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Trematoda, Tape Worms: Infections by Larval and Other Tape Worms; and Nematoda in African Fish (A Review)

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Abstract: The study reviews the taxonomy, description diagnosis, pathology, life history and ecology epizootiology and control of Trematoda, Tape worms: infections by larval and other tape worms; and Nematoda in African fish to educate fish culturist on some problems and way forward in culture fisheries in Africa.Trematoda s a class of the phylum Platyhelmnthes whose members are all parasitic flukes. Most species are hermaphrodites, except the schistosomes in holdfast which the sexes are separate. Tape worms are cestodes, dorsoventrally flattened parasites. Generally the adults inhabits the intestines of their hosts, being anchored to the intestinal wall by means of type-specific organs. Nematoda is a phylum of invertebrate animals not closely related to each other, but with certain common characteristics. For instance, cylindrical unsegmented bodies; acoelomate structure; a gut composed of mouth, pharynx and an intestinal tube. Members of the phylum include round worms, threadworms and hookworms. Many nematodes are free-living in soil and water.

Key words: Cestoda, trematoda, infection and African fish, nematoda, other tape worms

INTRODUCTION

Trematoda s a class of the phylum Platyhelmnthes whose members are all parasitic flukes. Most species are hermaphrodites, except the schistosomes in which the sexes are separate. Khalil (1971) lists over 50 species of trematodes, from 15 families, occurring in a variety of freshwater fish in Africa. Of these, only the extraintestinal species are potentially harmful to fish; species of *Sanguinicola* (the blood fluke) infect *Synodontis schall* and *Auchenoglanis occidentalis* in the Sudan (Khalil, 1969) and *Clarias lazera* (Paperna, 1964) and *Oreochromis* spp. in Israel. Callodistomid and opistorchid species infect the gall bladder and bile ducts of diverse fish species such as *Polypterus bichir, Synodontis schall* and *Gymnarchus niloticus*, while species of *Phyllodistomum* are found in the urinary bladder of siluroids, *Ctenopoma kingsleye*, *Mastacembalus nigromarginatus* and *Gymnarchus niloticus*. One representative of the Didimozoidae (parasites of fish tissues and internal cavities), *Nemathobothrium labeonis*, occurs (unencysted) in the eye orbits of *Labeo* spp. in the Sudan Nile.

Tape worms are cestodes, dorsoventrally flattened parasites. Generally the adults inhabits the intestines of their hosts, being anchored to the intestinal wall by means of type-specific holdfast organs (Bassey, 2011). Known world-wide from fish of the families Cyprinidae, Poecilidae, Cichlidae and Centrarchidae. Records of African hosts, all from southern Africa (Transvaal), include common carp, *Barbus kimberleyensis*, *B. trimaculatus* (Brandt *et al.*, 1981; Van As *et al.*, 1981) and *Oreochromis mossambicus*. Records of hosts from the Near East include, Common and Koi carp, *Tor* (=*Barbus*) *canis*, *Mirogrex terrae sanctae*, *Tristramella* spp. (Cichlidae), *Gambussia affinis* (Israel); common carp, *Barbus* spp. (Khalifa, 1986).

The worms, originally described in Japan and China, were apparently already introduced populations, while the natural host and geographical origin of this tape worm is the grass carp (*Ctenopharyngodon idella*) of the Amur River. By 1954-1962, infections had become widespread in farmed fish (in European and Chinese carp) as well as in a variety of wild fish in both the Asian and European USSR (Bauer and Hoffman, 1976). By 1970-1975 records of infections came from Hungary, Yugoslavia, East and West Germany (Molnar and Murai, 1973; Korting, 1974; Bauer and Hoffman, 1976), and by 1980, worms had become prevalent in France (Donges *et al.*, 1966), Britain (Andrews *et al.*, 1981), South Africa (Van As *et al.*, 1981), USA, and Mexico. Worms were introduced into Mauritius via South Africa. New records also came from

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Asia; Israel, Iraq (Khalifa, 1986), Malaysia (Fernando and Furtado, 1964), Sri Lanka (Fernando and Furtado, 1963) and Korea (Kim *et al.*, 1985). Allied species: *B. aegypticus*, known only from Egypt (Amin, 1978), and *B. kivuensis*, which occurs in Central and South Africa (Mashego, 1982). Nematoda is a phylum of invertebrate animals not closely related to each other, but with certain common characteristics. For instance, cylindrical unsegmented bodies; acoelomate structure; a gut composed of mouth, pharynx and an intestinal tube. Members of the phylum include round worms, threadworms and hookworms. Many nematodes are free-living in soil and water (Bassey, 2011). Potentially all freshwater and brackish water fish may be affected, with heavier infections in predatory fish, particularly by species also utilising fish as intermediate or transient hosts. Prevalent species are host specific and distributed as widely as their suitable hosts. An endemic species, *Anguillicola* (*A. papernai* (Moravec and Taraschewski, 1988), occurs *s laevionchus* and *Paracamallanus cyathopharynx* are parasitic on *Clarias* (Khalil, 1969; Moravec, 1974a; Boomker, 1982) and also occur in the same host in the Near East (Paperna, 1 in the eels (*Anguilla mossambica*) of the Cape region of South Africa. The stomachs of Cape eels were also infected by the widespread Indo-Pacific eel parasite, *Heliconema anguillae* (syn. *Ortleppina longissima*) (Jubb, 1961), and elvers with *Paraquimperia* sp. (Jackson, 1978). The study reviews the taxonomy, description diagnosis, pathology, life history and ecology epizootiology and control of Trematoda, Tape worms: infections by larval and other tape worms; and Nematoda in African fish to educate fish culturist on some problems and way forward in culture fisheries in Africa.

TREMATODA (DIGENEA)

Taxonomy, description and diagnosis: Trematodes or Digenea are flatworms (Platyhelminthes), heteroxenous (with a multiple host life cycle) and require (with only one exception) a mollusc as their first intermediate host. Adult-stage digeneans usually have a dorso-ventrally flattened, oval body with a smooth, spiny or corrugated surface, a sucker around the antero-ventral mouth, and an additional ventral sucker or acetabulum. Both suckers are used for attachment and locomotion. The digestive system consists of a pharynx connected to the mouth opening, a short oesophagus and two blind intestinal caeca. Most trematodes are hermaphrodite, containing both male organs (testes, ducts and copulatory system) and female organs (ovary, vitelline glands, ducts and uterus). Some also contain a specialised copulatory organ (gonotyl in *Heterophyes* spp.) which is useful for differential diagnosis. Eggs are evacuated to the genital opening, and are usually oval and operculated.

Blood flukes (Sanguinicolidae) are slender, spiny, and lack anterior ventral suckers and pharynx. The intestinal caeca are short, X- or H-shaped. Eggs are thin-shelled and lack an operculum. Didymozoidae are thread-like, with or without an expanded posterior region, and occur in pairs or small groups inside body cavities or within cysts or cyst-like formations in the tissues. Some are hermaphrodite, while others show variable degrees of separation into sexes. Differential diagnosis is difficult and requires experience with trematode taxonomy. Fixation, which allows further processing and adequate staining, should be done with Alcohol (70-95%) under moderate pressure of a glass slide or cover slip (depending on specimen size). Staining for demonstrating internal organs, if desired, may be done with either haematoxylin or carmine stains.

Life history and biology: The life histories of the trematodes which (at the adult stage) infect African fish have so far not been studied and their first molluscan host and other intermediate hosts remain unknown as yet. Data available on trematodes else where (Hoffman, 1967), may be summarized as follows: Eggs of gut dwelling digeneans are released via defaecation, while eggs of those living in the gall-bladder are evacuated into the gut with bile. Eggs, produced by digeneans in the kidney or gonads, are evacuated from their host with the respective organ's products. If they are located in tissue or closed internal cavities they can only be liberated following death of the host or predation (Didymozoid eggs).

Eggs of blood flukes (Sanguinicolidae), containing a fully developed miracidium, accumulate in the terminal (distal) blood capillaries. Only those reaching the gill filament blood vessels release their miracidia, which then actively break through the gill tissue into the water. Eggs of *Sanguinicola dentata* in *Clarias lazera* (Paperna, 1964) were accumulating in the kidney and seemed to evacuate via the urinary system. Eggs, if laid undeveloped (Paramphistomatidae), begin their embryonic development only after evacuation from the host, apparently after being triggered by appropriate stimuli (the presence of oxygen and light). Eggs of many piscine digeneans, however, when laid contain a fully developed miracidium. Such eggs hatch immediately or soon after evacuation from the definitive host (*Asymphilodora tincae*. Fully embryonated eggs of Ophistorchiidae do not hatch, but infect snail hosts upon being swallowed.

Free-swimming miracidia are pyriform, and covered with cilia. Both bivalve and gastropod molluscs serve as intermediate hosts for trematodes which reach the adult stage in fish. In fresh waters, both prosobranchs and pulmonates are involved. Trematodes demonstrate a high degree of specificity to their molluscan hosts. Bivalves are first intermediate hosts for Fellodistomatidae, Gorgoderidae and Allocreadiidae (Hoffman, 1967). Pulmonates are the molluscan hosts of blood flukes (*Sanguinicola* spp.), infecting freshwater fish (*Lymnaea* spp. of *S. inermis* of carp), and of Plagiorchidae. Freshwater prosobranch snails are hosts to both Ophistorchiidae and Monorchidae.

The miracidium, upon reaching the molluscan host, transforms into a "mother" sporocyst. Sporocysts yield a new generation of either sporocysts or rediae. Daughter stages migrate and settle in the molluscan hepato-pancreas. The sporocyst consists of only a tegumental sac, while the redia contains a muscular pharynx connected to a sac-like intestine, and a birth-pore located near the pharynx. In these, or their sporocyst or redia offspring, the cercariae are formed. Intramolluscan development of the Allocreadiidae, Haploporidae, and Monorchiidae includes both sporocyst and redia stages. In Sanguinicolidae and Plagiorchidae (Hoffman, 1967), the cercariae are formed in the daughter sporocyst stage.

Cercariae already have the elements of mature digenean organisation, but with primordial genital organs. Cercariae may also have locomotive devices; a tail, in some forked, fins (the forked-tailed cercariae of sanguinicoliids also have a characteristic dorso-median fin fold), and a pair of eyes. The latter are lost when cercariae transform into metacercariae. Of all piscine trematodes, only the blood flukes (Sanguinicolidae) and Transversotrematidae have cercariae which develop directly into adults in their definitive host. Cercariae of these flukes actively penetrate into their definitive piscine host (Hoffman, 1967). All other flukes which attain maturity in piscine hosts, reach their definitive host as waiting stage metacercariae.

Cercariae transform into metacercariae when penetrating aquatic invertebrate or vertebrate (fish, tadpoles) organisms, or after encystment on plant material or other substrates in the water; example Haploporidae, (Hoffman, 1967). Transmission into the definitive hosts occurs when metacercariae are predated with their intermediate hosts, or browsed from the substrate by suitable fish hosts. Infection of fish by metacercarial stages is therefore closely linked to their food preferences. Bucephalidae, and Acanthostomidae (in part) life histories involve fish as hosts for both metacercariae and adult stages. Tadpoles are second intermediate hosts for some Gorgoderidae.

Life histories involving molluscs as second intermediate hosts are found among members of very diverse digenean families; Monorchidae, Phyllodistomatidae, Azygiidae and Lepocreadiidae. Monorchidae, developing in *Bithynia* or in bivalves, also exploit their first molluscan host for metacercarial encystment. Other digeneans reach their definitive piscine host via planktonic or benthic organisms consumed as food. Common second intermediate hosts of digeneans infecting freshwater fish (such as Allocreadiidae), are larvae of aquatic insects; mayflies (Ephemeroptera), caddis-flies (Trichoptera), Dragon flies (Odonata) and Chironomidae and also various Crustacea, leeches, oligochaetes and planarians (Hoffman, 1967).

Pathology: Adult trematodes, infecting the digestive tract of fish, are considered harmless, even when their numbers are high. Extraintestinal trematode infections, on the other hand, are potentially pathogenic. Thus far, only the pathological data on blood flukes (sanguinicolids which can cause considerable damage to the gills and impair respiration) are relevant to African fish. Adult worms and trapped eggs can physically obstruct the passage of blood, causing thrombosis and subsequent necrosis (Hoffman, 1980), while escape of miracidia through the gill epithelium causes loss of blood and may lead to anaemia (Evans, 1974)

TAPEWORMS (CESTODA)

Taxonomy, description and diagnosis: Bothriocephalus acheilognathii was originally described as three different species, but these were later recognised as synonyms (Korting, 1975; Molnar, 1977), described from wild fish in Japan (*B. acheilognathii* and *Bothriocephalus opsariichthydis*) and from grass carp (*Ctenopharyngodon idella*) from South China (as *B. gowkongensis* Yeh, 1955). Infection can be readily detected from faecal material, revealing eggs, or residues of segments, and by autopsy, with the recovery of tape worm segments and scolices from the gut contents.

Eggs are operculated, 46-48 × 32-34 μm (Korting, 1975), 50-52 × 33-37 μm (Molnar and Murai, 1973) 53-54 × 33-38 μm (Yeh, 1955) and premature when laid. Worms are variable in size and number of segments. The scolex is heart-shaped, laterally flat, usually with a distinct terminal disk and deep lateral grooves (bothridia). Mature segments are broader than long, while gravid segments are longer than broad. Each segment contains 50–90 testes, the cirrus is located immediately in front of the vagina, the cirrus sac is round and the genital atrium is situated in the median line of the dorsal surface of the segment. The ovary is comprised of two lateral lobes connected by an isthmus, and vitellaria, approximately 200, scattered laterally (Yeh, 1955).

Plate 1 shows Tape worms (Cestoda): a. Scolex of *Bothriocephalus acheilognathii* from carp, Transvaal, South Africa. b. *B. acheilognathii*, whole worm (living) from farmed carp, Israel. c. Embryonated eggs of b. d. *Ligula* sp. from *Rastrineobola argenteus* from L. Victoria. Infected fish are recognised by their inflated abdomen (top fish) and may accommodate even three worms (bottom group).

Differential diagnosis Holarctic species of Bothriocephalus have a characteristically elongated

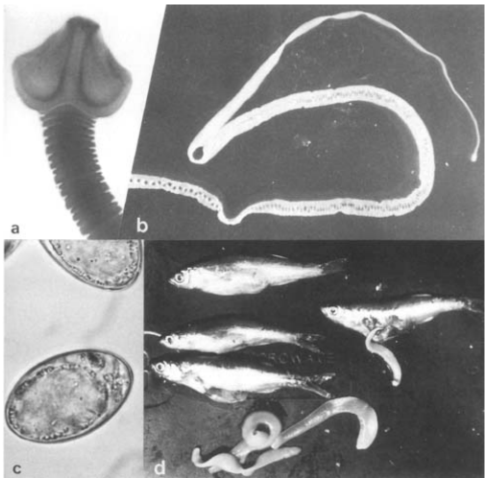

Plate 1:Tape worms (Cestoda)

scolex. Heart-shaped scolices also occur in *B. kivuensis* and *B. aegypticus* (Rysavy and Moravec, 1973), reported from African cyprinids (*Barbus* spp.). *B. aegypticus*, however, has 140-200 testes (140-280, Amin, 1978) and its eggs are 66 × 34-46 μm (Rysavy and Moravec, 1973) 38-66 × 26-46 μm (Amin, 1978). *B. kivuensis* has 50-75 testes and its eggs are 50-54 × 34-36 μm in size. *B. kivuensis*, however, seems to be a valid species as it has been described from *L. kivu* prior to the spread of *B. acheilognathii* into Africa. This may not be the case for the more recently reported and future from findings of bothriocephalids in cyprinid fish from habitats where *B. acheilognathii* is already present in South Africa (Mashego, 1982). Differentiation between the autochthonous and the introduced bothriocephalid from such regions may be extremely difficult by morphological criteria alone. *B. prudhoei*, from *Clarias anguillaris* in Egypt, distinctly differs from the above by its elongate rather than heart-shaped scolex (Tadros, 1966).

Life history and ecology: The life history of *B. acheilognathii* involves a definitive host, a fish and an intermediate host, a copepod. The Asian tape worm seems to be a thermophilic species (Hoffman, 1980). Low temperatures seem to delay or even interrupt development and consequently completion of the life cycle. At 28-30ºC, 77% of the eggs hatched in the first day after release, the remainder during the following five days. At 14-15ºC, the incubation period extended to 10-28 days and was for all practical purposes interrupted below 12ºC. The ubiquitous, cosmopolitan copepod, *Mesocyclops leuckarti*, is a frequent intermediate host of the Asian tapeworm, particularly in large bodies of water. Other genera of copepods, *Thermocyclops*, *Ectocyclops* and *Paracyclops*, found in fish ponds in China and Korea (Liao and Shih, 1956; Kim *et al.*, 1985), and *Cyclops abyssorum* in Northern Germany (Korting, 1975), are also compatible intermediate hosts. *Thermocyclops oblongatus*, common in certain dam reservoirs in Transvaal, has been suggested as the intermediate host there (Van As *et al.*, 1981). The copepod Acanthodiaptomus and cladocerans (*Daphnia*) have been found to be incompatible as hosts (Molnar, 1977).

In *Mesocyclops leuckarti* from Lake Kinneret fed on coracidia, the ciliated larvae hatched from eggs incubated for 24 h at 24ºC, up to 14 procercoids became established per copepod and developed into infective stages after 15 days at the same temperature. Kim *et al*. (1985) report completion of procercoid growth in the copepod 17 days after infection, at 25ºC. Korting (1975) reports completion of development, at the same temperature, after 10 days. Liao and Shih (1956) report completion of development to the infective stage after five days at 20ºC, four days at 25ºC and 21 days at 14ºC. Differences in the reported timing of development may be explained by the following: procercoids may become infective before they complete their growth, also, copepods of different genera and species may vary in their compatibility as intermediate hosts, and lastly, growth is apparently affected by the number of procercoids in the copepod (Korting, 1975).

Procercoids develop into mature worms within 21-23 days at 28-29ºC (Liao and Shih, 1956) and 1.5-2 months at 15-22ºC (Davidov, 1978). In the spring-summer ambient conditions of Lake Kinneret (16-28ºC) it has been extrapolated that worms require at least two months to reach the gravid stage. Davidov (1978) found that temperatures below 15ºC will delay development to 6-8 months and suggested a life span of two or more years for populations of worms infecting fish in cold water systems. The absence of adult worms in *B. canis*, in Lake Kinneret, by mid-summer may imply a life span of one year. This may be the rule for infections existing in fish in warm water environments. The life-span of the reduced-sized worms of small fish is apparently even shorter, as they disappear by the turn of the season from the on-growing fish. Worms demonstrate exceptional versatility in accommodating their sizes, i.e., biomass, to their host size, usually irrespective of species.

In young (about 100-150 mm in length) carp and grass carp mature tapeworms consisted of up to 500-600 segments, (Molnar and Murai, 1973). In *T. canis* longer than 60mm and cichlids longer than 40 mm from Lake Kinneret, mature worms consisted of at least 100 proglotids and gravid worms contained 150-350 and exceptionally up to 580 proglotids. Worms with the same range of proglotids were recovered from pond cultured, 50-61 mm long, Koi carp. In small fish, juvenile *T. canis*, <50 mm in length and cichlids, <35 mm in length and also in *G. affinis*, mature worms consisted of less than 60 proglotids and gravid worms of less than 100 proglotids.

In very small fish, cichlid fry 17-20 mm in length and young *G. affinis*, mature and gravid worms contained less than 50 proglotids and even as few as 17-20. Other African species of *Bothriocephalus* B. kivuensis: Rysavy and Moravec (1973) report (at 20-25ºC ambient temperatures) hatching of eggs within 41hrs and 50% of coracidia survived 20 h (maximum to 34 h). A local (L. Kivu system) copepod, *Ectocyclops rubescens*, feeding on coracidia, yielded precercoids which completed development in 16-19 days, but attempts to infect tilapia by feeding them on these copepods failed.

B. aegypticus: Eggs completed development to coracidia in 24 h at 24ºC and in 6 days at 18-20ºC. In Egypt, in the Nile, the copepod host is *Mesocyclops leuckarti*. Procercoids complete development in the copepods in 8-10 days (Rysavy and Moravec, 1973).

Pathology: Heavily infected fish have a distended abdomen. Sometimes infected fish also develop a variable degree of aseptic dropsy. Tapeworm-infected grass carp in China suffered from high mortalities (Yeh, 1955). Bauer *et al*. (1969) report high mortality among heavily infected juvenile carp (90%) and also report pathological changes in infected fish, which include pressure lesions, inflammation of the intestine and severe "catarrhal-haemorrhagic enteritis" at the parasite attachment point, with proliferation of the peripheral connective tissue. Hoffman (1980) reports that the intestines of infected small fish, such as the golden shiner, become plugged by the worms and in some instances are perforated. Minnow farmers report mortality among infected stocks.

Granath and Esch (1984) state that survival of *G. affinis* is significantly reduced compared with uninfected fish. Laboratory experiments also demonstrated that mortality caused by tape worms was a function of parasite density and host size. At elevated temperatures (to 25 and 30ºC) survival of both infected and non infected fish declined, but infected fish died sooner. Scott and Grizzle (1979) found considerably less pronounced pathological changes in infected grass carp and golden shiner (*Notemigonus crysoleucas*). Lesions were restricted to the attachment site. They also found similar haematocrit and condition values in both infected and control fish.

Accurate evaluation of the pathological effects of infection should be related not only to worm burden, but also to the size and condition of the host. Although the Asian tape worm is not fastidious in the choice of host, it may have different degrees of compatibility with different host species, which may also be expressed as variation in tolerance and defense response among infected fish species.

Epizootiology: In most introductions the actual route of entry was not identified, however, in most instances it was connected to the introduction of Chinese or European carp (Bauer and Hoffman, 1976; Brandt *et al.*, 1981). In warm water fish farms, as well as in temperate and cold regions, infections occurred primarily in the introduced carp species; European (*Cyprinus carpio*) and grass carp (*Ctenopharyngodon idella*) and also in pond reared ornamental carp (Koi). The tapeworm, once introduced, did not remain confined to farmed carp but also spread to native cyprinids and non cyprinid fish. Among the latter, *Gambussia affinis*, also a widely introduced species, became an important carrier of infection in both natural and man-made waters in the USA (Granath and Esch, 1983).

In Southern Africa infection became highly prevalent in native *Barbus* spp. (Brandt *et al.*, 1981; Van As *et al*., 1981). Infection may reach 30-156 mature and gravid worms per pond-reared carp 90-160 mm in length (Kim *et al.*, 1985), and up to 20, although usually less than 10, in fully-grown grass carp (Scott and Grizzle, 1979). In large *T. canis* and cichlids, infection is rare (1-0.1%), but some of the infected fish harboured as many as 83 gravid worms. In juvenile *T. canis*, cichlids and Koi carp, the number of gravid worms is rarely higher than 10, averaging one to five. In cichlid fry (<25 mm in length) or in *G. affinis*, the number of mature worms rarely exceeds five.

Granath and Esch (1983) report a worm burden of 2-33 in *G. affinis*, in a reservoir in North Carolina. Scolices (young, unsegmented worms) are far more numerous in all hosts, small or large, but only a few (<10%) apparently succeed in developing into adults. Infections assume a clear seasonal pattern, with peak incidence in the summer or otherwise during spring and autumn, not only in temperate and cold climatic regions (Chubb, 1982) but also in the Mediterranean regions where ambient winter water temperatures rarely drop below 10ºC (in Israel, in *L. kinneret* and in South Africa). Infestation seems to become interrupted during the coldest part of the year as is evident from the complete absence of young scolices. The latter becoming predominant during the warmer part of the year. A study of *G. affinis* by Granath and Esch (1983) in southern USA showed, on the other hand, peak occurrences of early stage ("non segmented") tape worms during periods of lower water temperatures.

Distribution and seasonality of Asian tapeworm infections depends not only on ambient temperatures but also on the abundance of compatible copepods, which is also seasonal, and their part in the composition of the fish's food, which is both age and season related. The Asian tape worm in Lake Kinneret is sustained concurrently in three host communities; a perennial cycle in young of the year *T. canis* and seasonal (spring, summer) infections of inshore small fish including fry and fingerlings of cichlids and *G. affinis*. Infection is lost from the juvenile fish (*T. canis* and cichlids) as their diet changes from zooplankton to phytoplankton and detritus, to predation. The perennial nature of infection in the lake seems to be maintained by the sporadic infections which occur in *T. canis* older than the year. Prevalence of infection in juvenile *T. canis* is 35-50%, in fry of cichlids 25-40% and in *G. affinis* of all ages 50-99%.

Control: Several chemotherapeutic formulations, when applied in food, effectively relieved fish from infection. Drugs should be mixed in oil (corn, soy, and fish) and sprayed on to pellets or mixed with feeds at a rate of one litre per 70 kg dry weight. Di-n-butyl tin oxide: recommended dose, a total of 250 mg/kg of fish, fed over a period of 3 days (Mitchell and Hoffman, 1980). Dibutyl tin dilurate (Tinostat): a poultry product, recommended to have better efficacy than the above tin formulation (Mitchell and Hoffman, 1980).

YOMESAN (NICLOSAMIDE, LINTEX)

Fifty (50) mg (active ingredient) per kg fish. Options for application are as follows: 500 g / 500 kg dry pellets fed at 1.5% of body weight, 2-3 times at weekly intervals; 28 g/40 kg, fed for 3 days. A further option is the incorporation of either of the recommended doses into pellets and distributed over 7 feeding days at 5% of fish body mass (Korting, 1974; Mitchell and Hoffman, 1980; Brandt *et al*., 1981). Yomesan, however, is toxic to fish in aquaria and tanks without running water (Molnar, 1970; Hoffman, 1980).

***Droncit* (Praziquantel of Beyer):** 5 mg/kg of fish, by direct application or incorporated into pellets. Eradication of infection will be more complete if combined with a control of copepods in the pond water. Recommended for use are insecticides employed as ectoparasiticides; Neguvon (Masoten, or Dipterex) or similar compounds (Bromex [Naled]).

Other tapeworm infections: A variety of adult stage tapeworms (over 40 species) occur in native African fish; monozoic (unsegmented) forms, notably Caryophyllaeidae as well as one amphilinid representative, and the segmented pseudophyllideans and Proteocephalidae (Khalil, 1971; Van As and Basson, 1984). Tapeworms are widespread throughout all major water systems of Africa and demonstrate a high degree of host specificity. Siluriform fish are the most common hosts for both monozoic and segmented cestodes. Caryophyllaeidae occur in a wider range of host families (Cyprinidae - *Barbus* spp., the characid *Alestes nurse* and in mormyrids). Common hosts of segmented tapeworms are also Polypterus spp.

There is only a single record of tapeworms from cichlid fish - *Proteocephalus bivitellatus*. Figure 1 shows

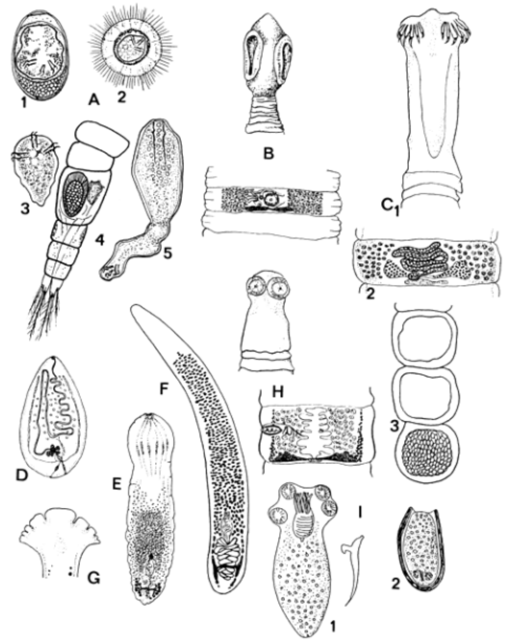

Fig. 1: Tape worms (Cestoda) (docrep_redirector_head_cache_data)

some Tape worms (Cestoda): Bothriocephalus aegypticus: ×40 μm) (1), coracidium (60×70 μm) (2), onchosphere removed from (3) and inside the body cavity of *Mesocyclops* (4) and 7-day old procercoid (350×80 μm) from the *Mesocyclops* B. Scolex, C. mature proglotid. C. *Polyonchobothrium polypteri* Scolex (1), mature proglotid (2) and gravid proglotid (3). D. *Amphilina*, general view. E. Monobothrioides woodlandi (Caryophyllidae) (length 0.4 mm). F. *Lytocestes marcuseni* (Caryophyllidae) (length 0.6 mm). H. *Proteocephalus largoproglotis*, scolex and mature proglotid. I. Dilepidid scolices from A. egg (60Oreochromis leucostictus, Lake Naivasha, free in gut (1) and still within egg shell in the stomach (2) (size: 1. scolex = 0.5×0.35 mm; 2. egg = 0.3×0.15 mm).

Life history and biology*Nesolecithus africanus*, like other amphilinids occurs in the coelomatic cavity of its fish host, the mormyrid *Gymnarchus niloticus* (Donges and Harder, 1966). All other cestodes, monozoic and segmented, occur in the digestive tract. Wabuke-Bunoti (1980) reports entry of *Polyonchobothrium clarias* to its host *Clarias mossambicus* (= *C. gariepinus*) gall bladder. Eggs of amphilinids apparently escape from the coelom through the genital opening and hatch only when ingested by an invertebrate intermediate host, such as amphipods in the case of sturgeon amphilinids (Bauer, 1959).

The first intermediate hosts of Caryophyllaeid cestodes are oligochaete worms, *Tubifex* and allied genera. Eggs, contained within, or released from evacuated dead worms are ingested and hatched within the digestive tract of the tubificid worm. The definitive host becomes infected when consuming infected oligochates (Bauer, 1959; Scholtz, 1991). First intermediate hosts of segmented tapeworms; pseudophyllideans and proteocephalids are copepods. In *Proteocephalus*, a second larval stage, pleurocercoids, develops in fish species non compatible as definitive hosts (Hoffman, 1967).

Pathology and epizootiology: In naturally occurring infections, among fish in African aquatic habitats, damage to the host is rarely evident. These worms, however, pose a potential risk to native fish species introduced to farming (*Clarias* spp. and *Heterotis niloticus*). Wabuke-Bunoti (1980) reported some tissue response (inflammation) around bothria of *P. clarias* attached to gut mucosa in infected Lake Victoria *C. gariepinus*. In the same fish, however, bothridial penetration into the gall bladder mucosa causes pronounced nodules. Such nodules contained granulomatous and fibrous tissue. Entry of *P. clarias* to the gall bladder, however, was not observed in *Clarias* spp. infected by the same parasite elsewhere in Africa and the Near East (Paperna, 1964; Khalil, 1969, 1971).

Caryophyllideans infecting cultured European and Chinese carp (Caryophylleus, Khawia) were reported to cause, in heavily infected farmed fish, severe damage to the intestine (obstruction and enteritis) as well as upsetting the general condition of the fish (Bauer, 1959; Mitchell and Hoffman, 1980). However, these tapeworms have not, thus far, been found in exotic carp species farmed in tropical or southern Africa.

Control: The same as for *Bothriocephalus acheilognathii*.

INFECTIONS BY LARVAL TAPEWORMS

Infections with *Ligula* pleurocercoids in the body cavity and by encysted cyclophyllidean cysticercoids are widespread in Central and South African fish (Khalil, 1971; Mashego, 1982; Van As and Basson, 1984). *Ligula* infections are very common in *Barbus* spp. and in the open water cyprinid *Rastrineobola* (= *Engraulicypris*) *argenteus* of Lake Victoria. It also occurs occasionally in cichlids (*Haplochromis* spp. from L. Victoria, and *Oreochromis* sp. from Israel).

Cyclophyllidean cysticercoids are common and numerous in mesenteries of siluriforms, *Clarias* and *Bagrus* spp., and in cichlids; they have also been reported from *Barbus* spp. Infections occur in the Sudan (Prudhoe and Hussey, 1977), in *L. victoria* (Khalil and Thurston, 1973) and the lesser Rift Valley lakes, in *L. kariba*, Zambia (Batra, 1984), the Niger (Ukoli, 1969) and in Ghana (Prah, 1969).

Taxonomy, description and diagnosis: Ligula pleurocercoids show very limited structural differentiation. They are flat, unsegmented and have a tapering anterior end with two bothridia. Pleurocercoids from different host fish vary in size, which ranges from 67-245 mm in length, and 3-10 mm in width. *Ligula* pleurocercoids collected from African fish were referred to as *L. intestinalis* (Prudhoe and Hussey, 1977; Mashego, 1982), a species widespread in European cyprinid fish which develops to the adult stage chiefly in gulls. In Africa, *L. intestinalis* has been reported from cormorants (Prudhoe and Hussey, 1977). It is, however, questionable whether *Ligula* from fish in Africa are conspecific with those from European fish, and if pleurocercoids found in different fish families are of the same species (Prudhoe and Hussey, 1977).

Cyclophyllidean cysticercoids are located in cysts up to 1 mm in size and are recognised by their hook-armed and sucker-bearing scolex. The cysticercoids were recognised as dilepidides, one species (encysting in *Oreochromis niloticus*), *Paradilepis delachauxi*, developed into the mature stage in a cormorant (*Phalacrocorax africanus*) (Prudhoe and Hussey, 1977). Cysticercoids from South African species of *Barbus* were assigned to the genus *Parvitaenia* (Mashego, 1982).

Life history and biology: First intermediate hosts of *L. intestinalis* are planktonic copepods which ingest the free swimming larvae (the coracidia hatched from the eggs). Procercoids develop to the stage infective to fish within 9-10 days in ambient European conditions, and will survive in the copepods for another 3-5 days (Bauer, 1959). Definitive hosts of *L. intestinalis* are various piscivorous birds. In the northern hemisphere, gulls are a very common hosts. African *Ligula* occurs in cormorants and *L. intestinalis* var. *africana* (Joyeux and Baer, 1942 was described from *Phalacrocorax africanus* (Prudhoe and Hussey, 1977). Eggs containing cyclophyllidean scolices were found in stomachs of very young cichlids in Lake Naivasha. Definitive hosts of these parasites are piscivorous birds, *Paradilepis delachauxi*, which as larvae infect *Oreochromis niloticus*, develop in the intestine of *Phalacrocorax africanus* (Prudhoe and Hussey, 1977).

Pathology: Severe pathological changes were reported in infections of *Ligula intestinalis* in the northern hemisphere; fibrosis, inflammation and atrophy of the viscera, resulting from compression and displacement of the organs by the parasites, often together with accumulation of blood stained ascitic fluid (Bauer, 1959; Sweeting, 1977; Mitchell and Hoffman, 1980). Worms may comprise up to 10% of their host weight and exert pressure upon visceral organs and on the abdominal wall, but nonetheless, the effect on the host is variable, and such naturally infected fish often do not demonstrate a decline in condition. The more severely affected fish could, however, have escaped our attention by being eliminated through selective die-offs. Infected *Barbus* spp. in Southern Africa and *R. argenteus* in Lake Victoria are very noticeable due to the considerable distention of their abdomen, but evidently with no other clinical signs, except for diffuse haemorrhages in the abdominal wall in some fish.

Infection in cichlids is not recognisable externally. In both *Barbus* and cichlids, only one *Ligula* pleurocercoid is usually recovered per individual fish and only exceptionally are 2-3 worms found in the abdomen of one fish. In *R. argenteus*, which exceptionally reaches an adult length of 80 mm, it is not unusual to find two or even three, 40-60 mm long, 5-7 mm wide worms. Infection with *L. intestinalis* leads to interruption of reproductive functions (Sweeting, 1977). This, however, has not been examined critically in infections affecting fish in Africa. Encysted cyclophyllaeid larvae usually occur in the mesenteries and as such do not interfere, even when numerous, with the physiological functions of the fish.

Epizootiology: Data are too scanty and only available from wild fish. In some dam reservoirs in South Africa, prevalence of infection among certain species of *Barbus* (*B. unitaeniatus*) reaches 85% (Mashego, 1982). In some catches in Lake Victoria (in Kavirondo Gulf), over 70% of the *R. argenteus* were infected. Newly introduced *Tinca tinca* into fish ponds, in Israel, died out following infection with *Ligula*, however, precise details are lacking. Heavy infections of encysted cyclophyllaeid larvae were found in large *Clarias gariepinus* and *Bagrus docmac* in Lake Victoria, and in Lake Naivasha in young *Oreochromis* spp., but there are no quantitative data.

Control: Some chemotherapeutic agents used to treat adult stage cestode infections may be effective, in particular Droncit. Mebendazole (5-benzoyi-1H-benzimidazol-2-vl) has been recommended specifically against migrating pleurocercoids (Mitchell and Hoffman, 1980). Treatment of ponds to eliminate copepods has also been recommended.

NEMATODA

Taxonomy, description and diagnosis: Nematoda (round worms) are very distinctive in shape, with a solid cuticle. Because of their resistant cuticle these worms last longer than flatworms in post-mortem conditions. Most adult forms are large enough to be visible to the naked eye. Khalil (1971) reports 40 species of adult nematodes, representatives of 9 families from fish in Africa. The majority occurs in the alimentary system and only a few enter tissues or inner cavities (Philometridae and *Anguillicolla*, the swim bladder).

Isolated nematodes should be fixed in warm (80-90ºC) 10% neutral or saline formalin, or in 70% alcohol, and preserved in either solution, mixed with 1% glycerine. There are several morphological criteria which will allow recognition of representatives of most families and even some genera, and readers are referred to the relevant literature (CIH Keys for Nematode parasites of Vertebrates, Commonwealth Agricultural Bureaux: Fantham, UK (Kabata, 1985). Taxonomic determination, to genera and species, nonetheless needs wider experience in nematodology.

Life history and biology: Oxyuroidea (such as the Oxyuridae and Kathlanidae) are monoxenous (single host) and occur in the intestines of detritus feeders (*Citharinus*, *Distichodus*) and omnivorous fish (*Synodontis*, *Oreochromis* and *Barbus* - Khalil, 1971). Copepods are first intermediate hosts to Camallanidae, Cucullanidae, Philometridae and Anguillicolidae. In Egypt, Moravec (1974b, 1975a) studied the life cycles of *Procamallanus laevionchus* and *Paracamallanus cyathopharynx* and obtained a development of the first three larval stages in *Mesocyclops leuckarti*. Camallanidae give birth to first stage larvae, which are ingested by the copepods. The larvae reach the third stage after two moults, *P. cyathopharynx* in 8-9 days at temperatures of 23-24ºC (Moravec, 1974b).

Nematodes are often very fastidious in their choice of copepod hosts (and will not develop in species of *Cyclops*, *Diaptomus* or cladocerans). However, larvae of *Anguillicola crassus* developed successfully in an ostracod. Ingested larvae pass from the gut into the copepod haemocoel. Longevity of such larvae in the copepods is variable (Thomas and Ollevier, 1993). Eggs of some species of *Rhabdochona* are provided with filaments and some also *bdochona* and *Spinitectus* are aquatic larvae of insects (Mayflies) (Gustafson, 1939) Hoffman, have a gelatinous polar cap (Moravec, 1975b).

Larvae in copepods, or other invertebrate intermediate hosts, will develop to fourth stage larvae and further into adult males and females when ingested by a suitable definitive host (Moravec, 1974b). Larvae ingested by "wrong" piscine hosts often survive as waiting stages (fourth stage larvae) in the gut or other tissues for a variable length of time and continue development into the adult stage if their carrier host (parataenic host) is predated by the compatible host. This has been demonstrated in *Procamallanus laevionchus* (Moravec, 1975a), in the anisakids (Heterocheilidae) *Dujardinascaris* and *Rhapidascaroides*, and in species of *Anguillicola*. Capillariid larvae often develop in oligochaetes (tubificids) and may also be transmitted via a parataenic piscine host. Such larvae may be found in visceral organs such as the liver (Moravec *et al.*, 1984). Larvae of some species (*Capillaria pterophylli*) infecting several South American cichlids will, however, reach their definitive hosts without an intermediate (Moravec, 1983). One genus, *Schulmanela*, thus far unknown in African fish, parasitizes the liver and deposits its eggs there, which are only released after the host's death or predation (Moravec *et al*., 1987).

Philometridae occur in body cavities or penetrate subcutaneous tissues. Males, are short-lived and the ovoviviparous females extrude their posterior end through the skin to release larvae into the water. Fish become infected by ingesting infected copepods (Molnar, 1966; Paperna of *T. bagri* only appear during December-February. Strict seasonality reported in some species of *Philometra* was linked with the host reproductive season (Paperna and Zwerner, 1976). and Zwerner, 1976). The family Philometridae is represented in Africa by two genera: *Nilonema gymnarchi* in the lung-like air bladder sacs of *Gymnarchus niloticus* and *Thwaitia bagri*, under the skin lateral to the mouth in *Bagrus bayad* (Khalil, 1969). Gravid *N. gymnarchi* presumably escape from the lungs into the water to discharge larvae (Khalil, 1969). Gravid worms

Host specificity of nematodes is variable. Among the Camallanidae *Procamallanus laevionchus* has, thus far, been reported from fish hosts of six different families, while *Spirocamallanus spiralis* has only been reported from species of *Clarias* and *Synodontis, Paracamallanus cyathopharynx* only from species of *Clarias*, and *Camallanus kirandensis* only from a *Barbus* sp. Similarly *Rhabdochona congolensis* and *Spinitectus allaeri* have been reported from numerous diverse host species, while the other known species of the same genera occur in one or a few hosts, usually related species. Very host specific are species of *Capillaria*, most oxyurids and the philometrids *Nilonema gymnarchi* and *Thwaitia bagri* (Khalil, 1969, 1971; Moravec, 1974a). Species of *Anguillicola* will only infect species of *Anguilla* (Moravec and Taraschewski, 1988).

Pathology and epizootiology: Infections by camallanids (Paracamallanus cyathopharynx and Procamallanus laevionchus) are abundant and heavy (up to 20 or more) particularly in the stomach of *Clarias* spp,. and in many other catfish. Spirocamallanus spiralis are also common in the stomach of the latter (Paperna, 1964; Khalil, 1969; Mashego and Saayman, 1980; Boomker, 1982). None of these were reported as pathogenic, in spite of the firm attachment by their buccal capsule to the stomach mucosa. Little harm is also caused by species of *Rhabdochona* or *Spinitectus*, common in the intestines of fish of all families (Paperna, 1964; Khalil, 1971).

Massive infections by *Capillaria* (*Pseudocapillaria*) and *Capillostrongyloides* which attach to and feed on the intestinal mucosa, caused emaciation and mortalities in aquarium reared neotropical cichlids and siluroids (Moravec and Gut, 1982; Moravec *et al*., 1987). Another species, *C. brevispicula*, which is widespread in European cyprinids and which caused the death of aquarium held tropical Asian cyprinids (Moravec *et al.,* 1984) has also been introduced to carp reared in warm water ponds in Israel, but as yet, with no pathological implications. A massive infection by the cosmocercid nematode *Railletnema synodontis* has been reported from aquarium held *Synodontis eupterus* of African origin. These oxyurids feed only on the gut contents. Nonetheless, fish were in poor condition (emaciated) and their digestive tract exhibited signs of atrophy (Moravec and Rehulka, 1987).

Several species of *Philometra* and related filaroids cause mild to severe pathology in fish. Aged and dying worms locked in the abdomen or trapped in tissue provoke severe inflammatory responses, granuloma and fibrosis (Paperna and Zwerner, 1976). Infection with *N. gymnarchi* in the lungs and *T. bargi* in the vicinity of the mouth cause only light local tissue reaction (Khalil, 1969). Five species of *Anguillicola* occur in eels native to Japan/China, Australia, New Zealand and South Africa, two (from Japan/China and New Zealand) were recently introduced into Europe apparently with elvers imported as culture seed (Moravec and Taraschewski, 1988). Infection is widespread in wild eels (Peters and Hartmann, 1986) and occasionally occurs in earth ponds, but it is unlikely to spread in hyperintensive systems where copepods, the intermediate hosts, cannot usually survive (Hirose *et al.*, 1976). Pathological effects vary with growth conditions and eel species. Heavy infection causes haemorrhagic inflammation of the swim bladder, but it may not necessarily always disrupt fish growth. It may, however, decrease the eels tolerance to transport stresses. In South Africa, infection by an endemic species was found in cultivated eels only.

Control: Experimental treatment of *Anguillicola crassus* in european eels by helminthicides (levamizol, mebendazol, or ivermectin) has produced satisfactory results. Levamizol was most effective, applied as a bath of 1 mg/L for 24 h, when LD 50 to 20-40 cm eels was 250 mg/L for 24 h (Taraschewski *et al.,* 1988). Experience with other nematodes is lacking.

LARVAL NEMATODES

Potentially in all fresh and brackish water fish, with heavier infections occurring in fish occupying higher positions in the food-chain, e.g., predatory fish. *Contracaecum* occurs in Israel (Paperna, 1964), Egypt, Mali, most large and small East African (Rift Valley) lakes (including lakes Kivu (Campana-Rouget, 1961), Zaire, Mali (Niger) (Khalil, 1971) and South Africa, where it was also reported from brackish water hosts

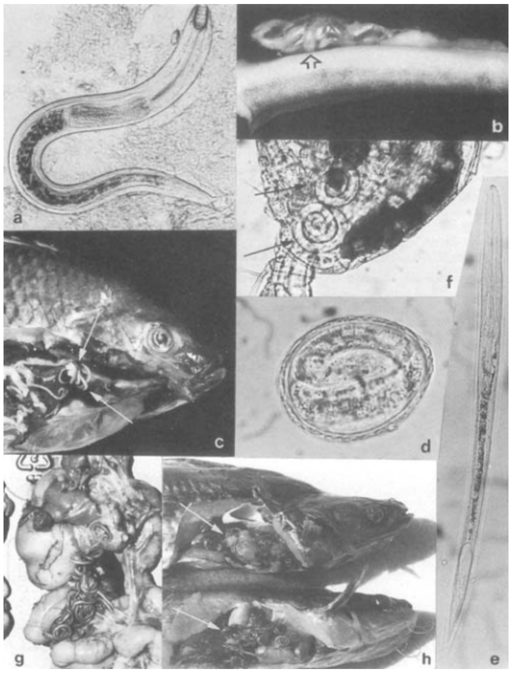

Plate 2 : Nematoda

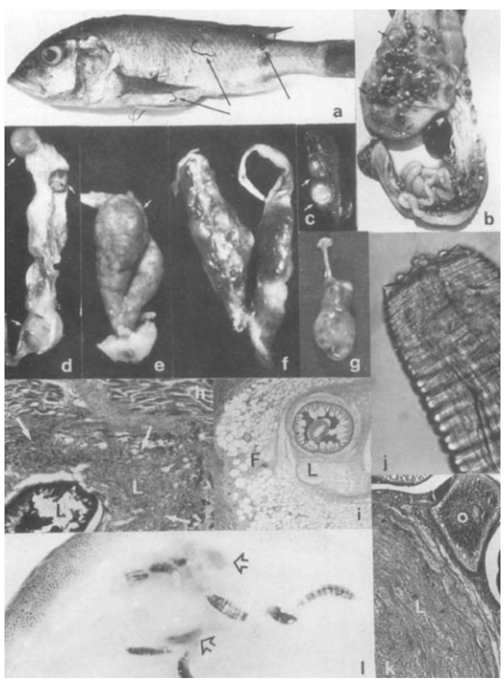

Plate 3: Nematoda continued; Leeches (docrep_ redirector_head_cache_data)

(Boomker, 1982; Van As and Basson, 1984). Infections of the pericardia in cichlid fish occur in Israel and in lakes Victoria, George, Nakuru, Naivasha, Baringo and Magadi (Paperna, 1974a; Malvestuto and Ogambo-Ongoma, 1978). *Amplicaecum* was reported from the Sudan (Khalil, 1969) and *Dujardinascaris* from Lakes Chad and Tanganyika. *Eustrongylides* has, thus far, only been found in the East African Lakes, including L. Tanganyika (Campana-Rouget, 1961; Khalil, 1971; Paperna, 1974b).

Taxonomy, description and diagnosis: Most notorious larval nematodes are representatives of the Anisakidae (Heterocheilidae); genera *Amplicaecum, Contracaecum* and *Porrocaecum*, Dioctophymidae; the genus *Eustrongylides* and Rhabdochonidae; the genera *Rhabdochona* and *Spinitectus*, the latter two genera also infect fish at an adult stage and are discussed above. Larval nematodes occur either encysted in tissues or free in body cavities, most often in the abdominal or pericardial cavity. Larvae of *Contracaecum* and *Eustrongylides* tend to escape from their cysts, and crawl out of their host body after its death. Larvae will usually emerge from isolated cysts if incubated in 0.9% saline solution at 37ºC. Released worms can be examined live or after fixation in hot 4% formalin or 70% ethyl alcohol and cleared in glycerin or lactophenol.

Identification of larval nematodes, particularly to species level is not usually feasible, since the larvae lack genital systems and several other features of adult stages which are utilised as taxonomic criteria. In recent years a methodology of identification of larval stages (of Anisakidae) by biochemical (isoenzyme) methodology utilising multilocus electrophoresis analysis has been developed (Orecchia *et al.*, 1986). *Rhabdochona* and *Spinitectus* are very small (<10 mm in length), the former shows dentation in its mouth opening, while the cuticle of the latter bears circular rows of spines. *Eustrongylides* are large long red worms, 18-70 mm long, 0.3-0.8 mm thick, with a long oesophagus merging with an indistinct ventriculum (Paperna, 1974a, b).

Anisakiid larvae are variable in size, often very large and thick, up to 60 mm long and 3 mm in diameter, with characteristic outgrowths (appendices) of either the anterior end of the intestine or the posterior end of the oesophagus (the vetriculum) or both: in *Contracaecum* appendices are formed (in opposite directions) from both the ventriculum and the intestine, while *Porrocaecum* has only one appendix of the intestine present and the ventriculum is separated from the oesophagus. *Amplicaecum*, differs from the latter, lacking a ventriculum distinctly separated from the oesophagus and in *Dujardinascaris* an intestinal appendix is present as well as a muscular ventriculum.

Plate 2 shows Nematoda a. Juvenile (L5) of *Procamallanus laevionchus*, intestine of *Clarias gariepinus*, S. Africa. b. *Anguillicola papernai* in swimbladder of *Anguilla mossambica*, S. Africa. c. *Contracaecum* larvae in the pericard of pond *Oreochromis aureus x niloticus*, Israel. d. Egg of

Contracaecum micropapillatum from *Pelecanus onocrotalus*, 3 days old. e. Free stage *C. micropapillatum* larva (L2). f. *C. micropapillatum* larvae in a copepod. g. *Contracaecum* larvae in viscera of *Eutropius depressirostris*, S. Africa (Transvaal).

Plate 3 shows Nematoda continued; Leeches: a-k. *Eustrongylides* larvae in fish in L. Victoria: a, escape of larvae from a dead haplochromid fish; b, encapsulated and freed larvae on the gut wall of *Bagrus docmac*; c. Larval nodules in spleen of a haplochromid; d. nodules in testis, and e,f, in ovaries of haplochromids; g. atrophic infected ovary in a haplochromid; h, lesions (L, arrows) due to migrating larvae in muscles of a haplochromid; i, lesion (L) with infiltration of lipid cells (F) in the spleen; k. fibrous lesion (L) in the ovary (o- oocyt). I Piscicolid leeches on the roof of the mouth of *Liza tricuspidata*, S. Africa, arrows: haemorrhages.

Figure 2 shows Nematoda: A. Rhabdochona congolensis, anterior and posterior ends (length -males 6-8 mm., females 16-21 mm.) B. Spinitectus allaeri, anterior and posterior ends (length - males 3-5 mm, females 4-7 mm). C. Procamallanus laevionchus, anterior and posterior ends (length - males 5 mm, females 4-5 mm.). D. Cucullanus barbi, male anterior and posterior ends (length - males 10-13 mm., females 4-7 mm.). E. Paracamallanus cyathopharynx mouth capsule. F. Spirocammallanus spiralis mouth capsule. G-J. Position of ventricular (g) and intestinal (i) coecca in larval Heterocheilidae: G. Amplicaecum, H. *Porrocaecum*, I. Contracaecum, J. Dujardinascaris with muscular ventriculus (m). o, oesophagus. (A-D, after Moravec, 1974a.)

Life history and biology: Definitive hosts of *Contracaecum* are pelicans, cormorants and herons. Pelicans (*Pelecanus onocrotalus*), incriminated as the definitive hosts of *Contracaecum* (found in the pericardial cavity of farmed tilapia, *Oreochromis* hybrids), were found to be infected by two species, *C. multipapillatum* and *C. micropapillatum*, but only the former appears to be implicated in infections of tilapia. Eggs are released via defaecation. They are also released into water when whole nematodes are vomited from the stomach by regurgitation. Eggs are released from such discharged nematodes by oviposition or after death, following their decomposition. Eggs hatch within 2-3 days at 24ºC, 5-7 days at 21ºC; hatching is not simultaneous and is further delayed in some of the eggs. Free living infective (second) stage larvae can survive in water for several months. Larvae become firmly attached by their posterior end to a substrate in the aquatic habitat. Small crustaceans are the first intermediate hosts of anisakiid nematodes.

In Israeli fish ponds, copepods of the genus *Cyclops* were the first intermediate hosts to *C. multipapillatum* and *C. micropapillatum* obtained from pelicans and to

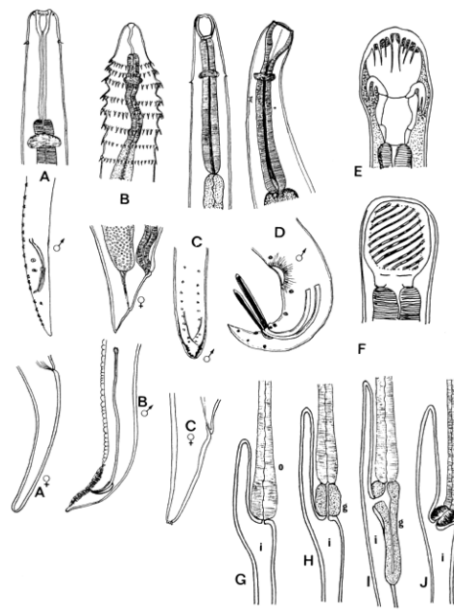

Fig. 2: Nematoda (docrep_redirector_head_cache_data)

C. rudolphi released from cormorants (*Phalacrocorax carbo*). Consumed larvae entered the haemocoel of the copepods while transforming into a subsequent developmental stage. Infection was retained in copepods for over 40 days. In those fish which became infected after consuming the infected copepods, larvae (third stage) migrated into the viscera, entered the swim bladder and finally accumulated in the pericardium (Landsberg, 1989). Within 2-4 months worms grew from 0.5 mm to 60 mm. They then persisted in the pericardium for up to 15 months, or through out the second year after infection.

In South Africa, where encysted *Contracaecum* are common in a wide variety of fish of diverse families (Boomker, 1982; Mashego, 1982; Mashego and Saayman, 1980; Van As and Basson, 1984), *C. micropapillatum*, *C. microcephalum* and *C. spiculigerum* are found in cormorants and pelicans, and the latter also in herons (Prudhoe and Hussey, 1977). Cormorants (*P. africanus*) also harboured *C. carlislei* (Boomker, 1982). The life histories of other anisakiid worms are unknown except that Nile monitors (*Varanus niloticus*), water snakes, crocodiles, frogs and toads are definitive hosts of *Amplicaecum* and crocodiles are also hosts for some *Porrocaecum* and *Dujardinascaris*. Definitive hosts of other species of the latter genus are fish (*Malapterurus electricus* and Gymnarchus niloticus).

The first intermediate hosts of Eustrongylides are unknown, although oligochaetes are the first intermediate hosts of a related dioctophymatoid from the genus Hystrichia. However, the latter do not develop via fish. In fish, larval infection passes from prey (cichlid fish, mainly Haplochromis) to predator, finally accumulating in the predatory catfish, *Bagrus docmac* and *Clarias gariepinus* (=*mossambicus*) and also in the lung fish (*Protopterus aethiopicus*). Numerous adult *Eustrongylides* sp. were found attached to the stomachs of cormorants (*Phalacrocorax africanus*) obtained from the same habitats (in Entebbe, L. Victoria) where fish were heavily infected (Paperna, 1974b). Herons, snakebirds (*Anhinga rufa*) and pelicans in the Sudan are hosts to *Eustrongylides africanus* (Jagerskiold, 1909).

Pathology: Neither encysted nor free *Contracaecum* larvae will severely affect fish. Tissue reaction, inflammation, epitheloid formation and fibrous encapsulation around encysted larvae is localised. Multiple infection of the mesenteries resulting in extensive inflammation, fibrosis and even some visceral adhesions, were seen only in large fish, with no apparent impact on their body condition (Mbahinzireki, 1980). Worms inhabiting the pericardial cavity do not induce any visible damage. Large (200-350 g) tilapia can accommodate up to 12 worms, which may reach a length of 6 cm and 2-3 mm in diameter. However, these infections, which affect the large fisheries of L. Naivasha in Kenya and intensive tilapia pond cultures in Israel, cause significant loss of income to these enterprises. As worms tend to migrate to the surface once fish die, such “wormy” fish deter customers. Fish have to be de-gutted and filleted in order to be sold for consumption, the cost of which has to be paid by the producers.

There are no indications of pathological effects caused by *Amplicaecum* larvae inhabiting the sinus venosus of cichlids or the body cavity of siluroids and other fish (Khalil, 1969). *Eustrongylides* larvae in cichlids, when unencysted, migrate under the skin and in the muscle causing extensive inflammation and necrosis. Encysted worms in the visceraliver, spleen and the gonads - cause severe pathological changes in the adjoining tissue. In the spleen, the tissue is replaced by lipid cells. Infection in the testes or ovaries causes severe pressure necrosis, degeneration of the spermatogenous and follicular tissue, being either replaced by lipid cells or undergoing complete necrosis, ultimately resulting in castration.

The incidence and the degree of damage to the gonads were positively correlated with the overall burden of infection in the fish. In large catfish and lungfish, larvae are numerous (often over 100) but they encyst only in mesenteries. Even heavy infection induces localized inflammatory response, while essential visceral organs are unaffected. One heavily infected *B. docmac* was emaciated, but otherwise fish condition (determined using weight/length indices) did not seem to be affected (Paperna, 1974b).

Epizootiology:Epizootiology of the pericardium inhabiting *Contracaecum* is linked with migration of piscivorous birds, particularly (or even only) pelicans, between Europe and tropical East Africa. Infection of ponds in Israel occurs after they have been visited by pelicans during spring migration. Definitive hosts of the other forms of *Contracaecum* (piscivorous birds), *Amplicaecum* (aquatic reptiles) or *Eustrongylides* (cormorants), are apparently sedentary as infection is geographically localized.

Prevalence of pericardial *Contracaecum* infection among tilapia in a contaminated pond often approaches 100%, usually with 1-4 worms per fish. In Lake Naivasha, Kenya, 85% of *Tilapia leucosticta* were reported infected with a mean of 9 worms per fish, in L. Baringo 70% of *O. niloticus* with 5 worms per fish, in L. Magadi 30% of *T. grahami* with a mean of 2 worms per fish and in Lake George 30% of (270 mm long) *O. niloticus* with a mean of 1 worm per fish (Paperna, 1974b; Malvestuto and Ogambo-Ongoma, 1978). Pericardial *Contracaecum* has not yet been seen in the numerous cichlids inspected in South Africa. Among cichlid fish in the Sudan Nile, 94% of *Oreochromis niloticus*, 82% of *Sarotherodon galilaeus* and 69% of *Tilapia zillii* were reported to have *Amplicaecum* larvae in the sinus venosus, at 2-8 worms per fish. *Amplicaecum* also occurred in the body cavity of various predatory fishes at prevalence levels of 10-37% with worm burdens of up to 36 per fish (Khalil, 1969).

Eustrongylides larvae, if ingested by another fish, will re-encyst in its new host, this causes larvae to accumulate in predators at higher trophic levels. These, usually large catfish and lungfish, are beyond the reach of cormorants and are therefore, a dead-end for the parasites' transmission cycle. Accumulation of nematode larvae in the large predator fish may have considerable ecological importance in moderating parasite populations in lake fish. Among *Haplochromis* spp. of northern Lake Victoria, incidence of infection ranged from 17 to 52% (mean 27%) with a mean worm burden of 5.1 (SD = 9.3) and up to 17 per fish. A quantitative study of *B. docmac* from the same fishing area in the lake revealed a 77% prevalence of infection, with a mean burden of 26 (SD = 29-overdispersed) and up to 125 worms per fish (Paperna, 1974b). Similar data were obtained in a later survey by Mbahinzireki (1980).

Castration, resulting from invasion of the gonads, with a prevalence of infection ranging from 5 to 17%, was found in 6 out of 15 representatives of *Haplochromis* and *Haplochromis* related species from L. Victoria. Incidences of castration were more abundant in species demonstrating an overall higher prevalence of infection. Although *Eustrongylides* infections occurred in *Haplochromis* from L. George in none of these were the gonads involved (Paperna, 1974b).

Control: Prevention of larval nematode infection by keeping away piscivorous birds is impractical not only in fishing areas in natural habitats or man-made impoundments but even in fish ponds. In fish ponds preventive treatments of *Contracaecum* by elimination of copepods (by insecticides such as Masoten or Bromex - see previous chapter on Cestoda) may be of some value if suitably timed, soon after its contamination by pelicans. Bromex, applied at a level of 2 ppm, killed free living larvae *in vitro*, but such a dose is about, or beyond, the tolerance limit of fish. Experiments with helminthicides (levamizol, mebendazol, or ivermectin) have not so far produced satisfactory results and it is not certain if costs of treatment (by use of medicated feeds) will be economical for tilapia farming.

CONCLUSION

The taxonomy, description diagnosis, pathology, life history and ecology epizootiology and control of Trematoda, Tape worms: Infections by larval and other tape worms; and Nematoda in African fish is necessary in educating fish culturist on some problems and way forward in culture fisheries in Africa.

REFERENCES

Amin, O.M., 1978. Intestinal helminths of some Nile fishes near Cairo, Egypt with redescription of *Camallanus kirandensis* Baylis 1928 (Nematoda) and *Bothriocephalus aegypticus* Rysavy and Moravec 1975 (Cestoda). J. Parasitol., 64: 93-101.

Andrews, C., J.C. Chubb, T. Coles and A. Dearsley, 1981. The occurrence of *Bothriocephalus acheilognathi* Yamaguti, 1934 (*B. gowkongensis*) (Cestoda: Pseudophyllidea) in the British Isles. J. Fish Dis., 4: 89-93.

Bassey, S.E., 2011. A Concise Dictionary of Parasitology. 1st Edn., Zetus Concepts, Port Harcourt, pp: 115, ISBN: 978-2954-40-3.

Batra, V., 1984. Prevalence of helminth parasites in three species of cichlids from a man-made lake in Zambia. Zool. J. Linn. Soc., 82: 319-333.

Bauer, O.N., 1959. The ecology of freshwater fish. *Inves. Gosud. Nauch-Issled. Inst. Ozer. Rech. Ryb. Khoz*. 49: 5-206 (In Russian, English transl. Israel Prog. Sci. Trans. cat. No. 622, 1962, 3-215).

Bauer, O.N., V.A. Musselius and Y.A. Strelkov, 1969. Diseases of Pond Fishes. Publisher "Kolos" Moskva. In English: Israel Program for Scientific Translations, Jerusalem, 1973.

Bauer, O.N. and G.L. Hoffman, 1976. Helminth Range Extension by Translocation of fish. In: Page, L.A. (Ed.), Wildlife Diseases, Plenum Publishing Corp, N.Y., pp: 163-172.

Boomker, J., 1982. Parasites of South African freshwater fish. I. Some nematodes of the catfish [*Clarias gariepinus* (Burchell, 1822)] from the Hartbeespoort dam. Onderstepoort J. Vet. Res., 49: 41-51.

Brandt, F.W., J.G. Van As, H.J. Schoombee and V.L. Hamilton-Attwell, 1981. The occurrence and treatment of bothriocephalosis in the common carp, *Cyprinus carpio* in fish ponds with notes on its presence in the largemouth yellow fish *Barbus kimberleyensis* from the Vaal Dam, Transvaal. Water S.A., 7: 35-42.

Campana-Rouget, Y., 1961. Nematodes de poissons. *Explor. Hydrobiol. Lacs Kivu, Edouard et Albert (1952-1954).* Brussels, 3: 1-61.

Chubb, J.C., 1982. Seasonal occurrence of helminths in freshwater fishes. Part IV Adult Cestoda, Nematoda and Acanthocephala. Adv. Parasitol., 20: 1-292.

Davidov, O.N., 1978. Growth development and fecundity of *Bothriocephalus gowkongensis* (Jeh, 1955), a cyprinid parasite. *Hydrobiologicheski Zournal*, 14: 70-77 (in Russian, English translation) Hydrobiol. J., 14: 60-66, 1979.

Donges, J. and W. Harder, 1966. *Nesolecithus africanus* n. sp. (Cestoda, Amphilinidae) aus dem coelom von *Gymnarchus niloticus* Cuvier, 1829 (Teleostei). Z. Parasitenk., 28: 125-141.

Fernando, C.H. and J.I. Furtado, 1963. A study of some helminth parasites of freshwater fishes in Ceylon. Zeit. Parasitenkunde, 23: 141-163.

Fernando, C.H. and J.I. Furtado, 1964. Helminth parasites of some Malaysian freshwater fishes. Bull. Natural Museum Singapore, 32: 45-71.

Granath Jr., W.O. and G.W. Esch, 1983. Temperature and other factors that regulate the composition and intrapopulation densities of *Bothriocephalus acheilognathi* (Cestoda) in *Gambusia affinis* (pisces). J. Parasitol., 69: 1116-1124.

Granath Jr., W.O. and G.W. Esch, 1984. Survivorship and parasite-induced host mortality among mosquito fish in a predator-free, North Carolina cooling reservoir. Am. Midl. Natur., 110: 314-323.

Gustafson, P.V., 1939. Life cycle studies on *Spinitectus gracilis* and *Rhabdochona* sp. (Nematoda: Spiruroidea). J. Parasitol., 25: 12-13.

Hirose, H., T. Sekino and E. Eugusa, 1976. Note on the egg deposition, larval migration and intermediate hosts of the nematode *Anguillicola crassa* parasitic in the swimbladder of eels. Fish Pathol., 11: 27-31.

Hoffman, G.L., 1967. Parasites of North American Freshwater Fishes. University of California Press, Berkeley & Los Angeles.

Hoffman, G.L., 1980. Asian tapeworm, *Bothriocephalus acheilognathi* Yamaguti, 1934, in North America. *Fisch* and *Umvelt*, Special volume in honor of Prof. Dr H-H. Reichenbach-Klinke 65th Birthday, 8: 6975.

Jackson, P.B.N., 1978. Health and disease in intensive aquaculture. J.S.A. Vet. Ass., 49: 57-59.

Jagerskiold, L.A., 1909. Nematoden aus Aegypten und dem Sudan. Results of the Swedish Zoological Expedition to Egypt and the White Nile 1901, 3: 166.

Jubb, R.A., 1961. The freshwater eels (*Anguilla* spp.) of South Africa. An introduction to their identification and biology. Annls. Cape Prov. Mus., 1: 15-48.

Kabata, Z., 1985. Parasites and Diseases of Fish Cultured in the Tropics. Taylor & Francis, London & Philadelphia.

Khalifa, K.A., 1986. Cestoda of freshwater farmed fishes in Iraq. J. Wild. Dis., 22: 278.

Khalil, L.F., 1969. Studies on the helminth parasites of freshwater fishes of the Sudan. J. Zool. London, 158: 143-170.

Khalil, L.F., 1971. Checklist of the Helminth Parasites of African Freshwater Fishes. Tech. Comm. 42, Comm. Inst. Helm C.A.B. England, pp: 80.

Khalil, L.F. and J.P. Thurston, 1973. Studies on the helminth parasites of freshwater fishes of Uganda including the description of two new species of digeneans. Rev. Zool. Bot. Afriq., 87: 209-248.

Kim, Y.G., J.Y. Kim and S.K. Chun, 1985. Life History of *Bothriocephalus opsariichthydis* Yamaguti (Cestoda; Pseudophyllida) parasitized on Israel carp *Cyprinus carpio* (Linne). 1. First intermediate host and developing procercoid. Bull. Fisheries Science Institute Kunsan. Fish J. Coll., 1: 1-10.

Korting, W., 1974. Bothriocephalosis of the carp. Veter. Med. Nachr., 2(74): 152-158.

Korting, W., 1975. Larval development of *Bothriocephalus* sp. (Cestoda: Pseudophyllidea) from carp (*Cyprinus carpio* L.) in Germany. J. Fish Biol., 7: 727-733.

Landsberg, J.H., 1989. Parasites and Associated Diseases of Fish in Warm Water Culture with Special Emphasis on Intensification. In: Shilo, M. and S. Sarig, (Eds.), Fish Culture in Warm Water Systems: Problems and Trends. CRC Press Inc., Boca Raton, Flo, pp: 195-252.

Liao, H.H. and L.C. Shih, 1956. On the biology and control of *Bothriocephalus gowkongensis* Yeh, a cestode parasitizing young grass carp (*Ctenopharyngodon idella*). Act. Hydrobiol. Sinica, 2: 129-185 (in Chinese, Russian and English summaries).

Malvestuto, S.P. and A. Ogambo-Ongoma, 1978. Observation on the infection of *Tilapia leucosticta* (Pisces: Cichlidae) with *Contracaecum* (Nematoda: Heterocheilidae) in Lake Naivasha, Kenya. J. Parasitol., 64: 383-384.

Mashego, S.N. and J.E. Saayman, 1980. Observation on the prevalence of nematode parasites of the catfish, *Clarias gariepinus* (Burchell, 1822) in Lebowa, South Africa. S.A.J. Wild. Res., 11: 46-48.

Mashego, S.N., 1982. A seasonal investigation of the helminth parasites of *Barbus* species in water bodies in Lebowa and Venda, South Africa. Ph.D. Thesis, University of the North, Sovenga, South Africa, pp: 191.

Mbahinzireki, G.B., 1980. Observation on some common parasites of *Bagrus docmac* Forskahl (Pisces: Siluroidea) of Lake Victoria. Hydrobiol., 75: 273-280.

Mitchell, A.J. and G.L. Hoffman, 1980. Important tapeworms of North American freshwater fishes. US Dep. Int. Fish & Wildlife Serv. Fish Dis. Leaflet, 59: 17.

Molnar, K., 1966. Life history of *Philometra ovata* (Zeder, 1803) and *Ph. rischta* Skryabin, 1917. Act. Vet. Acad. Sci. Hungar., 16: 227-242.

Molnar, K., 1970. An attempt to treat fish bothriocephalosis with Devermin. Toxicity for the host and anti-parasitic effect. Act. Vet. Acad. Sci. Hung., 20: 325-331.

Molnar, K., 1977. On the synonyms of *Bothriocephalus acheilognathi* Yamaguti, 1934. Parasitol. Hungar., 10: 61-62.

Molnar, K. and F. Murai, 1973. Morphological studies on *Bothriocephalus gowkongensis* Yeh, 1955 and *B. phoxini* Molnar, 1968 (Cestoda, Pseudophyllidea). Parasitol. Hungar., 6: 99-110.

Moravec, F., 1974a. On some nematodes from Egyptian freshwater fishes. Vest. Cs. Spol. Zool., 38: 32-51.

Moravec, F., 1974b. The development of *Paracamallanus cyathopharynx* (Baylis, 1923) (Nematoda, Camallanidae). Folia Parasitol. (Praha), 21: 333-343.

Moravec, F., 1975a. The development of *Procamallanus laevionchus* (Wed, 1862) (Nematoda, Camallanidae). Vest. Cs. Spol. Zool., 39: 23-38.

Moravec, F., 1975b. Reconstruction of the nematode genus *Rhabdochona* Raillet, 1916 with a revision of the species parasitic in fishes of Europe and Asia. Studie *CSAV No.* 8, Academia, Prague.

Moravec, F., 1983. Some remarks on the biology of *Capillaria pterophylli* Heinze, 1933. Folia Parasitol. (Praha), 30: 129-130.

Moravec, F., R. Ergens and R. Repova, 1984. First record of the nematode *Pseudocapillaria brevispicula* (Linstow, 1873) from aquarium fishes. Folia Parasitol., 3: 241-245.

Moravec, F. and J. Gut, 1982. Morphology of the nematode *Capillaria pterophylli* Heize 1933, a pathogenic parasite of some aquarium fishes. Folia Parasitol., 29: 227-231.

Moravec, F., M. Gelnar and J. Rehulka, 1987. *Capillostrongyloides ancistri* n. sp. (Nematoda: Capillariidae) a new pathogenic parasite of aquarium fishes in Europe. Folia Parasitol. (Praha), 34: 157161.

Moravec, F. and J. Rehulka, 1987. First record of the cosmocercid nematode *Raillietnema synodontisi* Vassiliades, 1973, from the aquarium-reared upside-down catfish *Synodontis eupterus* Boulanger. Folia Parasitol. 34: 163-164.

Moravec, F., J. Prokopic and A.V. Shlikas, 1987. The biology of nematodes of the family Capillariidae Neveu-Lemaire 1936. Folia Parasitol. (Praha), 39-56.

Moravec, F. and H. Taraschewski, 1988. Revision of the genus *Anguillicola* Yamaguti, 1935 (Nematoda: Anguillicolidae) of the swimbladder of eels, including description of two new species: *A. novezelandiae* sp. Nov. and *A. papernai* sp. n. Folia Parasitol., 35: 126-146.

Orecchia, P., L. Paggi, S. Mattiucci, J.W. Smith, G. Nascetti and L. Bullini, 1986. Electrophorhetic identification of larvae and adults of *Anisakis* (Ascaridia, Anisakidae). J. Helminth., 60: 337-339.

Paperna, I., 1964. The metazoan parasite fauna of Israel inland water fishes. Bamidgeh. Bull. Fish Cult. Israel, 16: 3-66.

Paperna, I., 1974a. Larval *Contracaecum* in the pericardium of fishes from East African lakes. Proc. Helminthol. Soc. Was., 41: 252.

Paperna, I., 1974b. Host distribution and pathology of infections with larvae of *Eustrongylides* (Dioctophymidae, Nematoda) in fishes from East African lakes. J. Fish Biol., 6: 67-76.

Paperna, I. and D.E. Zwerner, 1976. Parasites and diseases of striped bass, *Morone saxatilis* (Walbaum) from the lower Chesapeake bay. J. Fish Biol., 9: 267-287.

Peters, G. and F. Hartmann, 1986. *Anguillicola*, a parasitic nematode of the swimbladder spreading among eel population in Europe. Dis. Aqua. Org., 1: 229-230.

Prah, S.K., 1969. Observation on Parasitic Infection in Freshwater Fish in Ghana. In: Obeng, L.E., (Ed.), Man-made lakes, the Accra symposium. University Press for Ghana Academy of Sciences, Ghana, pp: 261-268.

Prudhoe, S. and C.G. Hussey, 1977. Some parasitic worms in freshwater fishes and fish predators from Transvaal, South Africa. Zool. Africana, 12: 113-147.

Rysavy, B. and F. Moravec, 1973. *Bothriocephalus aegypticus* sp. n. (Cestoda: Pseudophyllidea) from *Barbus bynni*, and its life cycle. Vest. Cs. Spol. Zool., 39: 68-75.

Scholtz, T., 1991. Early development of *Khawia sinensis* Hsu, 1935 (Cestoda: Caryophyllidea), a carp parasite. Folia Parasitol., 38: 133-142.

Scott, A.L. and J.M. Grizzle, 1979. Pathology of cyprinid fishes by *Bothriocephalus gowkongensis* Yea, 1955 (Cestoda: Pseudophyllidea). J. Fish Dis., 2: 69-73.

Sweeting, R.A., 1977. Studies on *Ligula intestinalis*. Some aspects of the pathology in the second intermediate host. J. Fish Biol., 10: 43-50.

Tadros, G., 1966. On a new cestode *Bothriocephalus prudoei* sp. Nov. from the Nile catfish *Clarias anguillaris* with some remarks on the genus *Clestobothrium* June, 1899. Bull. Zool. Soc. Egypt, 21: 74-89.

Taraschewski, H., C. Renner and H. Mehlhorn, 1988. Treatment of fish parasites. 3. Effect of levamisole HCI, metrifonate, fenbenazole and ivermectin on *Anguilla crassus* (nematodes) pathogenic in the air bladder of eels. Parasitol. Res., 74: 281-289.

Thomas, K. and F. Ollevier, 1993. Hatching, survival, activity and penetration efficiency of second-stage larvae of *Anguinicolla crassus*. Parasitol., 107: 2217.

Ukoli, F.M.A., 1969. Preliminary Report of the Helminth Infection of Fish in the River Niger at Shagnum. In: Obeng, L.E., (Ed.), Man-made Lakes; the Accra Symposium. Accra, Ghana, University Press for Ghana Academy of Sciences, Ghana, pp: 269-283.

Van As, J.G., H.J. Schoobee and F. Brandt, 1981. Further records of the occurrence of *Bothriocephalus* (Cestoda: Pseudophyllidea) in the Transvaal. S. Afr. J. Sci., 77: 343.

Van As, J.G. and L. Basson, 1984. Checklist of freshwater fish parasites from southern Africa. *S.* Afr. J. Wild., 14: 49-61.

Wabuke-Bunoti, M.A.N., 1980. The prevalence and pathology of the cestode

Polyonchobothrium clarias (Woodland, 1925) in the teleost, *Clarias mossambicus* (Peters). J. Fish Dis., 3: 223-230.

Yeh, I.S., 1955. On a tapeworm *Bothriocephalus gowkongensis* n. sp. (Cestoda: Bothriocephalidae) from freshwater fish in China. Act. Zool. Sinica,7: 69-74 (in Chinese, English summary).