Bothriocephalus acheilognathi - Asian tapeworm

Scientific Classification

Kingdom: Animalia

Phylum: Platyhelminths

Class: Cestoda

Order: Pseudophyllidea

Family: Bothriocephalidae

Genus: *Bothriocephalus*

Species: ***B. acheilognathi***

Binomial name: ***Bothriocephalus acheilognathi*** Yamaguti, 1934

Synonyms:

- ✓ *Bothriocephalus opsariichthydis* Yamaguti, 1934
- ✓ *Bothriocephalus gowkongensis* Yeh, 1955

Disease: *Bothriocephalus acheilognathi* infection
Bothriocephaliasis

International Common Names: English - Asian fish tapeworm; Asian tapeworm

Risk and Impact Factors

Invasiveness

- Proved **invasive** outside its native range
- Has a **broad** native range
- **Abundant** in its native range
- Highly **adaptable** to different environments
- Is a habitat **generalist**
- **Fast growing**
- Has **high reproductive potential**

Impact outcomes

- Host **damage**
- Negatively impacts **animal health**
- Negatively impacts **livelihoods**
- Negatively impacts **aquaculture / fisheries**
- Threat to / loss of **endangered species**
- Threat to / loss of **native species**

Impact mechanisms

- ✓ **Parasitism**

Likelihood of Entry / Control

- Highly likely to be **transported** internationally accidentally
- Difficult to identify / detect as a commodity contaminant
- Difficult to identify / detect in the field

Overview

Bothriocephalus acheilognathi, also known as the **Asian tapeworm**, is a **freshwater fish parasite** that originated from China and Eastern Russia. It is a **generalized parasite** that affects a wide variety of **fish hosts**, particularly cyprinids, contributing to its overall success.

The Asian tapeworm is an **intestinal parasite** of an estimated 200 species of freshwater fish, but primarily cyprinid (carp) fish species. It is native to East Asia and is now present in all continents, except Antarctica, due to human activities.

Since the tapeworm's first description, it has been identified under **20 different specific epithets**, which was often the result of **morphological variability** and **sample fixation procedures** (the scolex and bothria are affected by how they are mounted on slides).

Recent studies have declared that **all *Bothriocephalus*** in cyrpinids **are the same species**. Three species can be confused with *B. acheilognathi* - *Eubothrium tulipai, E. rectangulum*, and *Bathybothrium rectangulum* have similar scolex (head), but have lateral rather than medial genital openings.

Introduction

The Asian Tapeworm *Bothriocephalus acheilognathi* Yamaguti 1934 (Cestoda: Bothriocephalidea), is the most important **pathogenic cestode of cyprinid fish**, which causes **bothriocephaliasis** and one of the most dangerous helminth parasites of cultured carp. The parasite has also been recorded in a range of other freshwater teleost fishes, prompting concern of the disease in wild fish populations. It is listed as a 'Pathogen of Regional Concern' by the US Fish and Wildlife Service (2010). *B. acheilognathi* has been reported under more than 20 different specific names and the most frequently used are *Bothriocephalus gowkongensis* Yeh 1955 and *Bothriocephalus opsariichthydis* Yamaguti 1934 . According to Pool and Chubb (1985) and Pool (1987), all descriptions of *Bothriocephalus* tapeworms from cyprinid hosts represent the same parasite, differing only in length and the shape of the scolex because different methods were used to fix the worm. *B. acheilognathi* is indigenous to East Asia, but has spread rapidly throughout the world with the trade of fish. The parasite has now been recorded from every continent excluding Antarctica. The ability to successfully colonize new geographical regions has been facilitated by its **simple, two-host life cycle** (involving common copepod species as an

intermediate host) and **euryxenous host specificity** (very wide range of suitable fish hosts). This has led to the transmission and establishment of *B. acheilognathi* to many new host species in areas where it has been introduced. Once established it may endanger native fish populations, including ecologically sensitive species and fishes that are phylogenetically unrelated to those in which it was introduced. *B. acheilognathi* can have pronounced detrimental effects on fish. These include severe damage to the intestinal tract, physiological disturbance, reduced growth, condition loss and death. Records of 100 % mortality in hatchery reared common carp (*Cyprinus carpio*) highlight the pathogenic potential of this parasite.

Identification

Mature *B. acheilognathi* have a **segmented body** with an **arrowhead or heart-shaped scolex**, with an undeveloped terminal disc. **Bothria** (slit-like openings) are located along the axis of the dorsal and ventral surfaces of the scolex. The **proglottids** (body segments) begin directly behind the scolex; therefore, it has no neck. The proglottids are much narrower than the scolex.

Often their presence is noted through an autopsy, examination of the faecal material, or for heavily infected fish, through a distended abdomen.

Description

B. acheilognathi has a **fleshy scolex** (head region) with an **undeveloped terminal disc** and **two long attachment grooves** called **bothria** positioned dorsoventrally. The scolex is distinctively shaped like an inverted heart or an arrowhead. Its ribbon-like body consists of flattened segments called proglottids. Asian Tapeworm **length varies with host**, the **ecological setting**, **age of infection**, and the **number of worms** but typically grows to a length of 3.5 to 8 cm (1.4 to 3.1 in) with widths of up to 4 mm (0.16 in), but exceedingly large specimens reaching 60 to 100 cm (2.0 to 3.3 ft) have been recorded. They are remarkable in their ability to adapt their sizes depending on the size of their hosts.

Size is a highly variable morphological parameter as it depends on: (i) Ecological conditions; (ii) Host size; (iii) Host species; (iv) Host age; and (v) Intensity of infection. Upon relaxation, parasites can also increase in length by a factor of 1.5–2. Consequently, parasite size is not a valid feature on which to base identification, despite earlier beliefs.

An important morphological characteristic of *B. acheilognathi* is its **heart-shaped scolex**, with a weakly developed apical disc and a pair of deep, slit-like grooves (bothria) positioned dorsoventrally along the scolex. The scolex is much wider than the first body segments (proglottides).

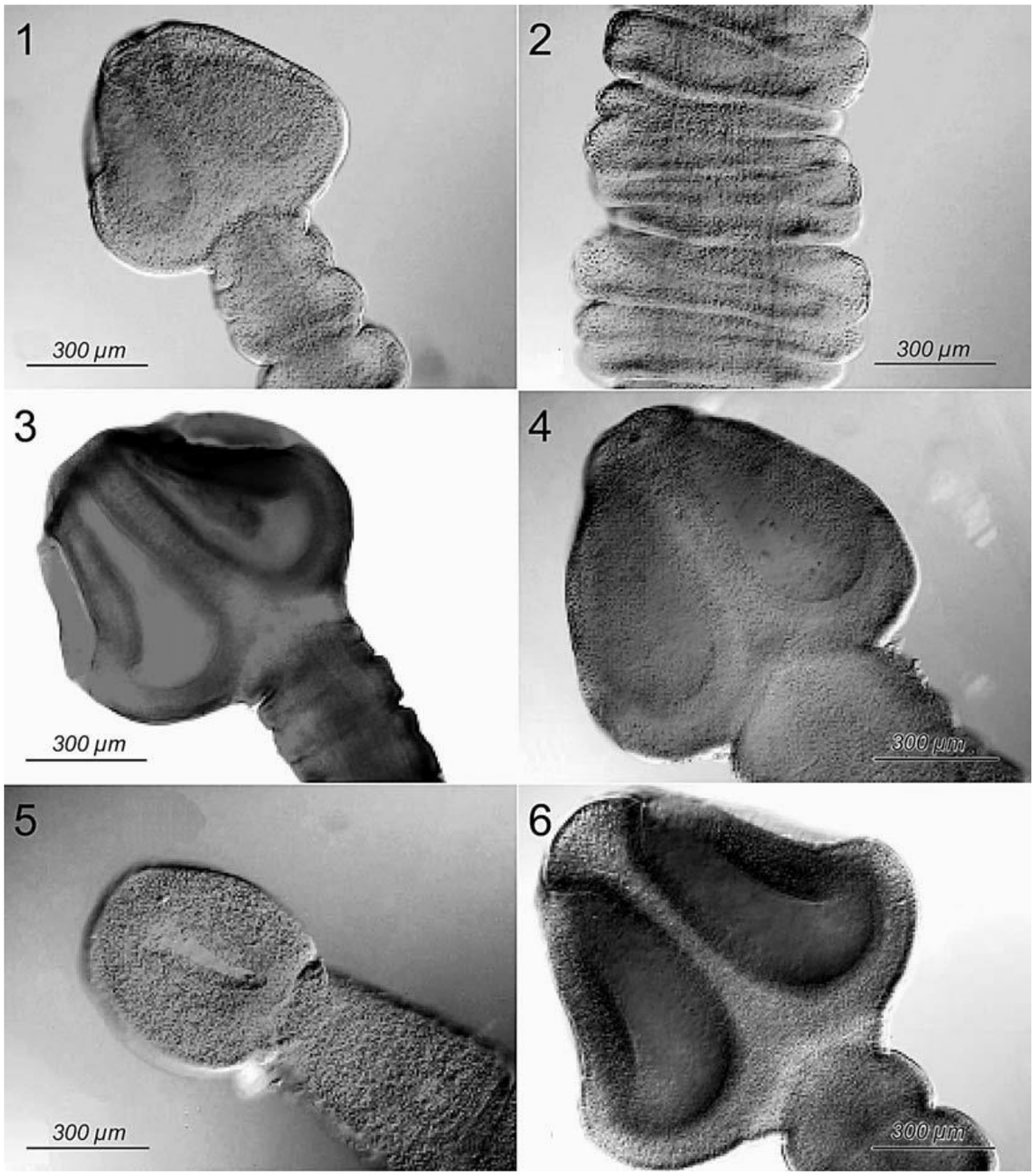
The **strobila** (body) of the tapeworm consists of numerous proglottides each containing **one set of reproductive organs**. The shape of these segments differs with maturity. Immature

segments lacking fully developed genital organs are always wider than they are long; whereas more developed gravid segments bearing eggs are rectangular and longer than they are wide. However, contraction and relaxation of the segments also causes extreme variation in the length and width ratio of the strobila.

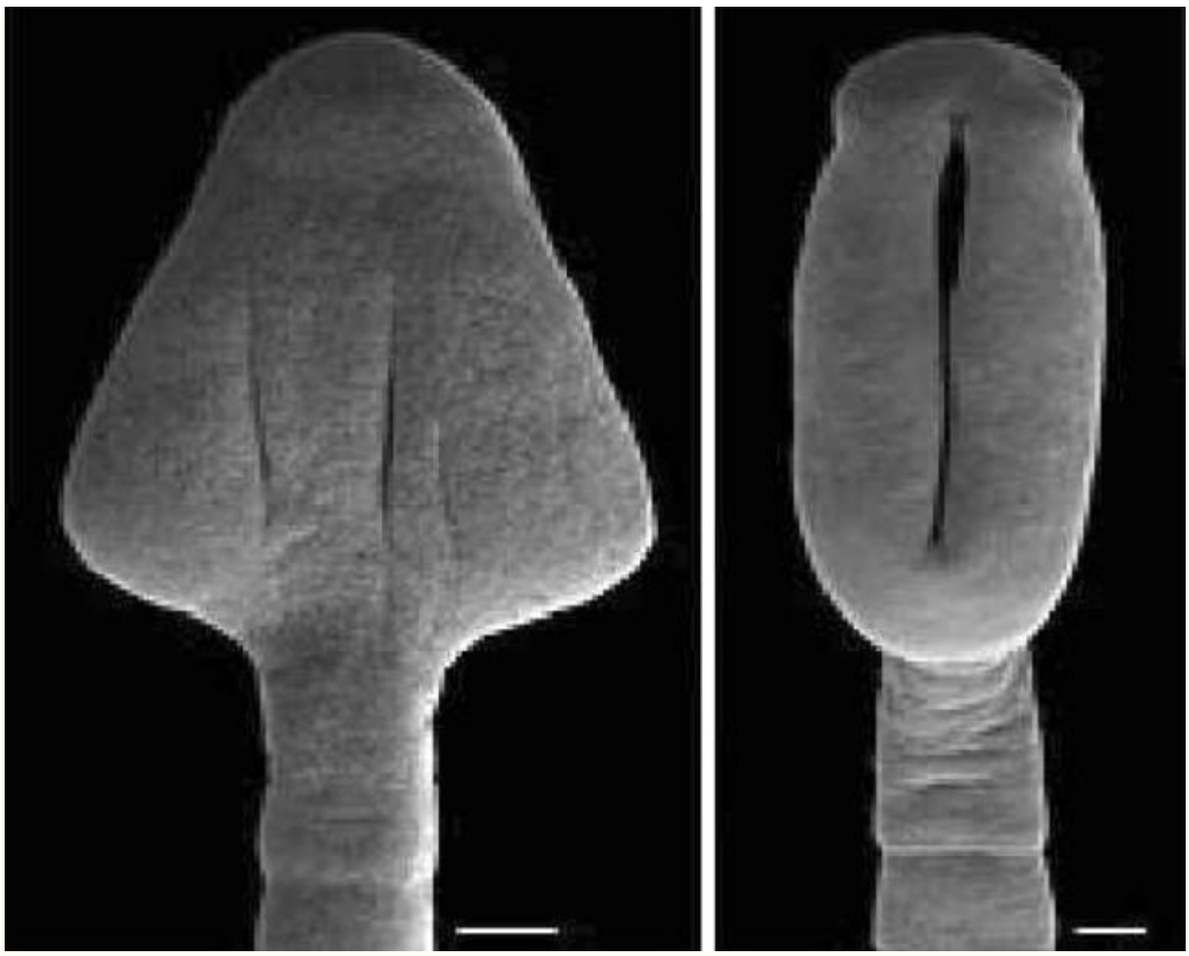
The **male reproductive system** is formed by numerous spherical testes situated in the medulla (the region internal to the inner longitudinal musculature). A muscular cirrus sac localized anterior to the ovary opens on the dorsal side of segments into a common genital atrium, which is situated alongside the median line of the body.

The **female reproductive system** is composed by a bilobed ovary situated near the posterior margin of each segment. The vagina, which is short and slightly sinuous, opens into the common genital atrium posterior to the male genital pore. Vitelline follicles are very numerous, circumcortical and confluent between segments. The uterus is saccular, spherical to oval, and opens on the ventral side in the anterior third of the segment. The eggs are thick-walled, operculate (*i.e.*, with a cap - the operculum) on a narrower pole, and usually unembryonated (without a formed embryo) when released into the water.

Morphology of Asian fish tapeworm (*Bothriocephalus acheilognathi*) showing scolex and proglottids (arrows)



Representative specimens of *Bothriocephalus acheilognathi*
1. Scolex; 2. Strobila; 3 to 6. Scolex



Scanning electron micrographs of the scolex of *Bothriocephalus acheilognathi* (*Bar* = 100 µm)

Taxonomy

Bothriocephalus acheilognathi has more than **twenty known synonyms**. It was originally described as three species, all of them from non-native populations. In 1934, the Japanese helminthologist Satyu Yamaguti first described specimens from wild fish recovered from Ogura Lake, Japan. He named them as two different species – *Bothriocephalus acheilognathi* and *Bothriocephalus opsariichthydis*. In 1955, the Chinese helminthologist Liang-Sheng Yeh described more specimens recovered from grass carp (*Ctenopharyngodon idella*) in South China as *Bothriocephalus gowkongensis*. These species were later recognized as synonyms by later authors, and Yamaguti's original name for the species was retained by the rules of precedence.

Distribution and habitat

The natural host of *Bothriocephalus acheilognathi* is the **grass carp** which is native to the Amur River in China and eastern Russia. But it has become widespread throughout the world by means of **introductions of the grass carp**. Even the type specimens were not native. It is now known to exist in Europe, Australia, Mexico, Panama, Honduras, the United States, Canada, and Puerto Rico. It can infect species of fish that belong to the families Cyprinidae, Poecilidae, Cichlidae and Centrarchidae.

Pathology

The parasite attaches near the **anterior portion of the intestine**, just posterior to the bile duct. An accumulation of tapeworms in this area leads to **digestive tract blockage** that distends the intestinal wall leading to **perforation**. When attached, *B. acheilognathi* envelopes parts of the intestines and induces an **inflammatory response**. The inflammation can lead to **hemorrhage and necrosis**. Clinical signs also include, **weight loss, anemia, and mortality** (especially in young fishes). Infections can be detected by the presence of eggs or body parts in faeces, and by the presence of the tapeworm in the gut of the fish.

Life cycle

The life cycle of *B. acheilognathi* involves a definitive host - a **fish**, and an intermediate host - a **copepod**.

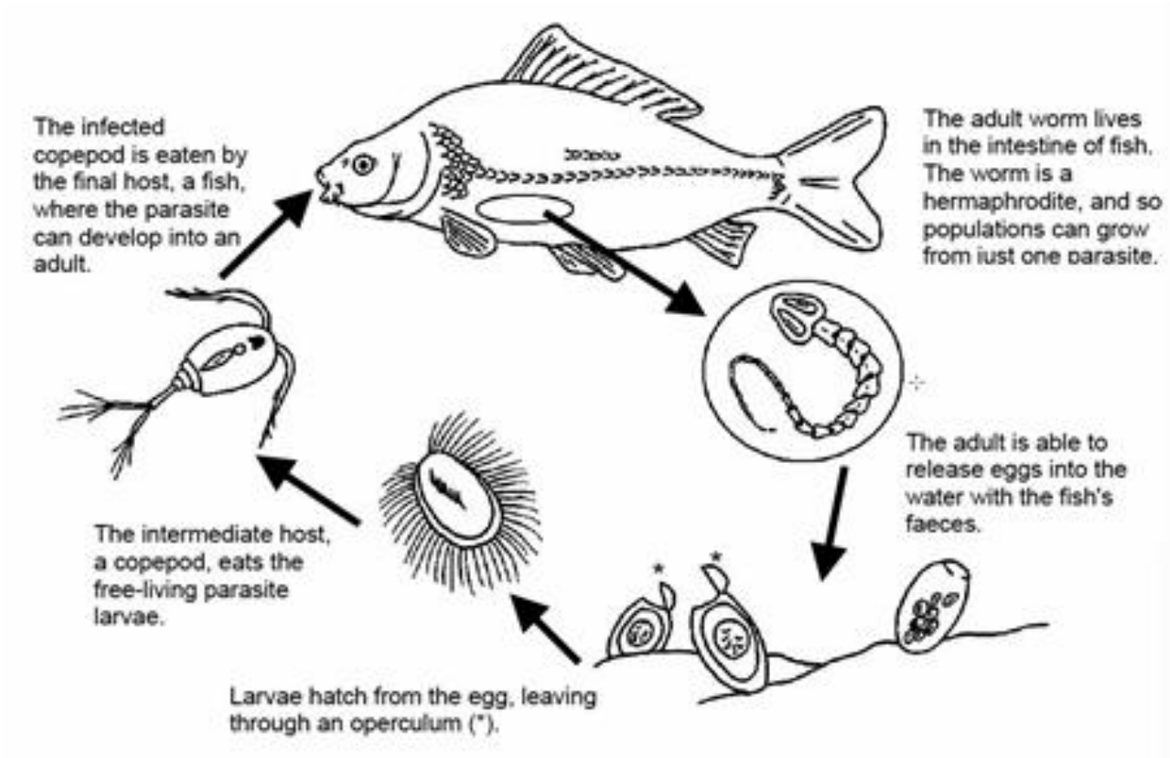
Adult *B. acheilognathi* are hermaphroditic, each proglottid having a complete set of male and female reproductive organs. Eggs are produced via self-fertilization and shed into the water with the host's faeces. The tapeworm is sensitive to temperature, in addition the species is thermophilic; lower temperatures interfere and delay development and completion of the life cycle. Hatching occurs in water temperatures of 12 to 37ºC and free-swimming **hexacanth** (six-hooked) larvae emerge. Hatching at 28-30ºC takes

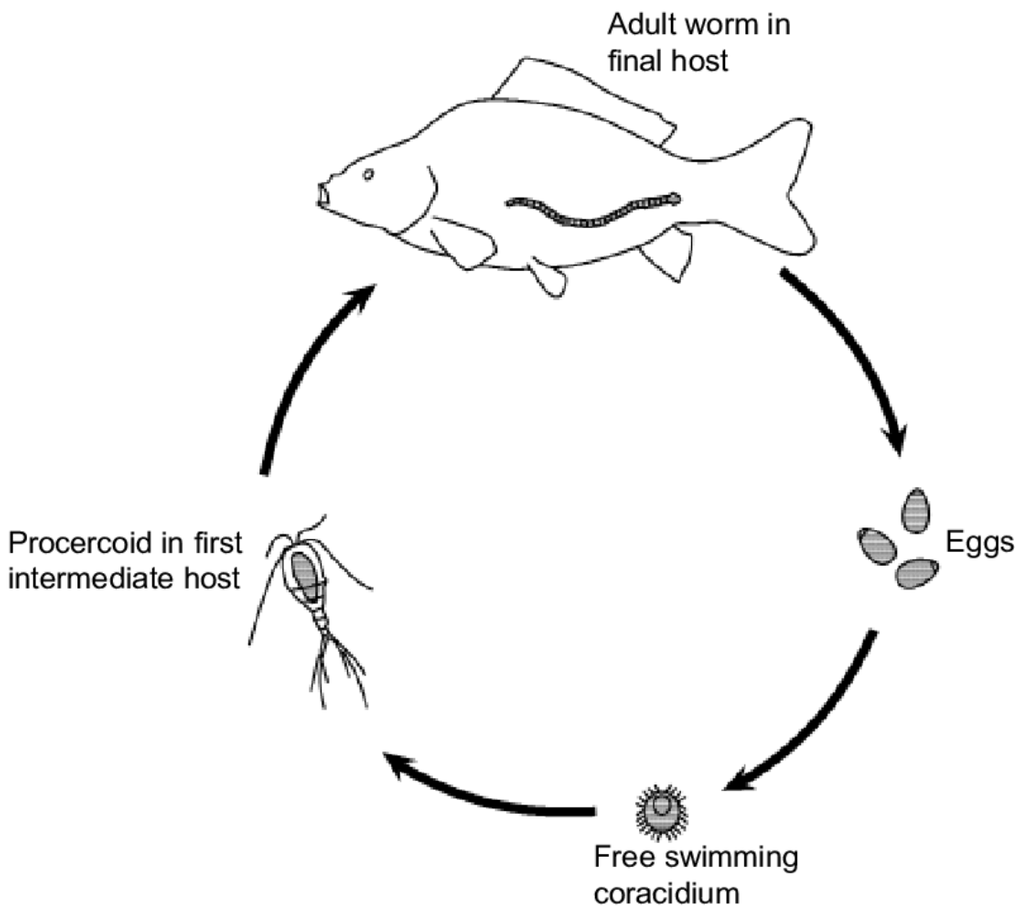
1-5 days and 10-28 days at 14-15ºC. The free-swimming larvae, **coracidia**, are consumed by **copepods** (intermediate host), it **penetrates into the gut wall**, **travels to the coelom**, and **develops into a second larval stage** called a **procercoid** (infective form) all within 6–10 days. This is also temperature dependent: 11 to 18 days at 29-31ºC and 49 days at 20ºC. Fish are normally infected by consuming the copepods, although predatory fish can also consume infected fish. Once in the fish's intestines the larvae mature into adult worms in 21-23 days at 28- 29ºC.

Movement of water containing tapeworm eggs or **infected copepods** can also disperse this parasite; however, it is primarily dispersed through infected fish. Introductions of common carp and grass carp are the most likely vectors for this parasite; however, the discovery of the Asian tapeworm often **lagged** the introduction of the host, in some cases, by **decades**. In 2000, *B. acheilognathi* was collected from fish in Kashmir. Fish eating birds, which consume infected fish can transport eggs, and spread them via defecation.

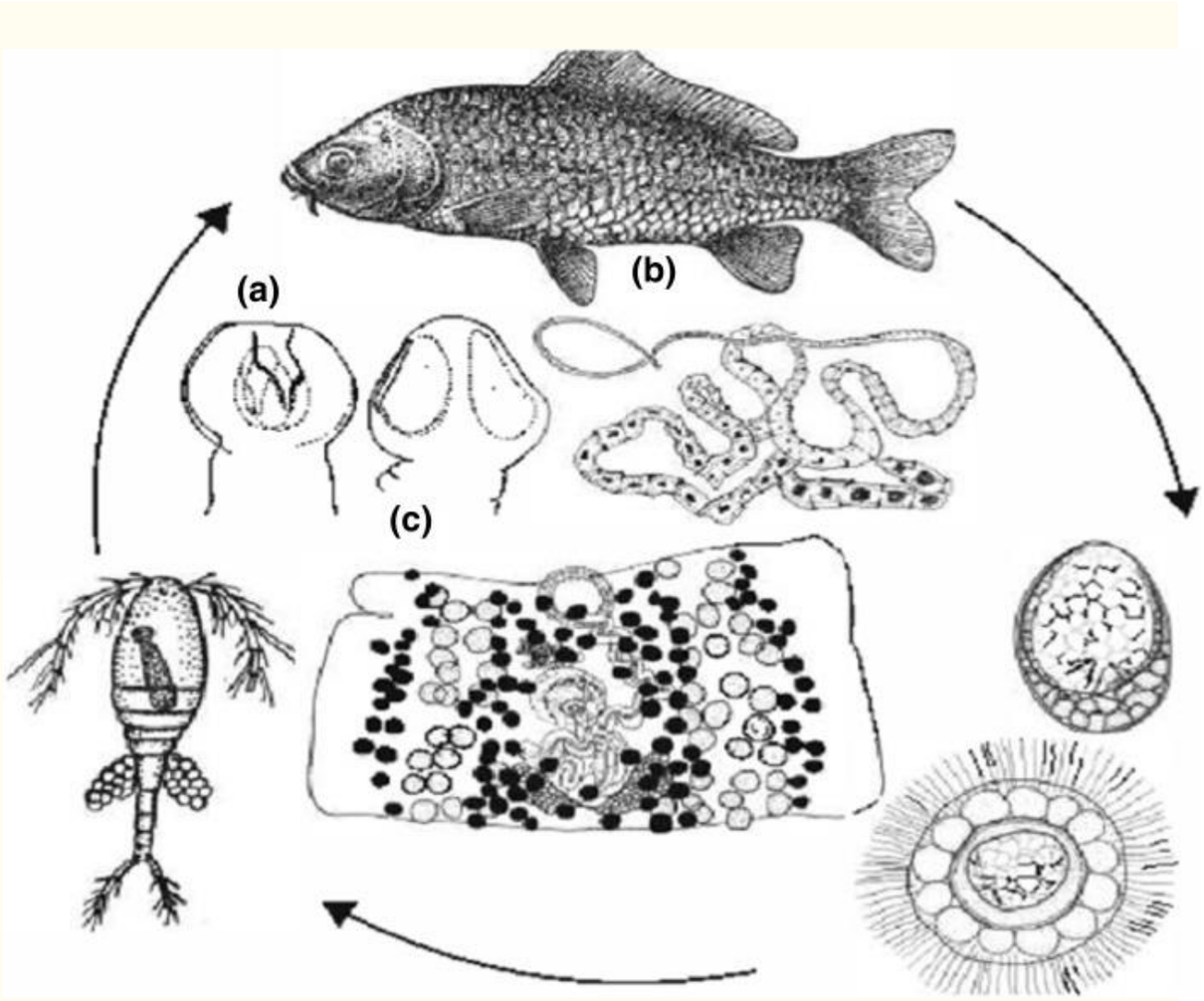
Definitive (fish) hosts

The most suitable hosts of *B. acheilognathi* are **cyprinids**, especially the **common carp** (*C. carpio*) and **grass carp** (*Ctenopharyngodon idella*). However, the parasite has been reported from approximately 200 species of freshwater fishes, representing ten orders and 19 families. Nevertheless, maturity of the worm may be reached in only a proportion of these fish species. Holmes (1979) identified three classes of host, in terms of their ability to allow the maturation of parasites: (i) '**required hosts**'; (ii) '**suitable hosts**'; and (iii) '**unsuitable hosts**'. In 'required hosts' parasites usually obtain full maturity. In 'suitable hosts' parasites may gain sexual maturity, but are only found in small numbers, while in 'unsuitable hosts' parasites may establish but do not reach maturity. Consequently, although a parasite may infect many fish species, the maintenance of the parasite population may rely on a much narrower range in which reproduction takes place. Small fish are more commonly and intensively infected with *B. acheilognathi* than large hosts. Brouder (1999) detailed a strong negative correlation between size of host and infection intensity of *B. acheilognathi.*





Life cycle of *Bothriocephalus acheilognathi*



Life cycle and Morphology of *Bothriocephalus acheilognathi*

a) Scolex, b) Total view (segmented body), c) Mature segments (proglottis)

Importance of the disease

B. acheilognathi is an important **pathogen in aquaculture** in Asia and Europe. Losses of juvenile fish, with up to 100 % mortality, occur in hatchery ponds. In commercial carp farms, fry (length 38 - 42 mm) can be infected 28 - 29 days after hatching. The susceptibility of fry is probably because copepods make up a large proportion of the diet of these fish, and the limited space within the intestinal tract to accommodate these large parasites. Heavy tapeworm burdens cause blockage of the intestine and severe pathological changes, leading to reduced growth, condition and survival. The tapeworm has also been the cause of disease problems in ornamental fish farms in Australia and Central Europe, involving *Poecilia reticulata* and *Xiphophorus maculates* and mortality of koi carp. Far less information exists on the impact of *B. acheilognathi* in wild fish populations. The introduction of this alien tapeworm to new localities can endanger native fish species. This

may be particularly serious in fish that attain only a small size at maturity, with potential for reduced recruitment, growth, fitness and survival. However, equilibrium between host and parasite can develop in a relatively short period, limiting disease impacts. It is recognized that identification and evaluation of the effects of parasites in wild fish populations is problematic, as sick fish are rapidly removed by predators, water flow and necrophages.

Juvenile common carp (*Cyprinus carpio*) with infection of *Bothriocephalus acheilognathi*

Ecological impact

Studies have shown that *B. acheilognathi* decreases the size of fish worldwide causing great economic loss in hatcheries and fish farms. The Asian tapeworm was introduced globally via grass carp. Infestation is intermittent and follows a clear seasonal pattern with peak incidence in the summer. There are multiple chemotherapeutic solutions to fight infection. Tinostat, Yomesan, Droncit are examples of drugs (when mixed in fish food with oil) that are effective in relieving infection. Eliminating an infestation can be amplified by control of copepods in water.

The discovery of the tapeworm's substantial infections within the crucian carp population is of particular concern because there have not been any known natural tapeworm parasites of these crucian carp. A plausible cause may be that the crucian carp have limited immunological defenses against this parasite.

Economic Impacts

Fish culture operations will face economic losses from fish mortalities, reduced fitness, disinfection of facilities, and the costs of treating fish. Any declines in native sport-fish populations due to tapeworm infection could have significant impacts on recreation and tourism.

Environmental Impacts

Infection by *B. acheilognathi* reduces a fish's ability to cope with reduced food availability and may lead to decreased fitness, growth, and temperature-dependent mortality, especially in juveniles. Infection also causes intestinal inflammation, protein depletion and alters digestive enzyme activity.

Sociological Impacts

Asian tapeworm infected fish are safe for human consumption provided thorough cooking, smoking or pickling. The transformation of native aquatic communities results in the intrinsic loss of natural capital and enjoyment of natural areas.

Prevention

B. acheilognathi can be spread by infected fish or contaminated water containing eggs or infected copepods. It can also be spread by infected baitfish. Dispose of fish guts, unused bait and other refuse parts in land fill bound garbage. Koi and goldfish are both cyprinids, and could be vectors for the Asian tapeworm. Never release fish or dump aquariums into natural waters. Thoroughly drain boat motors, bilge, transom, live wells, and bait buckets of any water that may harbour eggs or infected copepods.

Control

Prevention of spread is the only control method currently known for Asian tapeworm.

Conclusions

The Asian tapeworm is pathogenic to fresh-water fishes, especially young carp fry, and may cause great economic loss in hatcheries and fish farms. It has the ability to colonize new regions, and adapt to a wide spectrum of fish hosts. It represents one of the most impressive and deplorable examples of a parasite widely disseminated by man assisted movements of fish. The rate of dissemination and success of colonization has been aided by the cosmopolitan distribution of both intermediate and definitive hosts. However, the spread of *Bothriocephalus acheilognathi* to many parts of the world has also been the result of inadequate legislative controls, poor preventative measures and lack of appropriate health-checking procedures prior to fish introductions (Scholz and Di Cave 1993; Hoffman 1999; Heckmann 2000). Recent data indicate that the impact of the tapeworm in Europe may have decreased during the last decade. However, surveillance should be maintained to prevent its further expansion to new areas. Efforts are underway to identify the resistance of different strains of common carp used in European aquaculture. Hoole (1994) proposed the development of a vaccine against *Bothriocephalus acheilognathi*, although practical and economic constraints continue to limit this approach. Exported fish, especially cyprinids and ornamental species (like guppies), should be inspected by veterinarians before their translocation to prevent further dissemination of the tapeworm into new regions. Control measures are generally effective, including treatment of infected fish, but the use of some anthelmintics are no longer allowed because of their negative effect on human health or the environment. Future work must therefore seek to accommodate novel and effective treatments to minimize economic loss. Many aspects of the biology, ecology and pathology of *Bothriocephalus acheilognathi* are well understood and comprehensively documented. However, many of these observations are restricted to cultured fish populations. Due to the expanding host and geographical ranges of *Bothriocephalus acheilognathi*, the importance of the parasite to wild fish populations requires further assessment and documentation. This is an important consideration in view of declining global biodiversity and the growing conservation efforts to protect aquatic environments. Comparative studies are needed to understand differences in species susceptibility and disease potential in newly infected hosts and the consequences of the parasite in new environments. Sub lethal effects of the parasite on fish growth, fitness, fecundity, behaviour or tolerance to environmental changes may also hold important ecological implications. The physiological and bioenergetics costs of the parasite under natural conditions also require clarification. This information is necessary to provide better understanding of future disease risks and to evaluate the role of this introduced parasite on the health and stability of fish populations.