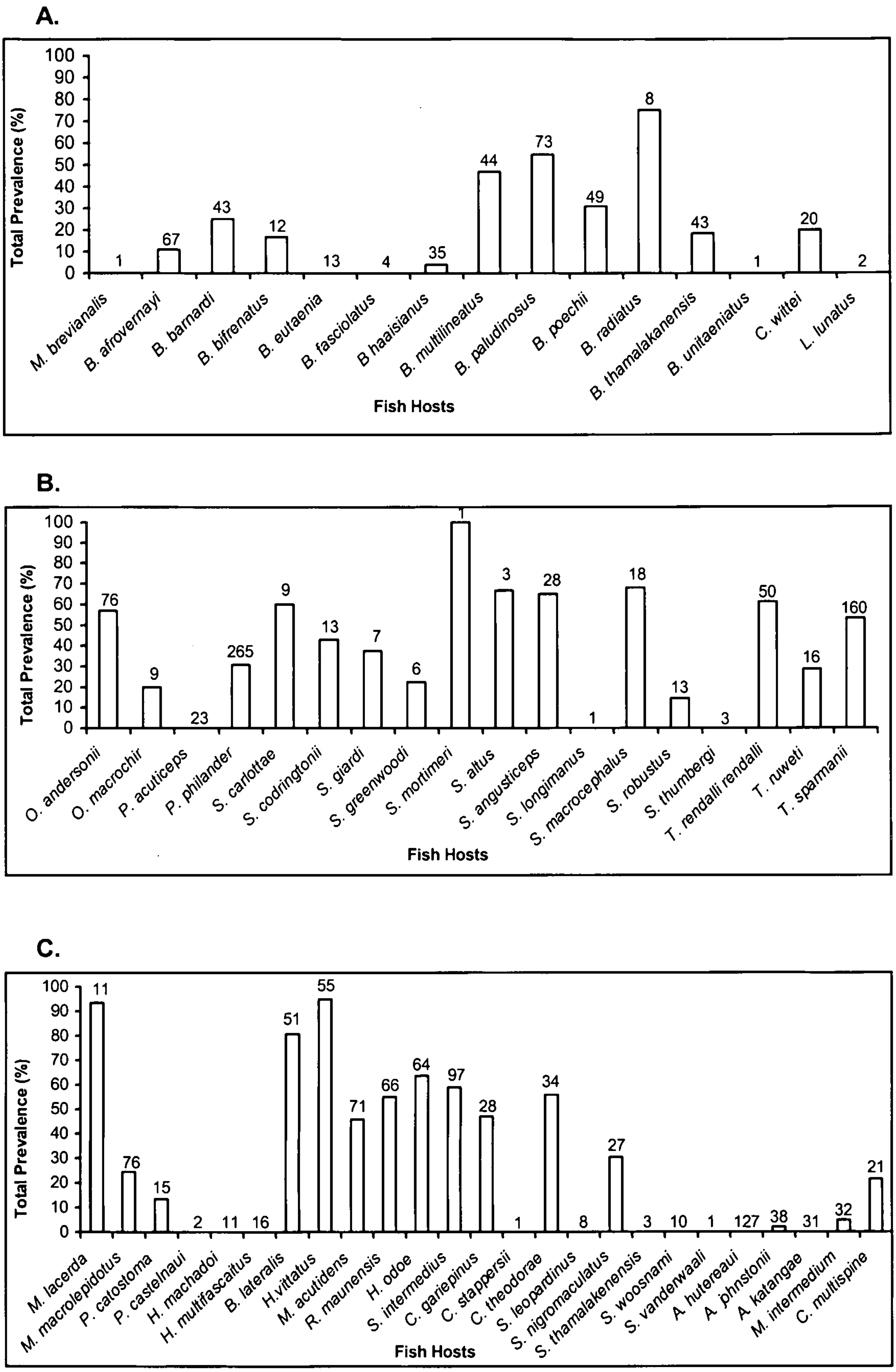

Figure 7.3 Histograms showing dactylogyridean prevalence in Okavango fishes over a period of four years from 1997-2000. A. Representatives of the Cyprinidae, B. Representatives of the Cichlidae, C. Other fish families. The number above each bar represents the respective number of hosts examined.

Monogenean prevalence data of the various collection sites were consolidated to represent the four distinct habitat types obtained from the cluster analysis of figure 7.2, namely mainstream and channel habitats, Panhandle lagoons, lagoons south of the Panhandle and backwaters and floodplains. The prevalences of the individual fishes from each habitat type are illustrated in figure 7.4.A-D for the cyprinids, figure 7.5 A-D for the cichlids and figure 7.6 A-D for all the other fish families present at those localities. With a few exceptions, most of the monogeneans collected from the Okavango fishes showed strict host-specificity to a specific host species or a few closely related species. The distribution of dactylogyridean monogeneans therefore is closely related to the distribution of their fish hosts. On closer examination of monogenean prevalence infesting the fishes of the various habitats represented in figure 7.2, there is greater variance in monogenean infestation between different fish species within the same community than between different communities, hence there is no significant difference between the overall monogenean prevalence of the fishes between the various habitat types, the major difference being as a result of fish community structure (figures 7.4, 7.5 and 7.6).

Differences in the prevalence of infestation are observed when considering individual fish species occurring in more than one of the identified habitat types. This implies that not only is the family Dactylogyridae diverse in terms of morphology and numbers of species, but also in the way the various representative species of the family react to environmental pressures. The extrinsic factors of certain habitats, however, may promote or be beneficial to monogenean transmission even if only of secondary importance. Prevalence in this case does not take into account species richness, as observed in *Oreochromis andersonii* which hosted three *Cichlidogyrus* species, namely, *C. halli*, *C. sclerosus* and *C. mohemboensis* (See table 7.4 and 7.5). The measure of prevalence as illustrated in figures 7.4-7.6, similarly does not take into account parasite abundance or common species as observed in *Dactylogyrus viviersi, Cichlidogyrus karibae* and *Cichlidogyrus botswanensis* which were recorded from more than one host, but nevertheless provides an initial level of analysis.

According to Paperna (1969a), intense speciation and consequently high numbers of endemic species with restricted distribution to one habitat or water system is particularly evident in the genus *Dactylogyrus* parasitic on *Barbus* species and in *Annulotrema* species parasitic on characins. This was more evident from the infestation data of *Dactylogyrus* species collected from the Okavango cyprinids than that of the genus *Annulotrema* infesting the Okavango characins and *Hepsetus odoe*. Most of the *Dactylogyrus* species collected from the Okavango cyprinids were collected from the backwater and floodplain habitats (figure 7.4D). The representatives of the genus *Annulotrema* infesting *Brycinus lateralis, Hydrocynus vittatus, Micralestes acutidens, Rhabdalestes maunensis* and *Hepsetus odoe* respectively show a more uniform distribution throughout the habitat system with no preference to habitat type (figure 7.6). The description of five new species from the Okavango system also show some consistency with the findings of Paperna (1969a). In the siluriform genera, and in the cichlids, associated dactylogyrids underwent only limited speciation and the species are generally widely distributed (Paperna 1969). Once again the Okavango data elucidates the findings of Paperna (1969a), with high prevalences of the genus *Cichlidogyrus* being recorded from nearly all the habitat types (figure 7.5). With the exception of *Synodontis nigromaculatus* the silurids, represented by *Clarias gariepinus, Clarias theodorae* and *Schilbe intermedius,* also exhibited relatively uniform infestations throughout the system, showing similar prevalences regardless of habitat type (figure 7.6).

Quantitative, representative sampling of the hosts as well as determining monogenean intensity and interspecific associations on hosts with multiple infestations, would reveal more detail regarding monogenean distribution between fish hosts and habitat types. Specific information regarding monogenean species collected and host information are given in table 7.2 the Parasite / Host checklist for the Okavango Delta, Botswana and table 7.3 Host/ Parasite checklist for the Okavango Delta, Botswana. Further, more these results can be compared to the checklist for all African monogenean species in appendix 1.

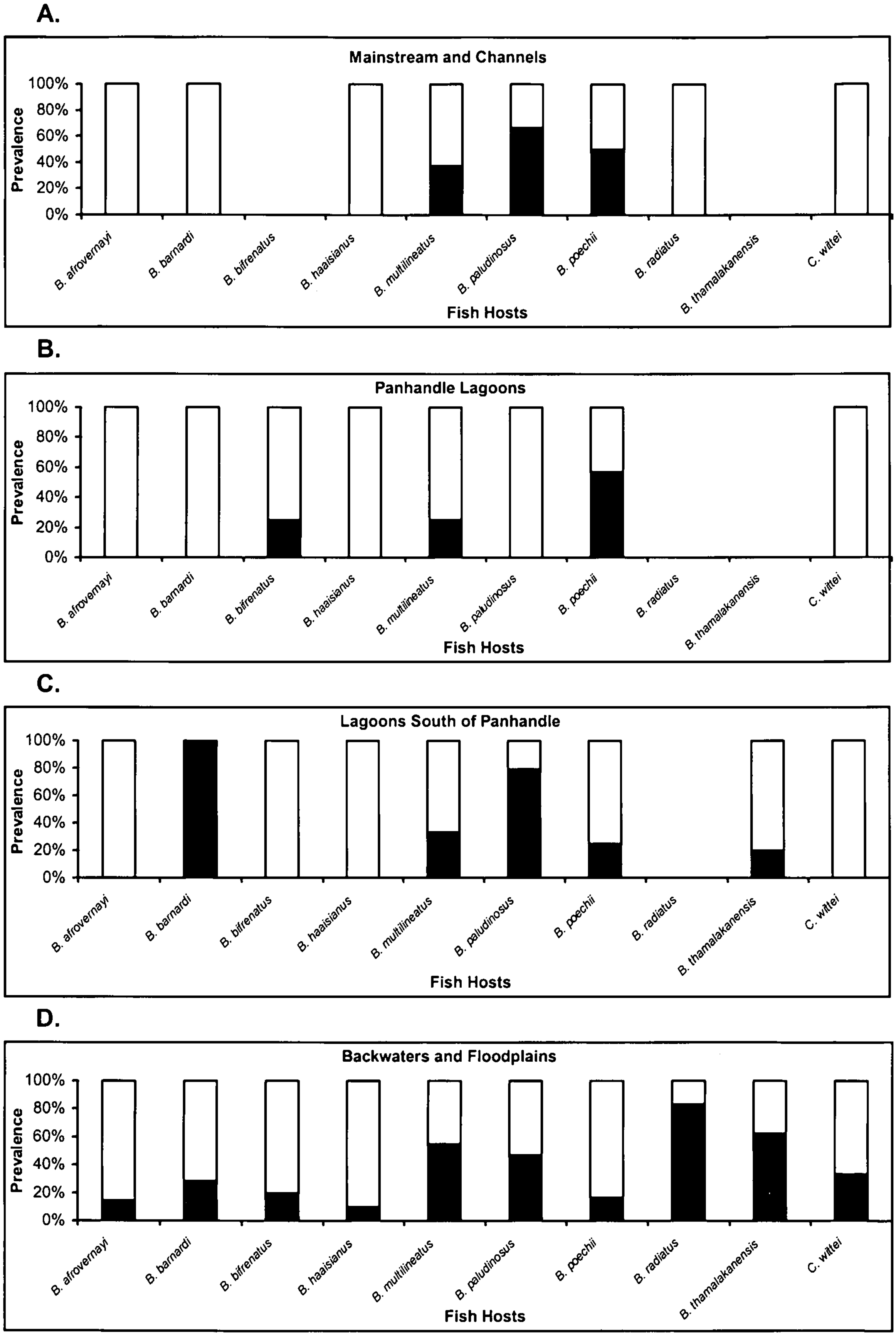

Figure 7.4 Histograms showing the distribution of dactylogyridean prevalence infesting cyprinid fishes from different habitat types in the Okavango Delta, collected in the same season over a period of four years. A. Mainstream and channel habitats, B. Panhandle lagoons, C. Lagoons south of the Panhandle, D. Backwaters and floodplains. Habitat types determined according to figure 7.2. □ - fraction of uninfested hosts from a sample, ■ - fraction of infested hosts in a sample.

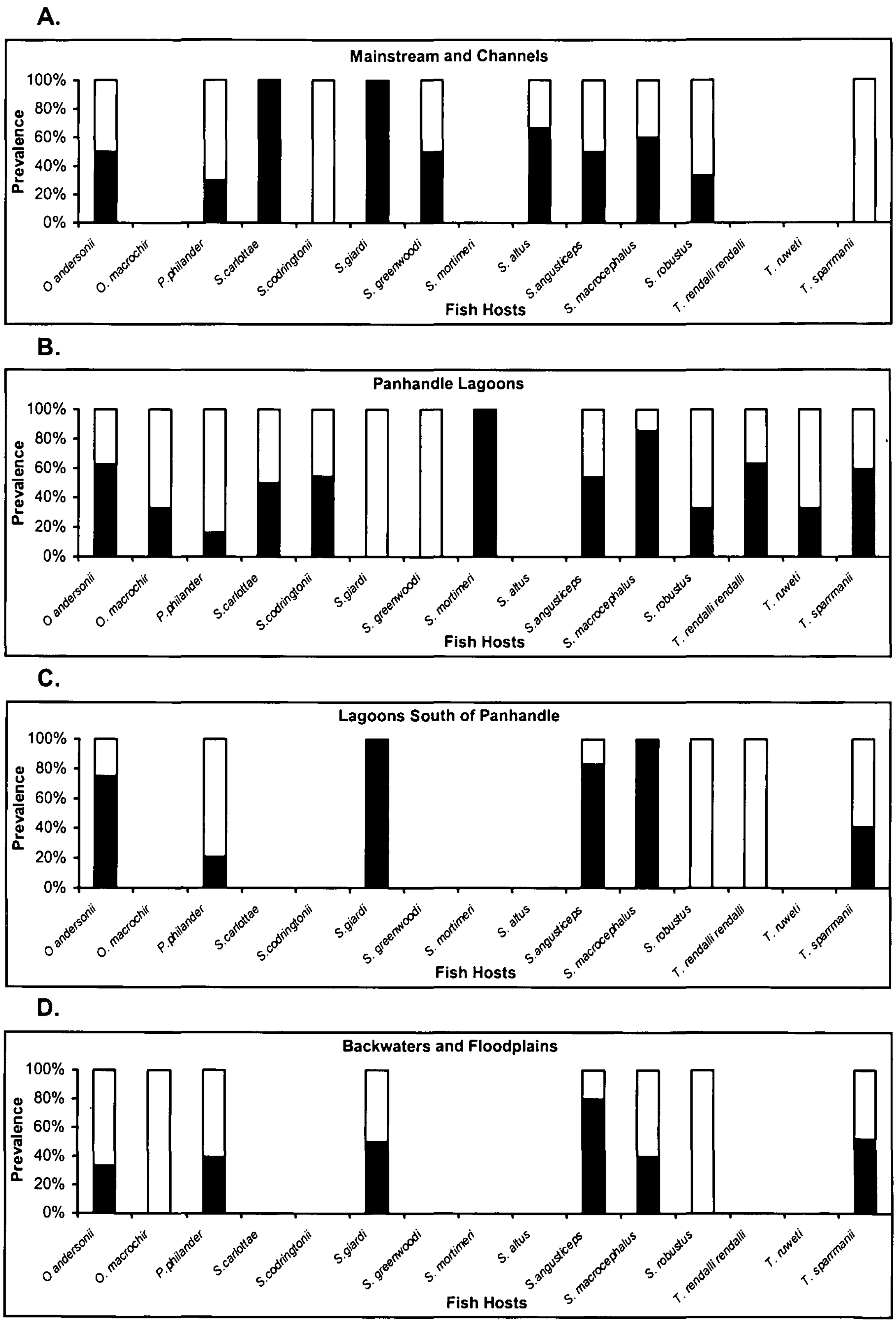

Figure 7.5 Histograms showing the distribution of dactylogyridean prevalence infesting cichlid fishes from different habitat types in the Okavango Delta, collected in the same season over a period of four years. A. Mainstream and channel habitats, B. Panhandle lagoons, C. Lagoons south of the Panhandle, D. Backwaters and floodplains. Habitat types determined according to figure 7.2. □ - fraction of uninfested hosts from a sample, ■ - fraction of infested hosts in a sample.

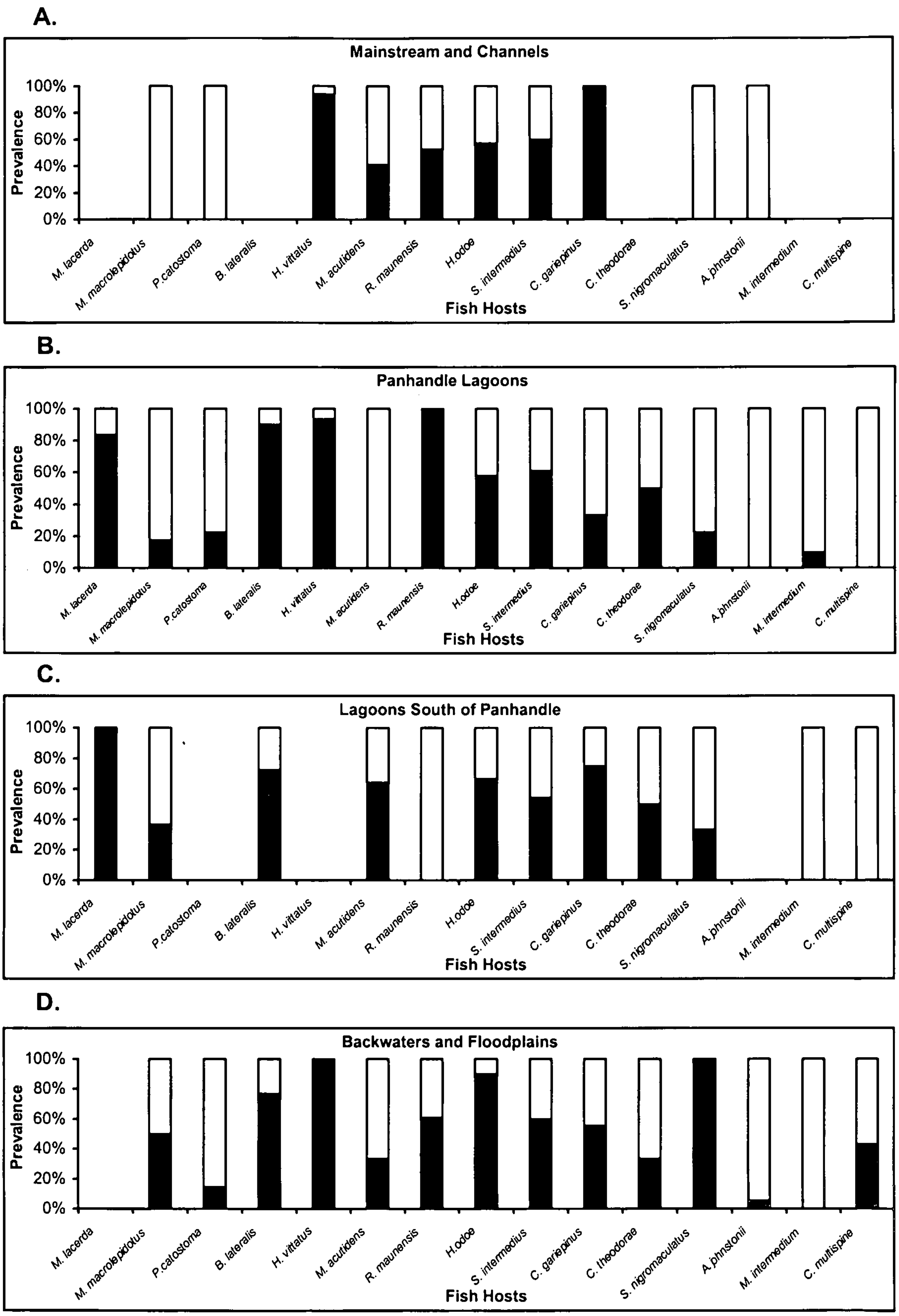

Figure 7.6 Histograms showing the distribution of dactylogyridean prevalence infesting fish families other than the Cyprinidae and Cichlidae from different habitat types in the Okavango Delta, collected in the same season over a period of four years. A. Mainstream and channel habitats, B. Panhandle lagoons, C. Lagoons south of the Panhandle, D. Backwaters and floodplains. Habitat types determined according to figure 7.2. □ - fraction of uninfested hosts from a sample, ■ - fraction of infested hosts in a sample.

Table 7.2 Parasite / Host Checklist for the Okavango Delta, Botswana

No.	Species	Okavango Hosts
	***Characidotrema* Paperna & Thurston, 1968**	
1.	*C. nursei,* Ergens, 1973	*Brycinus lateralis*
	***Dactylogyrus* Diesing, 1850**	
1	*D. barrilus* n. sp.	*Barbus radiatus*
2	*D. dominici* Mashego, 1983	*Barbus paludinosus*
3	*D. myersi* Price *et al.*, 1969	*Barbus poechii*
4	*D. viviersii* n. sp.	*Barbus multilineatus*
		Barbus barnardi
	***Quadriacanthus* Paperna, 1961**	
1	*Q. kalatensis* n. sp.	*Clarias gariepinus*
2	*Q. theodorae* n. sp.	*Clarias theodorae*
	***Schilbetrema* Paperna & Thurston, 1968**	
1	*S. acornis* Paperna & Thurston, 1968	*Schilbe intermedius*
2	*S. quadriacornis* Paperna & Thurston, 1968	*Schilbe intermedius*
	***Annulotrema* Paperna & Thurston, 1969**	
1	*A. curvipenis* Paperna, 1969	*Brycinus lateralis*
2	*A. hepseti* Paperna & Thurston, 1969	*Hepsetus odoe*
3	*A. pikei* (Price, Peebles & Bamford, 1969)	*Hydrocynus vittatus*
4	*A. micralesti* n. sp.	*Micralestes acutidens*
5	*A. rhabdalesti* n. sp.	*Rhabdalestes maunensis*
	***Bouixella* Euzet & Dossou, 1976**	
1	*B. marcusenia* n. sp.	*Marcusenius macrolepidotus*
2	*B. duba* n. sp.	*Mormyrus lacerda*
	***Cichlidogyrus* Paperna, 1960**	
1	*C. halli* (Price & Kirk, 1967)	*Oreochromis andersonii*
2	*C. karibae* Douëllou, 1993	*Serranochromis macrocephalus*
		Serranochromis robustus
		Sargochromis giardi
		Sargochromis codringtonii
3	*C. philander* Douëllou, 1993	*Pseudocrenilabrus philander*
4	*C. sclerosus* Paperna & Thurston, 1969	*Oreochromis andersonii*
5	*C. botswanensis* n. sp.	*Sargochromis codringtonii*
		Sargochromis giardi
		Serranochromis macrocephalus
6	*C. mohemboensis* n. sp.	*Oreochromis andersonii*

Table 7.3 Host / Parasite Checklist for the Okavango Delta, Botswana

Fish Host	Dactylogyrid
Mormyridae	
Mormyrus lacerda Castelnau, 1861	*Bouixella duba* n. sp.
Marcusenius macrolepidotus (Peters, 1852)	*Bouixella marcusenia* n. sp.
Petrocephalus catostoma (Günther, 1866)	
Pollimyrus castelnaui (Boulenger, 1911)	
Cyprinidae	
Mesobola brevianalis (Boulenger, 1908)	
Barbus afrovernayi Nichols & Boulton, 1927	
Barbus barnardi Jubb, 1965	*Dactylogyrus viviersii* n. sp.
Barbus bifrenatus Fowler, 1935	
Barbus eutaenia Boulenger, 1904	
Barbus fasciolatus Günther, 1868	
Barbus haaisianus David, 1936	
Barbus multilineatus Worthington, 1933	*Dactylogyrus viviersii* n. sp.
Barbus paludinosus Peters, 1852	*Dactylogyrus dominici* Mashego, 1983
Barbus poechii Steindachner, 1911	*Dactylogyrus myersi* Price, McClellan, Druckenmiller & Jacobs, 1969
Barbus radiatus Peters, 1853	*Dactylogyrus barrilus* n. sp.
Barbus thamalakanensis Fowler, 1935	
Barbus unitaeniatus Günther, 1866	
Coptostomabarbus wittei David & Poll, 1937	
Labeo lunatus Jubb, 1963	
Distichodontidae	
Hemigrammocharax machadoi Poll, 1967	
Hemigrammocharax multifasciatus Boulenger, 1923	
Characidae	
Brycinus lateralis (Boulenger, 1903)	*Characidotrema nursei* Ergens, 1973 *Annulotrema curvipenis* Paperna, 1969
Hydrocynus vittatus Castelnau, 1861	*Annulotrema pikei* (Price, Peebles and Bamford, 1969)
Micralestes acutidens (Peters, 1852)	*Annulotrema micralesti* n. sp.
Rhabdalestes maunensis (Fowler, 1935)	*Annulotrema rhabdalesti* n. sp.
Hepsetidae	
Hepsetus odoe (Bloch, 1794)	*Annulotrema hepseti* Paperna & Thurston, 1969
Schilbeidae	
Schilbe intermedius Rüppell, 1832	*Schilbetrema acornis* Paperna & Thurston, 1968 *Schilbetrema quadriacornis* Paperna & Thurston, 1968
Clariidae	
Clarias gariepinus (Burchell, 1822)	*Quadriacanthus kalatensis* n. sp.
Clarias stappersii Boulenger, 1915	
Clarias theodorae Weber, 1897	*Quadriacanthus theodorae* n. sp.
Mochokidae	
Synodontis leopardinus Pellegrin, 1914	
Synodontis nigromaculatus Boulenger, 1905	
Synodontis thamalakenensis Fowler, 1935	
Synodontis woosnami Boulenger, 1911	
Synodontis vanderwaali Skelton & White, 1990	
Cyprinidontidae	
Aplocheilichthys hutereaui (Boulenger, 1913)	
Aplocheilichthys johnstonii Günther, 1893	
Aplocheilichthys katangae (Boulenger, 1912)	

Cichlidae	
Oreochromis andersonii (Castelnau, 1861)	*Cichlidogyrus halli* (Price & Kirk, 1967) *Cichlidogyrus sclerosus* Paperna & Thurston, 1969 *Cichlidogyrus mohemboensis* n. sp.
Oreochromis macrochir (Boulenger, 1912)	
Pharyngochromis acuticeps (Steindachner, 1866)	
Pseudocrenilabrus philander (Weber, 1897)	*Cichlidogyrus philander* Douëllou, 1993
Sargochromis carlottae (Boulenger, 1905)	
Sargochromis codringtonii (Boulenger, 1908)	*Cichlidogyrus karibae* Douëllou, 1993 *Cichlidogyrus botswanensis* n. sp.
Sargochromis giardi (Pellegrin, 1903)	*Cichlidogyrus karibae* Douëllou, 1993 *Cichlidogyrus botswanensis* n. sp.
Sargochromis greenwoodi (Bell-Cross, 1975)	
Sargochromis mortimeri (Bell-Cross, 1975)	
Serranochromis altus Winemiller & Kelso-Winemiller, 1990	
Serranochromis angusticeps (Boulenger, 1907)	
Serranochromis longimanus (Boulenger, 1911)	
Serranochromis macrocephalus (Boulenger, 1899)	*Cichlidogyrus karibae* Douëllou, 1993 *Cichlidogyrus botswanensis* n. sp.
Serranochromis robustus (Günther, 1864)	*Cichlidogyrus karibae* Douëllou, 1993
Serranochromis thumbergi (Castelnau, 1862)	
Tilapia rendalli rendalli (Boulenger, 1896)	
Tilapia ruweti Poll & Thys van den Audenaerde, 1965)	
Tilapia sparrmanii Smith, 1840	
Anabantidae	
Microctenopoma intermedium (Pellegrin, 1920)	
Ctenopoma multispine Peters, 1844	
Mastacebelidae	
Atheomastyaxembelia frenatus (Boulenger, 1901)	

CHAPTER 8

Fisheries and aquaculture

8.1 The Okavango fisheries programme

The River San or River Bushmen were the first inhabitants of the Okavango Delta and also the first to harvest the wild fish stocks from this system, marking the beginnings of a subsistence fishery (Mosepele 2000). Various ethnic groups, mostly of Zambesian origin, maintained the early subsistence fishery in the Okavango Delta. Fishing was carried out using an assortment of traditional techniques. In the 1960's, the fisheries extension service was established by the Oxford Committee for Famine Relief (OXFAM), to popularise improved fishing techniques and to make fishing equipment available to the fishing community. Apart from the tourist angling for *Hydrocynus vittatus* (tigerfish), which marked the beginnings of the recreational fishery, fisheries remained a subsistence activity for most of the following two decades. In the early 1980's a small scale commercial fishery was initiated in the Okavango Delta, which created an increased fishing activity and supply soon exceeded demand. Commercial fishermen primarily targeted the species which have high economic value like the large cichlids (Alonso *et al.* 2000). Other smaller fish species like *Schilbe intermedius* (silver catfish) and *Brycinus lateralis* (striped robber) were not fished for, even though they formed a large untapped resource. Various efforts were employed to develop fisheries for these species like increasing the economical value of these species (Merron and Bruton 1989). These efforts, however, failed primarily due to local consumer resistance (Alonso *et al.* 2000). Unwanted by-catch species like *Hydrocynus vittatus* (tigerfish) were taken home by the fishermen or bartered for other items in the village. If supply exceeded demand, the excess by-catch was wasted. Initially the fishes were dried and salted and distributed by the local government for local food supplementary programmes at schools and clinics. Unfortunately this market collapsed in the early 1990's, but the fishery, with the assistance of the Fisheries Section, reverted to a fresh/frozen product (Mosepele 2000). The commercial fishery now mainly operates from the Panhandle area because of a lack of access to electrical power for freezing outlets, trade off in cost benefits between fuel and maintenance costs and fish catches, inaccessibility of some areas, wildlife regulations and dangers to fishing gear by crocodiles and hippos (Alonso *et al.* 2000).

Mosepele (2000) estimated the fishery in the Okavango Delta to be comprised of approximately 1000 subsistence and small-scale fishermen. In addition to this there are about 32 tourist lodges distributed throughout the Delta, which receive approximately 2000 visitors annually, and represent the bulk of the recreational fishery (Merron 1993).

It is evident that fishes of the Okavango River and Delta are an important resource for Botswana, and as such, needs constant monitoring due to the complex ecology of the Delta and the many diverse user groups currently exploiting this resource. Conservation of the fishes does not mean preservation, but rather wise exploitation of this natural resource. According to Merron and Bruton (1989), this can only be achieved if fish communities are managed in such a way that they can sustain themselves, which in turn depends on preservation of genetic diversity and maintenance of essential ecological processes like flooding and draining.

8.2 Aims and potential of aquaculture in the Okavango Delta

The primary purpose of fish farming or fish culture is the controlled rearing of fish including the control of growth and breeding. Rearing of fish is concerned with improving the quality of the product whilst optimising quantitative growth for food or for restocking open waters. Fish culture permits the management of reproduction, feeding, quantitative growth and control of the size of the fish.

Two major advantages of aquaculture in the Okavango are the exploitation of lagoons, backwaters and floodplain pools resulting in the utilisation of land that would otherwise remain unproductive, either because of too much water or because it is just marsh land. Secondly aquaculture could also sufficiently contribute to the production of protein, which can provide substantial addition to food, particularly in conjunction with the reestablishment of livestock farming. The high productivity per acre of aquaculture greatly reduces the surface area of water needed to produce a sustainable yield. In effect natural production can be greatly increased by the possibilities which intensive aquaculture presents. According to Huet (1970), fish culture can be divided into two categories, firstly, fish culture for restocking, which is aimed at the production of young fish. This form of fish culture can have either economic or recreational aims. It is economic when it is practised to improve the yield on commercial fishing by repopulating natural water bodies with young fish or fish fry. It is recreational when its aim is to increase fish population for angling. Secondly, fish culture for food extends fish farming to the production of fish for consumption.

According to Huet (1970) fish cultivation is suitable only for a restricted number of species. In order that a fish be useful for pond cultivation it must: (1) withstand the climate of the region in which it will be raised; (2) its rate of growth must be sufficiently high; (3) successfully reproduce under conditions of rearing; (4) if possible accept and thrive on abundant and cheap artificial food; (5) prove satisfactory to the consumer; (6) support high population density in the ponds and (7) be resistant to disease. Very few species of fish meet all or most of these requirements.

The successful harvesting of wild fish stocks is greatly dependant on the sustainability thereof. Besides other fishery management strategies, aquaculture in the Okavango could sufficiently contribute to the restocking of certain target species (e.g. large bream species and catfish). An added advantage of the culture of desirable or target fish species is that it reduces the waste incurred by the harvesting of any unwanted by-catch species, e.g. *Schilbe intermedius, Synodontis* species, *Mormyrus macrolepidotus* and *Hepsetus odoe.*

The cultivation of fish in the Okavango Delta could offer an excellent means of employment and food for large numbers of people hence reducing the current pressure on the wild fisheries (Jackson 1978, Merron 1993 and Andrew, Rouhani and Seti 2000).

8.3 Fishery productivity and aquaculture potential

Fish farming is a rapidly growing sector of agriculture in Southern Africa. The sharptooth catfish (*Clarias gariepinus*), and some tilapias including the Mozambique tilapia (*Oreochromis mossambicus*), the greenhead tilapia (*Oreochromis macrochir*), threespot bream (*O. andersonii*) and the redbreast tilapia (*Tilapia rendalli rendalli*) are some of the more important species being cultured at present. Although tilapias are important aquaculture species in certain countries, local use has not been very successful, and production in South Africa for 1998 amounted to about 45 tonnes with a market value of ZAR 13.00 / kg or 2.2US$/ kg (Hoffman, Swart and Brink 2000). This production value shows a substantial increase in production of tilapia species since 1988 (11 tonnes produced) (Hecht and Britz 1990). According to Hoffman *et al.* (2000), the production of tilapia species in Southern Africa has shown a rapid increase with commercial projects being recognised in Namibia, Zambia, Botswana, Zimbabwe and Swaziland. The cumulative catch or production from these regions amounts to 600 tonnes for 1998. The potential of indigenous tilapias for aquaculture thus remains high, and they are likely to be used more extensively in future (Skelton 1993).

Likewise, catfish farming is a rapidly growing industry and the sharptooth catfish (*Clarias gariepinus*) is likely to become a major local production species. The sharptooth catfish has many favourable attributes for an aquaculture species: it is extraordinarily hardy, can be bred artificially, eats practically anything, is fast growing and provides a large white fillet. Currently catfish production in Southern Africa is about 120 tonnes per annum, worth over ZAR 1 million (Skelton 1993).

The commercial fishermen in the Okavango target the large bream species but also catch many clariid catfishes and tigerfish. The large bream are frozen and transported to Maun for sale. The fishermen earn P 9 per kg and the fish are sold for approximately P 14 per kg in Maun.

The local currency of Botswana is the Pula (P) and P1.00 is equivalent to approximately ZAR 1.70.

The initial failure of aquaculture to develop successfully in the past in South Africa was partially a result of legal and administrative obstacles on the one hand and as a consequence of inappropriate marketing strategies on the other (Hecht and Britz 1990). Clearly a market for particularly cichlid species and catfish already exists in Botswana, even to the extent where external revenue is generated through the export of some of the total yield. The success of aquaculture in Botswana would thus not rely on its marketability as the market already exists and no consumer resistance is evident regarding potential aquaculture species. However, successful fish culture in Botswana would rely on the availability of sufficient expertise and infrastructure. Aquaculture development cannot rely simply on the transfer of technology from elsewhere in the world. Local support for research and development is therefore fundamental for the successful future of the industry (Hecht and Britz 1990).

8.4 Important fisheries and aquaculture species

Various fish species are regarded as important by the commercial fishermen of the Delta as these species are either favourable to eat or are of higher economic value than other species. Mosepele (2000) listed various species according to their importance to commercial fishermen. *Oreochromis andersonii* was regarded as the most important fish species collected by the commercial industry and constituted 36.8% of the total catch. *Tilapia rendalli rendalli* was the next most important fish constituting 13.88% of the total catch. According to Mosepele (2000), the four most important species to the commercial fishing trade were cichlids followed by *Clarias gariepinus* (catfish), which constituted 4.55 % of the total catch. All of these species have also been recognised by Skelton (1993) as potential aquaculture species (table 8.1).

When regarding the subsistence fishery, *Schilbe intermedius* is the most important species caught, constituting 21.82% of their catch. This is followed by catfishes (*C. gariepinus* and *C. ngamensis*) which constitute 12.23% of their total catch. Various representatives of the Mochokidae and Mormyridae make up a large part of the subsistence fishermen's catch and are hence regarded as important. These species combined constitute 36.05 % of the total catch. Important or sought after food fish, like the various cichlid species, do not form an important part of the subsistence fishermans catch by numbers and collectively constitute only 18.55 %.

Table 8.1 List of fish species from the Okavango Delta with particular importance to commercial and subsistence fisheries and aquaculture (Skelton 1993)

Important to commercial and subsistence fisheries	Important aquaculture species
Mormyrus lacerda	*Clarias gariepinus*
Marcusenius macrolepidotus	*Clarias ngamensis*
Labeo lunatus	*Tilapia rendalli rendalli*
Hydrocynus vittatus	*Oreochromis andersonii*
Hepsetus odoe	*Oreochromis macrochir*
Schilbe intermedius	
Claria gariepinus	
Clarias ngamensis	
Hemichromis elongatus	
Sargochromis carlottae	
Sargochromis codringtonii	
Sargochromis giardi	
Sargochromis greenwoodi	
Serranochromis altus	
Serranochromis angusticeps	
Serranochromis macrocephalus	
Serranochromis robustus	
Serranochromis thumbergi	
Tilapia rendalli rendalli	
Tilapia sparrmanii	
Oreochromis andersonii	
Oreochromis macrochir	

Table 8.1 taxonomically lists the fish species which, Skelton (1993), regarded as important to both the commercial and subsistence fishery. Many of the other species that are found in the Delta could potentially represent a valuable food resource but are met with resistance and are thus not sought after. Skelton (1993) also identifies at least five species (table 8.1) which naturally occur in the Okavango System as potential aquaculture species. These all exhibit most of the characters needed for a suitable aquaculture species (Huet 1970).

8.5 Potential fish pathogens in aquaculture

Ichthyoparasites are an integral part of aquatic ecosystems and they are common in culture populations of fish. Diseases caused by parasites are much more frequently manifested in cultured fish, which endure artificial conditions and various stresses that influence their ability to protect themselves efficiently against parasitic infections (Scholz 1999). In fish culture some parasites are able to reproduce rapidly and as the fish hosts are concentrated, the parasites are able to heavily infest a large proportion of the farmed fishes. As a result fish are exposed to many diseases, which may cause considerable losses especially when farming is intensive. The frequency and importance of diseases can be a result of stocking density, poor culture conditions and the small number of species farmed, which favours the development of specific diseases. Fish are widely dispersed under natural conditions, and diseases are often not noticed as the risks of contamination are fewer and the losses less (Huet 1970 and Scholz 1999). Although research, advancement of methods of eradication of pathogens as well as the improvement of environmental conditions have resulted in better conditions for commercial fish culture in ponds, disease still remains a major problem in aquaculture with the increasing tendency to culture aquatic organisms more intensively (Sarig 1971).

Artificial stresses such as overcrowding, unbalanced nutrition, reduced oxygen content of water, an increase in organic material as well as changes in pH and temperature are factors which enhance the probability of diseases occurring amongst cultured fish (Sarig 1971). Parasites and mainly ectoparasites form the largest group of pathogenic organisms, especially in warm water fishponds and in temperate climates. Long term exposure to suitable temperature and high levels of organic matter enhance shortened life-cycles and extensive infection by many pathogenic parasites, causing heavy mortalities. The increased density of fish populations in commercial fish ponds increases the possibility of epidemic outbreaks (Sarig 1971).

According to Van As and Basson (1988), protozoan parasites like sessiline ciliophorans (*Apiosoma* spp., *Scopulata* spp. and *Epistylus* spp.), trichodinids (*Trichodina* spp. and *Tripartiella* spp.), *Chilodonella* spp. and *Ichthyophthirius multifiliis* are widely distributed on wild and cultured fish stocks, where they are found on the skin and gills of the fish. With the exception of *I. multifilis*, low concentrations of these parasites rarely cause significant pathology on large fishes. "White spot" caused by *I. multifiliis* is probably the worlds most prevalent pathogen of fish and is primarily a problem of very young fish, where even mild infestations may result in mortalities (Sarig 1971, Van As and Basson 1988 and Hecht and Britz 1990).

The fish of the Okavango host a naturally high diversity of protozoan parasites (table 8.2, table 8.3 and table 8.5) and in some cases prevalence is also high. Table 8.2 summarises the protozoan and myxosporidean parasites that infest some cichlids from the Okavango Delta. Eleven protozoan genera have been recorded from these potentially important aquaculture pathogens including the hematozoic genus *Trypanosoma*. Most of these parasites have been known to cause severe pathology in culture conditions.

Table 8.2 Observations of protozoan and myxosporidean parasites infesting cichlids important to fisheries and aquaculture, from the Okavango Delta.

Cichlidae	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Oreochromis andersonii	S G	G	S G	G	S G	S	G	S				
Oreochromis macrochir	S					S						
Sargochromis carlottae	S	G	G			S						
Sargochromis codringtonii							G				R	
Sargochromis giardi							S G					
Sargochromis greenwoodi	S	G	G			S	S G					S
Serranochromis angusticeps	S	G	G			G	S					
Serranochromis robustus											R	
Serranochromis macrocephalus		G				S	S	S				
Serranochromis thumbergi	S G					G	S	S				
Tilapia rendalli rendalli	S G	S G	S G	S	S	S	S	S	G			
Tilapia ruweti	S G		S G			S	S					
Tilapia sparrmanii	S G	G	S G	S	G	S G	S G	S	S G	S		

1=*Trichodina*, 2=*Tripartiella*, 3=Myxosporidea, 4=*Ichthyophthirius*, 5=*Chilodonella*, 6=*Apiosoma*, 7=*Scopulata*, 8=*Epistylus*, 9=*Ichthyobodo*, 10=Suctoria, 11=*Trypanosoma*, 12=*Paratrichodina*, G=Gills, S=Skin, R=Between the Erythrocytes

Table 8.3 Preliminary identifications of mobiline peritrichs from some cichlid fish from the Okavango Delta (L. Basson, Pers. comm.)

Fish Host	Mobiline Peritrich
Oreochromis andersonii	*Trichodina compacta* *Trichodina magna* *Trichodina centrostrigeata* *Trichodina minuta* *Tripartiella spatula*
Oreochromis macrochir	*Trichodina magna* *Trichodina centrostrigeata* *Trichodina minuta*
Pseudocrenilabrus philander	*Trichodina magna* *Trichodina centrostrigeata* *Tripartiella* sp.
Sargochromis carlottae	*Trichodina centrostrigeata* *Trichodina minuta* *Tripartiella spatula* *Tripartiella leptospina* *Tripartiella cichlidarum*
Sargochromis greenwoodi	*Trichodina centrostrigeata*
Tilapia rendalli rendalli	*Trichodina compacta* *Trichodina centrostrigeata* *Trichodina minuta* *Trichodina magna*
Tilapia ruweti	*Trichodina compacta* *Trichodina magna* *Trichodina centrostrigeata* *Trichodina* sp.
Tilapia sparrmanii	*Trichodina magna* *Trichodina centrostrigeata* *Tripartiella spatula*

Digeneans may present a potential problem for fish farmers in the Okavango Delta, as 20 snail species, which are intermediate hosts for various digenetic trematodes, are present throughout the Delta. Jansen van Rensburg (2001) recorded eight different digenean cercariae from six of the 20 snail species from the Okavango System, these included cercaria belonging to the families Cyathocotylidae, Diplostomidae and Echinostomatidae, which may use fish as an intermediate host and the family Heterophyidae which are known parasites of fishes in either the metacercarial or adult stages or both. Good management under culture conditions, however, can prevent the outbreak of digenetic trematodes by eliminating the snail intermediate host (Van As and Basson 1988).

Various endoparasitic worms may be encountered, including larval cestodes which are found in the peritoneum, mesenteries or visceral organs, adult cestodes which are usually found in the intestine, both larval and adult nematodes and larval and adult acanthocephalans. Most of these parasites have multiple host life-cycles and have not been known to pose any severe threat to the aquaculture industry in Southern Africa (Paperna, Van As and Basson 1983, Van As 1984 and Van As and Basson 1988).

Although parasitic crustaceans are not as numerous as protozoans or helminths, some of them are important pathogens and diseases caused by them may result in considerable economic losses (Paperna Van As and Basson 1983, Van As 1984, Van As and Basson 1988 and Scholz 1999).

According to Paperna *et al.* (1983) and Molnar (1987), there is very little information regarding parasites infesting cichlid cultures from Africa. This suggests that with the intensification of culturing of these species, problems will arise which may be directly related to natural parasite infestations. Table 8.4 summarises the metazoan parasites collected from cichlids which may be important in aquaculture in the Okavango Delta.

Table 8.4 Observations of metazoan parasites infesting fisheries and aquaculturally important cichlids from the Okavango Delta.

Cichlidae	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Oreochromis andersonii			S G			G	G		G	
Oreochromis macrochir			S G				G			
Sargochromis carlottae		I	G		G	G				
Sargochromis codringtonii	L		G			G				
Sargochromis giardi			S G		S	G				
Sargochromis greenwoodi	V L		S G	V	S V	G				
Serranochromis angusticeps	V		G	V	V	G		G		
Serranochromis robustus			S G			G		S		
Serranochromis macrocephalus	St		G			G				
Serranochromis thumbergi										
Tilapia rendalli rendalli			S G		G					
Tilapia ruweti			S G							
Tilapia sparrmanii			S G	G	S	G				S

13=Larval Nematodes, 14=Adult Nematodes, 15=Monogenea, 16=Adult Trematoda, 17=Metacercarial Trematoda, 18=*Lamproglena*, 19=*Opistolernea*, 20=*Ergasilus*, 21=*Dolops*, 22=*Lernea*, G=Gills, S=Skin, L=Liver, V=Viscera, St=Stomach, I=Intestine.

Table 8.5 Parasites infesting *Clarias gariepinus* from the Okavango Delta. Adapted from Jansen van Rensburg, Van As, Basson, Van As and Reed (2001)

Parasite	Skin & Fins	Gills	Ovaries	Between blood cells	Viscera	Liver	Intestine	Stomach
Protozoan Parasites								
Trypanosoma sp.				●				
Trichodina centrostrigeata		●						
Trichodina minuta	●							
Trichodina maritinkae		●						
Tripartiella cichlidarum		●						
Apiosoma sp.	●	●						
Scopulata sp.	●							
Epistylis sp.	●							
Henneguya branchialis		●						
Henneguya sp.		●						
Myxobolus sp.			●					
Monogenea								
Quadriacanthus sp.		●						
Gyrodactylus sp	●							
Digenetic Trematodes								
Metacercarial Trematodes		●						
Adult Trematodes		●						
Cestodes								●
Nematodes								
Larval nematodes					●	●		
Adult nematodes							●	●
Acanthocephala								
Larval Acanthocephala						●		
Adult Acanthocephala							●	
Parasitic Crustacea								
Ergasilus sp.		●						
Lamproglena sp.		●						
Afrolernaea sp.		●						
Opistolernaea sp.		●						
Dolops ranarum	●	●						
Argulus sp.	●							

Clarias gariepinus has a wide range of environmental tolerances and is able to endure harsh conditions such as high turbidity and desiccation (Skelton 1993). Furthermore, these fishes also possess an accessory air-breathing organ, which along with their high tolerance of adverse conditions is an advantage to the aquaculturist as this enables him to stock these fish at higher densities than other species. Van As and Basson (1988) discussed the parasites of *Clarias gariepinus* from Southern Africa and their possible implications in aquaculture. Catfish fry seem to be more susceptible to parasitic infestation and, according to Van As and Basson (1988), are sensitive to therapeutic and prophylactic chemicals. According to Jansen van Rensburg, Van As, Basson, Van As and Reed (2001), the assembly of parasites infesting *Clarias gariepinus* in the Okavango River and Delta comprises 21 genera of which some yield more than one species (table 8.5). Jansen van Rensburg *et al.* (2001) estimated about 30 parasite species infesting this host under natural conditions.

8.6 The role of monogeneans as potential pathogens in Okavango aquaculture

Monogeneans are very abundant in some parts of the world and constitute a considerable danger to intensive fish farming. *Dactylogyrus vastator* Nybelin, 1924 is known to be highly dangerous to warm water fish hatchlings a few days after hatching. Many heavy mortalities in spawning and nursing ponds have been described (Sarig 1971). Such mortalities may cause the loss of the total annual production on a commercial farm. Mongeneans are generally specific to the skin and gills of fish and in some cases to a specific host species. Infested fish show signs of epithelial hyperplasia and these regions are often secondarily infected by bacteria and fungi, often accompanied by protozoan parasites (Van As 1984). Timely diagnosis and suitable treatment of the infestation usually results in the eradication of the monogenean parasites and the regeneration of damaged tissue.

Van As and Basson (1988) reported on severe mortalities of *C. gariepinus* fry caused by monogeneans on the skin and gills of these fishes. In the Okavango System a *Gyrodactylus* spp. was collected from the skin and *Quadriacanthus kalatensis* was collected from the gills of *C. gariepinus*. These monogeneans pose a threat to especially catfish fry under culture conditions in the Okavango, which can be overcome by suitable husbandry techniques and conditions. According to Van As and Basson (1988), monogenean induced mortalities among catfish appears to be related to poor feeding regimes.

8.7 Present status of aquaculture in the Okavango System.

Despite its existence since the late 1980s, aquaculture in Botswana and particularly the Okavango Delta is still a fledgling industry. Merron (1988) reported on the first fish farm in Botswana, which consisted of the culture of *Oreochromis andersonii* and *Tilapia rendalli rendalli*. Broodstock of these species were placed in earthen ponds, which according to Merron (1988), produced 15000 fingerlings in the first six months. The fingerlings were placed in cages suspended in Guma Lagoon. Annual fish kills associated with seasonal flooding (Bills 1996), terminated the cage farming prospects in Guma lagoon. Subsequent to this, other small-scale aquaculture developments have been established and collapsed within the same year. The principal reason for aquaculture failure in this region is based on inadequate fish husbandry techniques and fish parasites. In September 1999, one such farm established at Nxamesere, suffered large-scale fish mortalities. On inspection of three moribund *Oreochromis andersonii* specimens, high levels of *Chilodonella* spp., *Trichodina* spp., an *Ichthyobodo* sp. and monogeneans were found on both the skin and gills. These high intensities are a direct result of high stocking densities of the fish cultured specimens and insufficient and inadequate infrastructure for intensive fish culture. For aquaculture to be a serious provider of fish both for food and restocking purposes in the Okavango Delta, large-scale investment in terms of finance and time are required. Suitable facilities are essential to the success of any aquaculture venture and dedicated, qualified personnel are also fundamental for the success of the industry.

Reliable diagnostics, preferably in the early stages of a disease, is an important aspect of effective control of fish diseases in any aquaculture system and often requires microscopic identification of parasites, which in turn requires skilled and experienced workers. This enables the application of adequate treatment measures, which may prevent serious outbreaks (Scholz 1999). The lack of manpower, laboratories and well organised extension services can aggravate the problem when suitable control measures are not known. Controlling fish parasites in general is as yet still inadequate and there is a high demand for improved methods. Effective chemical therapeutants are available, but their application is limited because of parasite resistance, toxicity of chemicals and persistence of chemical residues. Of the most effective preventative measures in fish parasite control is quarantine. This measure is, however, often ignored resulting in much higher expense and effort to control or eliminate introduced pathogens. The import of alien fish to the Okavango system is extremely dangerous, as man made introductions of parasities with foreign fish species have resulted in severe problems relating to both cultured and feral fish stocks in various parts of the world.

8.8 Potential threats of introduced fish species

Fishes have been introduced into and translocated within Southern Africa for a variety of reasons. Although some of the invasions may have been accidental as their origin cannot be traced, the majority were deliberately introduced either as ornamental fish (*Carassius auratus*), food fish (*Cyprinus carpio*), sport and forage fish (*Micropterus salmoides* and *Onchorynchus mykiss*), as biocontrol (*Gambusia affinis*) and most recently various species associated with aquaculture and the aquarium trade (Bruton and Van As 1987). The intended benefits of translocation of fishes, particularly for commercial or sport fisheries, have been thoroughly documented. However, these translocations hold inherent dangers for established fish populations. The direct effects of each introduction may be difficult to assess, but the possibility of extermination of native species accompanies every one (Deacon, Hubbs and Zahuranec 1964), especially where a fish fauna contains localised endemic species, such as that typical in the Okavango. According to Bruton and Van As (1987), one of the major impacts of invasive aquatic animals is through the introduction of alien parasites and diseases, which threaten natural communities and aquaculture. Introductions and transfers of fish hosts within a continent have the effect of accelerating the pathogenic infestation of fish (Paperna and Thurston 1969). A well documented account of this is that of *Gyrodactylus salaris* Malmberg, 1957, which is the most infamous monogenean parasite in recent years. *Gyrodactylus salaris* has eliminated several salmon populations in Norwegian rivers and caused significant losses in fish farms (Scholz 1999). Parasitic introductions into Southern Africa thus far include several protozoans (*Ichthyobodo necator*, *Trichodina acuta, T. mutabilis, T. nigra* and *Trichodinella epizootica*), the monogeneans (*Dactylogyrus anchoratus, D. extensus, D. minutus* and *Pseudacolpenteron pavlovskii*), the asian tapeworm (*Bothriocephalus acheilognathi*) and the fish louse (*Argulus japonicus*) (Van As 1987).

Whilst aquaculture is still a young industry in Botswana, care should be taken to avoid the same mistakes made in the past in other agricultural disciplines, i.e. the introduction of pathogens from elsewhere (Jackson, 1978). There are enough resident fish species with suitable qualities for use as aquaculture subjects and there is no need to introduce any fish species for the recreational fishery. The history and spreading of *G. salaris* and its detrimental effect on native fish should serve as an object lesson of how a presumed harmless organism may become a pathogen if it is introduced to new areas where the host lacks effective responses against it (Scholz 1999). Controls over invasive animals, according to Bruton and Van As (1987), should be as strict as those over chemical pollutants or physical alterations to aquatic systems. Furthermore, as no introduced or translocated fish species were collected from the Okavango Delta in the present study and no records of such introductions are known, it is strongly advised that the Okavango Delta be treated as a genetic reserve, free of introduced or translocated species as suggested by Bruton and Van As (1987).

CHAPTER 9

Discussion

9.1 Host-specificity

The concept of host-specificity is a way of characterising the relationships between the host and parasite and the challenges that confront their two genomes in a given environment. The resulting equilibrium is determined by physiological, ethological and ecological factors (Lambert and El Gharbi 1995). Host-specificity is determined by the combined relative influence of these factors. Euzet and Combes (1980) defined three types of host-specificity for animal parasites, namely: strict specificity (oioxenic), narrow specificity (stenoxenic) and wide specificity (euryxenic). According to Lambert and El Gharbi (1995), only oioxenic specific monogeneans can confidently be used as biological tags of their hosts, as this strict specificity is the only type where a particular monogenean is specific to a single host species. Stenoxenic monogeneans can be used as indicators of a host spectrum or group and may reflect paraphyletic genetic origins of the respective hosts they infest. These parasites generally infest hosts of the same genus or family as was observed in the following instance recorded from the Okavango system, *Dactylogyrus viviersii* infested both *Barbus multilineatus* and *B. barnardi. Cichlidogyrus karibae* was found to infest *Serranochromis robustus* and *S. macrocephalus* as well as *Sargochromis giardi* and *S. codringtonii*, suggesting that the four host species are paraphyletic at the supraspecific level or that the two host genera originated from the same hypothetical ancestor.

Oioxenic specificity among the Okavango monogeneans is difficult to interpret as this study represents the first records of monogeneans from Botswana and hence the Okavango Delta. Furthermore, all sampling was confined to a specific season over a period of four years. Although many monogenean species were recorded from single respective hosts from the Okavango Delta, this does not indicate strict or oioxenic specificity as no seasonal data were collected and hence no information regarding parasite community structure throughout the year is available to determine the level of specificity of the respective monogenean species. Strict host-specificity would, however, be expected from monogeneans infesting monospecific genera or small host groups, like *Annulotrema hepseti,* which has only been recorded from *Hepsetus odoe* throughout its distribution in Africa, and *Schilbetrema quadriacornis* recorded from *Schilbe intermedius.*

It has been shown that various ecological factors have determined the distribution of the fish throughout the Delta. Most of the mongeneans infesting the Okavango fishes exhibit relative stenoxenic or oioxenic specificity to their hosts. It thus follows that ecological factors play an important role in the distribution of these parasites throughout the system and also on their hosts.

This hypothesis is supported by a study conducted by Guégan, Lambert, Lévêque, Combes and Euzet (1992), where they found that a combination of historical as well as ecological factors are primarily responsible for the current distribution of monogeneans in the West African cyprinid fishes. According to Guégan *et al.* (1992), host ecology affects parasite species richness or diversity significantly. In the study conducted by Guégan *et al.* (1992), host ecology was related to relative position in the water column. In the present study the hosts specific ecological position is probably closer related to habitat distribution.

Ecosystems that are primarily driven by physico chemical events that originate from outside the system, are characterised by lower levels of complexity and ever-changing biotic relationships, and achieve stability by the continual, though often unpredictable, repetition of cycles, e.g. many wetlands and riverine floodplains and rivers subject to episodic floods. It is hypothesised that these ecosystems are typically inhabited by species with reproductive styles that are suited for environments that have predominantly density-independent mortality, i.e. non-guarding guilds that invest a small amount of energy in each of a large number of small young (Bruton and Merron 1990).

The Okavango is characterised by diverse habitat types, which can broadly be considered as stable or unstable with respect to water level, which in turn varies from habitat to habitat or from season to season. Stable habitats are relatively uniform throughout the year, (e.g. mainstream habitats) and support biota that are more dependent on this stability and less tolerant of change. Unstable habitats are characterised by severe change from season to season and even more drastic change may be encountered from hour to hour. The flood inundates floodplain habitats annually and the extent of inundation is also dependent on the extent of the flood. However, when the water starts to recede, the floodplains generally take the form of pools which, are shallow with large surface areas and hence are characterised by extreme conditions like temperature change, variation in oxygen content, changes in salinity and desiccation. The biota inhabiting these severe or unstable habitats are generally tolerant of the harshness of the habitat. It would appear as if the monogeneans infesting fishes, which inhabit these habitats, have also adapted strategies to survive. In the stable habitats where conditions are more predictable, the dactylogyrids infesting Okavango fishes appeared to demonstrate closer specificity to a specific host species. In habitats that were less predictable, host switching occurred, resulting in the same monogenean species being collected from a few closely related host species. An example of this was *Dactylogyrus viviersi,* which was collected from only *Barbus multilineatus* in the mainstream and channel habitats, but was collected from both *B. multilineatus* and *B. barnardi* in the lagoons south of the Panhandle and backwater and floodplain habitats (figure 7.4). According to Kearn (1998), monogeneans that spread from host to host by contagion, like gyrodactylids or those infesting gregarious host species which often make physical contact with one another, may be more likely to switch hosts than monogeneans that disperse only by freely deposited eggs and oncomiracidia.

According to Guegan *et. al.* (1992), parasite diversity is often greatest in host taxa which have the greatest diversity. However, they did not find this to be the main factor to explain monogenean species richness among the West African cyprinids. In the Okavango System, the most diverse host group, the cichlids, exhibited relatively low monogenean species diversity, with single parasite specimens infesting multiple hosts (*C. sclerosus* and *C. botswanensis*). This host group did, however, exhibit high monogenean species richness, with only one host being infested by three congeneric species (*Oreochromis andersonii* infested by *Cichlidogyrus halli, C. sclerosus* and *C. mohemboensis*). The coexistence of several related host species of freshwater fishes in the same drainage basin may have favored the maintenance of parasite species richness.

It appears as though there may be a turnover of gill parasite fauna in the Okavango cyprinids with respect to changing environmental conditions as the floodplains recede and conditions become more unpredictable. This mechanism, according to Guegan *et. al.* (1992), is a combined process of parasite extinction and colonisation. Parasite community construction is not only the result of probability and/or independent extinction-colonisation processes, but is also the final consequence of a long coevolution between species that will build together functional networks. Therefore, not only host ecology, but the history of host-parasite relationships is also an essential element to consider in analysing the structure of parasite communities. According to Guegan *et. al.* (1992), when related hosts cohabit an environment, exchanges of parasites can occur. In general non-specialised parasite species (stenoxenic species) must have more successful invaders than over-specialised species (oioxenic species). The shift in parasite colonisation eventually disturbs the older parasite structure. Inversely, when host fish species remain isolated for a long time in drainage basins that are themselves isolated, their parasites can be considered to result directly from host-parasite cospeciation. Most genera of African fishes have distinct groups of monogeneans, which are probably the result of long associations between hosts and parasites (Paperna 1979).

Host-specificity may in turn also have an effect on other aspects of monogenean interactions with their hosts and other congeneric specimens including site specificity and selection. According to Bagge and Valtonen (1999), several factors are responsible for monogenean site selection including host-specificity, sex, an immunological response of the fish, seasonality, micro- and macrohabitat (including water quality), geographical range, competition, predation, hyperparasitism and facilitation of mating. Site specificity of the monogeneans infesting Okavango fishes was, however, not determined as there was insufficient data regarding parasite intensities from the different habitats and interspecific interactions of congeneric species.

9.2 Transmission of dactylogyrid monogenean species

According to Euzet and Combes (1998), changes in habitat by monogeneans in fish reveal a tendency to abandon the ectoparasitic mode of life for a meso- or endoparasitic one. Although Euzet and Combes (1998) still consider the branchial cavity as an external habitat, Kearn (1998) suggests that these cavities must provide significant improvements in the life style for skin parasites. Avoidance of predation, avoidance of competition or niche restriction and better access to resources may be important incentives but more importantly the trend toward endoparasitism may be related to opportunities for cross insemination, which will be greater in a more confined living space. Observations regarding some *Cichlidogyrus* species infesting mouth brooding fish in the Okavango, suggest another possible reason for a move toward endoparasitism in some branchial monogeneans. The added advantage of a semi-internal habitat would be direct transmission of onchomiracidia to the juvenile fish being brooded in the buccal cavity of the adult fish. *Cichlidogyrus* species on the gills of the mother fish deposit eggs which do not pass into the water but are probably retained in the buccal or branchial cavity, possibly trapped in the gill mucus. The onchomiracidia may hatch due to a hormonal cue from mother fish or other chemical cues provided by juvenile fish and larvae being brooded. These onchomiracidia then infest the brooding fry. According to Guégan, *et al.* (1992), for a host-parasite relationship to occur, the parasite has to come into contact with the host (probability of contact), and then the parasite has to recognise it as a favourable environment and colonise it (compatibility of host and parasite genomes). This method of infestation ensures contact with the host and is elucidated when considering two closely related fish from the Okavango Delta, *Serranochromis robustus* and *Serranochromis macrocephalus*. Sixty eight percent of the specimens of *S. macrocephalus* were infested by *Cichlidogyrus karibae* whereas only 14% of the *Serranochromis robustus* specimens examined throughout the Delta were infested by the same parasite. This is significant when considering that these two fish species are very closely related and occur sympatrically throughout the Delta. The only major difference regarding their biology is that *S. macrocephalus* is a mouth brooder, whereas *S. robustus* is a nest builder. Further support for this hypothesis according to Caro, Combes and Euzet (1997) is that monogenean diversity or parasite richness reflects an equilibrium between acquisitions and extinctions and two important factors generally govern this, namely the genetic relatedness of host species and the spatial proximity of individuals (a short distance facilitates the transfer of infective stages. Similarly Guégan *et al.* (1992), regard water currents and the distance between the source of the parasite larval stage and the potential host as the two principal factors that regulate monogenean diversity or parasite richness. The high prevalence of *Cichlidogyrus karibae* specimens achieved in mouth brooding hosts is most probably achieved by direct infestation of the fry, thus ensuring a very short distance of infestation. This hypothesis is purely based on observation and still needs to be tested.

CHAPTER 10

References

ALONSO, L.E., ASHTON, P.E. & NORDIN, L. 2000. Preliminary report of the AQUARAP expedition to the Okavango Delta, Botswana. Conservation International. 80pgs.

AMIRTHALINGHAM, C. 1965. *Macrogyrodactylus polypteri* Malmberg on *Polypterus senegalus* in the Sudan. *Bulletin of Fisheries Research Station, Ceylon* **17**, 237-239.

ANDREW, T.G., ROUHANI, Q.A. & SETI, S.J. 2000. Can small-scale fisheries contribute to poverty alleviation in traditionally non-fishing communities in South Africa? *African Journal of Aquatic Science* **25**, 49-55.

BAGGE, A.M. & VALTONEN, E.T. 1999. Development of monogenean communities on the gills of roach fry (*Rutilus rutilus*). *Parasitology* **118**, 479-487.

BALFOUR, D. 1996. *Okavango: An African Paradise.* Struik Publishers, Cape Town, South Africa, 80 pgs.

BATRA, V. 1984. Prevalence of helminth parasites in three species of cichlids from a man-made lake in Zambia. *ZoologicalJournal of the Linnean Society* **82**, 319-333.

BILLS, R. 1996. Fish stock assessment of the Okavango River. J.L.B. Smith Institute of Ichthyology Investigational Report No. 56. 110 pgs.

BILONG-BILONG, C.F. 1988. *Enterogyrus malmbergi* n. sp. (Monogenea, Ancyrocephalidae) parasite de l'estomac du Cichlidae *Tilapia nilotica* Linne., 1757 au sud Cameroun. *Annals de la Faculte Science Biologique et Biochemie* **111**, 51-58.

BILONG-BILONG, C.F., BIRGI, E. & EUZET, L. 1991. *Enterogyrus barombiensis* n. sp. (Monogenea, Ancyrocephalinae) parasite stomacal de trios Cichlidae endemiques du lac du cratère Barombi Mbo (Cameroun). *Annales de Parasitologie Humaine Comparée* **66**, 105-108.

BILONG-BILONG, C.F., BIRGI, E. & LAMBERT, A. 1989. *Enterogyrus melenensis* n. sp. (Monogenea: Ancyrocephalidae) parasite stomacal de *Hemichromis fasciatus* Peters, 1857 (Teleosteen, Cichlidae) du Sud- Cameroun. *Journal of African Zoology* **103**, 99-105.

BILONG-BILONG, C.F., EUZET, L &. BIRGI, E. 1994. Deux nouveaux *Eutrianchoratus* Paperna, 1969 (Monogenea, Ancyrocephalidae), parasites branchiaux de *Parachanna obscura* (Günther, 1861) (Teleostei, Channidae), du Cameroun. *Parasite* **1**, 357-362.

BILONG-BILONG, C.F., EUZET, L &. BIRGI, E. 1996. Monogenean stomach parasites of cichlid fishes from Cameroon: two new species of the genus *Enterogyrus* Paperna, 1963 (Ancyrocephalidae). *Systematic Parasitology* **34**, 37-42.

BIRGI, E. 1988. Les Monogenes de Characoidea de la forestiere Camerounaise. *Annales de la Faculte des Sciences de la Biologie et Biochemie* **3**, 59-111.

BIRGI, E. & EUZET, L. 1983. Monogenes parasites des poisons des eaux douces du Cameroun. Presence des genres*Cichlidogyrus* et *Dactylogyrus* chez *Aphyosemion* (Cyprinodontidae). *Bulletin de la Societe Zoologique de France* **108**, 101-106.

BIRGI, E. & LAMBERT, A. 1987. Les Dactylogyridae (Platyhelminthes, Monogenea) des Cyprinidae du genre *Barbus* du Sud Cameroun. *Revue de Hydrobiologia Tropicales* **20**, 37-48.

BOEGER, W.A. & KRITSKY, D.C. 1993. Phylogeny and a revised classification of the Monogenoidea Bychowsky, 1937 (Platyhelminthes). *Systematic Parasitology* **26**, 1-32.

BOEGER, W.A. & KRITSKY, D.C. 1997. Coevolution of the Monogenoidea (Platyhelminthes) based on a revised hypothesis of parasite phylogeny. *International Jornal for Parasitology* **27**, 1495-1511.

BOEGER, W.A. & KRITSKY, D.C. 2001. Phylogenetic relationships of the Monogenoidea. (In) Littlewood, D.T.J., Bray, R.A., (eds.) *The Interrelationships of the Platyhelminthes.* Taylor and Francis, London, pp. 92-102.

BOOTH, A.J. & MCKINLAY, B.W. 2001. Spatial aspects of the reproductive and feeding biology of the striped robber, *Brycinus lateralis* (Pisces: Characidae), in the Okavango Delta, Botswana. *African Zoology* **36**, 31-40.

BRUTON, M.N. & JACKSON, P.B.N. 1983. Fish and fisheries of wetlands. *Journal of the Limnological Society of South Africa* **9**, 123-133.

BRUTON, M.N. & MERRON, G.S. 1990. The proportion of different eco-ethological sections of reproductive guilds of fishes in some African inland waters. *Environmental Biology of Fishes* **28**, 179-187.

BRUTON, M.N. & VAN AS, J.G. 1987. Faunal invasions of aquatic ecosystems in southern Africa with suggestions for their management. In: Macdonald, I.A., Kruger, F.J. & Ferrar, A.A. (Eds). *The Ecology and Management of Biological Invasions*. Oxford University Press. **344**, 47-61.

BUSH, A.O., FERNÁNDEZ, J.C., ESCH, G.W. & SEED, J.R. 2001. *Parasitism: The diversity and ecology of animal parasites*. Cambridge University Press, Cambridge, United Kingdom, 566 pgs.

BYCHOWSKY, B. E. 1937. Ontogenesis and phylogenetic relationships of parasitic flatworms. *Investiz Akademia Nauk SSSR., Ser. Biol.* **4**, 1353-1383.

BYCHOWSKY, B. E. 1957. *Monogenetic trematodes their systematics and phylogeny.* American Institute of Biological Sciences, Washington, 627pgs.

CARO, A., COMBES, C. & EUZET, L. 1997. What makes fish a suitable host for Monogenea in the Mediterranean? *Journal of Helminthology* **71**, 203-210.

*CARUS, J.V. 1863. Räderthiere, Würmer, Echinodermen, Coelenteraten und Protozoen. In PETERS, W.C.H., CARUS, J.V. & GERSTAECKER, C.E.A. (eds). *Handbuch der Zoologie* 2: 422-600.

DEACON, J.E., HUBBS, C. & ZAHURANEC, B.J. 1964. Some effects of introduced fishes on the native fish fauna of Southern Nevada. *Copeia* **2**, 384-388.

DOSSOU, C. 1982. Parasites de poisons d'eau douce de Benin III. Especes nouvelles du genre *Cichlidogyrus* (Monogenea) parasites de Cichlidae. *Bulletin de l'Institut Francaise d'Afrique Noire Serie A* **44**, 295-322.

DOSSOU, C. & BIRGI, 1984. Monogenes parasites d'*Hemichromis fasciatus* Peters, 1857 (Teleostei: Cichlidae). *Annales des Sciences Naturelles, Zoologie et Biologie Animale* **6**, 101-109.

DOSSOU, C. & EUZET, L. 1984. Parasites de poisons d'eau douce du Benin. II. Especes nouvelles du genre *Bouixella* (Monogenea) parasites de Mormyridae. *Bulletin du Muséum National d' Histoire Naturelle, Serie A (Zoologie, Biologie et Ecologie Animales)* **6**, 41-47.

DOSSOU, C. & EUZET, L. 1993. *Synodontella* n. g. (Monogenea, Ancyrocephalidae) parasites de Mochokidae africains du genre *Synodontis* Cuvier, 1817. *Journal of African Zoology* **107**, 175-185.

DOUËLLOU, L. 1993. Monogeneans of the genus *Cichlidogyrus* Paperna, 1960 (Dactylogyridae: Ancyrocephalinae) from cichlid fishes of Lake Kariba (Zimbabwe) with descriptions of five new species. *Systematic Parasitology* **25**, 159-186.

DOUËLLOU, L. & CHISHAWA, A.M.M. 1995. Monogeneans of three Siluriform fish species in Lake Kariba, Zimbabwe. *Journal of African Zoology*, **109**, 99-115.

EID, N. & NEGM, M. 1987. Some morphological study on a new species of endoparasitic monogenetic trematode *Enterogyrus niloticus* in the intestine of *Tilapia nilotica*. *Journal of the Egyptian Veterinary Medical Association* **47**, 79-86.

EL GHARBI, S., BIRGI, E. & LAMBERT, A. 1994. Monogènes Dactylogyridae parasites de Cyprinidae du genre *Barbus* d'Afrique du Nord. *Systematic Parasitology* **27**, 45-70.

EL NAGGAR, M.M. 1985. *Schilbetrema aegyptica* n. sp., a monogenean gill parasite of the Egyptian freshwater fish *Schilbe mystus*. *Journal of the Egyptian Society of Parasitology* **15**, 571-580.

EL NAGGAR, M.M. 1987. *Protoancylodiscoides mansourensis* n. sp. A monogenean gill parasite of the Egyptian freshwater fish *Chrysichthys auratus* (Geoffroy, 1809). *Arab Gulf Journal of Scientific Research* **5**, 441-454.

EL-NAGGAR, M.M. & KHIDR, A.A. 1986. Survey of population dynamics of Cichlidogyrid monogeneans from the gills of three *Tilapia* spp. From Damietta branch of the River Nile in Egypt. *Proceedings of the Zoological Society, A.R. Egypt* **12**, 275-286.

EL-NAGGAR, M.M., KHIDR, A.A., & KEARN, G.C. 1990. Ultrasrtuctural observations on the oviduct, Mehlis glands and oötype of the monogenean *Cichlidogyrus halli typicus* (Price & Kirk, 1967) Paperna, 1979. *International Journal of Parasitology* **20**, 203-209.

EL-NAGGAR, M.M., KHIDR, A.A., & KEARN, G.C. 1991. Ultrasrtuctural observations on the tegument and associated structures of the monogenean *Cichlidogyrus halli typicus* (Price & Kirk, 1967) Paperna, 1979. *International Journal of Parasitology* **21**, 707-713.

EL-NAGGAR, M.M. & SERAG, H.M. 1985. The monogenean *Quadriacanthus kearni* n. sp. And a report of *Q. clariadis clariadis* Paperna, 1979 on the gills of *Clarias lazera* in Nile Delta. *Journal of the Egyptian Society of Parasitology* **15**, 479-492.

EL-NAGGAR, M.M. & SERAG, H.M. 1987. Redescription of *Macrogyrodactylus clarii* Gussev, 1961, a monogenean gill parasite of *Clarias lazera* in Egypt. *Arab gulf Journal of Scientific Research, B (Agricultural and Biological Sciences)* **5**, 257-271.

ERGENS, R. 1973a. *Characidotrema nursei* sp. nov. from the gills of *Alestes nurse* from River Nile. (Vermes, Trematoda, Monogenoidea). *Revue de Zoologie et de Botanique Africaines* **87**, 195-197.

ERGENS, R. 1973b. Two new species of *Gyrodactylus* from *Clarias lazera*. *Revue de Zoologie et de Botanique Africaines* **87**, 77-80.

ERGENS, R. 1981. Nine species of the genus *Cichlidogyrus* Paperna, 1960 (Monogenea: Ancyrocephalinae) from Egyptian fishes. *Folia Parasitologica* **28**, 205-214.

ERGENS, R. 1988. Four species of the genus *Annulotrema* Paperna et Thurston, 1969 (Monogenea:Ancyrocephalinae) from Egyptian freshwater fish. *Folia Parasitologica* **35**, 209-215.

EUZET, L. & BIRGI, E. 1975. *Heterobothriumfluviatilis* n. sp (Monogenea, Diclidophoridae) parasite branchial de *Tetraodon fahaka* Bennett, 1834 (Teleostei) au Tchad. *Bulletin de la Society Zoologique de France* **100**, 411-420.

EUZET, L. & COMBES, C. 1980. Les problémes de l'espéce chez les animaux parasites. In: *Les problémesde l'espéce dans le règne animal*, ed. C. Bocquet, J. Genermont & M. Lamotte. *Mém. Soc. Zool. Fr.* **40**, 239-285.

EUZET, L. & COMBES, C. 1998. The selection of habitats among the Monogenea. *International Journal for Parasitology* **28**, 1645-1652.

EUZET, L. & DOSSOU, C. 1975. Parasites de poisons d'eau douce du Dahomey. I. Especes nouvelles du genre *Heteronchocleidus* (Monogenea) parasites d'Anabantidae. *Bulletin du Museum National d'Histoire Naturelle, Paris* 3e Serie 282 Zoologie **192**, 23-34.

EUZET, L. & DOSSOU, C. 1976. Découverte de monogènes (*Bouixella* n. g.) chez les Mormyridae (Teleostei) au Bénin. *Comptes Rendus Hebdomadaires des Séances de L'Academie des Sciences, Paris* D. **283**, 1413-1416.

EUZET, L. & LE BRUN, N. 1990.Monogenes du genre *Bagrobdella* Paperna 1969, paraites branchiaux d'*Auchenoglanis occidentalis* (Cuvier et Valenciennes, 1840) (Teleostei: Siluriformes: Bagridae). *Journal of African Zoology* **104**, 37-48.

EUZET, L. & PROST, M. 1981. Report of the meeting on Monogenea: problems of systematics, biology and ecology. In: Slusarski, W. (Ed.) *Review of advances in parasitology*. Warsaw: P.W.N. Polish Scientific Publishers, 1003-1004.

FIELD, J.G., CLARKE, K.R. & WARWICK, R.M. 1982. A practical strategy for analysing multispecies distribution patterns. *Marine Ecology Progress Series* **8**, 37-52.

FISCHTHAL, J.H. & KUNTZ, R.E. 1963. Trematode parasites of fishes from Egypt. Part II. *Diplozoon aegypticus* n. sp. (Monogenea: Polyopisthocotylea: Diclidophoroidea) from *Labeo forskalli*. *Proceedings of the Helminthological Society of Washington* **30**, 31-33.

GUÉGAN, J. & LAMBERT, A. 1990. Twelve new species of dactylogyrids (Platyhelminthes, Monogenea) from West African barbells (Teleostei, Cyprinidae), with some biogeographical implications. *Systematic Parasitology* **17**. 153-181.

GUÉGAN, J. & LAMBERT, A. 1991. Dactylogyrids (Platyhelminthes: Monogenea) of *Labeo* (Teleostei: Cyprinidae) from West African coastal rivers. *Journal of the Helminthological Society of Washington* **58**. 85-99.

GUÉGAN, J., LAMBERT, A. & BIRGI, E. 1988. Observations sur le parasitsm branchial des Characidae du genre *Hydrocynus* en Afrique de L'Oest. Description D'*Annulotrema pikoides* n. sp. (Monogenea, Ancyrocephalidae) Chez *Hydrocynus vittatus* (Castelnau, 1861). *Annales de Parasitologie Humaine Comparée* **63**, 91-98.

GUÉGAN, J., LAMBERT, A. & EUZET, L. 1988. Etude des Monogènes des Cyprinidae du genre *Labeo* en Afrique de l'ouest. I. Genre *Dactylogyrus* Diesing, 1850. *Revue d'Hydrobiologie Tropicale* **21**. 135-151.

GUÉGAN, J., LAMBERT, A. & EUZET, L. 1989. Etude des Monogènes des Cyprinidae du genre *Labeo* en Afrique de l'ouest. II. Genre *Dogielius* Bykhowski, 1936. *Revue d'Hydrobiologie Tropicale* **22**, 35-48.

GUÉGAN, J., LAMBERT, A., LÉVÊQUE, C., COMBES, C. & EUZET, L. 1992. Can host body size explain the parasite species richness in tropical freshwater fishes? *Oecologia* **90**, 197-204.

GUSSEV, A.V. 1961. A viviparous monogenetic trematode from freshwater basins of Africa. *Doklady Akademii Nauk SSSR Seriya Biologiya* **136**, 490-493. [In Russian]

HECHT, T. & BRITZ, P.J. 1990. *Aquaculture in South Africa: History , status and prospects*. The Aquaculture Society of South Africa, NMB Printers (Pty) Ltd. Port Elizabeth. South Africa, 58 pgs.

HOFFMAN, L.C., SWART, J.J. & BRINK.D. 2000. The 1998 production and status of aquaculture in South Africa. *Water SA* **26**, 133-135.

HUET, M. 1970. *Textbook of fish culture: Breeding and cultivation of fish*. Fishing News (Books) Ltd. England, 436 pgs.

JACKSON, P.B.N. 1978. Health and disease in intensive aquaculture. *Journal of the South African Veterinary Association* **49**, 57-59.

JANSEN VAN RENSBURG, C. 2001. Snail borne larval trematodes of the Okavango Delta, Botswana. M.Sc. Dissertation, University of the Free State, Bloemfontein, South Africa.

JANSEN VAN RENSBURG, C., VAN AS, J.G., BASSON, L., VAN AS, L.L. & REED, C.C. 2001. Parasites infecting the sharptooth catfish in the Okavango Delta, Botswana. *Microscopy Society of Southern Africa – Proceedings* **31**, 78.

JUSTINE, J.L. 1991. Cladistic study in the Monogenea (Platyhelminthes), based upon a parsimony analysis of spermiogenetic and spermatozoal ultrastructural characters. *International Journal for Parasitology* **21**, 821-838.

JUSTINE, J.L. 1998. Non-monophyly of the monogeneans? *International Journal for Parasitology* **28**, 1653-1657.

JUSTINE, J.L., LAMBERT, A. & MATTEI, X. 1985. Spermatozoan ultrastructure and phylogenetic relationships in the monogeneans (Platyhelminthes). *International Journal for Parasitology* **15**, 601-608.

KEARN, G.C. 1998. *Parasitism and the Platyhelminthes*. Chapman & Hall. London, UK. 544 pgs.

KHALIL, L.F. 1964. On the biology of *Macrogyrodactylus polypteri* Malmberg, 1956, a monogenetic trematode on *Polypterus senegalus* in the Sudan. *Journal of Helminthology* **38**, 210-222.

KHALIL, L.F. 1969. Studies on the helminth parasites of freshwater fishes of the Sudan. *Journal of Zoology, London* **158**, 143-170.

KHALIL, L.F. 1970. Further studies on *Macrogyrodactylus polypteri*, a monogenean on the African freshwater fish *Polypterus senegalus*. *Journal of Helminthology* **44**, 329-348.

KHALIL, L.F. & POLLING, L. 1997. *Checklist of the Helminth Parasites of African Freshwater Fishes.*Department of Zoology/Botany, University of the North. Pietersburg, South Africa. 185 pgs.

KHIDR, A.A. 1990. Population dynamics of *Enterogyrus cichlidarum* (Monogenea: Ancyrocephalinae) from the stomach of *Tilapia* spp. in Egypt. *International Journal of Parasitology* **20**, 741-745.

KHIDR, A.A. & HASSAN, S.H. 1989. Observations on egg production in *Cichlidogyrus halli typicus* (Monogenea: Ancyrocephalinae). *Delta Journal of Science* **13**, 1145-1156.

KHIDR, A.A. & HASSAN, S.H. 1990. Observations on hatching and the onchomiracidium of the gill parasite, *Cichlidogyrus arthracanthus*, Paperna, 1960. (Monogenea: Ancyrocephalinae). *Proceedings of the Zoological Society of the Arab Republic of Egypt* **18**, 221-228.

KHIDR, A.A., HASSAN, S.H. & KEARN, G.C. 1990. Redescription of *Enterogyrus cichlidarum* Paperna, 1963 (Monogenea: Ancyrocephalidae) from the stomach of *Tilapia* spp. in Egypt. *Proceedings of the Zoological Society of the Arab Republic of Egypt* **18**, 269-280.

KRITSKY, D.C. & KULO, S.D. 1988. The African species of *Quadriacanthus* with proposal of *Quadriacanthoides* gen. n. (Monogenea: Dactylogyridae). *Proceedings of the Helminthological Society of Washington* **55**, 175-187.

KRITSKY, D.C. & KULO, S.D. 1992. A revision of *Schilbetrema* (Monogenoidea: Dactylogyridae), with descriptions of four new species from African Schilbeidae (Siluriformes). *Transactions of the American Microscopical Society* **111**, 278-301.

KRITSKY, D.C., KULO, S.D. & BOEGER, W.A. 1987. Resurrection of *Characidotrema* Paperna & Thurston, 1968 (Monogenea: Dactylogyridae) with description of two new species from Togo, Africa. *Proceedings of the Helminthological Society of Washington*, **54**, 175-184.

KRITSKY, D.C. & THATCHER, V.E. 1974. Monogenetic trematodes (Monopisthotylea: Dactylogyridae) from freshwater fishes in Colombia. South America. *Journal of Helminthology* **48**, 59-66.

LAMBERT, A. & EL GHARBI, S. 1995. Monogenean host specificity as a biological and taxonomic indicator of fish. *Biological Conservation* **72**, 227-235.

LEBEDEV, B.I. 1988. Monogenea in the light of new evidence and their position among platyhelminthes. *Angewandte Parasitologie* **29**, 149-167.

LEBEDEV, B.I. 1995. *Biodiversity and Evolution of Oligonchoinean Monogenoidea.* The Russian Academy of Sciences, Far East Branch, Institute of Biology & Pedology. Vladivostok. 31pgs.

LIM, S. 1998. Diversity of monogeneans in Southeast Asia. *International Journal for Parasitology* **28**, 1495-1515.

LITTLEWOOD, D.T.J., ROHDE, K. & CLOUGH, K.A. 1999. The interrelationships of all major groups of Platyhelminthes: phylogenetic evidence from morphology and molecules. *Biological Journal of the Linnean Society* **66**, 75-114.

LLEWELLYN, 1965. The evolution of parasitc Platyhelminthes. (In:) *Evolution of Parasites*. Third Symposium of the British Society of Parasites. Blackwell, Oxford, U.K. 47-78.

MALMBERG, G. 1957. Om förekonsten av *Gyrodactylus* på svenska fiskar. *Skrofter Utgivna Av Södra Sveriges Fiskeriförening Arsskrift*, 19-76.

MALMBERG, G. 1990. On the ontogeny of the haptor and the evolution of the Monogenea. *Systematic Parasitology* **17**, 1-65.

MASHEGO, S.N. 1983. South African monogenetic parasites of the genus *Dactylogyrus*: new species and records (Dactylogyridae: Monogenea). *Annals of the Transvaal Museum* **33**, 337-346.

MASHEGO, S.N. 2000. Occurence of *Neodiplozoon polycotyleus* Paperna, 1973 (Diplozoidae: Monogenea) in Cyprinid fish in South Africa. *Onderstepoort Journal of Veterinary Research* **67**, 153-154.

MC CARTHY, T.S. & ELLERY, W.N. 1998. The Okavango Delta. *Transactions of the Royal Society of South Africa* **53**, 157-182.

MERRON, G.S. 1988. Botswana's first fish farm. *Ichthos Newsletter* **18**, 15.

MERRON, G.S. 1991. The ecology and management of the fishes of the Okavango Delta, Botswana, with particular reference to the seasonal floods. Ph.D. Thesis, Rhodes University, Grahamstown, South Africa.

MERRON, G.S. 1993. A synopsis of presentations and discussions on the fish and fishery in the Okavango Delta, Botswana. *Botswana Notes and Records* **25**, 133-140.

MERRON, G.S. & BRUTON, M.N. 1986. Where are all the Okavango fishes. *Kalahari Conservation Society Newsletter* **13**, 4-5.

MERRON, G.S. & BRUTON, M.N. 1989. Recent fisheries research in the Okavango Delta. *South African Journal of Science* **85**, 416-417.

MERRON, G.S., HOLDEN, K. & BRUTON, M.N. 1990. The reproductive biology and early development of the African pike, *Hepsetus odoe*, in the Okavango Delta, Botswana. *Environmental Biology of Fishes* **28**, 215-235.

MIZELLE, J.D. & KRITSKY, D.C. 1969. Studies on the monogenetic trematodes. XXXIX. Exotic species of Monopisthocotylea with the proposal of *Archidiplectanum* gen. n. and *Longihaptor* gen. n. *The American Midland Naturalist* **81**, 370-386.

MOLNAR, K. 1987. Solving parasite related problems in cultured freshwater fish. *International Journal for Parasitology* **17**, 319-326.

MOLNAR, K. & MOSSALAM, I. 1985. Monogenean parasites of fishes of the Nile in Egypt. *Parasitologia Hungarica* **18**, 5-9.

MOSEPELE, K. 2000. Preliminary length based stock assessment of the main exploited stocks of the Okavango Delta Fishery. Mphil. Thesis, University of Bergen, Bergen, Norway.

N'DOUBA, V. & LAMBERT, A. 1999. Un nouveau *Macrogyrodactylus* (Monogenea, gyrodactylidae) parasite de *Heterobranchus longifilus* valenciennes, 1840 (Teleosteen, siluriforme) en cote d'lvoire. *Zoosystema* **21**, 7-11.

N'DOUBA, V. & LAMBERT, A. 2001. Deux monogènes nouveaux parasites branchiaux de *Clarias ebriensis* Pellegrin, 1920 (siluriformes, Clariidae) en Côte-d' Ivoire. *Zoosystema* **23**, 411-416.

N'DOUBA, V., LAMBERT, A. & EUZET, L. 1999. Seven new species of *Quadriacanthus* Paperna, 1961 (Monogenea) from the gills of *Heterobranchus longifilis* and *H. isopterus* from the Ivory Coast, West Africa. *Systematic Parasitology* **44**, 105-118.

N'DOUBA, V., PARISELLE, A. & EUZET, L. 1997. Espèces nouvelles du genre *Annulotrema* Paperna et Thurston, 1969 (Monogenea, Ancyrocephalidae) parasites de *Hepsetus odoe* (Bloch, 1794) (Teleostei, Hepsetidae) en Côte D'Ivoire. *Parasite* **4**, 55-61.

N'DOUBA, V., PARISELLE, A., THYS VAN DEN AUDENAERDE, D.P.E. & EUZET, L. 1997. Espèces nouvelles du genre *Schilbetrema* Paperna & Thurston, 1968 (Monogenea, Ancyrocephalidae) parasites de *Schilbe mandibularis* (Günther, 1867) (Schilbeidae) en Côte-d'Ivoire. *Journal of African Zoology* **111**, 481-487.

OBIEKEZIE, A.I., MOLLER, H. & ANDERS, K. 1988. Diseases of the African estuarine catfish *Chrysichthys nigrodigitatus* (Lacepede) from the Cross River Estuary. *Journal of Fish Biology* **32**, 207-221.

ODHNER, T. 1912. Die homologeien der weiblichen genitalwege bei den Trematoden und Cestoden. Nebst bemerkungen zum naturlichen system der monogenen Trematoden. *Zoologisher Anzeiger* **39**, 327-351.

PAPERNA, I. 1961. Studies on monogenetic trematodes in Israel. 3. Monogenetic trematodes of the Cyprinidae and Claridae of the Lake of Galilee. *Bamidgeh* **13**, 14-29.

PAPERNA, I. 1965. Monogenetic trematodes collected from freshwater fishes in southern Ghana. *Bamidgeh* **17**, 107-111.

PAPERNA, I. 1968. Monogenetic trematodes collected from freshwater fish in Ghana. *Bamidgeh* **20,** 88-99.

PAPERNA, I. 1969a. Monogenetic Trematodes of the fish of the Volta Basin and South Ghana. *Bulletin de l'Institut Francais d' Afrique Noire* **31**, 840-880.

PAPERNA, I. 1969b. Monogenea of the subfamily Heteronchocleidinae, Price, 1968 (Dactylogyridae) from African freshwater fish. *Parasitology* **59**, 557-561.

PAPERNA, I. 1973. New species of Monogenea (Vermes) from African freshwater fish. A preliminary report. *Revue de Zoologie et de Botanique Africaines* **87**, 505-518.

PAPERNA, I. 1979. *Monogenea of inland water fish in Africa.* Musee Royal De L'Afrique Centrale. Eilat, Israel. 131pgs.

PAPERNA, I. & THURSTON, J.P. 1968. Monogenetic trematodes (Dactylogyridae) from fish in Uganda. *Revue de Zoologie et de Botanique Africaines*, **78**, 284-294.

PAPERNA, I. & THURSTON, J.P. 1969a. *Annulotrema* n. gen., a new genus of monogenetic trematodes (Dactylogyridae, Bychowski, 1957) from African Characin fish. *Zoologisher Anzeiger* **182**, 444-449.

PAPERNA, I. & THURSTON, J.P. 1969b. Monogenetic trematodes from cichlid fish in Uganda; including the description of five new species of *Cichlidogyrus*. *Revue de Zoologie et de Botanique Africaines* **79**, 15-33.

PAPERNA, I., VAN AS, J.G. & BASSON, L. 1983. Review of diseases affecting cultured cichlids. *Proceedings of the International Symposium on Tilapia in Aquaculture*, 174-184.

PARISELLE, A. & EUZET, L. 1994. Three new species of *Cichlidogyrus* Paperna, 1960 (Monogenea, Ancyrocephalinae) parasites on *Tylochromis jentinki* (Steindachner, 1895) (Pisces, Cichlidae) in West Africa. *Systematic Parasitology* **29**, 229-234.

PARISELLE, A. & EUZET, L. 1995. Trois Monogènes nouveaux parasites branchiaux de *Pelmatochromis buettikorferi* (Steindachner, 1895) (Cichlidae) en Guinée. *Parasite* **2**, 203-209.

PARISELLE, A. & EUZET, L. 1996. *Cichlidogyrus* Paperna, 1960 (Monogenea, Ancyrocephalidae): gill parasites from West African Cichlidae of the subgenus *Coptodon* Regan, 1920 (Pisces), with descriptions of six new species. *Systematic Parasitology* **34**, 109-124.

PARISELLE, A. & EUZET, L. 1997. New species of *Cichlidogyrus* Paperna, 1960 (Monogenea, Ancyrocephalidae) from the gills of *Sarotheradon occidentalis* (Daget) (Osteichthyes, Cichlidae) in Guinea and Sierra Leone (West Africa). *Systematic Parasitology* **38**, 221-230.

PARISELLE, A. & EUZET, L. 1998. Five new species of *Cichlidogyrus* (Monogenea: Ancyrocephalidae) from *Tilapia brevimanus*, *T. buttikoferi* and *T. cessiana* from Guinea, Ivory Coast and Sierra Leone (West Africa). *Folia Parasitologica* **45**, 275-282.

PRICE, C.E. 1967. A revised definition of the monogenetic trematode genus *Dactylogyrus*, with descriptions of four new species. *Proceedings of the Helminthological Society of Washington* **34**, 117-124.

PRICE, C.E. & GERY, J. 1968. Parasites de poisons du Gabon – generalités sur les trématodes monogenetiques, et description de six nouvelles espèces parasites du genre *Barbus*. *Biologica Gabonica* **4**, 83-103.

PRICE, C.E. & KIRK, R.G. 1967. First description of a monogenetic trematode from Malawi. *Revue de Zoologie et de Botanique Africaines* **76**, 137-143.

PRICE, C.E., KORACH, K.S. & McPOTT, R. 1969. The monogenean parasites of African fishes. V. Two new *Dactylogyrus* species from Natal Cyprinids. *Review de Zoologie et de Botanique Africaine* **79**, 273-279.

PRICE, C.E. & MC CLELLAN, E.S. 1969. The Monogenean parasites of African fishes. IX. A new genus, *Gussevstrema*, recovered from the gills of *Terapon jarbua* (Forskål) from South Africa. *Proceedings of the Biological Society of Washington* **82**, 171-176.

PRICE, C.E., MC CLELLAN, E.S., DRUCKENMILLER, A. & JACOBS, L.G. 1969. The monogenean parasites of African fishes. X. Two additional *Dactylogyrus* species from South African *Barbus* hosts. *Proceedings of the Biological Society of Washington* **82**, 461-468.

PRICE, C.E., PEEBLES, H.E. & BAMFORD, T. 1969. The monogenean parasites of African fish. –IV. Two new species from South African hosts. *Revue de Zoologie et de Botanique Africaines* **79**, 117-124.

PRICE, C.E. & PIKE, T. 1969. The monogenean parasites of African fishes. VII. Dissolution of the family Protogyrodactylidae, Johnson and Tiegs, 1922. *Proceedings of the Helminthological Society of Washington* **36**, 259-264.

PRICE, C.E. & YURKIEWICZ, W.J. 1968. The monogenean parasites of African fishes. VIII. A re-evaluation of the genus *Dogielus* Bychowsky, 1936, with the description of a new species. *Revista Iberica de Parasitology* **28**, 467-472.

PRICE, E.W. 1937. North American monogenetic Trematodes. I. The superfamily Gyrodactyloidea. *Journal of the Washington Academy of Sciences* **27**, 114-130, 146-164.

PRUDHOE, S. 1957. Trematoda. *Exploration du Parc National de l'Upemba Mission G. F. de Witte en collaboration avec W. Adam, A. Janssens, L. van Meel & R. Verheyen (1946-49) Bruxelles* **48**. 1-28.

PRUDHOE, S. & HUSSEY, C.G. 1977. Some parasitic worms in freshwater fishes and fish predators from the Transvaal, South Africa. *Zoologica Africana* **12,** 113-147.

RAKOTOFIRINGA, S. & EUZET, L. 1983. Monogenes parasites de Cichlidae (Teleostei) endemiques de Madagascar. *Bulletin de la Societe Zoologique de France* **108**, 107-114.

ROHDE, K. 1996. Robust phylogenies and adaptive radiations: a critical examination of methods used to identify key innovations. *The American Naturalist* **148,** 481-500.

ROSS, K. 1987. *Jewel of the Kalahari: Okavango.* BBC Books, London. 256 pgs.

SARIG, S. 1971. *The prevention and treatment of diseases of warmwater fishes under subtropical conditions with special emphasis on intensive fish farming.* T.F.H. Publications, Jersey City. 199 pgs.

SAOUD, M.F.A. & MAGEED, A. 1969. Host-parasite relationships of *Macrogyrodactylus polypteri* (Trematoda: Monogenea) in some fishes of the Sudan. *Current Science* **38**, 209-210.

SCHMIDT, G.D. & ROBERTS, L.S. 1989. *Foundations of Parasitology.* Times Mirror / Mosby College Publishing, St. Louis, USA, 750 pgs.

SCHOLZ, T. 1999. Parasites in feral and cultured fish. *Veterinary Parasitology* **84**, 317-335.

SHAW, S. 1998. Rape of the Okavango. *Keeping Track.* February/March: 22-25.

SHOTTER, R.A. & MEDAIYEDU, J.A. 1977. The parasites of *Polypterus endlicheri* Heckel (Pisces: Polypteridae) from the river Galma at Zaria, Nigeria, with a note on its food. *Bulletin de l'Institute Fondamental d'Afrique Noire*, Serie A **39**, 177-189.

SKELTON, P. 1993. *A complete guide to the freshwater fishes of Southern Africa.* Southern Book Publishers, Halfway House, South Africa, 388 pgs.

SKELTON, P. 2001. *A complete guide to the freshwater fishes of Southern Africa.* Southern Book Publishers, Halfway House, South Africa, 388 pgs.

SKELTON, P., BRUTON, M., MERRON, G.S. & VAN DER WAAL, B.C.W. 1985. The fishes of the Okavango drainage system in Angola, South West Africa and Botswana: Taxonomy and distribution. *Ichthyological Bulletin Of The J.L.B. Smith Institute Of Ichthyology* **50**, 1-21.

THOMAS, J.D. 1957. A new monogenetic trematode, *Diplozoon ghanense* sp. nov., (Polyopisthocotylea: Discocotylea) from a West African freshwater fish *Alestes macrolepidotus* (C. & V., 1849) in West Africa. *Journal of the West African Science Association* **3**, 178-182.

THURSTON, J.P. 1970. The incidence of monogenea and parasitic crustacea on the gills of fish in Uganda. *Revue de Zoologie et de Botanique Africaine* **82** , 111-130.

TIMOFEEVA, T.A., GERASEV, P.I. & GIBSON, D.I. 1996. New names for homonyms in the genus *Dactylogyrus* Diesing, 1850 (Monogenea, Dactylogyridae). *Systematic Parasitology* **35**, 1-2.

*VAN BENEDEN, P.J. 1858. Mémoire sur les vers intestinaux. Mémoire qui a obtenu de l'Institut de France (Académie des Sciences) le Grand Prix des Sciences physiques pour l'année 1853. *Comptes Rendus des Séances de l'Académie des Sciences, Supplément,* 2, 1-176.

VAN AS, J.G. 1984. Parasites and diseases of freshwater fish in South Africa: An ecological approach. In: HECHT, T., BRUTON, M.N. & SAFRIEL, O (Eds.). Aquaculture in South Africa. Occasional Report No. 1. Ecosystem Programmes. Foundation for Research Development. CSIR. Pretoria. 118-127.

VAN AS, J.G. 1987. Parasitological consequences of introducing foreign fish species. In: Aquaculture 1986. Occasional Report Series No. 15. Ecosystem Programmes. Foundation for Research Development. CSIR. Pretoria. pp 120-123.

VAN AS, J.G. & BASSON, L. 1988. Parasites of Sharptooth Catfish and their possible implication in aquaculture. CSIR. Chapter 10 pp 98-104.

*WEDL, C. 1861. Zur helminthenfauna Aegyptiens (2 Abt). *Sber. Dt. Akad. Landwiss. Wien.* 44: 463-482.

WELCOMME, R.L. 1979. *Fisheries Ecology of Floodplain Rivers.* Longman Group Limited. New York, United States. 315pp.

WHEELER, R.L. & CHISHOLM, L.A. 1995. Monogenea versus Monogenoidea: the case for stability in nomenclature. *Systematic Parasitology* **30**, 159-164.

WHITTINGTON, I.A. 1998. Diversity "down under": Monogeneans in the Antipodes (Australia) with a prediction of monogenean biodiversity world wide. *International Journal for Parasitology* **28**, 1481-1493.

YAMAGUTI, S. 1963. *Systema Helminthum: Volume 4 Monogenea and Aspidocotylea.* Interscience Publishers. New York, U.S.A. 190 pgs.

*References not seen in original form.

References referred to in Appendix 1.

Acknowledgements

I would like to express my sincere thanks to the following people or institutions for their contributions to this study and the Okavango Fish Parasite Project as a whole.

1. **Prof. J.G. van As and Prof. Linda Basson** for their supervision and guidance throughout the duration of this study and for providing me with the opportunity to be part of, and contribute to the Okavango Fish Parasite Project.
2. **Dad, Mom, Megan, Lourens and Carmen** for all their love and support and assistance throughout my study.
3. **Jeandré Combrinck** for all her love, support and prayer throughout my study.
4. **Oom Werner, Tannie Wilna and Leon** for all their support and encouragement and hospitality during the final stages of my study.
5. **Jonathan Venter and Candice Jansen Van Rensburg** and other friends and colleagues at both the University of the Free State and the University of Zululand, for all their help and patience.
6. **The Government of Botswana** for their support and assistance with the project, with special mention of the following people; Hon. R. Sebego (Minister of Agriculture), Mr. K. V. Masupu (Director of Animal Health and Production), Mr. Trevor Mmopelwa (Fisheries Section), Mr. Kita Mosepele (Fisheries Section) and Mr. Shaft Nengu (Fisheries Section).
7. **Debswana Diamond Company** for their vision to support a project such as the Okavango Fish Parasite Project. I would like to make special mention of the following people for the assistance provided and the special interest expressed in the project; Mr. L. Nchindo, Mr. G. A. Beavers and Mr. J. M. Matome.
8. **Land-Rover South Africa** for the sponsorship of vehicles for the study with special mention of Frieda Scherman for her enthusiasm and efficiency towards the project.
9. **Mr. I Barr and Mr. N. Smith, Sovereign Motors (Bloemfontein),** for their role in the delivery of the two Land Rovers.
10. **Land-Rover Botswana** for their efficiency in servicing and maintenance of the vehicles.
11. **Kalahari Conservation Society** for their exceptional administration of the project with special mention of the Board of Trustees chaired by Mr. L. Nchindo and Mr. K. Legget, Ms. J Addy and Mr. F. Monggae
12. **Conservation International,** Dr. Karen Ross for making available office equipment and further logistic support.

13. **Prof. G.N. Van Wyk Dean of the Faculty of Natural and Agricultural Sciences at the University of the Free State** for his enthusiastic support and encouragement.
14. **Tim and June Liversage** for their wonderful hospitality and support of the project as well as making their camp and facilities available for study in the swamps.
15. **Jan, Eileen, Donovan and Lourens Drotsky** for providing accommodation in the field and logistic support.
16. **Barry and Elain Pryce** for providing accommodation in the field
17. **Geoff and Nookie Randall** for providing accommodation in the field.
18. **50/50,** Erald Felix, Attie Gerber, Marike Williams and Andre Gouws, for the making of the various television documentaries about the project.
19. **Dan and Paula Rawson** for logistic support.
20. **Dave Bodington** for construction of the boat and other logistical support.
21. **Foundation for Research Development** for making available a bursary and for financial support during the study.
22. **Department of Zoology and Entomology, University of the Free State** for the use of facilities and support received during both my undergraduate and postgraduate studies.
23. **University Foundation** Mr. Rudo Pyper, Catherine Castagno (Development Director), Veronica Kirchner (Development manager), Debbie Bosch (Office Manager) for the efficient and professional manner in which the project was marketed and developed.
24. **Motor and General** for supplying of equipment and advice fundamental to the success of the project.

Abstract

The Okavango Delta has received much popularity for the host of wildlife that it sustains. More recently it has gained increasing interest for the rich diversity of fish species that occur there. The fishes of the Okavango are also becoming increasingly important as a natural resource attracting revenue to Botswana in the forms of ecotourism and aquaculture and also as an important food source for the local community.

The Okavango Delta is a flood driven system and much of the fish distribution throughout the Delta and the timing of certain behavioural activities are dependent on the timing and magnitude of the flood. For the purpose of determining the distribution of fish parasites throughout the system, the distribution of the fish hosts was determined and it was found that fish community structure could be used to distinguish different habitat types within the different ecological regions.

Fifty-nine of the expected 68 fish species for the Delta have been collected. These species represent 12 families of which the families Cichlidae and the Cyprinidae are the most abundant, making up about 50 percent of the species collectively. Various parasites have been collected from these fishes of which the monogeneans seem to be the most prevalent and abundant and currently represent approximately 36% of the parasites collected. Most of the monogeneans recorded thus far were representatives of the subclass Polyonchoinea. Of these, all belonged to the families Dactylogyridae and Gyrodactylidae.

Of the monogenean parasites infesting the Okavango fishes, the representatives of the family Dactylogyridae were the most diverse. Genera of African dactylogyrids are either endemic to Africa or belong to genera with wider geographical ranges. In general dactylogyrids are host specific and their zoogeographical affinities are therefore linked to the faunistic origin of their hosts. The distribution of dactylogyrid species within Africa is determined by the distribution pattern of their hosts.

Twenty-two dactylogyrid species comprising seven genera were recorded, of these 10 species were previously undescribed. This study represents the first records of representatives of the class Monogenea from Botswana and hence the Okavango Delta.

Opsomming

Die Okavango Delta is baie beroemd vir die diversiteit van natuurlewe wat dit onderhou. Daar is onlangs toenemende belangstelling vir die diversiteit van visspesies wat daar voorkom. Die visse van die Okavango word as al hoe meer belangriker beskou as ‘n natuurlike hulpbron wat inkomste vir Botswana se ekonomie verwerf, in die vorm van ekotourisme en akwakultuur asook as belangrike voedselbron vir die plaaslike gemeenskap.

Die Okavango Delta is ‘n vloedaangedrewe stelsel en die verspreiding van die visse en die tydsberekinge van sekere gedragsaktiwiteite, is van die tydsberekening en omvang van die jaarlikse vloed afhanklik. Om die verspreiding van visparasiete in die stelsel te bepaal, was die visverspreiding bepaal en daar was gevind dat visgemeeskappe gebruik kan word om tussen verskeie habitattipes binne verskillende ekologiese gebiede te onderskei.

Nege-en-vyftig van die verwagte 68 visspesies vir die Delta was versamel. Hierdie spesie verteenwoordig 12 visfamilies van wie die families Cichlidae en Cyprinidae die volopste was en het sowat 50% van al die spesies opgemaak. Verskeie parasiete was van die visse versamel, waarvan teenwoordigers van die klas Monogenea blyk om die mees volopste te wees, en verteenwoordig tans 36% van die parasiete wat versamel was.

Van die teenwoordigers van die Monogenea was die meeste daarvan verteenwoodigers van die subklas Polyonchoinea, waarvan almal aan die families Dactylogyridae en Gyrodactylidae behoort het. Van die verteenwoordigers van die klas Monogenea wat Okavango visse besmet, was verteenwoordigers van die familie Dactylogyridae die mees divers. Die verteenwoordigers van die Afrikagenera van die familie Dactylogyridae is óf endemies, óf behoort aan genera met wyer geografiese verspreiding. Oor die algemeen is hierdie parasiete gasheerspesifiek en hulle verspreiding is dus van hulle gashere afhanklik.

Twee-en-twintig spesies verteenwoordigend van die familie Dactylogyridae was in die Okavango Delta versamel, waarvan tien van hulle onbeskryfde spesies was. Hierdie proefskrif verteenwoordig dus die eerste rekords van die verteenwoordigers van die klas Monogenea van Botswana asook die Okavango Delta.

APPENDIX 1: Checklist of the monogeneans Infesting African Freshwater Fishes Adapted from Khalil & Polling (1997)

	SPECIES	AUTHOR	TYPE HOST	TYPE COUNTRY	OTHER HOSTS	OTHER REFERENCES	COUNTRY
	Family: **Gyrodactylidae**	Van Beneden & Hesse, 1863					
	Afrogyrodactylus	**Paperna, 1968**					
1	*A. characinis*	Paperna, 1968	*Micralestes sp.*	Ghana			
	Gyrodactylus	**von Nordmann, 1832**					
1	*Gyrodactylus alberti*	Paperna, 1973	*Clarias lazera*	Uganda			
2	*G.amphiluisi*	Paperna, 1973	*Amphilius atesusnsis*	Ghana			
3	*G. anabantii*	Paperna, 1973	*Ctenopoma murieri*	Uganda			
4	*G. cichlidarum*	Paperna, 1968	*Hemichromis bimaculatus*	Ghana	*Hemichromis fasciatus*	Paperna (1969)	Ghana
					Sarotherodon galilaea	Paperna (1968 &1969)	Ghana
					T. guineensis	Paperna (1969)	Ghana
					T. heudeloti	Paperna (1969)	Ghana
5	*G. clarii*	Paperna, 1973	*Clarias lazera*	Uganda			
6	*G. ctenopomi*	Paperna, 1973	*Ctenopoma murieri*	Uganda			
7	*G. cyprinodontii*	Paperna, 1968	*Epiplatys fasciatus*	Ghana		Paperna (1969)	Ghana
8	*G. cytophagus*	Paperna, 1968	*Aplocheilichthys normani*	Ghana		Paperna (1969)	Ghana
9	*G. groschafti*	Ergens, 1973	*Clarias lazera*	Egypt			
10	*G. haplochromii*	Paperna, 1973	*Haplochromis angustifrons*	Uganda	*Haplochromis elegans*	Paperna (1973)	Uganda
11	*G. ivindoensis*	Price & Gery, 1968	*Barbus holotaenia*	Gabon			
12	*G. kyogae*	Paperna, 1973	*Barbus perince*	Uganda	*Barbus neumayeri*	Paperna (1973)	Uganda
13	*G. microalestis*	Paperna, 1968	*Micralestes sp.*	Ghana		Paperna (1969)	Ghana
14	*G. nyanzae*	Paperna, 1973	*Tilapia variabilis*	Uganda			
15	*G. rysavyi*	Ergens, 1973	*Clarias lazera*	Egypt			
16	*G. transvaalensis*	Prudhoe & Hussey, 1977	*Clarias gariepinus*	South Africa			
17	*G. sp.*				*Polypterus endlicheri*	Shotter & Medaiyedo (1977)	Nigeria
					Clarias lazera	Molnar & Mossalam (1985)	Egypt
	Macrogyrodactylus	**Malmberg, 1957**					
1	*M. anabantii*	Paperna, 1973	*Ctenopoma murieri*	Uganda			
2	*M. clarii*	Gussev, 1961	*Clarias sp.*	Ethiopia	*Clarias lazera*	Paperna (1969)	Ghana
						El-Naggar & Serag (1987)	Egypt
						Serag (1988)	Egypt
3	*M. congolensis*	(Prudhoe, 1957)	*Clarias lazera*	Zaire	*Clarias mossambicus*	Thurston (1970)	Uganda
4	*M. c. karibae*	Douëllou & Chishawa, 1995	*Clarias gariepinus*	Zimbabwe			
5	*M. ctenopomii*	Paperna, 1973	*Ctenopoma murieri*	Uganda			
6	*M. heterobranchii*	N'Douba & Lambert, 1999	*Heterobranchus longifilis*	Ivory Coast			
7	*M. latesi*	Paperna, 1969	*Lates niloticus*	Ghana			
8	*M. polypteri*	Malmberg, 1957	*Polypterus senegalus*	Gambia	*Polypterus senegalus*	Khatil (1964, 1969, 1970)	Sudan
						Amirthalingham (1965)	Sudan
					Polypterus bichir	Saoud & Mageed (1969)	Sudan
	Family: **Dactylogyridae**	Bychowsky, 1933					
	Afrocleidodiscus	**Paperna, 1969**					
1	*A. distichodis*	Paperna, 1969	*Distichodus rostratus*	Ghana			
2	*A. hydrocynuous*	Paperna, 1969	*Hydrocynus sp.*	Ghana			
3	*A. paracleidodiscus*	Paperna, 1973	*Distichodus niloticus*	Uganda			
4	*A. sp.*				*Distichodus niloticus*	Thurston (1970)	Uganda
	Bagrobdella	**Paperna, 1969**					
1	*B.anthopenis*	Euzet & Le Brun, 1990	*Auchenoglanis occidentalis*	Mali			
2	*B. auchenoglanii*	Paperna, 1969	*Auchenoglanis occidentalis*	Ghana	*Auchenoglanis occidentalis*	Thurston (1970)	Uganda
3	*B. fraudulenta*	Euzet & Le Burn, 1990	*Auchenoglanis occidentalis*	Mali			
	Characidotrema	**Paperna & Thurston, 1968**					
1	*C. brevipenis*	Paperna, 1969	*Alestes baremoze*	Ghana	*Alestes nurse*	Paperna (1969)	Ghana
2	*C. elongata*	Paperna & Thurston, 1968	*Alestes nurse*	Uganda	*Alestes leuciscus*	Paperna (1969)	Ghana
3	*C. nursei*	Ergens, 1973	*Alestes nurse*	Egypt	*Alestes nurse*	Paperna (1973 & 1979)	Ghana
					Alestes dentex	Molnar & Mossalam (1985)	Egypt
					Alestes leuciscus	Paperna (1979)	Ghana
					Brycinus lateralis	Current Study	Botswana
4	*C. nzoiae*	Paperna, 1979			*Alestes jacksoni*	Kritsky, Kulo & Boeger (1968)	Kenya
5	*C. regia*	Birgi, 1988	*Brycinus kingsleyae*	Cameroon			
6	*C. ruahae*	Paperna, 1979	*Alestes imberi*	Tanzania			
7	*C.spinivaginus*	Paperna, 1973	*Alestes nurse*	Uganda			
				Ghana			
8	*C. spiropenis*	Birgi, 1988	*Phenacogrammus major*	Cameroon	*Phenacogrammus urptaenia*		
					Hemigrammopetersius pulcher		
9	*C. undifera*	Kritsky, Kulo & Boeger, 1987	*Alestes nurse*	Togo			
10	*C. zelotes*	Kritsky, Kulo & Boeger, 1987	*Alestes nurse*	Togo			
	Dactylogyrus	**Diesing, 1850**					
1	*D. afer*	Price & Gery, 1968	*Barbus sp.*	Gabon			
2	*D. aferoides*	Guegan & Lambert, 1990	*Barbus bynni*	Mali	*Barbus occidentalis*	Guegan & Lambert (1990)	Mali
					Barbus parawaldroni	Guegan & Lambert (1990)	Mali
					Barbus petitjeani	Guegan & Lambert (1990)	Mali

					Barbus waldroni	Guegan & Lambert (1990)	Mali
3	*D. afrobarbae*	Paperna, 1968	*Barbus sublineatus*	Ghana	Barbus sublineatus	Paperna (1969)	Ghana
					Barbus trispilus	Paperna (1968 &1969)	Ghana
					Labeo coubie	Paperna (1969)	Ghana
4	*D. afrochelatus*	Paperna, 1973	*Barbus amphigramma*	Uganda	*Barbus paludinosus*	Paperna (1973)	Kenya
5	*D. afrofluviatilis*	Paperna, 1973	*Barbus cf. perince*	Lake Edward, Uganda	*Barbus neglectus*	Paperna (1973)	Uganda
					Barbus sp.	Paperna (1973)	Kenya
6	*D. afrolongicornis*	Paperna, 1973	*Barbus cf. kerstenii*	Lake George, Uganda	*Barbus cf. kerstenii*	Paperna (1973)	Lake Edward, Uganda
					Barbus trimaculatus	Mashego (1983)	South Africa
7	*D. a. alberti*	Paperna, 1973	*Barbus perince*	Lake Albert, Uganda	Barbus kerstenii	Paperna (1979)	Lake Albert, Uganda
					Barbus trimaculatus	Mashego (1983)	South Africa
8	*D. afrospilovaginus*	Paperna, 1973	*Barbus amphigramma*	Uganda			
9	*D. afroruahae*	Paperna, 1973	*Barbus sp.*	Tanzania			
10	*D. afrosclerovaginus*	Paperna, 1973	*Barbus neglectus*	Lake Edward, Uganda	*Barbus magdalene*	Paperna (1973)	Lake Victoria
					Barbus (Enteromius) sp.	Paperna (1973)	Uganda
					Barbus paludinosus	Mashego (1983)	Uganda
11	*D. afrotoxopous*	Paperna, 1973	*Barbus kerstenni*	Lake George, Uganda	*Barbus cf. kerstenii*	Paperna (1973)	Uganda
12	*D. allolongionchus*	Paperna, 1973	*Barbus perince*	Lake Albert, Uganda	*Barbus trimaculatus*	Mashego (1983)	South Africa
13	*D. amieti*	Birgi & Lambert, 1987	*Barbus camthacanthus*	Cameroon			
14	*D. archeopenis*	Guegan & Lambert, 1990	*Barbus parawaldroni*	West Africa	*Barbus petitjeani*	Guegan & Lambert (1990)	West Africa
					Barbus sacratus	Guegan & Lambert (1990)	West Africa
15	*D. aspili*	Birgi & Lambert, 1987	*Barbus aspilus*	Cameroon			
16	*D. atlasensis*	El Gharbi, Birgi & Lambert, 1994	*Barbus pallaryi*	Morocco			
17	*D. barbus*	Price & Gery, 1968	*Barbus sp.*	Gabon			
18	*D. barrilus*	Current Study	*Barbus radiatus*	Botswana			
19	*D. batesii*	Birgi & Euzet, 1983	*Aphyosemon batesii*	Cameroon	*Aphyosemon batesii*	Birgi (1988)	Cameroon
20	*D. biradius*	Birgi & Lambert, 1987	*Barbus jae*	Cameroon			
21	*D. birgii*	Timofeeva, Gerasev & Gibson, 1996			*Barbus martorelli*	Birgi & Lambert (1987)	Cameroon
22	*D. bopeleti*	Birgi & Lambert, 1987	*Barbus martorelli*	Cameroon			
23	*D. borjensis*	El Gharbi, Birgi & Lambert, 1994	*Barbus nasus*	Morocco			
24	*D. brachydiscus*	Paperna, 1973	*Labeo victorianus*	Kenya			
25	*D. brevicirrus*	Paperna, 1973	*Barbus altianalis*	Kenya	*Barbus kerstenii*	Paperna (1979)	Uganda
					Barbus neglectus	Paperna (1979)	Uganda
					Barbus perinci	Paperna (1979)	Uganda
					Barilius niloticus	Paperna (1979)	Uganda
					Labeo cylindricus	Paperna (1979)	Tanzania
					Labeo forskalii	Paperna (1979)	Uganda
					Labeo parvus	Guegan & Lambert (1991)	West Africa
					Labeo parvus	Guegan, Lambert & Euzet (1988)	Mali
					Labeo victorianus	Paperna (1973)	Uganda
26	*D. brevicornis*	Paperna, 1973	*Barbus cf. Kerstenii*	Uganda			
27	*D. clani*	Guegan & Lambert, 1990	*Barbus petitjeani*	Guinea			
28	*D. clavatovaginus*	Paperna, 1973	*Barbus amphigramma*	Uganda	*Barbus paludinosus*	Paperna (1973)	Kenya
29	*D. cyclocirrus*	Paperna, 1973	*Labeo coubie*	Ghana	*Labeo cylindricus*	Paperna (1973)	Tanzania
					Labeo senegalensis	Paperna (1973)	Ghana
						Guegan, Lambert & Euzet (1988)	West Africa
					Labeo victorianus	Paperna (1973)	Kenya
30	*D. decaspirus*	Guegan, Lambert & Euzet, 1988	*Labio coubie*	Mali	*Labeo coubie*	Paperna (1979)	Ghana
31	*D. digitalis*	Paperna, 1969	*Labio coubie*	Ghana	*Labeo coubie*	Guegan, Lambert & Euzet (1988)	Mali
32	*D. dominici*	Mashego, 1983	*Barbus paludinosus*	South Africa	*Barbus paludinosus*	Current Study	Botswana
33	*D. draaensis*	El Gharbi, Birgi & Lambert, 1994	*Barbus pallaryi*	Morocco			
34	*D. enidae*	Mashego, 1983	*Barbus neefi*	South Africa			
35	*D. falcilocus*	Guegan, Lambert & Euzet, 1988	*Labeo coubie*	Mali	*Labeo coubie*	Guegan, Lambert & Euzet (1990)	Mali
					Labeo coubie	Guegan & Lambert (1990)	Mali
					Labeo parvus	Guegan & Lambert (1990)	West Africa
					Labeo wurtzi	Guegan & Lambert (1990)	West Africa
					Labeo wurtzi	Guegan & Lambert (1991)	West Africa
36	*D. fimbiphallus*	El Gharbi, Birgi & Lambert, 1994	*Barbus figuiensis*	Morocco	*Barbus issenensis*	El Gharbi, Birgi & Lambert (1994)	Morocco
					Barbus lepineyi	El Gharbi, Birgi & Lambert (1994)	Morocco
					Barbus massaensis	El Gharbi, Birgi & Lambert (1994)	Morocco
					Barbus pallaryi	El Gharbi, Birgi & Lambert (1994)	Morocco
37	*D. gabonensis*	Price & Gery, 1968	*Barbus sp.*	Gabon			
38	*D. gaei*	Birgi & Lambert, 1987	*Barbus jae*	Cameroon			
39	*D. guirenis*	El Gharbi, Birgi & Lambert, 1994	*Barbus pallaryi*	Morocco			
40	*D. helicophallus*	Paperna, 1973	*Labeo forskalii*	Uganda			
41	*D. heteromorphus*	El Gharbi, Birgi & Lambert, 1994	*Barbus callensis*	Tunesia			
42	*D. insolitus*	Birgi & Lambert, 1987	*Barbus martorelli*	Cameroon			
43	*D. jaculus*	Guegan, Lambert & Euzet, 1988	*Labeo coubie*	Mali	*Labeo coubie*	Paperna (1979)	Ghana
44	*D. jubbstrema*	Price, Korach & McPott, 1969	*Glossogobius giuris*	South Africa			
45	*D. jucundus*	Guegan & Lambert, 1991	*Labeo parvus*	West Africa	*Labeo rouaneti*	Guegan & Lambert (1991)	Guinea
46	*D. kii*	Birgi & Lambert, 1987	*Barbus jae*	Cameroon			
47	*D. ksibii*	El Gharbi, Birgi & Lambert, 1994	*Barbus ksibii*	Morocco	*Barbus magniatlantis*	El Gharbi, Birgi & Lambert (1994)	Morocco
					Barbus setivimensis	El Gharbi, Birgi & Lambert (1994)	Morocco

48	*D. ksibioides*	El Gharbi, Birgi & Lambert, 1994	*Barbus moulouyensis*	Morocco	*Barbus setivimensis*	El Gharbi, Birgi & Lambert (1994)	Morocco
49	*D. kulindri*	El Gharbi, Birgi & Lambert, 1994	*Barbus fritschii*	Morocco	*Barbus reinii*	El Gharbi, Birgi & Lambert (1994)	Morocco
50	*D. labeous*	Paperna, 1969	*Labeo coubie*	Ghana	*Labeo senegalensis*	Paperna (1969)	Ghana
					Labeo senegalensis	Guegan, Lambert & Euzet (1988)	West Africa
51	*D. longionchus*	Paperna, 1973	*Barbus cf. Kerstenii*	Lake George, Uganda	*Barbus kerstenii*	Paperna (1973)	Lake Victoria
52	*D. longiphalloides*	Guegan & Lambert, 1991	*Labeo alluaudi*	Sierra Leone			
53	*D. longiphallus*	Paperna, 1973	*Labeo victorianus*	Kenya	*Labeo victorianus*	Paperna (1973)	Uganda
					Labeo parvus	Guegan & Lambert (1991)	West Africa
54	*D. l. gracilis*	Paperna, 1979	*Barbus ablabes*	Ghana			
55	*D. macrocleithrum*	Price & Gery, 1968	*Barbus sp.*	Gabon			
56	*D. maillardi*	Birgi & Lambert, 1987	*Barbus martorelli*	Cameroon			
57	*D. marocanus*	El Gharbi, Birgi & Lambert, 1994	*Barbus fritschii*	Morocco	*Barbus harteti*	El Gharbi, Birgi & Lambert (1994)	Morocco
					Barbus ksibi	El Gharbi, Birgi & Lambert (1994)	Morocco
					Barbus nasus	El Gharbi, Birgi & Lambert (1994)	Morocco
					Barbus paytonii	El Gharbi, Birgi & Lambert (1994)	Morocco
					Barbus reinii	El Gharbi, Birgi & Lambert (1994)	Morocco
					Barbus setivimensis	El Gharbi, Birgi & Lambert (1994)	Morocco
58	*D. mawli*	Paperna, 1969	*Barbus macrops*	Ghana			
59	*D. mendehei*	Birgi & Lambert, 1987	*Barbus aspilis*	Cameroon	*Barbus guirali*	Birgi & Lambert (1987)	Cameroon
60	*D. myersi*	Price, McClellan, Druckenmiller & Jacobs, 1969	*Barbus trimaculatus*	South Africa	*Barbus trimaculatus*	Mashego (1983)	South Africa
					Barbus poechii	Current Study	Botswana
61	*D. nanocirrus*	Paperna, 1973	*Barbus apleurogramma*	Lake Victoria	*Barbus neglectus*	Paperna (1973)	Lake Edward, Uganda
					Barbus perince	Paperna (1973)	Lake Albert, Uganda
					Barbus trispilus	Paperna (1973)	Lake Edward, Uganda
62	*D. nathaliae*	Guegan, Lambert & Euzet, 1988	*Labeo sp.*	Mali			
63	*D. nyongenses*	Birgi & Lambert, 1987	*Barbus aspilus*	Cameroon	*Barbus guirali*	Birgi & Lambert (1987)	Cameroon
64	*D. oligospirophallus*	Paperna, 1973	*Labeo coubie*	Ghana			
65	*D. omega*	Guegan & Lambert, 1991	*Labeo rouaneti*	Guinea			
66	*D. oumiensis*	El Gharbi, Birgi & Lambert, 1994	*Barbus harteti*	Morocco	*Barbus paytonii*	El Gharbi, Birgi & Lambert (1994)	Morocco
					Barbus reinii	El Gharbi, Birgi & Lambert (1994)	Morocco
67	*D. papernai*	Timofeeva, Gerasev & Gibson, 1996	*Barbus macrolepis*	Tanzania			
68	*D. parawaldronii*	Guegan & Lambert, 1990	*Barbus parawaldroni*	Guinea			
69	*D. parviphallus*	Paperna, 1973	*Barbus apleurogramma*	Uganda	*Barbus kerstenii*	Paperna (1973)	Uganda
70	*D. petitjeani*	Guegan & Lambert, 1990	*Barbus petitjeani*	Guinea			
71	*D. pienaari*	Price, Korach & McPott, 1969	*Labeo rosae*	South Africa			
72	*D. pokoase*	Paperna, 1973	*Barbus ablabes*	Pokoase River			
73	*D. pseudanchoratus*	Price & Gery, 1968	*Barbus sp.*	Gabon	*Barbus occidentalis*	Guegan & Lambert (1990)	West Africa
					Barbus parawaldroni	Guegan & Lambert (1990)	West Africa
					Barbus petitjeani	Guegan & Lambert (1990)	West Africa
					Barbus sacratus	Guegan & Lambert (1990)	West Africa
74	*D. p. micronchus*	Paperna, 1979	*Labeo sp.*	Tanzania			
75	*D. rastellus*	Guegan, Lambert & Euzet, 1988	*Labeo senegalensis*	Mali			
76	*D. reinii*	El Gharbi, Birgi & Lambert. 1994	*Barbus reinii*	Morocco			
77	*D. retroversus*	Guegan, Lambert & Euzet, 1988	*Labeo coubie*	Mali			
78	*D. ruahae*	Paperna, 1973	*Barbus macrolepis*	Tanzania	*Barbus parawaldroni*	Guegan & Lambert (1990)	West Africa
					Barbus sacratus	Guegan & Lambert (1990)	West Africa
					Varicorhinus wurtzi	Guegan & Lambert (1990)	West Africa
79	*D. rufijii*	Paperna, 1973	*Barbus macrolepis*	Tanzania			
80	*D. sacrati*	Guegan & Lambert, 1990	*Barbus sacratus*	Guinea			
81	*D. sahelensis*	Guegan & Lambert, 1990	*Barbus bynni*	West Africa	*Barbus occidentalis*	Guegan & Lambert (1990)	West Africa
					Barbus petitjeani	Guegan & Lambert (1990)	West Africa
					Barbus waldroni	Guegan & Lambert (1990)	West Africa
82	*D. sematus*	Guegan & Lambert, 1990	*Labeo rouaneti*	Guinea			
83	*D. senagalensis*	Paperna, 1969	*Labeo coubie*	Ghana	*Labeo senagalensis*	Paperna (1969)	Ghana
84	*D. spinicirrus*	(Paperna & Thurston, 1968)	*Barbus altianalis*	Uganda	*Barbus marequensis*	Mashego (1983)	South Africa
					Barbus nyangae	Paperna (1979)	Uganda
					Barbus somerini	Paperna (1979)	Uganda
85	*D. teresae*	Mashego, 1983	*Barbus paludinosus*	South Africa			
86	*D. titus*	Guegan, Lambert & Euzet, 1988	*Labeo coubie*	Mali			
87	*D. tubarius*	Guegan, Lambert & Euzet, 1988	*Labeo senegalensis*	Mali			
88	*D. tunesiensis*	El Gharbi, Birgi & Lambert, 1994	*Barbus callensis*	Tunesia			
89	*D. valeti*	Birgi & Lambert, 1987	*Barbus camptacanthus*	Cameroon			
90	*D. varicorhini*	Bychowsky, 1959			*Barbus kimberleyensis*	Price, McClellan, Druckenmiller & Jacobs (1969)	South Africa
91	*D. volutus*	El Gharbi, Birgi & Lambert, 1994	*Barbus fritschii*	Morocco			
92	*D. viviersii*	Current Study	*Barbus multilineatus*	Botswana	*Barbus barnardi*	Current Study	Botswana
93	*D. wurtzi*	Guegan & Lambert, 1990	*Varicorhinus wurtzi*	Guinea			
94	*D. zatensis*	El Gharbi, Birgi & Lambert, 1994	*Barbus fritschii*	Morocco			
	Dogielius	**Bychowsky, 1936**					
1	*D. anthocolpus*	Guegan, Lambert & Euzet, 1989	*Labeo coubie*	Mali			
2	*D. clavipenis*	Guegan, Lambert & Euzet, 1989	*Labeo coubie*	Mali			
3	*D. complicatus*	Guegan, Lambert & Euzet, 1989	*Labeo coubie*	Mali			
4	*D. djolibaensis*	Guegan & Lambert, 1990	*Barbus occidentalis*	Mali	*Barbus occidentalis*	Guegan & Lambert (1990)	Guinea
					Barbus petitjeani	Guegan & Lambert (1990)	Guinea

					Barbus waldroni	Guegan & Lambert (1990)	Ivory Coast
5	*D. dublicornis*	Paperna, 1973	*Labeo cylindricus*	Tanzania			
6	*D. flagellatus*	Guegan, Lambert & Euzet, 1989	*Labeo coubie*	Mali			
7	*D. flosculus*	Guegan, Lambert & Euzet, 1989	*Labeo senegalensis*	Mali			
8	*D. grandijugus*	Guegan, Lambert & Euzet, 1989	*Labeo coubie*	Mali			
9	*D. grandiphallus*	Paperna, 1973	*Barbus macrolepis*	Tanzania			
10	*D. harpagatus*	Guegan, Lambert & Euzet, 1989	*Labeo coubie*	Mali			
11	*D. junorstrema*	Price & Yurkiewicz, 1968	*Labeo ruddi*	Zimbabwe			
12	*D. j. ruahae*	Paperna, 1979	*Labeo cylindricus*	Tanzania	*Labeo sp.*	Paperna (1979)	Tanzania
13	*D. j. victorianus*	Paperna, 1979	*Labeo victorianus*	Kenya	*Barbus altianalis*	Paperna (1979)	Kenya
14	*D. kabaensis*	Guegan & Lambert, 1991	*Labeo alluaudi*	West Africa	*Labeo parvus*	Guegan & Lambert (1991)	West Africa
15	*D. martorellii*	Birgi & Lambert, 1987	*Barbus martorelli*	Cameroon			
16	*D.njinei*	Birgi & Lambert, 1987	*Barbus camptacanthus*	Cameroon			
17	*D. parvus*	Guegan, Lambert & Euzet, 1989	*Labeo parvus*	Mali			
18	*D. pedalae*	Guegan & Lambert, 1990	*Barbus parawaldroni*	Guinea	*Varicorhinus wurtzi*	Guegan & Lambert (1990)	Guinea
19	*D. phrygieus*	Guegan & Lambert, 1990	*Barbus sacratus*	Guinea			
20	*D. rosumplicatus*	Guegan & Lambert, 1991	*Labeo parvus*	West Africa	*Labeo rouaneti*	Guegan & Lambert (1991)	Guinea
21	*D. tropicus*	Paperna, 1969	*Labeo coubie*	Ghana	*Labeo senagalensis*	Paperna (1969)	Ghana
22	*D. vexillus*	Guegan & Lambert, 1990	*Varicorhinus wurtzi*	Ivory coast			
	Gussevstrema	**Price & McClellan, 1969**					
1	*G. amacleithrium*	Price & McClellan, 1969	*Therapon jarbua*	South Africa			
	Heteronchocleidus	**Bychowsky, 1957**					
1	*H. adjanohouni*	Euzet & Dossou, 1975	*Ctnopoma kingsleyae*	Dahomey	*Ctenopoma petherici*	Euzet & Dossou (1975)	Dahomey
2	*H. ctenopomae*	Paperna, 1969	*Ctnopoma kingsleyae*	Ghana	*Ctenopoma kingsleyae*	Euzet & Dossou (1975)	Dahomey
					Ctenopoma petherici	Euzet & Dossou (1975)	Dahomey
3	*H. niloticus*	Paperna, 1973					
4	*H. ouemensis*	Euzet & Dossou, 1975	*Ctenopoma kingsleyae*	Dahomey	*Ctenopoma petherici*	Euzet & Dossou (1975)	Dahomey
5	*H. tuzetae*	Euzet & Dossou, 1975	*Ctenopoma kingsleyae*	Dahomey	*Ctenopoma petherici*	Euzet & Dossou (1975)	Dahomey
	Nanotrema	**Paperna, 1969**					
1	*N. citharini*	Paperna, 1969	*Citharinus citharus*	Ghana			
	Protoanclodiscoides	**Paperna, 1969**					
1	*P. chrysichthes*	Paperna, 1969	*Chrysichthys nigrodigitatus*	Ghana	*Chrysichthys nigrodigitatus*	Obiekezie, Moller & Anders (1988)	Nigeria
2	*P. mansourensis*	El Naggar, 1987	*Chrysichthys auratus*	Egypt			
	Protogyrodactylus	**Johnston & Tiegs, 1922**					
1	*P. johnstonettiegsi*	Price & Pike, 1969	*Therapon jarbua*	South Africa			
	Quadriacanthus	**Paperna, 1961**					
1	*Q. aegypticus*	El Naggar & Serag, 1986	*Clarias lazera*	Egypt	*Clarias lazera*	Kritsy & Kulo (1988)	Egypt
					Clarias gariepinus	Douëllou & Chishawa (1995)	Zimbabwe
2	*Q. agnebiensis*	N'Douba, Lambert & Euzet, 1999	*Heterobranchus isopterus*	Ivory coast			
3	*Q. allobychowskilla*	Paperna, 1979	*Clarias lazera*	Uganda	*Clarias lazera*	El Naggar & Serag (1985)	Egypt
					Clarias lazera	Kritsky & Kulo (1988)	Egypt
4	*Q. ashuri*	Kritsky & Kulo, 1988	*Clarias lazera*	Egypt			
5	*Q. ayameensis*	N'Douba, Lambert & Euzet, 1999	*Heterobranchus isopterus*	Ivory coast			
6	*Q. bagrae*	Paperna, 1979	*Bagrus bayad*	Uganda	*Bagrus docmac*	Paperna (1979)	Uganda
					Bagrus orientalis	Paperna (1979)	Tanzania
					Clarias gariepinus	Douëllou & Chishawa (1995)	Zimbabwe
					Clarias lazera	Kritsky & Kulo (1988)	Egypt
7	*Q. clariadis*	Paperna, 1961			*Bagrus docmac*	Paperna & Thurston (1968)	Uganda
					Clarias gariepinus	Douëllou & Chishawa (1995)	Zimbabwe
					Clarias lazera	Paperna (1969)	Ghana
					Clarias lazera	Paperna (1979)	Ghana
					Clarias lazera	Paperna (1979)	Uganda
					Clarias lazera	Molnar & Mossalam (1985)	Egypt
					Clarias lazera	El Naggar & Serag (1985)	Egypt
					Clarias lazera	Kritsky & Kulo (1988)	Egypt
					Clarias mossambicus	Paperna & Thurston (1968)	Uganda
					Clarias mossambicus	Paperna (1979)	Uganda
					Heterobranchus isopterus	Paperna (1969)	Ghana
					Heterobranchus isopterus	Paperna (1979)	Uganda
8	*Q. dageti*	Birgi, 1988	*Clarias jaensis*	Cameroon			
9	*Q. eboreus*	N'Douba & Lambert, 2001	*Clarias ebriensis*	Ivory coast			
10	*Q. gourenei*	N'Douba, Lambert & Euzet, 1999	*Heterobranchus isopterus*	Ivory coast			
11	*Q. ivoiriensis*	N'Douba & Lambert, 2001	*Clarias ebriensis*	Ivory coast			
12	*Q. kalatensis*	Current Study	*Clarias gariepinus*	Botswana			
13	*Q. lavequei*	Birgi, 1988	*Clarias pachynema*	Cameroon			
14	*Q. longifilisi*	N'Douba, Lambert & Euzet, 1999	*Heterobranchus longifilis*	Ivory coast			
15	*Q. macrocirrus*	N'Douba, Lambert & Euzet, 1999	*Heterobranchus isopterus*	Ivory coast			
16	*Q. numidus*	Kritsky & Kulo, 1988	*Clarias lazera*	Egypt	*Clarias gariepinus*	Douëllou & Chishawa (1995)	Zimbabwe
17	*Q. nyangensis*	Birgi, 1988	*Clarias jaensis*	Cameroon	*Clarias pachynema*	Birgi (1988)	Cameroon
18	*Q. papernai*	Kritsky & Kulo, 1988	*Clarias lazera*	Egypt			
19	*Q. simplex*	N'Douba, Lambert & Euzet, 1999	*Heterobranchus isopterus*	Ivory Coast			
20	*Q. teugelsi*	Birgi, 1988	*Clarias jaensis*	Cameroon	*Clarias pachynema*	Birgi (1988)	Cameroon
21	*Q. theodorae*	Current Study	*Clarias theodorae*	Botswana			

22	*Q. thysi*	N'Douba, Lambert & Euzet, 1999	*Heterobranchus longifilis*	Ivory Coast			
23	*Q. tilapiae*	Paperna, 1973	*Tilapia esculenta*	Uganda			
24	*Q. voltaensis*	Paperna, 1965	*Clarias walkeri*	Ghana	*Clarias lazera*	Kritsky & Kulo (1988)	Egypt
25	*Q. sp*				*Heterobranchus isopterus*	Kritsky & Kulo (1988)	Ghana
	Schilbetrema	**Paperna & Thurston, 1968**					
1	*S. acornis*	Paperna & Thurston, 1968	*Schilbe mystus*	Uganda	*Schilbe mystus*	Paperna (1969)	Ghana
					Schilbe intermedius	Current Study	Botswana
					Schilbe intermedius	Kritsky & Kulo (1992)	
2	*S. aegyptica*	El Naggar, 1985	*Schilbe mystus*	Egypt	*Schilbe intermedius*	Kritsky & Kulo (1992)	Togo
3	*S. bicornis*	Paperna, 1969	*Physalia pellucida*	Ghana			
4	*S. biclavula*	N'Douba, Pariselle, Thys van den Audenaerde & Euzet, 1997	*Schilbe mandibularis*	Ivory Coast			
5	*S. calamocleithrum*	Kritsky & Kulo, 1992	*Schilbe intermedius*	Togo			
6	*S. dissimilis*	N'Douba, Pariselle, Thys van den Audenaerde & Euzet, 1997	*Schilbe mandibularis*	Ivory Coast			
7	*S. eutropii*	Paperna, 1969	*Eutropius niloticus*	Ghana	*Schilbe mystus*	Kritsky & Kulo (1992)	Togo
8	*S. hexacornis*	Paperna, 1969	*Eutropius niloticus*	Ghana	*Schilbe intermedius*	Kritsky & Kulo (1992)	Togo
9	*S. quadricornis*	Paperna & Thurston, 1968	*Schilbe intermedius*	Uganda	*Schilbe intermedius*	Kritsky & Kulo (1992)	Togo
					Schilbe intermedius	Current Study	Botswana
10	*S. schilbae*	Paperna & Thurston, 1968	*Schilbe mystus*	Uganda	*Schilbe intermedius*	Kritsky & Kulo (1992)	Togo
					Schilbe intermedius	Douëllou & Chishawa (1995)	Zimbabwe
					Schilbe mystus	Paperna (1969)	Ghana
11	*S. spirocirra*	Paperna, 1969	*Eutropius niloticus*	Ghana	*Schilbe mystus*	Kritsky & Kulo (1992)	Togo
12	*S. torula*	Kritsky & Kulo, 1992	*Schilbe mystus*	Togo			
13	*S. tricera*	Paperna, 1973	*Eutropius sp.*	Tanzania			
14	*S. undinula*	Kritsky & Kulo, 1992	*Schilbe intermedius*	Togo	*Schilbe intermedius*	Douëllou & Chishawa (1995)	Zimbabwe
15	*S. vacillaus*	Kritsky & Kulo, 1992	*Schilbe intermedius*	Togo			
Sub-Family: **Ancyrocephalidae** Bychowsky, 1937							
	Ancyrocephalus	**Creplin, 1839**					
1	*A. barilli*	Paperna, 1973	*Barilius loati*	Uganda	*Barilius sp.*	Paperna (1973)	Uganda
2	*A. claveaui*	Birgi, 1988	*Aplocheilichthys macrophthalmus*	Cameroon			
3	*A. limnotrissae*	Paperna, 1973	*Limnothrissa miodon*	Tanzania			
4	*A. mormyris*	Paperna, 1973	*Mormyrus niloticus*	Uganda			
5	*A. pellonulae*	Paperna, 1969	*Pellonula afzeliusi*	Ghana			
6	*A. synodonti*	Paperna & Thurston, 1968	*Synodontis victoriae*	Uganda	*Synodontis membranaceus*	Paperna (1969)	Ghana
					Synodontis sp.	Paperna (1969)	Ghana
	Annulotrema	**Paperna & Thurston, 1969**					
1	*A. alberti*	Paperna, 1973	*Alestes macrolepidotus*	Uganda			
2	*A. alestesimberi*	Paperna, 1973	*Alestes imberi*	Tanzania			
3	*A. alestesnursi*	Paperna, 1973	*Alestes nurse*	Uganda	*Alestes nurse*	Paperna (1973)	Ghana
					Alestes nurse	Ergens (1988)	Egypt
4	*A. allogravis*	Paperna, 1973	*Alestes imberi*	Tanzania			
5	*A. amieti*	Birgi, 1988	*Hemigrammopetersius pulcher*	Tanzania	*Phenacogrammus major*	Birgi (1988)	Cameroon
6	*A. armorata*	Paperna, 1969	*Hydrocynus sp.*	Ghana	*Hydrocynus forskahlii*	Thurston (1970)	Uganda
7	*A. biaensis*	N'Douba, Pariselle & Euzet, 1997	*Hepsetus odoe*	Ivory coast			
8	*A. bilongi*	Birgi, 1988	*Neolebias trewavasae*	Cameroon			
9	*A. bouix*	Birgi, 1988	*Brycinus kingsleyae*	Cameroon			
10	*A. cambesi*	Birgi, 1988	*Brycinus kingsleyae*	Cameroon			
11	*A. cryptophallus*	Paperna, 1973	*Hydrocynus forskahlii*	Uganda			
12	*A. curvipenis*	Paperna, 1969	*Alestes baremoze*	Ghana	*Hydrocynus forskahlii*	Thurston (1970)	Uganda
					Brycinus lateralis	Current Study	Botswana
13	*A. delta*	Paperna, 1973	*Alestes nurse*	Uganda	*Alestes nurse*	Paperna (1973)	Ghana
					Alestes nurse	Ergens (1988)	Egypt
14	*A. edeensis*	Birgi, 1988	*Micralestes sp.*	Cameroon			
15	*A. elongata*	Paperna & Thurston, 1969	*Alestes baremoze*	Uganda	*Alestes baremoze*	Paperna (1969)	Ghana
					Alestes dentex	Thurston (1970)	Uganda
					Alestes macrolepidotus	Thurston (1970)	Uganda
16	*A. endjami*	Birgi, 1988	*Neolebias trewavasae*	Cameroon			
17	*A. fomenai*	Birgi, 1988	*Neolebias trewavasae*	Cameroon			
18	*A. gabrioni*	Birgi, 1988	*Hemigrammopetersius pulcher*	Cameroon	*Phenacogrammus major*	Birgi (1988)	Cameroon
19	*A. gracilis*	Wedl,1861	*Hydrocynus forskahlii*				
20	*A. gravis*	Paperna & Thurston, 1969	*Alestes jacksoni*	Uganda	*Alestes nurse*	Paperna & Thurston (1969a)	Uganda
					Alestes nurse	Paperna (1969)	Ghana
21	*A. heliocirra*	Paperna, 1973	*Alestes macrolepis*	Uganda			
22	*A. hepseti*	Paperna & Thurston, 1969	*Hepsetus odoe*	Ghana	*Hepsetus odoe*	Paperna (1969)	Ghana
					Hepsetus odoe	Birgi (1988)	Cameroon
					Hepsetus odoe	N'Douba, Pariselle & Euzet (1997)	Ivory Coast
					Hepsetus odoe	Current Study	Botswana
23	*A. hydrocynusi*	Paperna, 1973	*Hydrocynus forskahlii*	Uganda			
24	*A. kribiensis*	Birgi, 1988	*Brycinus longipinnis*	Cameroon			
25	*A. lamberti*	Birgi, 1988	*Brycinus longipinnis*	Cameroon			
26	*A. longipenis*	Paperna, 1969	*Alestes baremoze*	Ghana	*Aletes macrolepidotus*	Paperna (1969)	Ghana
27	*A. macropenis*	N'Douba, Pariselle & Euzet, 1997	*Hepsetus odoe*	Ivory coast			
28	*A. magna*	Paperna, 1973	*Hydrocynus vittatus*	Tanzania			

29	*A. magnihamula*	Paperna, 1973	*Hydrocynus vittatus*	Uganda			
30	*A. maillardi*	Birgi, 1988	*Brycinus kingsleyae*	Cameroon			
31	*A. micralesti*	Current Study	*Micralestes acutidens*	Botswana			
32	*A. moanko*	Birgi, 1988	*Brycinus longipinnis*	Cameroon			
33	*A. nannaethiopis*	Birgi, 1988	*Nannaethiops unitaeniatus*	Cameroon			
34	*A. nili*	Paperna, 1973	*Hydrocynus forskahlii*	Uganda			
35	*A. n. ruahae*	Paperna, 1979	*Hydrocynus vittatus*	Tanzania			
36	*A. noyongensis*	Birgi, 1988	*Brycinus kingsleyae*	Cameroon			
37	*A. pikei*	Price, Peebles & Bamford, 1969	*Hydrocynus vittatus*	South Africa	*Hydrocynus sp.*	Paperna (1979)	Ghana
					Hydrocynus forskahlii	Paperna (1979)	Tanzania
					Hydrocynus vittatus	Current Study	Botswana
38	*A. p. ruahae*	Paperna, 1979	*Hydrocynus vittatus*	Tanzania			
39	*A. pikoides*	Guegan, Lambert & Birgi, 1988	*Hydrocynus vittatus*	Mali			
40	*A. rhabdalesti*	Current Study	*Rhabdalestes maunensis*	Botswana			
41	*A. robusta*	Paperna, 1969	*Alestes leuciscus*	Ghana			
42	*A. ruahae*	Paperna, 1973	*Hydrocynus vittatus*	Tanzania			
43	*A. sangmelinensis*	Birgi, 1988	*Micralestes humulis*	Cameroon			
44	*A. spiropenis*	Paperna, 1969	*Alestes nurse*	Ghana	*Alestes nurse*	Ergens (1988)	Egypt
					Hydrocynus forskahlii	Thurston (1970)	Uganda
45	*A. tenuicirra*	Paperna, 1973	*Alestes macrolepidotus*	Uganda			
46	*A. sp.*	Ergens, 1988	*Alestes nurse*	Egypt			
	Bouixella	**Euzet & Dossou, 1976**					
1	*B. beninensis*	Euzet & Dossou, 1976	*Mormyrus rume*	Benin			
2	*B. deliciosa*	Dossou & Euzet, 1984	*Mormyrops deliciosus*	Benin			
3	*B. duba*	Current Study	*Mormyrus lacerda*	Botswana			
4	*B. furcillata*	Dossou & Euzet, 1984	*Marcusenius senegalensis*	Benin			
5	*B. marcusenia*	Current Study	*Marcusenius macrolepidotus*	Botswana			
6	*B. mormyrume*	Euzet & Dossou, 1976	*Mormyrus rume*	Benin			
7	*B. mormyris*	(Paperna, 1973)	*Mormyrus niloticus*	Uganda			
8	*B. torta*	Dossou & Euzet, 1984	*Mormyrops deliciosus*	Benin			
	Cichlidogyrus	**Paperna, 1960**					
1	*C. aegypticus*	Ergens, 1981	*Tilapia zillii*	Egypt	*Tilapia dageti*	Pariselle & Euzet (1996)	Ivory Coast
					Sarotherodon galilaea	El Naggar & Khidr (1986)	Egypt
					Oreochromis niloticus	El Naggar & Khidr (1986)	Egypt
					Tilapia zillii	Pariselle & Euzet (1996)	Burkina Faso
					Tilapia zillii	Pariselle & Euzet (1996)	Ivory Coast
2	*C. agnesi*	Pariselle & Euzet, 1995	*Tilapia guineensis*	Ivory coast			
3	*C. albareti*	Pariselle & Euzet. 1998	*Tilapia brevimanus*	Guinea			
4	*C. amieti*	Birgi & Euzet, 1983	*Aphyosemion cameronensis*	Cameroon	*Aphyosemion obscurum*	Birgi & Euzet (1983)	Cameroon
5	*C.amphoratus*	Pariselle & Euzet, 1996	*Tilapia louka*	Guinea			
6	*C. arfii*	Pariselle & Euzet, 1995	*Pelmatochromis beuttikoferi*	Guinea			
7	*C. arthracanthus*	Paperna, 1960			*Sarotherodon galilaea*	El Naggar & Khidr (1986)	Egypt
					Oreochromis niloticus	El Naggar & Khidr (1986)	Egypt
					Tilapia zillii	Paperna (1965)	Ghana
					Tilapia zillii	Paperna (1969)	Ghana
					Tilapia zillii	Paperna & Thurston (1969b)	Uganda
					Tilapia zillii	Ergens (1981)	Egypt
					Tilapia zillii	Khider & Hassan (1990)	Egypt
8	*C. bilongi*	Pariselle & Euzet, 1995	*Tilapia guineensis*	Ivory coast			
9	*C. berrebii*	Pariselle & Euzet, 1994	*Tylochromis gentinki*	Ivory coast	*Tylochromis gentinki*	Pariselle & Euzet (1994)	Guinea
10	*C. bifurcatus*	Paperna, 1960			*Haplochromis aeneocolor*	Paperna (1979)	Lake George
					Haplochromis elegans	Paperna (1979)	Lake George
					Haplochromis limax	Paperna (1979)	Lake George
					Haplochromis multicolor	Paperna (1979)	Uganda
					Haplochromis squamipinnis	Paperna (1979)	Lake George
					Haplochromis sp.	Paperna (1979)	Lake Edward
					Haplochromis sp.	Paperna (1979)	Uganda
11	*C bonhommei*	Pariselle & Euzet, 1998	*Tilapia buttikoferi*	Sierra Leone			
12	*C. botswanensis*	Current Study	*Sargochromis codringtonii*	Botswana	*Sargochromis giardi*	Current Study	Botswana
					Serranochromis macrocephalus	Current Study	Botswana
13	*C. bouvii*	Pariselle & Euzet, 1997	*Sarotherodon occidentalis*	Guinea			
14	*C. brevicirrus*	Paperna & Thurston, 1969	*Haplochromis guiarti*	Uganda	*Haplochromis longirostris*	Paperna & Thurston (1969b)	Uganda
					Haplochromis obesus	Paperna & Thurston (1969b)	Uganda
					Haplochromis obliquidens	Paperna & Thurston (1969b)	Uganda
					Haplochromis sp.	Paperna & Thurston (1969b)	Uganda
					Hoplotilapia retrodens	Paperna & Thurston (1969b)	Uganda
					Tilapia discolor	Paperna (1969)	Ghana
					Tilapia zillii	Paperna & Thurston (1969b)	Uganda
15	*C. bychowskii*	(Markevitch, 1934)	*Hemichromis bimaculatus*	?	*Hemichromis fasciatus*	Paperna (1965)	Ghana
					Hemichromis fasciatus	Paperna (1968)	Ghana
					Hemichromis fasciatus	Paperna (1969)	Ghana
					Sarotherodon galilaea	Paperna (1968)	Ghana
16	*C. cirratus*	Paperna, 1964			*Sarotherodon galilaea*	El Naggar & Khidr (1986)	Egypt

					Oreochromis niloticus	Ergens (1981)	Egypt
					Tilapia zillii	El Naggar & Khidr (1986)	Egypt
17	*C. dageti*	Dossou & Birgi, 1984	*Hemichromis fasciatus*	Benin	*Hemichromis fasciatus*	Dossou & Birgi (1984)	Cameroon
18	*C. digitatus*	Dossou, 1982	*Tilapia louka*	Benin	*Tilapia dageti*	Parisella & Euzet (1996)	Senegal
					Tilapia guineensis	Pariselle & Euzet (1996)	Ivory Coast
					Tilapia guineensis	Pariselle & Euzet (1996)	Gambia
					Tilapia louka	Pariselle & Euzet (1996)	Guinea
					Tilapia zillii	Dossou (1982)	Benin
					Tilapia zillii	Pariselle & Euzet (1996)	Ivory Coast
					Tilapia zillii	Pariselle & Euzet (1996)	Guinea
19	*C. dionchus*	Paperna, 1968	*Hemichromis fasciatus*	Ghana	*Pelmatochromis guentheri*	Paperna (1969)	Ghana
					Sarotherodon galilaea	Paperna (1969)	Ghana
20	*C. dossoui*	Douëllou, 1993	*Oreochromis mortimeri*	Zimbabwe	*Serranochromis macrocephalus*	Douëllou (1993)	Zimbabwe
					Tilapia renadalli	Douëllou (1993)	Zimbabwe
21	*C. euzeti*	Dossou & Birgi, 1984	*Hemichromis fasciatus*	Benin	*Hemichromis fasciatus*	Dossou & Birgi (1984)	Cameroon
22	*C. facifer*	Dossou & Birgi, 1984	*Hemichromis fasciatus*	Benin	*Hemichromis fasciatus*	Dossou & Birgi (1984)	Cameroon
23	*C. flexicolpos*	Pariselle & Euzet, 1995	*Tilapia guineensis*	Ivory coast			
24	*C. fontanai*	Pariselle & Euzet, 1997	*Sarotherodon occidentalis*	Guinea			
25	*C. gallus*	Pariselle & Euzet, 1995	*Tilapia guineensis*	Ivory coast	*Tilapia guineensis*	Pariselle & Euzet (1996)	Benin
26	*C. guirali*	Pariselle & Euzet, 1997	*Sarotherodon occidentalis*	Guinea			
27	*C. halinus*	Paperna, 1969	*Tilapia guineensis*	Ghana	*Tilapia heudeloti*	Paperna (1969)	Ghana
28	*C. halli*	(Price & Kirk, 1967)	*Tilapia shirana shirana*	Malawi	*Oreochromis niloticus*	Paperna & Thurston (1969b)	Uganda
					Oreochromis mortimeri	Douëllou (1993)	Zimbabwe
					Serranochromis macrocephalus	Douëllou (1993)	Zimbabwe
					Oreochromis andersonii	Current Study	Botswana
29	*C. h. typicus*	(Price & Kirk, 1967)			*Sarotherodon galilaea*	Paperna (1979)	Lake Albert, Uganda
					Sarotherodon galilaea	El Naggar & Khidr (1986)	Egypt
					Sarotherodon galilaea	El Naggar & Khidr (1989)	Egypt
					Sarotherodon galilaea	Khider & Hassan (1989)	Egypt
					Tilapia leucostica	Paperna (1979)	Ghana
					Oreochromis niloticus	Paperna (1979)	Lake George
					Oreochromis niloticus	Paperna (1979)	Lake Albert, Uganda
					Oreochromis niloticus	Paperna (1979)	Lake Edward
					Oreochromis niloticus	El Naggar & Khidr (1986)	Egypt
					Oreochromis niloticus	El Naggar & Khidr (1989)	Egypt
					Tilapia shirana shirana	Paperna (1979)	Malawi
					Tilapia vulcani	Paperna (1979)	Lake George, Uganda
					Tilapia vulcani	El Naggar & Khidr (1986)	Egypt
					Tilapia zillii	El Naggar & khidr(1989)	Egypt
					Tilapia zillii	El Naggar, Khidr & Kearn (1990)	Egypt
					Tilapia zillii	El Naggar, Khidr & Kearn (1991)	Egypt
30	*C. h. victorianus*	(Price & Kirk, 1967)			*Tilapia esculenta*	Paperna (1979)	Uganda
					Tilapia variabilis	Paperna (1979)	Uganda
31	*C. haplochromii*	Paperna & Thurston, 1969	*Haplochromis guiarti*	Uganda	*Haplochromis macrognathus*	Paperna & Thurston (1969b)	Uganda
					Haplochromis nubilus	Paperna & Thurston (1969b)	Uganda
					Haplochromis obliquidens	Paperna & Thurston (1969b)	Uganda
					Haplochromis wingatii	Paperna & Thurston (1969b)	Uganda
					Haplochromis sp.	Paperna & Thurston (1969b)	Uganda
					Hoplotilapia retrodens	Paperna & Thurston (1969b)	Uganda
					Macropleurodus bicolor	Paperna & Thurston (1969b)	Uganda
					Pharyngochromis darlingi	Douëllou (1993)	Zimbabwe
					Platytaeniodus degeni	Paperna & Thurston (1969b)	Uganda
32	*C. hemi*	Pariselle & Euzet, 1998	*Tilapia brevimanus*	Guinea			
33	*C. inconsultus*	Birgi & Lambert, 1987	*Polycentropsis abbreviata*	Cameroon			
34	*C. karibae*	Douëllou, 1993	*Oreochromis mortimeri*	Zimbabwe	*Serranochromis codringtonii*	Douëllou (1993)	Zimbabwe
					Sargochromis codringtonii	Current Study	Botswana
					Sargochromis giardi	Current Study	Botswana
					Serranochromis macrocephalus	Current Study	Botswana
					Serranochromis robustus	Current Study	Botswana
35	*C. kothiase*	Pariselle & Euzet, 1994	*Tylochromis gentinki*	Ivory coast	*Tylochromis gentinki*	Pariselle & Euzet (1994)	Guinea
36	*C. kouassii*	N'Douba, Thys van den Audenaerde & Pariselle, 1997	*Tilapia guineensis*	Ivory coast			
37	*C. lagoonaris*	Paperna, 1969	*Tilapia guineensis*	Ghana	*Tilapia heudeloti*	Paperna (1969)	Ghana
38	*C. levequei*	Pariselle & Euzet, 1996	*Tilapia coffea*	Guinea			
39	*C. longicirrus*	Paperna, 1965		Ghana	*Hemichromis fasciatus*	Paperna (1968)	Ghana
					Hemichromis fasciatus	Paperna (1969)	Ghana
					Hemichromis fasciatus	Dossou & Birgi (1984)	Benin
					Hemichromis fasciatus	Dossou & Birgi (1984)	Cameroon
					Pelmatochromis guentheri	Paperna (1969)	Ghana
40	*C. louipaysane*	Pariselle & Euzet, 1995	*Tilapia guineensis*	Guinea	*Tilapia guineensis*	Pariselle & Euzet (1995)	Senegal
41	*C. microscutus*	Pariselle & Euzet, 1996	*Tilapia dageti*	Senegal	*Tilapia guineensis*	Pariselle & Euzet (1996)	Congo
42	*C. mohemboensis*	Current Study	*Oreochromis andersonii*	Botswana			
43	*C. nandidae*	Birgi & Lambert, 1986	*Polycentropsis abbreviata*	Cameroon			
44	*C. nematocirrus*	Paperna, 1969	*Oreochromis niloticus*	Ghana	*Sarotherodon galilaea*	El Naggar & Khidr (1986)	Egypt

					Tilapia zillii	El Naggar & Khidr (1986)	Egypt
45	*C. nuniezi*	Pariselle & Euzet, 1998	*Tilapia essiana*	Ivory coast			
46	*C. ornatus*	Pariselle & Euzet, 1996	*Tilapia dageti*	Ivory coast	*Tilapia zillii*	Pariselle & Euzet (1996)	Ivory Coast
47	*C. ouedraogoi*	Pariselle & Euzet, 1996	*Tilapia coffea*	Guinea			
48	*C. paganoi*	Pariselle & Euzet, 1997	*Sarotherodon occidentalis*	Guinea	*Sarotheradon occidentalis*	Pariselle & Euzet (1997)	Sierra Leone
49	*C. papernastrema*	Price, Peebles & Bamford, 1969	*Tilapia sparmanii*	South Africa			
50	*C. philander*	Douëllou, 1993	*Pseudocrenilabrus philander*	Zimbabwe	*Pseudocrenilabrus philander*	Current Study	Botswana
51	*C. pouyaudi*	Pariselle & Euzet, 1994	*Tylochromis gentinki*	Ivory coast	*Tylochromis gentinki*	Pariselle & Euzet (1994)	Guinea
52	*C. quaestio*	Douëllou, 1993	*Serranochromis codringtoni*	Zimbabwe	*Serranochromis macrocephalus*	Douëllou (1993)	Zimbabwe
					Tilapia renadalli	Douëllou (1993)	Zimbabwe
53	*C. sanjeani*	Pariselle & Euzet, 1997	*Sarotherodon occidentalis*	Guinea	*Sarotheradon occidentalis*	Pariselle & Euzet (1997)	Sierra Leone
54	*C. sclerosus*	Paperna & Thurston, 1969	*Tilapia zillii*	Uganda	*Haplochromis sp.*	Paperna & Thurston (1969b)	Uganda
					Oreochromis mortimeri	Douëllou (1993)	Zimbabwe
					Serranochromis macrocephalus	Douëllou (1993)	Zimbabwe
					Sarotherodon galilaea	El Naggar & Khidr (1986)	Egypt
					Tilapia leucostica	Paperna & Thurston (1969b)	Uganda
					Oreochromis mossambicus	Paperna & Thurston (1969b)	Uganda
					Oreochromis niloticus	Paperna & Thurston (1969b)	Uganda
					Oreochromis niloticus	Thurston (1970)	Uganda
					Oreochromis niloticus	El Naggar & Khidr (1986)	Egypt
					Tilapia zillii	El Naggar & Khidr (1986)	Egypt
					Oreochromis andersonii	Current Study	Botswana
55	*C.slembroucki*	Pariselle & Euzet, 1998	*Tilapia buttikoferi*	Guinea			
56	*C. thurstonae*	Ergens, 1981	*Oreochromis niloticus*	Egypt			
57	*C. tiberianus*	Paperna, 1960			*Haplochromis longirostris*	Paperna & Thurston (1969b)	Uganda
					Sarotherodon galilaea	Paperna (1968)	Ghana
					Sarotherodon galilaea	Paperna (1969)	Ghana
					Sarotherodon galilaea	El Naggar & Khidr (1986)	Egypt
					Tilapia melanopleura	Thurston (1970)	Uganda
					Oreochromis niloticus	Paperna & Thurston (1969b)	Uganda
					Oreochromis niloticus	El Naggar & Khidr (1986)	Egypt
					Tilapia renadalli	Douëllou (1993)	Zimbabwe
					Tilapia zillii	Paperna (1965)	Ghana
					Tilapia zillii	Paperna (1969)	Ghana
					Tilapia zillii	Ergens (1981)	Egypt
58	*C. tilapiae*	Paperna, 1960			*Haplochromis macrognathus*	Paperna & Thurston (1969b)	Uganda
					Hemichromis fasciatus	Paperna (1968)	Ghana
					Pelmatochromis guentheri	Paperna (1969)	Ghana
					Pelmatochromis guentheri	Paperna (1979)	Ghana
					Tilapia aurea	Paperna (1979)	Ghana
					Tilapia busumana	Paperna (1968)	Ghana
					Tilapia busumana	Paperna (1979)	Ghana
					Sarotherodon galilaea	Paperna (1965)	Ghana
					Sarotherodon galilaea	Paperna (1968)	Ghana
					Sarotherodon galilaea	Paperna (1969)	Ghana
					Sarotherodon galilaea	El Naggar & Khidr (1986)	Egypt
					Tilapia leucostica	Paperna & Thurston (1969b)	Uganda
					Tilapia leucostica	Paperna (1979)	Uganda
					Oreochromis mossambicus	Paperna & Thurston (1969b)	Uganda
					Oreochromis mossambicus	Paperna & Thurston (1969b)	Uganda
					Oreochromis niloticus	Paperna (1965)	Uganda
					Oreochromis niloticus	Paperna (1968)	Uganda
					Oreochromis niloticus	Paperna (1969)	Uganda
					Oreochromis niloticus	Thurston (1970)	Uganda
					Oreochromis niloticus	Ergens (1981)	Egypt
					Oreochromis niloticus	Paperna (1979)	Ghana
					Oreochromis niloticus	Paperna (1979)	Uganda
					Oreochromis niloticus	El Naggar & Khidr (1986)	Egypt
					Tilapia spilurus nigra	Paperna (1979)	Uganda
					Tilapia urolepis	Paperna (1979)	Tanzania
					Tilapia vulcani	Paperna (1979)	Uganda
					Tilapia zillii	Paperna & Thurston (1969b)	Uganda
					Tilapia zillii	Paperna (1979)	Uganda
					Tilapia zillii	Ergens (1981)	Egypt
					Tilapia zillii	El Naggar & Khidr (1986)	Egypt
59	*C. tubicirrus longipenis*	Paperna & Thurston, 1969	*Astatoreochromis alluaudi*	Uganda			
60	*C.t. magnus*	Paperna & Thurston, 1969	*Sarotherodon galilaea*	Uganda	*Sarotherodon galilaea*	Paperna (1968)	Ghana
					Sarotherodon galilaea	Paperna (1969)	Ghana
					Tilapia leucostica	Paperna & Thurston (1969b)	Uganda
					Oreochromis niloticus	Paperna & Thurston (1969b)	Uganda
					Tilapia zillii	Ergens (1981)	Egypt
61	*C. t. minutus*	Paperna & Thurston, 1969	*Haplochromis angustifrons*	Uganda	*Haplochromis guiarti*	Paperna & Thurston (1969b)	Uganda
					Haplochromis longirostris	Paperna & Thurston (1969b)	Uganda

					Haplochromis macrops	Paperna & Thurston (1969b)	Uganda
					Haplochromis obesus	Paperna & Thurston (1969b)	Uganda
					Haplochromis obliquidens	Paperna & Thurston (1969b)	Uganda
					Haplochromis schubotzi	Paperna & Thurston (1969b)	Uganda
					Haplochromis squamipinnis	Paperna & Thurston (1969b)	Uganda
					Haplochromis sp.	Paperna & Thurston (1969b)	Uganda
					Hoplotilapia retrodens	Paperna & Thurston (1969b)	Uganda
					Tilapia leucostica	Paperna & Thurston (1969b)	Uganda
62	*C. vexus*	Pariselle & Euzet, 1995	*Tilapia guineensis*	Ivory coast	*Tilapia zillii*	Pariselle & Euzet (1995)	Ivory Coast
63	*C. yanni*	Pariselle & Euzet, 1996	*Tilapia dageti*	Mali	*Tilapia dageti*	Pariselle & Euzet (1996)	Senegal
					Tilapia guineensis	Pariselle & Euzet (1996)	Ivory Coast
					Tilapia guineensis	Pariselle & Euzet (1996)	Senegal
					Tilapia louka	Pariselle & Euzet (1996)	Guinea
					Tilapia walteri	Pariselle & Euzet (1996)	Ivory Coast
					Tilapia zillii	Pariselle & Euzet (1996)	Burkina Faso
					Tilapia zillii	Pariselle & Euzet (1996)	Guinea
64	*C. zambezensis*	Douëllou, 1993	*Oreochromis mortimeri*	Zimbabwe	*Serranochromis macrocephalus*	Douëllou (1993)	Zimbabwe
65	*C. sp.*				*Oreochromis andersonii*	Batra (1984)	Zambia
					Oreochromis macrochir	Batra (1984)	Zambia
					Sarotherodon galilaea	El Naggar & Khidr (1986)	Egypt
					Oreochromis niloticus	El Naggar & Khidr (1986)	Egypt
					Tilapia renadalli	Batra (1984)	Zambia
					Tilapia zillii	Ergens (1981)	Egypt
					Tilapia zillii	El Naggar & Khidr (1986)	Egypt
	Enterogyrus	**Paperna, 1963**					
1	*E. amieti*	Bilong-Bilong, Euzet & Birgi, 1996	*Sarotherodon galilaeus sanagensis*	Cameroon			
2	*E. barombiensis*	Bilong-Bilong, Birgi & Euzet, 1991	*Konia eisentrauti*	Cameroon	*Pungu maclareni*	Bilong-Bilong, Birgi & Euzet (1991)	Cameroon
					Stomatepia pindu	Bilong-Bilong, Birgi & Euzet (1991)	Cameroon
3	*E. cichlidarum*	Paperna, 1963			*Sarotherodon galilaea*	Khidr (1990)	Egypt
					Oreochromis niloticus	Bilong-Bilong, Birgi & Lambert (1989)	Cameroon
					Oreochromis niloticus	Khidr (1990)	Egypt
					Oreochromis niloticus	Khidr, Hassan & Kearn (1990)	Egypt
					Tilapia zillii	Khidr (1990)	Egypt
					Tilapia zillii	Khidr, Hassan & Kearn (1990)	Egypt
4	*E. crassus*	Bilong-Bilong, Euzet & Birgi, 1996	*Tilapia nyongana*	Cameroon			
5	*E. malmbergi*	Bilong-Bilong, 1988	*Oreochromis niloticus*	Cameroon			
6	*E. melenensis*	Bilong-Bilong, Birgi & Lambert, 1989	*Hemichromis fasciatus*	Cameroon			
7	*E. niloticus*	Eid & Negm, 1987	*Oreochromis niloticus*	Egypt			
	Eutrianchoratus	**Paperna, 1969**					
1	*E. chibami*	Bilong-Bilong, Euzet & Birgi, 1994	*Parachanna obscura*	Cameroon			
2	*E. magnus*	Paperna. 1969	*Ophiocephalus obscurus*	Ghana			
3	*E. malleus*	Bilong-Bilong, Euzet & Birgi, 1994	*Parachanna obscura*	Cameroon			
4	*E. minitus*	Paperna, 1969	*Ophiocephalus obscurus*	Ghana			
	Heterotesia	**Paperna, 1969**					
1	*H. voltae*	Paperna, 1969	*Ophiocephalus obscurus*	Ghana			
	Insulacleidus	**Rakotofiringa & Euzet, 1983**					
1	*I. Paratilapiae*	Rakotofiringa & Euzet, 1983	*Paratilapia polleni*	Madagascar			
2	*I. Paretropli*	Rakotofiringa & Euzet, 1983	*Paretroplus polyactis*	Madagascar			
3	*I. Ptychochromidis*	Rakotofiringa & Euzet, 1983	*Ptychochromis oligocanthus*	Madagascar			
	Onchobdella	**Paperna, 1968**					
1	*O. aframae*	Paperna, 1968	*Hemichromis fasciatus*	Ghana	*Hemichromis fasciatus*	Paperna (1969)	Ghana
					Pelmatochromis guentheri	Paperna (1969)	Ghana
2	*O. krachii*	Paperna, 1968	*Pelmatochromis guentheri*	Ghana	*Pelmatochromis guentheri*	Paperna (1969)	Ghana
3	*O. melissa*	Pariselle & Euzet, 1995	*Pelmatochromis buettikoferi*	Guinea			
4	*O. pterigyalis*	Paperna, 1968	*Hemichromis bimaculatus*	Ghana			
5	*O. spirocirra*	Paperna, 1968	*Hemichromis bimaculatus*	Ghana	*Hemichromis bimaculatus*	Paperna (1969)	Ghana
6	*O. sylverai*	Pariselle & Euzet, 1995	*Pelmatochromis buettikoferi*	Guinea			
7	*O. voltensis*	Paperna, 1968	*Hemichromis bimaculatus*	Ghana	*Hemichromis bimaculatus*	Paperna (1969)	Ghana
					Hemichromis fasciatus	Paperna (1968)	Ghana
					Hemichromis fasciatus	Paperna (1969)	Ghana
					Pelmatochromis guentheri	Paperna (1969)	Ghana
	Schilbetrematoides	**Kritsky & Kulo, 1992**					
1	*S. pseudodactylogyrus*	Kritsky & Kulo, 1992	*Schilbe intermedius*	Togo			
	Paraquadriacanthus	**Ergens, 1988**					
1	*P. nasalis*	Ergens, 1988	*Clarias lazera*	Egypt	*Clarias lazera*	Kritsky & Kulo (1988)	Egypt
	Scutogyrus	**Pariselle & Euzet, 1995**					
1	*S. bailloni*	Pariselle & Euzet, 1995	*Sarotherodon galilaeus*	Nigeria			
2	*S. chikhii*	Pariselle & Euzet, 1995	*Oreochromis mossambicus*	Congo			
3	*S. ecoutini*	Pariselle & Euzet, 1995	*Sarotherodon galilaeus*	Guinea			
4	*S. gravivaginus*	(Paperna & Thurston, 1969)	*Tilapia leucosticta*	Uganda			
5	*S. longicornis*	(Paperna & Thurston, 1969)	*Oreochromis niloticus*	Uganda	*Oreochromis mortimeri*	Douëllou (1993)	Zimbabwe
					Sarotherodon galilaea	Paperna (1968)	Ghana
					Sarotherodon galilaea	El Naggar & Khidr (1986)	Egypt

					Oreochromis niloticus	Paperna & Thurston (1969b)	Uganda
					Oreochromis niloticus	Paperna (1969)	Ghana
					Oreochromis niloticus	Ergens (1981)	Egypt
					Oreochromis niloticus	El Naggar & Khidr (1986)	Egypt
					Tilapia zillii	Paperna (1968)	Ghana
					Tilapia zillii	El Naggar & Khidr (1986)	Egypt
6	*S. minus*	(Dossou, 1982)	*Sarotherodon melanotheron*	Benin	*Sarotherodon melanotheron*	Pariselle & Euzet (1995)	Ivory Coast
	Synodontella	**Dossou & Euzet, 1993**					
1	*S. arcopenis*	Dossou & Euzet, 1993	*Synodontis sorex*	Benin	*Synodontis sorex*	Dossou & Euzet (1993)	Mali
2	*S. davidi*	Dossou & Euzet, 1993	*Synodontis membranaceus*	Mali			
3	*S. melanoptera*	Dossou & Euzet, 1993	*Synodontis melanopterus*	Benin			
4	*S. zambezensis*	Douëllou & Chishawa, 1995	*Synodontis zambezensis*	Zimbabwe			
Family: **Diplectanidae** Bychowsky, 1957							
	Archidiplectanum	**Mizelle & Kritsky, 1969**					
1	*A. archidiplectanum*	Mizelle & Kritsky, 1969	*Gnathonemus petersii*	West Africa			
	Diplectanum	**Diesing, 1858**					
1	*D. lacustris*	Thurston & Paperna, 1969	*Lates albertianus*	Uganda	*Lates niloticus*	Paperna (1969)	Ghana
Family: **Diplozoidae** Tripathi, 1959							
	Diplozoon	**Nordmann, 1832**					
1	*D. aegyptensis*	Fischthal & Kuntz, 1963	*Labeo forskalii*	Egypt	*Labeo coubie*	Paperna (1969)	Ghana
2	*D. ghanense*	Thomas, 1957	*Alestes macrolepidotus*	Ghana	*Alestes baremoze*	Paperna (1969)	Ghana
3	*D. sp*				*Alestes sp.*	Thurston (1970)	Uganda
	Neodiplozoon	**(Tripathi, 1959)**					
1	*N. polycotyleus*	Paperna, 1975	*Barbus cercops*	Kenya	*Barbus macrolepis*	Paperna (1975)	Tanzania
					Barbus paludinosus	Paperna (1975)	Kenya
					Labeo victorianus	Paperna (1975)	Kenya
						Mashego (2000)	South Africa
	Unidentified Diplozoid			Benin	*Tilapia rendalli*	Batra (1984)	Zambia
Family: **Diclidophoridae** Cerfontaine, 1895							
	Heterobothrium	**Cerfontaine, 1895**					
1	*H. fahaka*	Euzet & Birgi, 1974	*Tetradon fahaka*	Chad	*Tetradon fahaka*	Euzet & Birgi (1975)	Chad

APPENDIX 2- Presence / Absence Matrix of fish distribution in the Okavango Delta, Botswana.
Data collected from June to September for a period of four years (1997-2000)

	Backwaters at Mohembo	Floodplain at Mohembo	Okavango Mainstream at Drodsky's Cabins	Channel off Mainstream near Drodsky's Cabins	Samochima Lagoon	Backwaters at Shakawe Fishing Camp	Okavango Mainstream at Xaro Lodge	Backwaters at Xaro Lodge	Lagoon 1 near Xaro Lodge	Lagoon 2 near Xaro Lodge	Kalatog Channel and Lagoons	Floodplains at Nxamasere	Sepopa Lagoon	Floodplains at Sepopa	Backwaters at Seronga	Okavango Mainstream at Etsatsa	Backwaters at Etsatsa	Thaoge channel	Thaoge Lagoons	Guma Lagoon	Floodplain pools near Guma Lagoon	Lower Thaoge Channel near Makwena Lodge	Pepere Lagoon	Backwaters at Pepere Lagoon	Nqoga Mainstream	Backwaters on Nqoga Channel	Duba Lagoon	Jao Village	Perennial Swamp at Fly camp	Perennial Swamp at Film Camp	Seasonal Swamp at Nxabega	Boro River	Island Safari Lodge Maun	TOTAL
Collection Site Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	
Mormyridae																																		
Marcusenius macrolepidotus	0	1	0	0	1	0	0	0	1	1	1	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	1	0	0	1	0	0	0	**11**
Mormyrus lacerda	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	**3**
Petrocephalus catostoma	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	**6**
Pollimyrus castelnaui	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Cyprinidae																																		
Mesobola brevianalis	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Barbus afrovernayi	0	1	1	1	0	1	0	0	0	1	1	1	0	0	1	0	1	1	0	0	1	0	0	0	1	1	0	0	0	0	0	1	0	**14**
Barbus barnardi	0	1	1	0	0	1	0	1	0	0	0	1	0	1	1	0	0	0	1	0	1	0	0	0	1	1	0	0	1	0	0	0	1	**13**
Barbus bifrenatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	1	1	0	0	**5**
Barbus eutaenia	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Barbus fasciolatus	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Barbus haaisianus	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1	0	1	0	0	0	1	1	0	0	1	0	0	0	1	**12**
Barbus multilineatus	1	1	1	0	0	1	1	0	0	1	0	0	1	0	1	1	1	1	0	0	1	1	0	0	1	1	1	0	1	0	0	0	0	**17**
Barbus paludinosus	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	1	1	1	1	1	1	1	0	0	1	0	0	0	1	0	0	0	0	**12**
Barbus poechii	0	1	1	1	1	0	1	1	1	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	**12**
Barbus radiatus	1	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**5**
Barbus thamalakenensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0	**5**
Barbus unitaeniatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	**1**
Coptostomabarbus wittei	0	0	0	1	0	0	0	0	0	1	1	1	0	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	**9**
Labeo lunatus	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Distichodontidae																																		
Hemigrammocharax machadoi	0	0	1	0	0	1	0	0	0	1	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**6**
Hemigrammocharax multifaciatus	1	1	0	0	0	1	1	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**7**
Characidae																																		
Brycinus lateralis	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	**8**
Hydrocynus vittatus	0	0	1	1	1	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	**9**
Micralestes acutidens	0	0	1	0	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	**9**
Rhabdalestes maunensis	0	0	1	1	1	0	1	0	0	0	1	1	0	0	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	**13**
Hepsetidae																																		
Hepsetus odoe	0	1	0	1	1	0	0	0	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	**10**
Schilbeidae																																		
Schilbe intermedius	0	1	0	0	1	0	1	0	1	1	1	0	0	0	0	0	0	1	0	1	0	0	1	0	1	0	1	1	0	1	0	0	0	**13**
Clariidae																																		
Clarias gariepinus	0	1	1	0	1	0	1	0	1	0	1	0	1	0	0	1	0	0	1	1	0	0	1	0	0	0	1	0	0	1	0	0	0	**13**
Clarias stappersii	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Clarias theodorae	0	1	0	0	0	0	0	1	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	**8**
Mochokidae																																		
Synodontis leopardinus	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Synodontis nigromaculatus	0	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	**9**
Synodontis thamalakenensis	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**2**
Synodontis woosnami	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Synodontis vanderwaali	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Cyprinodontidae																																		
Aplocheilichthys hutereaui	1	1	0	1	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	1	0	0	0	1	1	1	0	1	0	0	1	1	**20**
Aplocheilichthys johnstonii	0	0	1	0	0	0	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	1	0	0	0	0	**9**
Aplocheilichthys katangae	0	1	0	0	0	1	0	0	1	0	0	0	1	0	1	0	1	1	0	0	1	0	0	1	1	1	0	0	1	0	0	0	0	**12**
Cichlidae																																		
Oreochromis andersonii	0	1	1	0	1	0	0	0	0	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	**12**
Oreochromis macrochir	0	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**5**
Phartngochromis acuticeps	0	0	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	**6**
Pseudocrenilabrus philander	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	1	1	0	1	0	**25**
Sargochromis carlottae	0	1	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**5**
Sargochromis codringtonii	1	1	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**6**
Sargochromis giardi	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Sargochromis greenwoodi	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Sargochromis mortimeri	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Serranochromis altus	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Serranochromis angusticeps	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	1	0	**7**
Serranochromis longimanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Serranochromis macrocephalus	0	0	1	1	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	**8**
Serranochromis robustus	0	0	1	0	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	**8**
Serranochromis thumbergi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	**2**
Tilapia rendalli rendalli	0	1	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**5**
Tilapia ruweti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	**2**
Tilapia sparmanii	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	0	0	1	1	1	1	1	**24**
Anabantidae																																		
Microctenopoma intermedium	0	11	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	1	0	0	1	0	1	0	1	0	0	0	0	0	**19**
Ctenopoma multispine	0	3	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	**9**
Mastacembelidae																																		
Aethiomastacembolus frenatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Total	**9**	**37**	**21**	**8**	**28**	**10**	**15**	**8**	**26**	**18**	**17**	**14**	**9**	**8**	**14**	**13**	**14**	**16**	**14**	**9**	**16**	**5**	**9**	**8**	**16**	**15**	**13**	**6**	**11**	**11**	**7**	**8**	**8**	**441**