

A Review of Acanthocephala, Leeches, Parasite Crustaceans and Some Other Parasites of Miscellaneous Taxa Infections in African Fish

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Abstract: A review of acanthocephala, leeches, parasite crustaceans and some other parasites of miscellaneous taxa infections in African fish was carried out to educate fish culturists, private and public sectors some challenges faced in culturist fisheries. The thorny headed worm, leeches, and parasitic crustaceans: Ergasilidae and Lernaecidae; other parasitic isopods: Argulidae and parasitic isopods; and other parasites of miscellaneous taxa: parasitic mites (Pentastomid larvae and larvae of bivalve mollusks) are reviewed to provide some level of education.

Key words: Leeches, other miscellaneous parasite taxa and african fish, parasitic crustaceans, parasitic isopods, thorny headed worm

INTRODUCTION

Acanthocephala, leeches, parasite crustaceans and some other parasites of miscellaneous taxa infections in African Fish is a major concern in culture fisheries. Present in representatives of diverse African fish families (Khalil, 1971). A wider range of anatomical details are considered for determination of higher taxa (Kabata, 1985). Host specificity of acanthocephalans is variable and may be evaluated only where sufficient data are available, which is not the case for most African fish species. *Acanthogyrus tilapiae* is specific to Cichlidae, while other species have been found in Cyprinidae, *Paragorgorhynchus albertianum* is indiscriminate in its choice of hosts (Khalil, 1971). Definitive hosts of such acanthocephalans are either predatory fish or piscivorous birds (Hassan and Qasim, 1960; Hoffman, 1967). Pathogenic effects of acanthocephalans are due to attachment of the adult parasite in the digestive tract and also to the encapsulation of larval stages in the tissues. The geographic range of these parasites is sometimes narrower than that of their specific hosts, for example, the cichlid parasite *Acanthogyrus tilapiae* is widespread in tropical Africa including Madagascar (introduced), but it has not yet been found in the Near East, the Sudan Nile or South African cichlids (Paperna, 1964; Khalil, 1969).

Leeches have so far only been reported from a few fish in Africa; *Bagrus docmac*, *Barbus altianalis*, *B. tropidolepis*, carp and *Protopterus aethiopicus*. However, leeches apparently attack a wider range of fish (Claridae, Synodontidae, Mormyridae and Cichlidae) and in a

greater number of water systems as is evident from the distribution of leech-transmitted trypanosomes in African fish. Leeches can survive for a considerable time, even when mailed in a vial inside wet cotton wool. Heavy leech infections have variable effects on fish hosts.

Most records of leeches removed from fish in Africa are of *Batrachobdelloides tricarinata*. This leech occurs from the Jordan system in Israel, infecting *Clarias lazera*, throughout tropical West and East Africa to Zululand in Southern Africa. Piscicolid leeches are common parasites of Mugilidae in the riverine-estuarine system of the southern Cape Province (Swartskop and Kowie estuaries) in South Africa. A review of acanthocephala, leeches, parasite crustaceans and some other parasites of miscellaneous taxa infections in african fish will educate fish culturists, private and public sectors some challenges faced in culturist fisheries. The thorny headed worm, leeches, and parasitic crustaceans: Ergasilidae and Lernaecidae; other parasitic isopods: Argulidae and parasitic isopods; and other parasites of miscellaneous taxa: parasitic mites (Pentastomid larvae and larvae of bivalve mollusks) are reviewed to provide some level of education.

THORNY-HEADED WORMS- ACANTHOCEPHALAN

Acanthocephala are readily recognised by their evaginable proboscis crowned with several rows of recurved hooks. In the encased larval stage, in tissues, the spiny proboscis is retracted. The worms are sac-like,

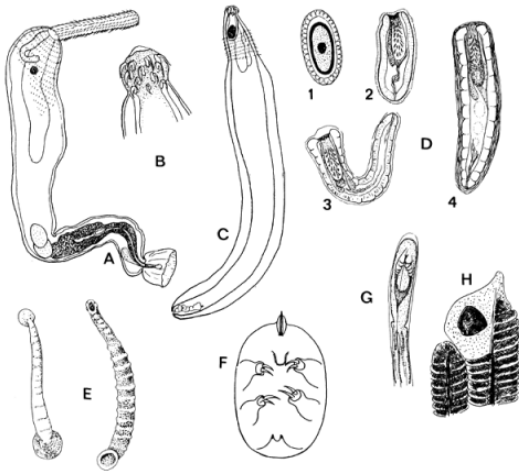


Fig. 1: Acanthocephala and various other parasites of fish (docrep_redirector_head_cache_data)

containing lemnisci connected to the proboscis and genital organs opening posteriorly. The sexes are separate and the male opening is within a membranous bursa. An alimentary canal is absent. The number and arrangement of the hooks on the proboscis are the main criteria for differentiation of species. Incubation in tap water helps to extract the proboscis prior to fixation in hot or cold alcohol 70%, formol saline 4%, or AFA.

Figure 1 shows Acanthocephala and various other parasites of fish. A. *Paragorgorhynchus chariensis*, male, 10-11 mm long. B,C. *Pallisentis tetraodontis*, female, 4.5 mm long, proboscis and whole view (A-C). D. Larval stages of acanthocephalans: 1. egg (of *Neoechinorhynchus*, 60×25 µm); 2. *Acanthella* from *Gammarus* amphipod, 1-4 mm long; 3. *Acanthella* from ostracods (2-4 mm long). 4. *Cystacanthus* (Acanthor) from fish (3-6 mm long). E. Piscicolid leeches (Hirudinea) (80-100 mm). F. Pentastomid larva. G. Parasitic larva of mutelid bivalve (Fryer, 1970). H. Unionid glochidium embedded in the gill tissue.

Life history and biology: All acanthocephalans develop via one or more intermediate hosts (heteroxenous). Adult acanthocephalans are all gut parasites. Eggs are laid into the intestinal lumen and evacuated with faeces. First intermediate hosts of piscine acanthocephala are amphipods, isopods, copepods or ostracods. The first larvae, the acanthella (acanthor), hatch from eggs after being swallowed by a suitable invertebrate host. Some species will develop to the adult stage when their larvae in the invertebrate host are ingested by the definitive vertebrate host (George and Nadakal, 1973; Schmidt, 1985). Fish can also serve as intermediate hosts, harbouring a second larval stage (the acanthor or

cystacanth). Life histories and intermediate hosts of acanthocephala of African fish are at present unknown.

Pathology: In low to moderate infections, pathological effects are localised around the attachment of the adult worm. The extent of damage is proportional to the depth of penetration of the proboscis. It is negligible when parasites are attached to the epithelial mucosa only (*Acanthogyrus* and *Acanthocephalus* spp.), and becomes extreme, with extensive granuloma and subsequent fibrosis, when the worm's proboscis is anchored in the muscle layer or entirely perforates the intestinal wall (*Pomphorhynchus* spp.) (Paperna and Zwerner, 1976; McDonough and Gleason, 1981; Kabata, 1985). The depth of penetration of some species, may vary in different host fish (Taraschewski, 1988). Extensive inflammation, peritonitis due to perforation of the gut and systemic clinical changes (anurhemia) will occur only in massive infections, most often in farmed fish (Bullock, 1963; Bauer, 1959).

In juvenile fish (cichlids <60 mm long) a single attached specimen of *Acanthogyrus tilapiae* obstructed the digestive tube, apparently with no clinical implications (Douellou, 1992 a, b). Low to moderate infections with larval stages (cystacanths) in visceral organs (liver, spleen) caused only local changes while heavy infection, in juvenile fish in particular, led to extensive granuloma, fibrosis and ultimately atrophy through fibrosis of either a portion of or the entire organ (Paperna and Zwerner, 1976). Information on infection among fish in Africa is very limited and none of the conditions described above have ever been reported.

Epizootiology: Epizootiological data are limited to natural infections: In the Sudan White and Blue Nile, 5-27 *Tenuisentis niloticus* occurred in 93% of *Heterotis niloticus*, 6-43 *Neoechinorhynchus* sp. in 26% of *Citharinus citharus* and 2-5 unidentified acanthocephala in 60% of *Synodontis batensoda* (Khalil, 1969). Similarly abundant infections were found in the same fish in L. Chad. *Acanthogyrus tilapiae* is a fairly common parasite of cichlid fish in tropical Africa, in Lake Kariba, 63% of the *Tilapia rendalli*, and all four *Oreochromis mortimeri* examined harboured worms, of which, one specimen had over 100 worms (Douellou, 1992a, b).

Control: To control infections in coldwater fish farms, medicated feed with Bithionol (2,2-thio bis (4,6-dichlorophenol), is recommended, at a dose of 0.2 g/kg fish (Hoffman, 1983). Feeds medicated with Di-N-butyl tin oxide are also potentially effective.

LEECHES

Leeches feeding on fish are Rhynchobdellae and belong either to the Glossiphoniidae or the Piscicolidae

(Mann, 1962). Most named records of Glossiphoniid leeches from African fish and many of those found free in the habitat were proven to be synonymous with *B. tricannata*. There is one record of another fish-feeding glossiphoniid, *Hemiclepsis quadrata* (Moore, 1939), from Ethiopia (Oosthuizen, 1987). Apart from the piscicolid leeches of Cape grey mullets, the only other African record of a piscicolid leech is of a species of *Phyllobdella* removed from *Barbus* (Moore, 1939). Rhynchobdellae have a small pore-like mouth on the oral sucker from which a proboscis may be protruded, no jaw is present, the blood is transparent (Gnathobdellae which feed on higher vertebrates have a large mouth with jaws and red blood). Differentiation even between Piscicolidae and Glossiphoniidae is not easy for the nonexpert:

Glossiphoniidae: The body at rest is depressed, not divided into distinct anterior and posterior regions; the head is usually much narrower than the body with an anterior sucker either indistinguishable or only slightly distinct from the body. There are usually 3 annuli per segment in the mid-body region and eyes are confined to the head.

Piscicolidae: The body at rest is cylindrical and (especially when contracted) usually divided at segment XIII into distinct anterior and posterior regions. The head sucker is usually distinctly marked off from the body which usually has more than three annuli per segment. Simple eyes may be present on the head, neck and posterior sucker (from Mann, 1962).

Experts would prefer leeches live, to be fixed to their own specifications. If fixed, it is best in 70% ethanol and preferably the leech should be relaxed first with menthol, ether, or by refrigeration, sometimes, if not too small, under glass slide pressure.

Life history and biology: Leeches, once engorged with the blood of the host, detach and rest on a protected substrate in the water (under stones or in plant debris) until their next meal. Reproduction takes place after several meals. *B. tricarinata* in tropical and subtropical waters breeds throughout the year (Oosthuizen, 1989). Glossiphoniidae exhibit parental care. The leeches produce a thin walled cocoon and immediately after deposition place their bodies over it and the hatching offspring attach themselves in a brood pouch which forms on the parent's ventral wall. They remain in the pouch until the first feeding stage when they are often brought to their first host by the parent. The entire life cycle may

last, depending on availability of hosts, from 24 days to several months. *B. tricarinata* feeds on fish, and if fish are unavailable will also feed on tadpoles and adult anurans (Oosthuizen, 1991).

Some glossiphoniids also feed on freshwater molluscs but, although *B. tricarinata* enters the mantles of molluscs, it does not feed on these hosts. *B. tricarinata* has been found feeding naturally and induced experimentally to feed on hosts of diverse fish families; *Clarias* spp., *Bagrus* spp., *Oreochromis* spp. *Barbus* spp. goldfish and *Protopterus aethiopicus* (Oosthuizen, 1991). However, populations of a given geographical region or a water system show preference for, or will exclusively occur on, one particular host, for example *Clarias lazera* in the Jordan system, Israel and *Bagrus docmac* in Lake Victoria.

Pathology and epizootiology: In Lake Victoria, 19% of all studied *Bagrus docmac* harboured leeches, with a mean of 26 per infected fish. Leeches were attached to the external perimeters of the mouth region and pathological changes were restricted to bite signs and mild tissue changes even in the most heavily infected individuals harbouring over 100 leeches. More severe damage was evident in piscicolid infection inside the mouth (mainly on the palate and the corners of the jaws) of grey mullets.

Infections occurred in several mullet species (in almost all examined *L. dummorelli* and *L. tricuspidata*, and occasionally also in *Liza richardsoni*, and *Mugil cephalus*) but only in mature fish (over 200 mm in length). The number of leeches per fish was variable and could reach up to 67. Lesions only partially corresponded to observed infection loads and developed in the mouth in the area with the highest predilection for leech attachment, i.e. in the anterior part of the mouth roof and the articulation zone of the lower and upper jaw. Damage to skin comprised of bite wounds, haemorrhages and erosion of the mucous membranes. In heavy infections leeches were also attached in the craters of the deeper lesions. In some heavy infections the gular membrane also became perforated.

Natural hyperinfection in an American catfish (*Ictalurus catus*) studies in USA, induced epithelial hyperplasia together with inflammatory changes and haemorrhages in the dermis (Paperna and Zwerner, 1974). Fish confined to ponds seem to be more vulnerable to leech attack. Heavy leech infection of eyes and nostrils of cultured carp, which resulted in mortalities, have been reported from Ghana (Ghana Ministry of Agriculture, 1965). An increase in *B. tricarinata* was noted in pond cultivated *Clarias lazera* in Israel, but fish were removed before leech populations reached high levels. In Iraq, *Hemiclepsis marginata* infection coincided with incidences of mortality in pond reared carp (Khalifa, 1985).

Leech attacks were reported from *Clarias* spp. and tilapia farmed in Southeast Asia. The leeches involved were unidentified local piscicolids or Glossiphoniids which induced pathology similar to that reported above (Kabata, 1985). Leeches are vectors of haemoprotozoans. *Piscicola geometra* was shown to transmit SVC virus to Carp (Ahne, 1985). Feeding wounds may become contaminated by opportunistic bacteria and fungi (Kabata, 1985).

Treatment: Species of *Piscicola* were eradicated from pond fish by application of 0.5 ppm Dipterex (Dylox) or 0.25-0.8 ppm (AI) Masoten (Neguvon). Analogous organophosphates such as Malathion are effective too. In higher temperatures the higher dose is recommended. Removal of leeches from fish was also achieved by a 15 min. flush treatment with 5 ppm CuCl_2 ; 0.5 ppm copper sulphate for 5-6 h or 25 ppt NaCl for 1 h (Prost, 1974; Kabata, 1985) [not effective for euryhaline leeches of grey mullets]. It was also recommended that ponds should be treated with unslaked lime (2500-3000 kg/ha) before stocking.

PARASITIC CRUSTACEAN

These include Ergasilidae and Lernaeidae.

Ergasilidae (copepoda): Freshwater and euryhaline fish of many families. Common in fish of all major African water systems (Fryer, 1968a). Several species occur in cichlids, in siluriforms and also in brackish waters (*E. latus* in *Sarotherodon melanotheron heudelotii* in Ghana). *Lates* spp. (Nile perches) in both West African water bodies and in some of the East African Great Lakes is infected by *Ergasilus kandti* (Fryer, 1968a; Paperna, 1969; Thurston, 1970). All freshwater species are endemic to Africa (Fryer, 1968a) the euryhaline *E. lizae* is widespread in the Atlantic and Mediterranean coastal regions (Roberts, 1970) and has also become established in freshwater ponds (in grey mullets, tilapia and carp) in Israel (Paperna and Lahav, 1971).

Description, taxonomy and diagnosis: Only subadult and adult females occur of fish, mostly on the gills, a few of the genus *Paraergasilus*, may attach to sites other than gills. The cephalothorax constitutes half or more of body length, the first of four thoracopods occurs at about mid-length. Segmentation of the thorax (except the first segment, fused with the head) and of the abdomen is distinct. The second antenna terminal segment is hook-like in *Ergasilus* and three clawed in *Paraergasilus*. Eggs are clustered in a bunch rather than arranged in a single line (in caligoids). For detailed morphological examination, parasites fixed in formalin or alcohol, should be treated by a clearing agent (- by graded transfer into lactic acid or glycerin, or digested in sodium hydroxide).

Life cycle and biology: In Ergasilidae only the female is parasitic, and is found on the gills of fish. Males are free-living and there is a prolonged, free-living larval development which includes three to six stages of nauplii and four to six stages of copepodites (lasting from 10 days to over a month). These free-living stages feed on nanoplankton. Females attached to gills produce eggs in two sacs which are attached to the genital segment. The number of eggs (20-100) is variable with species and apparently also with age and metabolic health as influenced by the location of attachment on the gills.

The time required for hatching is temperature dependent, 3-6 days in optimal ambient temperature. High subtropical summer temperatures, coupled with depletion of dissolved oxygen and elevated salinities in lagoon habitats, was shown to be detrimental to both developing eggs and the free living stages of *E. lizae* (syn. *E. nanus*). It has been established that elevated salinity delayed larval development from 10 days at 15 ppt to 27 days at 26 ppt. Biological data on ergasilids infecting fish of African tropical freshwaters are lacking.

Pathology: Ergasilids attached to gill filaments produce small foci of erosion; apparently feeding involves excretion of proteolytic enzymes for external digestion. Such erosion processes occur in *E. megacheir* infections in cichlids (Fryer, 1968a) and *E. lizae* infections in grey mullets. Erosion and degradation processes may extend beyond the epithelial lining, resulting in obstructed branchial blood vessels. Irritation often results in responsive hyperplasia of the epithelium, which, as infection is prolonged, may extend over large areas of the gills, causing fusion and embedding of lamellae, with a resulting decrease in the respiratory function of the gills (Kabata, 1970; Paperna and Zwerner, 1981).

The nature and magnitude of the pathological changes in the gills varies with host and ergasilid species. Infection by the more opportunistic species and under stressful conditions (adverse water conditions, deficient nutrition and overcrowding) is likely to induce severe clinical and pathological effects. Marked epithelial hyperplasia is stimulated in the gills of *L. albertianus* infected by *E. kandti*, in a variety of fish infected with *E. cunningtoni* (Fryer, 1968a) and in tilapia infected with *E. lizae*. Pond reared (70-80 g) *M. cephalus* infested with 100-200 copepods and those of 250 g infested by 1500-2000 copepods were severely emaciated. Losses at harvest reached 50% compared with 10% in uninfested ponds (Yashuv, 1972; Paperna and Overstreet, 1981). Emaciation was also observed in wild caught *E. lizae* infected *L. ramada*.

Epizootiology: Ergasilids vary in their level of host specificity, some are specific at least to their host genus (notably ergasilids infecting Cichlidae). Others, are less specific in their choice of hosts or are even opportunistic

(*E. cunningtoni* has been recorded from fish belonging to seven families, Fryer, 1968a). However, the least specific and even the opportunistic species (*E. lizae*, *E. kandti*, *E. cunningtoni*, *E. sarsi*, *Paraergasilus lagoonaris* (Fryer, 1968a; Paperna, 1969; Lahav and Sarig, 1968) still demonstrate, some predilection for a particular host, while the occurrence in other (not phylogenetically related) fish is either sporadic or linked to particular environmental or stressing circumstances.

In African lakes and rivers, infections with ergasilids are usually moderate. In habitats such as regressing pools in river beds at the dry seasons, confined fish may become heavily infected, for example, juvenile *Clarias lazera* found infected with about 100 *E. sarsi* in a pool in the upper reaches of the Volta River (Paperna, 1969). Heavy infestation with *E. lizae* (reported as *E. nanus*) has been reported to occur annually in *Mugil cephalus* congregating in the euryhaline L. Ischkeul in northern Tunisia, but other species of grey mullets in this lake were considerably less infected. Peak infestation in *M. cephalus*, in 100% of fish with up to 2000 copepods per fish, occurred in spring when water temperatures were moderately elevated (to 21°C) and while the salinity was declining (to 4 ppt). By mid-summer, when water temperatures are reaching 27°C and salinities are raised to 14 ppt, infestation sharply declines.

Individual *L. albertianus* in Lake Albert were found to be infected with 352-1926 *E. kandti*. It has been suggested that these heavy infections serve as a contributing factor in mass mortalities of this fish occurring at times in the lake. It is also noteworthy that this *Ergasilus* was absent from *L. albertianus* introduced from L. Albert into the Victoria Nile, L. Kyoga, and L. Victoria (Thurston, 1970). *E. kandti* infects *Lates* spp. of L. Tanganyika and has been found to infect *L. niloticus* in the man-made Lake Volta (Paperna, 1968). The fastidious, nutritive and environmental requirements of the free-living stages seem to limit distribution of ergasilids when their hosts are translocated. This is further emphasised by the fact that of the numerous species of *Ergasilus* (Kabata, 1985) and related copepod genera, very few ever become established in pond systems.

One of the few ergasilids which has adjusted well to fish ponds is *Ergasilus lizae* (syn. *E. fryeri*, Paperna, 1964b, "*E. seiboldi*" of Lahav and Sarig, 1968). It is also one of the few species whose free-living developmental stages could be demonstrated experimentally. Stocking fish ponds in Israel with *Liza ramada* caught in drainage canals resulted in the infestation of grey mullets (*Mugil cephalus* and *L. ramada*) farmed in the ponds. Heavy infections and mortalities occurred predominantly among *M. cephalus*. Thereafter, infection spread to further farms where tilapia hybrids also became infected and suffered heavy mortalities. Carp became moderately infected but with no clinical implications (Lahav and Sarig, 1968;

Sarig, 1971; Paperna and Lahav, 1971; Paperna and Overstreet, 1981).

Control: In Israeli fish farms, ergasilid infections were effectively treated through repeated bi-weekly applications of 0.125-0.150 ppm Bromex; the efficacy of each application is about 92%. Treatment of grey mullets is feasible only in ponds with water chlorinities above 400 ppm. At lower salinities recommended doses become toxic to the fish. This, however, does not apply to tilapia or carp which tolerate treatment in all ranges of salinities (with a safety index of 30). Other organophosphates - Neguvon (Dipterex, Masoten) or Malathion are effective at similar concentrations and may be used to treat mullets in freshwater too (Lahav and Sarig, 1968; Sarig, 1971).

LERNAEIDAE (COPEPODA)

Lernaea cyprinacea, an opportunistic species infecting fish of many families as well as amphibians (Yashuv, 1959), is widely distributed in Eurasia, North America and southern Africa mainly via translocations of edible and ornamental cyprinids (Hoffman, 1970). A lernaeid population found only on jaws of *Tilapia (Oreochromis)* spp. in L. Victoria (Fryer, 1961a) has been identified as *L. cyprinacea*. Other lernaeids of African fish are endemic, *L. barnimiana* may be found on both cyprinid and cichlid hosts, as well as on *Lates albertianus*, while all the rest restrict their host preferences to fish of the same families or genera. Fish of many diverse taxa are associated with either *Lernaea* spp. or representatives of allied genera; *Opistholernaea* (each species on a particular host genus - *O. longa* on *Lates*, *AfroLernaea* on *Mormyridae*, *Lernaeagiraffa* and *Dysphorus* on *Heterotis* - Fryer, 1968a).

Host preferences may differ in populations from different geographical regions; *L. hardingi* throughout Africa is associated with Cichlidae, in L. Bangweulu and L. Meru they principally infect *Chrisichthys mahusi* and also rarely *Synodontis nigromaculatus*. Alongside widely distributed species, there are species which are not only host specific but apparently also restricted to one lake; *L. bagri*, *L. tuberosa*, and *L. inflata* (Fryer, 1959, 1968a). The gill adapted lernaeids, *Lamproglena* and *Lamproglenoides* species from African fish are all endemic, each species occurring in representatives of different families: *L. monodi* (in cichlids), *L. hemprichii* (in the genus *Hydrocynus*, Characidae) and *L. clariae* (in *Clarias* spp.) are the most widely distributed (Fryer, 1968a).

Description, taxonomy and diagnosis: The rod-shaped, unsegmented, or partly segmented parasitic stage lernaeid female is anchored, with the aid of a specialised holdfast organ, to the host skin or buccal mucosa. Larval stages,

copepodites and copepod-shaped males are attached to the gills. Differentiation to lernaeid genera and to species in the genus *Lernaea* is based mainly on the morphology of the holdfast organ (anchors) of the parasitic females. The growth and branching of the latter, however, is greatly affected by the consistency of the tissue into which the holdfast organ is anchored. Infrageneric taxonomy may often be controversial, as intraspecific variations often overwhelm interspecific differences in the holdfast organ structure (Fryer, 1961a).

Differentiation to genera is as follows:

- Lernaea:** head with 2-3 (rarely 4) pointed or swollen horns, the trunk may thicken gradually towards its posterior end.
- Lernaeagiraffa:** head horns are soft, short and rounded; "neck" elongated; posterior part of the body (trunk) abruptly thickened and flattened dorso-ventrally.
- Opistholernaea:** head with 4 horns, with 2 posterior horns directed symmetrically backward to form a 90 degree angle. A lateral outgrowth extends from the "neck" region; it may be, however, located in very close proximity to the head to become functionally part of the anchor complex.
- Afrolernaea:** head with anterior short protruberences; the neck is very long and the trunk abruptly thickening.
- Dysphorus:** head horns are dendritic; the neck has branched appendages.
- Lamproglena and Lamproglenoides:** attach to gills; parasitic females retain copepodid features; segmentation, and large mouth parts, with cephalothorax always less than half total length, second antenna small and weak, maxilipeds with terminal claws, thoracopods present, but sometimes fewer than 4 pairs. Copepodites and males are reminiscent to those of *Lernaea*.

Copepodites of lernaeids attached to gills are readily differentiated from ergasilid parasitic females in lacking the hook (spine) type terminal segment of the second antenna.

Life cycle and biology: Parasitic females of *L. barnimiana* of L. George produce egg sacs containing 75-205 eggs. At 21-25°C, hatching occurs after 2 days. Hatched nauplii moult into second stage nauplii within 19 h, and further moult to the third stage nauplii

(metanauplius) within 42 h after hatching. Free, infective copepodite stages appear 97 hours after hatching. The latter survive up to 4 days in the absence of host fish. Copepodites preferentially attach to fish gills and, less readily, to the walls of the buccal cavity or the skin. Copepodites undergo four successive moults, while increasing in size from 0.3-0.4 to 0.6-0.8 mm. In fifth stage copepodites sexual dimorphism becomes apparent, with females being larger than males (0.8-0.9 vs 0.7-0.85 mm).

At this stage, 13-16 days after hatching, copepodites abandon their attachment to their host, and either leave in search of a new host or relocate themselves on the same host. In their new attachment sites in the skin, fins or buccal cavity, of new or the same hosts, copepodites moult into their last copepodite stage (male and female cyclopoid stages). Fertilisation occurs in the fifth copepodite or the cyclopoid stage. By the termination of larval development, 15-18 days after hatching, males gradually disappear and females continue their transformation into adults through elongation of the body, loss of external segmentation, degeneration of legs and the development of a holdfast organ. Early juvenile females first appear 19 days after hatching; the first egg sac in the mature female was observed 23 days after hatching. Egg sacs were produced at three day intervals. Females survived up to 9 days after first oviposition and 32 days after hatching yielded about 3 pairs of eggs sacs with a total progeny of 800-1200 eggs (Thurston, 1969).

The time required for larval development of *L. cyprinacea*, infecting fish outside the tropical regions, is temperature dependent. At ambient temperatures of 20-25°C, the rate of development of *L. cyprinacea* was slightly faster than that of *L. barnimiana*. At 25°C, hatching occurred after 36 hours, the first copepodites appeared 3-5 days later, early females appeared 13-17 days after hatching and the first egg sacs 18-22 days after hatching. Egg sacs contained 60-200 eggs, and females survived 7-10 days after the appearance of the first egg sac. At 27-30°C the first females appeared 9-12 days after hatching and adult females survived 8 days. Temperatures of 30°C seem to be the upper limit for optimal development; egg development seems to be affected as levels of dissolved oxygen decline. Lower temperatures did not affect egg production, but prolonged larval development; early adult females at 12-16°C appeared 60 days after hatching. The life span of females at these temperatures was, however, extended to 2-3 months (Yashuv, 1959; Lahav and Sarig, 1964). At ambient temperatures of 12-19°C, during the winter season outside the tropics, only three or less generations are produced, as compared with seven or eight generations in similar lengths of time during the Mediterranean summer or in tropical waters.

Yashuv (1959) noted considerable variability in the development time of the various stages as well as in the

life span of the anchored female. In addition to aquatic conditions, variations were related to the nature of the interaction between parasite and host. Repeated or prolonged infestation stimulated an accelerated host inflammatory response and ulceration around anchored females, which hastened their evacuation in being denied firm attachment and nutrition. Such processes have been suggested to be linked with activation of non-specific or specific defence mechanisms (Shields and Goode, 1978).

In the East African lakes, different fish species serve as preferential hosts for copepodites and adult *Lernaea*. Copepodites of *L. cyprinacea*, infecting cichlid fish in L. Victoria at the adult female-stage, develop in *Bagrus docmac*. *B. docmac* of L. George and *B. bayad* of L. Albert host copepodites of *L. barnimiana*, whose adult female stages attach to *Barbus altianalis*, cichlids and *Lates albertianus* (Thurston, 1969, 1970). Copepodites, however, are opportunistic in their host preferences and in the absence of preferential hosts (in ponds and experimentally), both larval development and female stage infection will take place in the same individual or conspecific hosts.

Other species and populations of *Lernaea* also seem to be less fastidious in their choice of hosts for larval development than for their adult stages. Adult females of *L. cyprinacea* in L. Kinneret preferentially infect cyprinid fish, while copepodites may also be found on cichlid fish (Paperna, 1964b). The life history of *Lamproglena* and *Lamproglenoides* follows the same pattern as other lernaeids, with at least two stages of copepodites attached to gills. Males are lost after fertilisation. *Lamproglenids* appear to develop and mature on the same host species.

Pathology: Both copepodites infecting gills, and females infecting any site on the fish integument, may harm the fish. Heavy infection of gills by copepodites of *L. barnimiana* or *L. cyprinacea* causes damage to the tissue which is in immediate contact with the parasite and stimulates extensive hyperplasia of the entire gill epithelium. Copepodite infections are potentially lethal to small fish, while large fish (such as *Bagrus*) will tolerate extremely heavy gill infections (over 1000 per fish). The attachment of the adult females to the integument stimulates an intense inflammatory response. The tissue around the anchor turns into a granuloma or necrotic lesion, and is later transformed into a fibrotic encapsulation (Kabata, 1970, 1985). A large proportion of the body of *Opistholernaea laterobranchialis* is embedded in the host tissue; in L. Bangweulu it is always found in the mouth of its host, while it is anchored within fibrous growth in or near the eye socket (Fryer, 1968a). Economic losses due to infection not only results from direct harm to the fish, but also from disfigurement which renders both fish grown for food and ornamental fish unsuitable for sale.

Pathogenicity of lernaeids largely depends on their host size and their attachment site preferences. Infection by a single or 2-3 females is very damaging or even deadly to young or small fish (<40 mm long). Parasites may anchor in the liver, the intestine or the brain (Paperna and Thurston, 1968). In the sardine-like *Engraulicypris (Rastrineobola)*, even one specimen of *L. tuberosa* or *L. inflata* was a serious encumbrance (Fryer, 1968a). The ubiquitous skin lernaeids, such as *L. cyprinacea* and *L. hardingi* and some populations of *L. barnimiana*, cause severe damage only in heavy infections.

Lernaeid species with narrower host ranges seem also to be more selective in their attachment site preferences (Harding, 1950). Species preferentially aggregating in particular sites induce severe local damage, often with adverse consequences to the host's function and survival. Aggregated infections of the mouth and lips occur in *Barbus altianalis* with *L. barnimiana* in the Victoria Nile, and in cichlids by *L. cf. cyprinacea* in Lake Victoria. Strong currents in the Victoria Nile enable copepodites to settle only in the buccal cavity in *B. altianalis*. Lip and mouth infection in other East African lakes occurs in *B. meridionalis* with *L. bagri* and in cichlids with *L. tilapiae*, *L. palati* and *Opistholernaea laterobranchialis*. In mouth breeding cichlids, mouth and gill infection impairs breeding (Fryer, 1968a, b; Fryer and Lles, 1972). Fin infections are caused by *L. lophiara* in cichlids, and *Afrolernaea longicollis* infects gills of mormyrid fish (Fryer, 1968a, b). In Southeast Asia *L. polymorpha* aggregating around the eye in bighead (*Aristichthys nobilis*) cause destruction of the lens and blindness (Shariff, 1981). Gill infections of *Lamproglena monodi* cause some localised hyperplasia of the epithelial tissue, while other gill infections by *L. clariae* and *L. intercedens* cause intense epithelial proliferation which may seriously interfere with respiration.

Epizootiology: The prevalence of natural infections even in large water bodies such as lakes reached 94% in *Mormyrus longirostris* infected by *Afrolernaea longicollis* and 56% in *B. meridionalis* infected with *L. bagri*. *L. albertianus* was frequently (50%) infected with *L. barnimiana* in L. Albert but free of such infection in lakes Kyoga and Victoria. Heavy infections of *L. barnimiana* were also frequent in *B. altianalis* in the Victoria Nile (up to 106 per fish). Nevertheless, in most fish populations infection was overdispersed, with few individuals attracting larger numbers of parasites (66 *L. cyprinacea* in the buccal cavity of *O. variabilis*, from *L. victoria*; 55 *L. bagri* in *B. meridionalis* in *L. malawi*) (Fryer, 1968a).

Secluded habitats such as small dams and fish ponds accelerate risks of infestation. In Ghana, *L. hardingi* occurs frequently in *O. niloticus*, *Sarotherodon galilaeus*, *Sarotherodon melanotheron heudelotii* and *T. zillii*

stocked in dam reservoirs and ponds. Infection is usually low to moderate (up to 28% in some habitats). At times, however, in some dams infestation becomes extremely severe (Paperna, 1969). *L. cyprinacea* introduced into southern Africa (reported as *Lernaea* sp.) is sometimes found in large numbers on carp in dams and rivers and on native *Barbus* and *Labeo* co-existing with native lernaeid species (*L. barbicola* and *L. barnimiana*).

Heavy infections are not infrequent in Israeli fish farms, mainly in carp, they are less frequent in Asian carps and occur rarely in cichlids. There are also some records of epizootic infection in grey mullet grown in freshwater ponds (Yashuv, 1959; Sarig, 1971). Infection with adult *L. cyprinacea* is also common in native cyprinid fishes and *Gambusia affinis* from natural habitats, while being absent from cichlids and *Clarias lazera*; copepodites occur also in cichlids (Paperna, 1964a). Infections of *L. cyprinacea* were reported from *Oreochromis mossambicus* and *O. niloticus* introduced to culture in Southeast Asia (Kabata, 1985). *L. lophiara*, parasitic on Central African cichlids has been identified in Thailand from *O. mossambicus* and various other indigenous and exotic fishes (Kabata, 1985).

Control: Parasitic females of lernauids are tolerant to organophosphate and organohalogen insecticides. A dip in potassium permanganate (KMnO₄) - 20-25 ppm for 2-3 hours or application of 8 ppm concentration to ponds effectively kills attached female lernauids. Treatment should be cautiously applied, preferably by experienced personnel, as effective concentrations are too close to toxic levels (safety index 1.7-2.0). Suitable only for fish over 25 g and tolerance will vary with species (Sarig, 1971; Kabata, 1985). Recently the insecticide Dimilin (R) (Philips-Dupar, Netherlands product) was found effective against adult females at concentrations of 0.03-0.05 ppm. This insecticide has not been cleared for use with food fish and its degradation in the environment is slow so that contaminated waters should not be released until at least 30 days after treatment.

An alternative strategy is treatment directed to suppress lernaeid infection through eradication of copepodite stages by repeated treatments of ponds with Dipterex (0.25 ppm) and Bromex (0.12 ppm). Treatments are repeated to coincide with the duration of larval metamorphosis from early copepodite to adult stage, which is temperature dependent. Recommended time intervals for treatment of *L. cyprinacea* copepodites are: 12 days at 20°C, 9 days at 25°C, 7 days at 30°C, 5 days at 35°C. Below 20°C one monthly treatment will be sufficient.

Other parasitic copepods: *Paeonodes lagunaris* is known only from the buccal cavity of *Sarotherodon melanotheron*, from Sakumo lagoon in southern Ghana (Van Banning, 1974; Pauly, 1974). *Mugilicola smithae*

occurs on *Anguilla mossambica*, in South Africa (Jones and Hine, 1978). *Achtheres micropteri* has been introduced with its host *Micropterus salmoides* into South Africa (Fryer, 1968a). *Sciaenophilus pharaonis* (syn. *S. inopius*) was reported from *Labeo niloticus* and *L. forskalii* from the Nile in Egypt (Humes, 1957).

Description, taxonomy and diagnosis: The parasitic females (the only known stage) of the genera *Mugilicola* and *Paeonodes* are Therodamasidae (Poecilostomatoida, the same suborder as Ergasilidae), and characterised by a small head, embedded in the host integument (both from the roof of the mouth), an unsegmented long neck and trunk bearing paired legs, and a minute abdomen. Eggs are arranged in bunches. *Paeonodes* has four pairs of thoracic legs, while *Mugilicola* has three. The head in *Mugilicola* is large, while in *Paeonodes* only the clawed second antenna is readily distinguishable.

Achtheres micropteri is a lernaepodid copepod. Females are permanently attached to the inner surface of their host gill arches by a specially modified leg, the first maxilliped. Segmentation and thoracic legs disappear in the mature stages. Egg sacs are claviform, in a bunch. Males are dwarfed and attached to females. *Sciaenophilus pharaonis* is a gill adapted caligiid, with the flattened cup shaped head reduced and enlarged and elongated thoracic and abdominal segments.

Life cycle and biology: The life histories of *Paeonodes lagunaris* and *Mugilicola smithae*, are unknown but are apparently reminiscent to that of ergasilids. In *Achtheres*, larvae hatch into a free swimming first copepodite stage, at the second copepodite stage they attach to fish by an attachment filament and develop into adults. After mating, males cling to females (Hoffman, 1967). The life history of *Sciaenophilus pharaonis* is unknown, but should be the same as other caligiids, e.g. copepodites hatch from eggs, attach to gills and develop into chalimi stages attached to the gill tissue by a specially formed filament. The chalimi undergo several moults until they transform into adult males and females.

Pathology and epizootiology: All these copepods seem to have little damaging effect on their host fish at the infection levels observed (all were natural infections). *Paeonodes*, *Mugilicola* and *Sciaenophilus* are marine copepods adapted to brackish water habitats, or carried with their host into inland waters (*Sciaenophilus*). *P. lagunaris* infection on *S. melanotheron* is highest (100%, mean 5.3 per fish) during the heavy rainy season when salinity (and temperature) of the lagoon water is low (<10 to 20 ppt; <26°C), and declines (up to 17%, with mean of 1 per fish) as salinities and temperatures are elevated (30 to 45 ppt, 27-8°C) (Pauly, 1974). Infestation of *M. smithae* occurs in elvers (in 0.6-3%) of the southeastern Cape rivers, and only very rarely in glass

eels (0-0.3%) (Jones and Hine, 1978). *Achtheres micropteri*, introduced with the black bass (*Micropterus salmoides*) remained confined to its exotic host (Fryer, 1968a).

ARGULIDAE (BRANCHIURA)

Twenty nine endemic species occur in Africa, in fish of diverse families. *Argulus africanus* and *Dolops ranarum* are opportunists and occur in diverse fish in all major systems of Africa. Allied species, *A. rhiphidiophorus* and *A. cunningtoni*, replace *A. africanus* in some East African lakes connected to the upper Nile, and co-exist in others, in part at least, due to later artificial introductions of fish. The remaining, including members of the genus *Chonopeltis*, are host specific with a restricted distribution to a single water system or to a lake. The largest number of species was reported from the Congo basin followed by that of L. Tanganyika. In West Africa few species, mainly the ubiquitous, occur (Fryer, 1968a). In South African fish, in addition to a few locally endemic species, *D. ranarum* is widespread as is the ubiquitous Eurasian species *A. japonicus* introduced apparently with carp (Kruger *et al.*, 1983; Van As, 1986; Avenant-Oldewage, 1991). In Lake Kinneret, an endemic species *A. tristramellae* was found infecting the endemic cichlid genus *Tristramella* (Paperna, 1964b).

Description, taxonomy and diagnosis: Argulids (“fish lice”) are dorso-ventrally flattened and covered dorsally by a rounded or horseshoe shaped carapace. Ventrally positioned head appendages are developed for attachment, four thoracic segments each bear a pair of bifid swimming legs. The abdomen is comprised of a single bi-lobed unit which contains testes or a round seminal receptacle. Only one species of *Dolops* is present in Africa, it differs from *Argulus* in having the second maxilla armed with a hook rather than a sucker, characteristic of the latter.

Chonopeltis are usually the smallest; head appendages are feeble and rudimentary, the mouth tube found in the other argulids is absent, whereas the cup-like sucker of the second maxilla is distinctly developed. The carapace is reduced in size and width. Unlike the above argulids, which are active swimmers, *Chonopeltis* is not capable of swimming if removed from the host.

For species diagnosis of *Argulus* and *Chonopeltis* readers should refer to relevant publications (Fryer, 1956, 1959, 1961b, 1968a, 1977; Avenant-Oldewage, 1991).

Life cycle and biology: Species of *Argulus* and *Dolops ranarum* are parasitic throughout life, but leave the host to moult or to lay eggs, and during this process will also change hosts. Both males and females may survive free living for as long as 15 days (Hoffman, 1977). *A. africanus*, *A. cunningtoni*, *A. rhiphidiophorus* and

D. ranarum have a preference for smooth-skinned fish (Siluriforms and lung fish), the same species may, however, infect buccal and opercular mucosal integuments of scaly fish, notably cichlids (Fryer, 1968a). These opportunistic argulids spread all over the body or the skin in smooth skinned hosts, (although in *Bagrus docmac* they preferentially settle on the head and near the mouth) while in scaled fish they occur only on the buccal and branchial cavity mucosa (Paperna, 1991). *Chonopeltis* are site specific and remain constantly on the host until departure for oviposition.

Eggs are deposited in masses on substrates in the water and may become covered by a gelatinous substance. Argulid species vary in the number of eggs they produce, in total (20-600) and per each batch (Fryer, 1968a; Hoffman, 1977). Egg strings laid by *A. japonicus* contained 5-226 eggs, and each female laid 1-9 strings. Newly hatched argulids either resemble modified nauplii (in *A. japonicus*), or more often, are already transformed to “juvenile adults” (in *A. africanus* and other spp. and in *D. ranarum*). In *Chonopeltis* the larvae are intermediate between nauplii-type and “juvenile adult” (Fryer, 1968a).

Dolops ranarum females deposit up to 566 eggs (Fryer, 1959); eggs are heavily yolked. Eggs develop to hatching 25-35 days at 24°C (Fryer, 1964). At 20°C, hatching occurs after 57 days (Avenant *et al.*, 1989a, b). Eggs do not hatch simultaneously; at 24°C, the time between hatching of the first and last egg is about 10 days. The annual cycle of *D. ranarum* in the tropical region is unknown, while outside the tropics, under a seasonal climatic regime (with winter temperatures declining below 14°C), *D. ranarum* has a one year life span which terminates in reproduction. Observations of seasonal occurrence in an impoundment near Pretoria in Transvaal (Avenant and Van As, 1986) showed that the highest infections occurred in its main hosts, *Oreochromis mossambicus* and *Clarias gariepinus*, by late summer and autumn (March to May) and the lowest by spring (October).

In these natural infections, individuals showed a progressive increase in total length from November (early summer) till August-September (late winter, early spring), when they reached maximum sizes, and 50% of the females, all exceeding 9 mm in length, were gravid. A departure from hosts for spawning is evident from the extreme decline of infection observed by October. After spawning females are apparently unable to relocate to new hosts. The smallest individuals found were 2 mm in length for males and 3.5 mm for females and while newly hatched juveniles were never found on these host fish, this could suggest that young stages utilize different hosts. Very small (1.45 mm long) individuals were revealed from the mouth folds of one *Oreochromis andersoni* (Avenant *et al.*, 1989a, b). Only brief data are available on other African argulids: duration of development of *A. africanus* eggs is longer than in *Dolops ranarum* (30-36

days at 22-24°C - Fryer, 1956) suggesting a longer generation time.

Egg development of the eurasian exotic *A. japonicus* is asynchronous as well as temperature dependent. Hatching started after 61-10 days within a temperature span of 15-35°C. There was some impairment of hatching success in temperatures above 30°C. When maintained at 25-27°C, eggs hatch after 10-20 days, parasites reach maturity 21 days later and the life cycle was completed in four to five weeks (Sarig, 1971). Adults can survive ambient water temperatures below 10°C, while oviposition ceases at temperatures below 16°C. Embryonic development is interrupted at 10°C and larval development is completely interrupted below 12°C (Bauer, 1959).

Finding gravid females at any time of the year suggests that, unlike *Dolops ranarum*, reproduction in *A. japonicus* in southern Africa, and evidently also in Israel, is continuous and not restricted to a particular season. Growth of the parasite population is, however, delayed in winter, when low temperatures slow down or even halt egg development to hatching. Another important factor in distribution of argulids is their tolerance to water quality, in particular dissolved oxygen. *D. ranarum*, the only branchiuran possessing haemoglobin, seems to be capable of withstanding low levels of dissolved oxygen and to survive on siluriforms and lungfish which enter eutrophic, deoxygenated habitats. *D. ranarum* seems to be capable of surviving on mud aestivating fish (Fryer, 1968a).

Pathology: Argulids infecting the skin or mouth of fish induce severe local damage to the integument. Damage is caused by the piercing proboscis stylet which enters deep into the skin's dermal layer and secretes lytic and toxic substances resulting in acute haemorrhagic, inflamed wounds. Attachment to and crawling on the skin also causes irritation and abrasions leading first to proliferation and later to desquamation and erosion of the epithelium. Damage is quickly alleviated where parasites can actively change attachment sites. When a shift of attachment site is slowed or prevented by overcrowding, in heavy infections, particularly with site specific parasite species, chronic inflammation develops, the infected surface of the integument ulcerates, the epithelium is destroyed and the dermis becomes exposed (Kabata, 1970, 1985; Paperna and Zwerner, 1976).

Histopathological changes include both proliferative changes in the epithelium and inflammatory changes; haemorrhages and infiltration, of either predominantly lymphocytes (in *A. japonicus* infections), or (in *D. ranarum* and *A. africanus* infections of *Bagrus docmac*) of eosinophiles. Persistent damage to the skin further leads to the depletion of mucous cells, to degeneration and disintegration of the epithelial layer, disruption of the basal membrane and distortion of the underlying sheets of

collagen of the dermis (Paperna and Zwerner, 1976). In *D. ranarum* infections there was a marked epithelial oedema (spongiosis), acantholysis (loss of adhesion between adjacent cells) and patchy cellular degeneration evident by karyolysis.

Persistent irritation caused in heavy infections may affect fish appetite with resulting anorexia, and cessation of growth (Kabata, 1985, 1970; Paperna, 1991). Induced wounds become secondarily contaminated by bacteria and fungi (*Saprolegnia*). *A. coregoni* infection of salmonids was followed by furunculosis caused by *Aeromonas salmonicida* (Shimura *et al.*, 1983). Another aspect of *Argulus* infection is their possible role as vectors of viral infections; spring viraemia of carp (SVC) has been transmitted via *A. foliaceus* (Ahne, 1985). In Israel, a decline in *A. japonicus* populations in fish farms during the past decade coincided with complete disappearance of papiloma (carp pox), once highly prevalent in farmed carp (Landsberg, 1989).

Epizootiology: *Dolops ranarum* is the only ubiquitous argulid potentially pathogenic to farmed fish. *Lates albertianus* of lakes Albert and Kyoga and of the Victoria Nile are infected with *D. ranarum* (Thurston, 1969). Particularly heavy natural infection (to over 30 per fish) has been noted in most fished *Bagrus docmac* (78%) landed in northern L. Victoria. Parasites were also often numerous on *Clarias gariepinus* and lungfish. The same fish were infected, though with smaller numbers, with *A. africanus* (41% of *B. docmac*). Mbahinzireki (1980) reports an average prevalence of 37% *D. ranarum* infection in *B. docmac* from the same waters, with a mean of six per fish. Infections were, as observed earlier, heavier (60-90% with up to 37 *D. ranarum*) in the larger market sized fish, and less abundant in the younger (less than 40 mm long) fish. In this survey *A. africanus* was reported to be rarely found.

A. africanus were as numerous as, or even outnumbered, *D. ranarum* in scaled fish, notably cichlids (in 55% of *T. esculenta* and in 29% of *T. variabilis*). In Lake Albert, *A. africanus* is absent and replaced with *A. cunningtoni* and *A. rhiphidiophorus* which heavily infect both smooth skinned siluriforms, scaled cichlids and *L. albertianus*. In other lakes, other species may produce massive infestations. In L. Tanganyika dead specimens of *Auchenoglanis occidentalis* were completely covered by *A. striatus* and *A. inciscus* (Fryer, 1968a).

In southern Africa *D. ranarum* occurs predominantly on two hosts, *C. gariepinus* and *O. mossambicus* (overall prevalence in surveyed impoundments in Transvaal, 24% of 793 and 26% of 2356 examined fish of the two species respectively). Infection is less frequent in *Eutropius depressirostris* and species of *Labeo* and *Barbus*. Natural infections are usually low (about six per fish) and only exceptionally high (up to 35, in *C. gariepinus*, in a dam where prevalence was as high as 88%). *A. japonicus*

introduced to southern Africa on carp and/or goldfish, is today an omnipresent parasite of both carp and native fish; species of *Barbus* and *Labeo*, *Clarias gariiepinus* and occasionally also cichlid fish. In some dams and lakes, prevalence of infection in cyprinids and in catfish can reach 93-100% and 78% respectively, with 10 to over 250 parasites per fish (Kruger *et al.*, 1983). Extremely heavy infections of *A. japonicus* occurred in winter on *C. gariiepinus* trapped in dams, restricted (and stressed?) by the low ambient temperatures (8-13°C) (Kruger *et al.*, 1983).

In Israel *A. japonicus* which in the past have been a serious pest of farmed carp, for several years has rarely been found on pond reared carp (Landsberg, 1989). However, it became a frequent parasite of fish in natural habitats, particularly of the Jordan system, and the population is also on the increase among pond reared ornamental carp and goldfish. In the ponds it occurred throughout the year, while its reproduction and abundance peaked in the summer months at ambient water temperatures of 20-28°C. It has been suggested that the decline in the population of this argulid in ponds has been due to successful eradication efforts with insecticides, taking into consideration the residual nature of Lindane (Paperna, 1991) (and in spite of the observed induced drug resistance, Lahav *et al.*, 1962). The reduction could also have been an outcome of intensification of stocking densities in ponds with a resulting acceleration of eutrophication and increase in nitrite waste levels (Landsberg, 1989).

Control: Both organohalogen and organophosphate insecticides effectively kill argulids with reliable safety margins to fish (safety indices of 12-20) (Sarig, 1971). Use of Lindane was abandoned because of its residual effects, risking humans and environmental safety as well as the resistance acquired by argulids following repeated treatments (Lahav *et al.*, 1962). Insecticides in current use are Malathion and Dipterex (Dylox, Masoten, Neguvon) applied to ponds at a dose of 0.25 ppm (safety index of 12 for carp and tilapia), or Bromex (Dibrom, Naled) at a dose of 0.12 ppm (safety index of 32) (Sarig, 1971). Pyrethrum extracts were tested with success, but were never introduced into routine use.

PARASITIC ISOPOD

Isopoda are parasites of marine fish and infections have been reported in euryhaline fish in estuaries. *Nerocila orbignyi*, a common parasite of marine and estuarine fish, including grey mullets was reported to infect *Sarotherodon galilaeus* in a Nile Delta lake. A few species of cymothoid isopods (*Lironeca* spp.) occur in African freshwater fish (apparently as marine relics) in the Congo basin and in *L. tanganyika* (in a cichlid, a clupeid

and a citharinid) (Fryer, 1965a, b, c, 1968a, b). Opportunistic euryhaline cymothoids of several families and genera infect farmed fish in Southeast Asia, including cultured tilapia (by *Aliotropus typus*, *A. egidae*) (Kabata, 1985).

Description, taxonomy and diagnosis: Isopoda are the largest crustaceans found on fish (20-50 mm long). The body consists of three regions, the head is unsegmented and bears two pairs of antennae, a pair of variable sized eyes and a mouth. The maxilliped covers all other mouth parts, a second region, the peraeon, of 7 segments, each with a pair of legs (peraeopods) and a six segmented pleon, with pairs of pleopods, except the last which together with biramous uropods form a swimming tail pleotelson. The rather uniform morphology makes identification, even to family and genera, difficult. A key and description of individual genera is provided by Kabata (1985).

Life cycle and biology: The 'cymothoid' isopods attach to fish early in life and pass through a male stage before becoming female. The presence of a mature female prevents male stage specimens from further development. Both males and females remain permanently attached to the fish. Egg and larval development takes place in a special brood-pouch on the females' ventrum. Another group, the 'gnathiid' isopods, is marine and only parasitic during the larval stage.

Pathology and epizootiology: Isopoda may be either highly host specific, opportunistic in their choice of hosts or facultative parasites, attaching to fish if they are weak or trapped in nets or cages. The host specific ones are the least harmful to their hosts. e.g. *Lironeca* spp. of African freshwater fish (Fryer, 1965a, b, c, 1968b). Even host specific species attached and causing degenerative changes in the tongue cartilage do not cause clinical harm to the fish (Kabata, 1970). With the opportunistic and facultative parasites, the degree of damage to fish varies with the site of attachment and ratio between the isopod and the host. Their *a priori* large size is likely to cause pressure damage and abrasions, if attached to fish skin, and even more so inside the gill chamber. Lesion to the integument causes hyperplasia, or desquamation and later on dermal inflammation and necrosis. Infection in the gill chamber often leads to mechanical damage to the lamellar structure (Paperna and Zwerner, 1976).

The parasite can also impede opercular respiratory movements (Kabata, 1985). The opportunistic *Nerocila orbignyi* is haematophage, and massive infection led to death of cage cultured *Dicentrarchus labrax*. There is a record of mortality of farmed milkfish (*Chanos chanos*) in the Philippines infested with *Aliotropus typus* (Kabata, 1985). Members of the genus *Ichthyoxenus* become enclosed in a pouch-like cavity in its host's (various

Southeast Asian cyprinids) body wall. The epithelial lining of the pouch wall undergoes degradation and large pouches could exert pressure on the viscera (Kabata, 1985).

Control: Not practiced. Organophosphate insecticides used for other piscine crustaceans are likely to be effective.

Other parasites of miscellaneous taxa: Parasitic mites (acarina) Larval stages of unidentified species, apparently belonging to Hydrachnellae (water mites), heavily infected the gills of *Synodontis membranaceus* in the Volta lake. Pentastomid (linguatulids or tongue worms) Larvae

Larval stages of the genus *Leiperia* were reported from tissues of fish of the genera *Alestes*, *Bathybates*, *Chrysichthys*, *Labeo* and *Mastacembalus* in the Congo basin (1961), and unidentified in *Sarotherodon galilaeus*, *S. heudelotii* and *Tilapia zillii* in a dam at Nungua, South Ghana (Prah, 1969). Larval stages in fish were also reported from tropical America. Recent studies regard Pentastomida as affiliated to arthropods (Riley, 1989). Crocodiles are the definitive hosts of the larval stages found in fish. Pentastomids settle in the lungs of their definitive hosts and eggs are released via the respiratory passages.

The larva, which hatches when ingested by a suitable host, enters the tissues. It has two double hooked appendages, a penetration spine at the anterior end of the cephalothorax and in some (in the neotropic *Subtriquetra*), a long strongly hooked tail. Experimental infections (with *Subtriquetra*) of small fish (30-50 mm) cause fish death even before larval development is completed (around 30-40 days after infection). Larger fish (*Aequidens* sp., 70 mm long) survived infections with seven, 2.5 mm long larvae, which were already infective (Riley, 1989).

Larvae of bivalve mollusks: Larval stages of freshwater bivalve molluscs of the superfamilies Unionoidea and Muteloidea are parasitic on fins and gills of fish. Mutelid bivalves are endemic to Africa, while unionids are distributed world-wide. Unionid larvae were reported from *L. victoria*, *L. george* in young cichlids and from *L. kinneret*, in Israel, also in juvenile or small cyprinids (Paperna, 1964a and Fryer, 1970). Mutelid larvae were found on *Barbus altianalis* and juvenile cichlids only in *L. victoria* (Fryer, 1970).

Description and diagnosis: The larvae of unionids, known as glochidia, have calcareous bivalved shells, often with little hooks on their inner edge. They clamp on to the gills and fins. The larvae of mutelids (haustorium larvae) differ distinctly from glochidia by having a non-calcareous pellicle and a very long tentacle. The larvae attach themselves to the fin and the gills, shed off the

tentacle, and envelop themselves completely in the non-calcareous pellicle. Then they proceed to thrust two prolongations into the host tissue which serve as an anchor and an organ for food absorption (Fryer, 1970).

Pathology and epizootiology: Intense epithelial hyperplasia develops in the gills around the attached glochidium, such proliferative reaction apparently also occurs in skin infections, but on the skin it is less conspicuous. Mortalities from heavy glochidial infections of the gills have been reported in farmed salmonids (Davis, 1953). Glochidial infections occurring in farmed fish in tropical regions (Southeast Asia), however, thus far, have not caused concern (Kabata, 1985). There are no records of infection in farmed fish in Africa and the Near East. Natural infections occur predominantly in small fish residing in shallow, inshore waters (young fish and littoral species). In Lake Victoria, infection was more prevalent in *Tilapia* and *Oreochromis* fry than in haplochromid cichlids. Fry 10-19 mm long were already infected and the highest incidence occurred in 20-50 mm long *O. variabilis* and *T. zillii* (50-75% in various samples).

The number of glochidia infecting single fish, however, never exceeded nine. Infection was less prevalent in the young cichlids of *L. george*. In *L. kinneret*, both cyprinids and cichlids hosted glochidia, with prevalence among the different species ranging from 1 to 33% (in *T. zillii*) (Paperna, 1964a). Host specificity of glochidia remains unresolved, since in all the habitats discussed several unionid species are present, while specific diagnosis of glochidia from these fish has never been attempted. Natural infections by Mutelid larvae are uncommon and unlikely therefore to be of any epizootiological significance.

CONCLUSION

The description, taxonomy, Pathology, epizootology, diagnosis, treatment and control of acanthocephala, leeches, parasite crustaceans and some other parasites of miscellaneous taxa infections in african fish will educate fish culturists, private and public sectors some challenges faced in culturist fisheries. The thorny headed worm, leeches, and parasitic crustaceans: Ergasilidae and Lernaecidae; other parasitic isopods: Argulidae and parasitic isopods; and other parasites of miscellaneous taxa: parasitic mites (Pentastomid larvae and larvae of bivalve mollusks) are essential for the management of African culture fisheries.

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