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INVITED REVIEW

Global status of fish-borne zoonotic trematodiasis in humans

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Abstract

Fishborne zoonotic trematodes (FZT), infecting humans and mammals worldwide, are reviewed and options for control discussed. Fifty nine species belonging to 4 families, i.e. Opisthorchiidae (12 species), Echinostomatidae (10 species), Heterophyidae (36 species) and Nanophyetidae (1 species) are listed. Some trematodes, which are highly pathogenic for humans such as *Clonorchis sinensis*, *Opisthorchis viverrini*, *O. felineus* are discussed in detail, i.e. infection status in humans in endemic areas, clinical aspects, symptoms and pathology of disease caused by these flukes. Other liver fluke species of the Opisthorchiidae are briefly mentioned with information about their infection rate and geographical distribution. Intestinal flukes are reviewed at the family level. We also present information on the first and second intermediate hosts as well as on reservoir hosts and on habits of human eating raw or undercooked fish.

Keywords

Clonorchis, *Opisthorchis*, intestinal trematodes, liver trematodes, risk factors

Fish-borne zoonotic trematodes

Fish-borne zoonotic trematodes (FZT) are found within four families, i.e. Opisthorchiidae, Heterophyidae, Nanophyetidae and Echinostomatidae (Class: Trematoda Rudolphi, 1808; phylum: Platyhelminthes Genenbaur, 1859). Fish serve as the second intermediate host in their life cycle (Fig. 1). FZTs inhabit mainly the liver or intestine of vertebrates, including humans (Chai *et al.* 2005a; Le 2000; Taylor *et al.* 2007).

Humans and fish-eating mammals and birds may serve as final hosts depending on trematode species involved (Le 2000; Murrell and Fried 2007; Taylor *et al.* 2007). People get infected with FZT if they eat raw or undercooked freshwater and sometimes brackish water fish containing active metacercariae (Chai *et al.* 2005a; Keiser and Utzinger 2009; Lemly and Esch 1983; Murrell and Fried 2007). When the fish tissue is broken down through digestion, metacercariae are released into the small intestine where they excyst and migrate to the suitable internal organs of the host and grow to adult trematodes. Fertilized eggs are released into the environment with feces of their host and the eggs may reach water sources such as ponds, lakes, streams or rivers. Either eggs containing a miracidium are eaten by an appropriate snail and they hatch inside the snail (e.g. species of Opisthorchiidae, Heterophyidae) or the eggs hatch (Echinostomatidae) and a free-living miracidium is released in the water. The miracidium must locate and infect a snail within few hours. When eggs are ingested by snails, the miracidium is released in the intestinal tract of the snails, and it penetrates the rectal wall and develops into a sporocyst, which asexually generate rediae. The rediae in turn migrate to the digestive gland-gonad complex of the host snail where they asexually produce cercariae continuously throughout the life of the snail. Cercariae released from the snail will seek out a freshwater fish, penetrate its skin, and encyst as metacercariae in the skin or muscle of the fish. The asexual multiplication within the snail host results in thousands of cercariae being produced from one egg, and the duration of this process depends on the species and survival of the snail host (Le 1998; Keiser and Utzinger 2009; Toledo *et al.* 2011).

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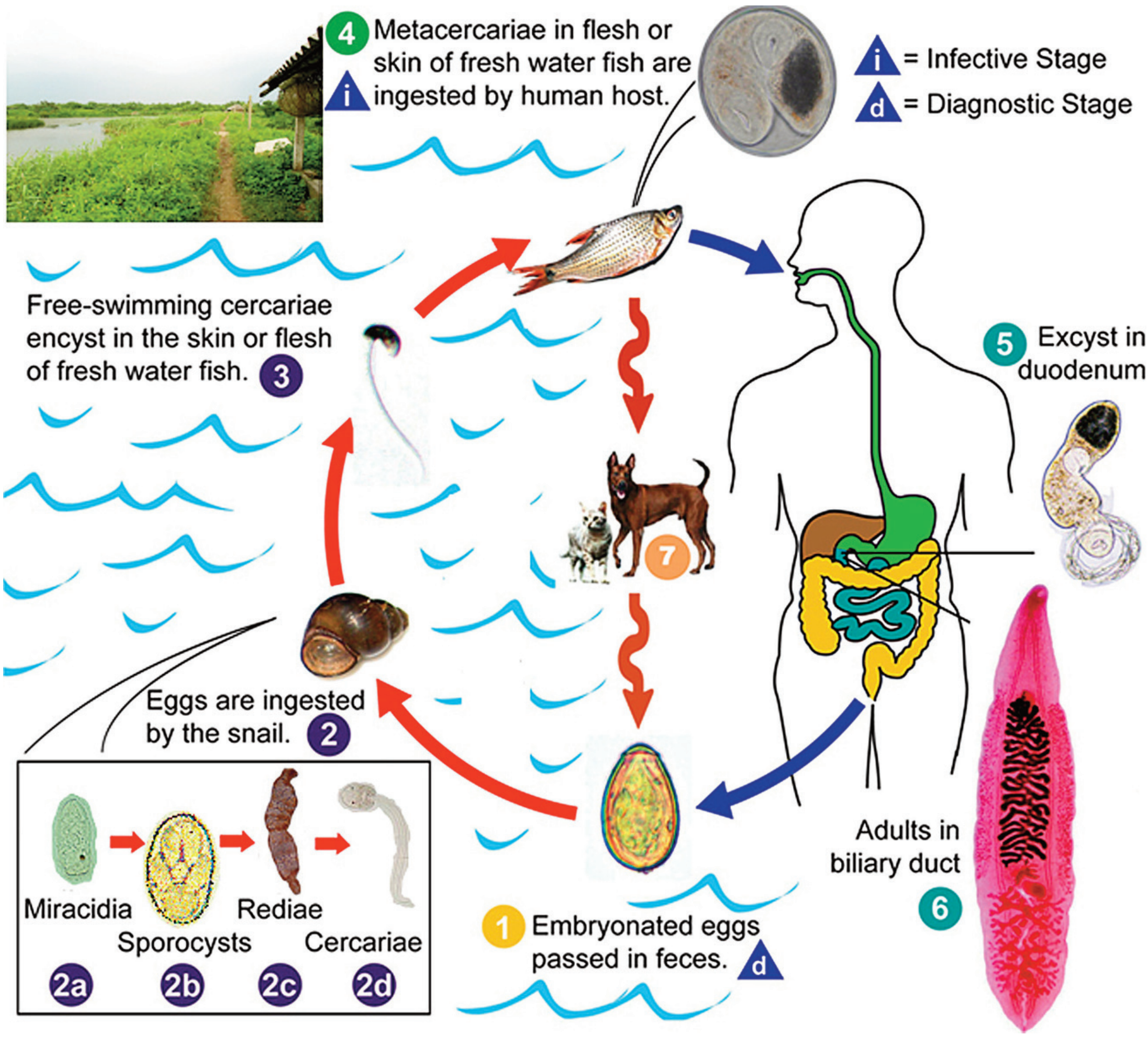

Fig. 1. The life cycle of *Clonorchis sinensis* (modified from http://www.dpd.cdc.gov/dpdx) as a representative for FZT species

The public health importance of fishborne zoonotic trematodes

Fish-borne zoonotic trematodiasis caused by flukes transmitted by fish products pose major public health problems worldwide. Among more than 100 trematode species infecting humans, 59 species are reported as FZT (Table 1). The number of people currently infected with only liver flukes (family Opisthorchiidae) exceeds 18 million and unknown millions are infected with intestinal flukes (Chai *et al.* 2009; World Health Oganization 1995), but it is estimated that more than half a billion are at risk of infection (Lima dos Santos and Howgate 2011; World Health Oganization 2004). Some of these parasites are highly pathogenic and human infection is the result of the consumption of raw or undercooked fish infected by the parasites (World Health Oganization 1995). Lima dos Santos and Howgate (2011) mentioned that these ichthyozoonoses have increased significantly in recent years for various reasons: (1) the development of new and improved diagnosis, (2) by the increase in raw fish consumption in those countries in which such dishes have commonly been eaten, (3) by the increased consumption elsewhere of regional fish dishes such as sushi, sashimi, ceviche, carpaccio based on raw or minimally processed fish, (4) by the growth in the international trade in fish and fish products, and (5) by the spectacular development of aquaculture.

The species of major importance to human health are the liver flukes (family: Opisthorchiidae) which parasitize the liver or bile-duct of the final host. The public health importance of these species is due to their wide geographical distribution, high prevalence and severe morbidity (Chai *et al.* 2005a; Keiser and Utzinger 2009; Lima dos Santos *et al.* 2011; MacLean *et al.* 2006; Mas-Coma and Bargues 1997). They have long been known to cause serious disease in certain areas of the world. Cholangitis, choledocholithiasis, pancreatitis, and cholangiocarcinoma are the major clinical problems, associated with the long chronic pattern of these infections (Chai *et al.* 2009; Mac-Coma and Bargues 1997). The causative agents of human infections include *Clonorchis sinensis*, *Opisthorchis viverrini*, *Opisthorchis felineus* and several minor species e.g. *Metorchis conjunctus*, *M. albidus* and *Amphimerus pseudofelineus*. In contrast although the intestinal trematode infections are more focal in distribution, they have been reported from a larger number of countries, representing a far greater number of species and are acquired from a wide range of intermediate hosts.

Intestinal trematodes are the commonest parasitic infections in humans and animals (Chai *et al.* 2009, Yu and Mott 1994). Although less associated with mortality than other groups of parasites, intestinal trematodes are responsible for significant morbidity, food safety and quality problems (Toledo *et al.* 2006; Yu and Mott 1994), but they have not attracted the interest of international agencies until recently. The intestinal trematodes transmitted by fish belong to the Echinostomatidae, Heterophyidae, and Nanophyetidae but there are several other intestinal or liver trematodes within Diplostomidae, Fasciolidae, Gastrodiscidae, Gymnophallidae, Lecithodendriidae, Microphallidae, Paramphistomatidae, Plagiorchiidae and Strigeidae (Chai 2007; Chai *et al.* 2005a; Dawer 1956; Kumar 1999; Mas-Coma and Bargues 1997; Yamaguti 1971; Yu and Mott 1994). All of these species are acquired by humans from ingestion of raw or undercooked fish, mollusks, amphibians, terrestrial snakes, aquatic insects and aquatic plants (Chai *et al.* 2009; Yu and Mott 1994). About 70 species of intestinal food-borne zoonotic trematodes have been reported to infect people (Yu and Mott 1994) and 47 of these were transmitted through fish (Table I). The endemicity of the parasites is associated with cultural and eating habits. The current understanding of the epidemiological distribution and pathology of intestinal trematodes is generally based on individual case reports rather than on systematic investigations in populations with specific high risk food habits (Yu and Mott 1994).

Diversity, occurrence, geographical distribution of FZT in humans and their clinical/epidemiology

The transmission of fish-borne trematodiases is restricted to areas where the first and second intermediate hosts coexist and where humans have the habit of eating raw, pickled, or insufficiently cooked fish (Keiser and Utzinger 2005, 2009; Sripa *et al.* 2007; Mas-Coma and Bargues 1997; World Health Oganization 2004). These contextual determinants explain why the distribution of fish-borne trematodiases is focal (Keiser and Utzinger 2009).

In the World, about 350 snail species are estimated to be of possible medical or veterinary importance (Keiser and Utzinger 2009). Several snail genera have been reported as second intermediate host for trematodes, i.e. *Pila conica*, of *Viviparus javanicus*, *Lymnaea rubiginosa brevis* are source of infection of *Echinostoma ilocanum* etc. (Yu and Mott 1994, Tropmed Technical Group 1986). First intermediate hosts of liver flukes (Opisthorchiidae) include: *Bithynia fuchsiana*, *B. chaperi*, *B. siamensis*, *B. funiculata*, *B. tentaculata*, *B. leachii*, *B. inflata*, *B. troscheli*, *Parafossarulus manchouricus* (Syn. *P. striatulus*), *P. anomalospiralis*, *P. sinensis*, *Allocinma longicornis*, *Melanoides tuberculata*, *Thiara scabra, Tarebia granifera*, *Assiminea lutea*, *Semisulcospira libertina*, *Amnicola limosa*, *Hua ningpoensis*, and *Opisthorchophorus hispanicus*; some of the bithynid species may be refered to *Codiella* (World Health Oganization 2004; Mas-Coma and Bargues 1997; Derraik 2008). The status of thiarid snail species e.g. *Melanoides* and *Thiara* as the first intermediate host of *Clonorchis sinensis* (De *et al.* 2003; Lun *et al.* 2005) has been refuted (Dung *et al.* 2010) and further research is required. Rohela *et al.* (2006) mentioned that *M. tuberculata* is not good host for *C. sinensis*.

A wide range of freshwater snails are the first intermediate hosts of minute intestinal trematodes, including *Bellamya*, *Melanoides*, *Thiara*, *Tarebia*, *Bithynia*, *Parafossarulus*, *Lymnaea*, *Radix*, *Gyraulus*, *Cipangopaludina*, *Hippeutis*, *Segmentina*, *Oxytrema*, *Heleobia*, *Semisulcospira*, *Melania*, *Stenomelania*, *Stagnicola*, *Koreanomelania* etc. (Tropmed Technical Group 1986, Dung *et al.* 2010; Le 2000; World Health Oganization 2004). Brackish water snails of the genera *Cerithidea*, *Tympanotonus* and *Sermyla* have been reported as intermediate hosts of FZT.

Most of the second intermediate hosts of FZT species are freshwater fish, except for some cases where estuary fish (mullet) or marine fish (salmon) are hosts. Snails, however, can also be second intermediate hosts for some echinostome species, particularly species of the Viviparidae and Pilidae (Le *et al.* 1993; Yu and Mott 1994). The association between transmission of FZT diseases and wild- and aquaculture-fish is well documented (Lima dos Santos and Howgate 2011), and FZT infections in farmed fish is a concern for human health (World Health Oganization 1995; Howgate 1998).

Fish belonging to the family Cyprinidae (carp) are the major intermediate hosts of liver flukes, especially *Clonorchis sinensis* and *Opisthorchis* spp. (Adam *et al.* 1997; IARC 1994; Le 2000; Mas-Coma and Bargues 1997). More than 100 species of freshwater fish have been shown to be naturally infected with *C. sinensis* and more than 35 with *Opisthorchis* spp. (Adam *et al*. 1997). The Cyprinidae also has been reported as the second intermediate hosts of many minute intestinal flukes. Marine fish (*Salmo* sp., *Oncorhynchus* sp., *Brachymystax* sp., *Coregonus* sp. and some non-salmon fish species) have been found to harbor metacercariae of *Nanophyetes salmincola* (Chai *et al.* 2005a; Yu and Mott 1994). Several estuary fish species, such as *Mugil* spp., *Liza* spp., *Acanthogobius* spp., and *Chaenogobius* spp. are the sec-

Table 1. Species of fish-borne zoonotic trematodes reported in humans and animals with their infection prevalence, distribution and host species

Echinostomatidae	
***Echinochasmus fujianensis* Cheng *et al*., 1992**	
Distribution	China
Infection in people	Prevalence of 3.2% in humans in 5 counties/cities of southern Fujian (China); patients were 3-15 years old. Infection rate in dogs was 29.2%
1st int. host	Freshwater snails: *Oncomelania* spp., *Bellamya aeruginosa*
2nd int. host	Snails. Freshwater fishes, such as: *Pseudorasbosa parv* and *Cyprinus carpio*.
Final hosts	Dog, cat, pig, rat (*Rattus rattoides losea*, *Rattus norvegicus*), human
References	Chai *et al*. 2009; Cheng *et al*. 1992; Yu and Mott 1994
***Echinochasmus japonicus* Tanabe, 1926**	
Distribution	China, Japan, Korea, Vietnam
Infection in people	Prevalence was 4.9% in humans in 6 counties of Fujuan and Guagdong (China).
1st int. host	Freshwater snail: *Oncomelania* spp., *Pila* spp., *Gyraulus* spp., *Parafossarulus manchouricus, Allocinma longicornis*
2nd Int. host	Marsh clams: *Corbicula* spp. Freshwater fish, i.e. *Pseudorasbora parva*, *Hypomesus olidus*, *Gnathopogon strigatus*, *Macropodus opercularis*
Final hosts	Avian species, such as ducks, chickens, egrets. Mammalian species, such as dog, cat, rat, human
References	Chai *et al*. 2005a, 2009; Le 2000; Lin *et al*. 1985; Sohn and Chai 2005; Yu and Mott 1994
***Echinochasmus jiufoensis* Liang and Ke, 1988**	
Distribution	China
Infection in people	Found in 6 months old girl in Guangzhou
1st int. host	Fresh water snails: *Oncomellania* spp.
2nd int. host	Molluscs and fishes
Final hosts	Dog, cat, pig, human
References	Chai *et al*. 2009; Yu and Mott 1994
***Echinochasmus liliputanus* (Looss, 1896) Odhner, 1910**	
Distribution	China, Egypt, Palestine, Syria
Infection in people	In Anhui province (China), prevalence was 13.4% among 2.426 people. Higher prevalence was recorded in a 3-15 years (22.7%) and a 16-30 years (16.4%) age group . Prevalence in dog and cat was 50% and 45% respectively.
1st int. host	Freshwater snails: *Parafossarulus manchouricus*, *Oncomelania* spp.
2nd int. host	Freshwater fishes: *Pseudorasbora parva*, gold fish
Final hosts	Dog, cat, fox (*Vulpes vulpes hoole*), badger (*Meles meles leptorynchus*), racoon (*Nyctereutes procyonoides procyonoides*), human
References	Chai *et al*. 2005a, 2009; Yu and Mott 1994
***Echinochasmus perfoliatus* (Ratz, 1908) Gedoelst, 1911**	
Distribution	China, Denmark, Hungary, Italy, Japan, Rumania, Russia, Taiwan, Vietnam
Infection in people	In Guangdong, Fujian, Anhui, Hubei province (China), prevalence was 1.8% (34/1846). This species has been reported in humans in Hanoi (Vietnam) but the prevalence was not reported
1st int. host	Freshwater snails: *Parafossarulus manchouricus*, *Bithynia leachi*, *Lymnaea stagnalis*, *Oncomelania* spp.
2nd int. host	Freshwater fishes: *Carassius* sp., *Zacco platypus*, *Z. teminckii*, *Pseudorasbora parva*
Final hosts	Dog, cat, pig, fox, rat, badger, human
References	Chai *et al*. 2005a, 2009; Le 2000; Saeed *et al*. 2006; Taylor *et al*. 2007; Toledo *et al*. 2006; Yu and Mott 1994
***Echinoparyphium paraulum* Dietz, 1909**	
Synonyms	Probably a synonym of *Echinostoma revolutum*
Distribution	Asia, Europe, New Zealand, and Brazil
Infection in people	Infected humans were found in Yunnan, Guangdong (China), Thailand, Indonesia, Russia. In 1929 in Taiwan, prevalence was estimated between 2.8% and 6.4%

1st int. host	Freshwater snails: *Lymnaea stagnalis*, *Physa* sp., *Paludina* sp., *Segmentina* sp., *Helisoma* sp., *Stagnicola palustris*, *Planorbarius corneus*, *Radix peregra*, *Acroloxus* spp., *Planorbis* sp.
2nd int. host	Tadpoles, snails, clam (*Corbicula*), freshwater fish
Final hosts	Avian: duck (*Anas boschas fereae*), goose, swan, and dove. Mammal: muskrat (*Ondatra zibethica*), human
References	Yu and Mott 1994; Murrell and Fried 2007

***Echinostoma angustitestis* Wang, 1997**

Distribution	China
Infection in people	Two infected humans were reported in Fujian (China)
1st int. host	Freshwater snails: *Oncomelania* spp., *Parafossarulus* sp.
2nd int. host	Freshwater fish
Final hosts	Dog, human
References	Cheng *et al*. 1992; Yu and Mott 1994

***Echinostoma cinetorchis* Ando and Ozaki, 1923**

Distribution	Indonesia, Japan, Korea, Taiwan, Vietnam
Infection in people	Infected people were found in Japan, Korea, Taiwan but no information of the infection prevalence in these countries.
1st int. host	Freshwater snails: *Hippeutis cantori*, *Segmentina nitidella*, *Gyraulus convexiusculus*, *Autropeplea ollua*
2nd int. host	Freshwater fishes: *Misgurnus anguillicandatus*. Freshwater snails: *Radix auricularia corcanus*, *Physa acuta*, *Planorbis compressus*, *Lymnaea japonica* and *Cipangopaludina* spp., *Hippeutis cantori*, *Segmentina nitidella*. Tadpoles and frogs (*Rana nigromaculata*, *R. catesbiana*). Larvae of salamander
Final hosts	Dog, cat, rat (*Rattus norvegicus*, *R. flavipectus*, *R. edwardsi*, *E. sladeni*), mouse (*Bandicota indica*), human
References	Chai *et al*. 2009; Chai and Lee 2002; Le 2000; Yu and Mott 1994

***Echinostoma hortense* Asada, 1926**

Distribution	China, Japan, Korea (Cheongsong-gun)
Infection in people	Liaoning province (China): 6/10 patients who had eaten raw loach were found infected. In Cheongsong-gun area (Korea), prevalence was 22.4%.
1st int. host	Freshwater snails: *Planorbis* spp., *Oncomelania* spp., *Lymnaea pervia*, *Radix auricularia correana*
2nd int. host	Freshwater fishes: *Misgurnus anguillicaudatus*, *M. mizolepis*, *Odontobutis obscura*, *Moroco oxycephalus*, *Coreopeca kawamebari*, *Squalidus coreanus*
Final hosts	Dog, cat, rat (*Rattus norvegicus*), human
References	Chai *et al*. 2005a, 2009; Fan and Sun 1989; Sohn and Chai 2005

***Episthmium caninum* (Verma, 1935) Yamaguti, 1958**

Distribution	Thailand, Vietnam, India
Infection in people	Several human cases have been reported in Thailand
1st int. host	Freshwater snails
2nd int. host	Freshwater fish
Final hosts	Bird, dog, pig, human
References	Chai *et al*. 2009; Le 2000; Radomyos *et al*. 1991; Toledo *et al*. 2006; Yu and Mott 1994.

Heterophyidae

***Appophalus donicus* (Skrjabin and Lindtrop, 1919) Price, 1931**

Synonyms	*Rossicotrema donicus* Skrjabin et Lindtrop, 1919; *Cotylophallus venustus* Ransom, 1920; *C. similis* Ransom, 1920
Distribution	Canada, East Europe, United States
Infection in people	Human infection was found in the United States; the prevalence was unknown
1st int. host	Snails: *Flumenicola virens*, *Lithoglyphus naticoides*
2nd int. host	Fishes: *Perca* sp., *Lusioperca* sp., *Blicca* sp., *Scardinius* sp.
Final hosts	Dog, cat, rat, fox, rabbit, human
References	Niemi and Macy 1974; Toledo *et al*. 2006; Yamaguti 1958; Yu and Mott 1994

***Ascocotyle longa* Ramson, 1920**	
Synonyms	*Phagicola* sp.
Distribution	Asia, Africa, America, Europe
Infection in people	Human infection was reported in Brazil; 9 out of 92 adults who lived in Sao Paulo were found egg-positive. The infection prevalence in dog was 1.6%.
1st int. host	Freshwater snail: *Heleobia australis*
2nd int. host	Estuary fish: *Mugil liza*
Final hosts	Hamster, mammals
References	Fried *et al*. 2004; Simões *et al*. 2010; Yu and Mott 1994
***Ascocotyle* sp.**	
Distribution	Asia, Africa, Americas, Europe
Infection in people	Unknown
1st int. host	Unknown
2nd int. host	Estuary fish: *Mugil* sp.
Final hosts	Dog, cat, human
References	Bray *et al*. 2008
***Centrocestus armatus* (Tanabe, 1922) Price, 1932**	
Distribution	Japan, Korea
Infection in people	Reported case: 42 year old man in Kyeongsangnam-do, Korea. In Japan, a successful experimental human infection was reported.
1st int. host	Freshwater snails: *Semisulcospira libertina*.
2nd int. host	Freshwater fishes: *Pseudorasbora parva*, *Pelteobagrus fulvidraco*, *Zacco platypus*, *Z. temminckii*, *Rhodeus ocellatus*, *Gobius similis*
Final hosts	Egret (*Egretta alba modesta*), dog, cat, rabbit, rat, human
References	Chai *et al*. 2009; Chai and Lee 1990; Hong *et al*. 1988; Sohn and Chai 2005
***Centrocestus caninus* (Leiper, 1912) Yamaguti, 1958**	
Synonyms	*Stephanopirumis longus* Onji and Nishio, 1916
Distribution	Taiwan, Thailand.
Infection in people	Human infection in Taiwan and 2 reported cases in Thailand
1st int. host	Freshwater snail: *Melanoides tuberculata*
2nd int. host	Freshwater fishes: *Anabas testudineus*, *Channa formosana*, *Channa striata*, *Cyprinus carpio*, *Carrassius auratus*, *Gnathopodon elongates*, *Glossogobius giuris*, *Hampala dispar*, *Hyporhamphus dussumieri*, *Puntius* spp., *Cyclocheilichthys* sp., *Tilapia nilotica*, *Terapon plumbeus*. Frog: *Rana limnochairis*, *Bufo melanostictus*
Final hosts	Dog, fox, cat, rat, human
References	Chai *et al*. 2009; Yamaguti 1958; Waikagul *et al*. 1997; Yu and Mott 1994
***Centrocestus cuspidatus* Looss, 1896**	
Distribution	Egypt and Taiwan
Infection in people	Human infection reported in Egypt and in Taiwan; no information on prevalence
1st int. host	Freshwater snail: *Oncomelania formosana*
2nd int. host	Freshwater fish
Final hosts	Yellow-billed Kite (*Milvus parasiticus*), rat, human
References	Yu and Mott 1994
***Centrocestus formosanus* Nishigori, 1924**	
Distribution	China, Japan, Hawaii, Mexico, Philippines, Taiwan and Vietnam
Infection in people	Human infection reported in Taiwan and Philippines
1st int. host	Snail: *Stenomelania newcombi*, *Oncomelania hupensis*
2nd int. host	Freshwater fishes: *Macropodus opercularis*, *Puntius semifasciolatus*, *Carassius auratus*, *Misgurnus anquillicaudatus*, *Cyclocheilichthys repasson*, *Puntius brevis*, *Osteochilus hasseltii,* *Chana formosana*. Frogs: *Rana limnochairis*, *Bufo melanostictus*
Final hosts	Chicken, duck, dog, cat, rat (*R. flavipectus*, *R. norvegicus*), human
References	Chai *et al*. 2009; Le 2000; Scholtz and Salgado-Maldonado 1999; Toledo *et al*. 2006; Yamaguti 1958; Yu and Mott 1994

Centrocestus kurokawai Kurokawa, 1935

Distribution	Japan
Infection in people	Human infection reported in Japan but no information on prevalence
1st int. host	Freshwater snail: *Oncomelania nosophora*
2nd int. host	Freshwater fish
Final hosts	Human
References	Chai *et al*. 2009; Yu and Mott 1994

Centrocestus longus Onji and Nishio, 1916

Synonyms	Probably a synomym of *C. canius*
Distribution	Taiwan
Infection in people	Human infection reported in Taiwan but no information on prevalence
1st int. host	Unknown
2nd Int. host	Freshwater fish
Final hosts	Human
References	Yu and Mott 1994

Cryptocotyle lingua (Creplin, 1825) Fischoeder, 1903

Distribution	Denmark, Greenland, North America, Russia, Japan
Infection in people	Human infection reported in Greenland
1st int. host	Snails: *Tautoglabrus* spp.
2nd int. host	Periwinkle: *Littorina littorea*. Fishes: *Gobius ruthensparri*, *Labrus bergylta*
Final hosts	Dog, cat, rat, wild animals, human
References	Chai *et al*. 2005; Chai and Lee, 2002; Saeed *et al*. 2006; Toledo *et al*. 2006; Yamaguti 1958; Yu and Mott 1994

Haplorchis microchis Matsuda, 1932

Distribution	Japan
Infection in people	Human infection reported in Japan
1st int. host	Snails
2nd int. host	Fish: e.g. mullet
Final hosts	Dog, cat, human
References	Yu and Mott 1994

Haplorchis pleurolophocerca Sonsino, 1896

Distribution	Egypt
Infection in people	Human infection reported in Egypt
1st int. host	Snails
2nd int. host	Fish: *Gambusia affinis*
Final hosts	Cat, human
References	Yu and Mott 1994

Haplorchis pumilio (Looss, 1886) Looss, 1899

Synonyms	*Monorchotrema taihokui* (Nishigori, 1924) Chen, 1936; *Haplorchis taihokui* Nishigori, 1924
Distribution	China, Egypt, Laos, Philippines, Taiwan, Thailand, Vietnam
Infection in people	In Thailand, 12 of 411 patients who were treated for opisthorchiasis were infected with *H. pumilio*. In Nam Dinh province (Vietnam), 33 of 610 examined persons were found with this species.
1st int. host	Freshwater snails: *Melanoides* spp., *Stenomelania* sp., *Melania reiniana*, *M. hitachiens*
2nd int. host	Freshwater fishes: *Ophiocephalus striatus*, *Glossogobius giurus*, *Acanthogobius* sp., *Mugil* sp., *Cyprinus* sp., *Carassius* sp., *Misgurnus* sp. Anura: Toad *Bufo spinulosus*, Frog *Rana esculenta*
Final hosts	Bird, dog, cat, human
References	Chai *et al*. 2005a, 2009; Dung *et al*. 2007; Yamaguti 1958; Yu and Mott 1994

Haplorchis taichui (Nishigori, 1924) Chen, 1936

Synonyms	*Monorchotrema taichui* Nishigori, 1924; *M. microrchia* Katsuda, 1932; *H. microrchis* Yamaguti, 1958
Distribution	Bangladesh, China, Egypt, Laos, Palestine, Philippines, Taiwan, Thailand, Vietnam
Infection in people	Human infection reported in Philippines, Laos, Thailand, Taiwan, Bangladesh, and Vietnam. In Nam Dinh province (Vietnam) 23 of 610 examined people were infected with this species.

1st int. host	Freshwater snails: *Melania obliquegranosa*, *M. juncea*, *Melanoides tuberculata*
2nd int. host	Freshwater fishes: *Gambusia affinis*, *Ctenopharyngodon idellus*, *Cyprinus carpio*, *Carassius auratus*, *Cyclocheilichthys repasson*, *Hampala dispar*, *Labiobarbus leptocheila*, *Puntius binotatus*, *P. brevis*, *P. gonionotus*, *P. leicanthus*, *P. orphoides*, *P. palata*, *Pseudorasbora parva*, *Rhodeus ocellatus*, *Zacco platypus*, *Raiamas guttatus*, *Mystacoleucus marginatus*, *Henichorhynchus siamensis*
Final hosts	Hawk (*Milvus migran*), Dog, cat, human
References	Chai *et al*. 2005a, 2009; Dung *et al*. 2007; Le 2000; Toledo 2006; Yu and Mott 1994

***Haplorchis vanissimus* Africa, 1938**

Distribution	Philippines, Australia
Infection in people	Human infection reported in Philippines
1st int. host	Snails
2nd int. host	Estuary fish: e.g. mullet
Final hosts	Pelicans, cat, dog, human
References	Chai *et al*. 2009; Murrell and Fried 2007; Yu and Mott 1994

***Haplorchis yokogawai* (Katsuta, 1932) Chen, 1936**

Synonyms	*Monorchotrema yokogawai* Katsuda, 1932
Distribution	Taiwan, China, India, Philippines, Malaysia, Australia, Egypt, Laos, Indonesia, Thailand, Vietnam
Infection in people	Human infection reported in Philippines, Thailand, China, Taiwan and Vietnam. In Nam Dinh province (Vietnam) 1 of 610 examined people were infected with this species.
1st int. host	Freshwater snails: *Melanoides tuberculata*, *Stenomelania newcombi*
2nd int. host	Fishes: *Mugil* spp., *Puntius* spp., *Misgurnus* sp., *Ophicephalus striatus*, *Cyclocheilichthys armatus*, *Hampala dispar*, *Labiobarbus leptocheila*, *Onychostoma elongatum*. Shrimp: *Perracus* spp.
Final hosts	Dog, cat, human
References	Chai *et al*. 2005a, 2009; Le 2000; Toledo *et al*. 2006; Yamaguti 1958; Yu and Mott 1994

***Heterophyes dispar* Looss, 1902**

Distribution	Egypt, North Africa, the Eastern Mediterranean, Korea, Thailand
Infection in people	Human infection reported in Korea and Thailand
1st int. host	Snail: *Pirenella conica*
2nd int. host	Fish of several genera: *Mugil cephalus*, *Epinephelus fasciatus*, *Tilapia* sp., *Lichia* sp., and *Barchus callipterus*
Final hosts	Dog, cat, human
References	Chai and Lee 1990; Yu and Mott 1994

***Heterophyes heterophyes* (v. Siebold, 1852) Stiles and Hassall, 1990**

Synonyms	*Distoma heterophyes v.* Siebold, 1852; *Heterophyes aegyptiaca* Cobbold, 1866; *Heterophyes nocens* Onji and Nishio, 1915
Distribution	Egypt, Turkey, Sudan, Palestine, Brazil, Spain, Iran, India, Russia, Japan, China, Philippines, Taiwan, Indonesia
Infection in people	Human infection reported in Korea, Egypt (0.01-1% in the 5 governorates), China (Guangdong, Hubei, Beijing) and Taiwan.
1st int. host	Freshwater snails: *Parafossarulus manchouricus*, *Pirenella conica*
2nd int. host	Fishes: *Mugil cephalus, Tilapia nilotica*, *Aphanius fasciatus* and *Acanthogobius* flavimanus, *Chelon haematocheilus*.
Final hosts	Dog, cat, fish-eating mammals, human
References	Chai *et al*. 2005a; Bray *et al*. 2008; Le 2000; Taraschewski and Nicolaidou 1987; Toledo *et al*. 2006; Yu and Mott 1994

***Heterophyes katsuradai* Ozaki and Asada, 1926**

Distribution	Japan
Infection in people	Human infection reported in Japan
1st int. host	Snail: *Cerithidia cingulata*
2nd int. host	Fish: *Mugil cephalus*
Final hosts	Dog, human
References	Yu and Mott 1994

***Heterophyes nocens* Onji and Nishio, 1916**

Distribution	Korea, Japan, Philippines, China

Infection in people	The prevalence ranged from 10 to 70% among residents in southwestern coastal areas in Korea. In Japan, *H. nocens* was reported in Kochi, Chiba, Yamaguchi, Chugoku, Hiroshima, Shizuoka.
1st int. host	Snails: *Pirenella conica*, *Cerithidia cingula alata*
2nd int. host	Estuary fishes: *Mugil cephalus*, *Liza* sp., *Acanthogobius* sp., and *Chaenogobius* sp.
Final hosts	Dog, cat, fish-eating mammals, human
References	Chai *et al*. 2005a; Chai and Lee 1990; Yu and Mott 1994

***Heterophyopsis continua* (Onji and Nishio, 1916) Yamaguti, 1958**

Synonyms	*Heterophyes continuus* Onji et Nishio, 1916; *Heterophyes expectans* Africa et Garcia, 1935
Distribution	Philippines, Japan, China, Korea
Infection in people	Human infection reported in Japan (2 cases), and Republic of Korea (8 cases), and China
1st int. host	Freshwater snail: *Parafossarulus manchouricus*
2nd int. host	Fishes: *Mulgi cephalus*, *M. affinis*, *Larus argentatus*, *Cyprinus carpio*, *Acanthogobius flavimanus*, *Lateolabrax japonicas*, *Clupadon punctatus*, *Conger myriaster*, *Plecoglossus alltivelis*, *Konosirus punctatus*, *Boleophthalmus pectinirostris*, *Scartelaos histophorus*, *Harengula zunasi*, *Dorosoma thrissa*.
Final hosts	Cat, dog, chick, human
References	Chai *et al*. 2009; Chai and Lee 1990; Toledo *et al*. 2006; Yamaguti 1958; Yu and Mott 1994

***Isthimiophora melis* (Schrank, 1788) Lühe, 1909**

Synonyms	*Euparyphium melis* Railliet, 1919; *Euparyphium jassyense* Leon et Ciurea, 1922
Distribution	China, Europe, North America, Taiwan
Infection in people	Human infection reported in Rumania, China, and Taiwan.
1st int. host	Freshwater snail : *Stagnicola emarginata*
2nd int. host	Freshwater fishes: loach, tadpoles and *Misgurnus* spp.
Final hosts	Domestic and wild animals, human
References	Chai *et al*. 2009

***Metagonimus minutus* Katsuta, 1932**

Distribution	Taiwan
Infection in people	Human infection reported in Taiwan
1st int. host	Snails
2nd int. host	Fish: mullet
Final hosts	Cat, mice, human
References	Chai *et al*. 2009; Yu and Mott 1994

***Metagonimus miyatai* Saito, Chai, Kim, Lee and Rim, 1997**

Distribution	Japan, Korea
Infection in people	Human infection reported in Korea (from people along the Gum River)
1st int. host	Freshwater snails: *Semisulcospira globus*, *S. libertine*, *S. dolorosa*
2nd int. host	Freshwater fishes: sweetfish, dace, common fat-minnow *Morocco steindachneri*, pale chub *Zacco platypus*, and dark chub *Zacco temmincki*
Final hosts	Mice, rats, hamsters, dog, human
References	Chai *et al*. 2009

***Metagonimus takahashii* Suzuki, 1930**

Distribution	Korea, Japan
Infection in people	Human infection reported in Korea (Umsong-gun, Chunchungnam-do, and along upper reaches of the Namhan River)
1st int. host	Freshwater snails: *Semisulcospira coreana*, *Koreanomelania nodifila*
2nd int. host	Freshwater fishes: *Cyprinus carpio*, *Carassius carassius*, *C. auratus*, *Gnathopodon* sp., *Tribolodon taczanowskii*, *Lateolabrax japonicus*
Final hosts	Mice, dog, human
References	Chai *et al*. 2009; Yu and Mott 1994

***Metagonimus yokogawai* Katsurada, 1913**

Synonyms	*Losotrema ovatum* Kobayashi, 1912; *Metagonimus ovatus* Yokogawa, 1913; *Loossia romanica* (Ciurea, 1915)
Distribution	China, Far East of Russia, Indonesia, Japan, Korea, Siberia, Spain, Taiwan

Infection in people	Human infection reported in China (Guangdong, Anhui, Hubei, and Zhejiang provinces), Japan (Hamana Lake), Korea, Siberia, Israel, Balkan states, and Spain. In Korea, the prevalence was highest in Gangwon-do (20%-70%). In Russia, the endemic areas include Amur and Ussuri valley (Khaborovsk territory) where the prevalence was between 20 and 70%. In the north of Sakhalin Island, the infection rate was 1.5% in Russians.
1st int. host	Freshwater snails: *Thiara* spp., *Semisulcospira coreana*, *S. libertine*
2nd int. host	Freshwater fishes: sweet oriental trout *Plecogossus altivelis*, dace *Tribolodon taczanowskii*, perch *Lateolabrax japonicas*, *Salmo perryi*, *Odontobutis obscurus*, etc.
Final hosts	Dog, cat, rat, pig, fish-eating animals, human
References	Chai *et al*. 2009; Chai and Lee 2002; Taylor *et al*. 2007; Toledo *et al*. 2006; Yu and Mott 1994

***Phagicola* sp.**

Distribution	Brazil, United States, Philippines
Infection in people	Human case reported of 31 year-old female in Southern Sao Paulo State, Brazil
1st int. host	Freshwater or brackish water snails
2nd int. host	Estuary fish: Mullets: *Mugil* sp., *Ambassis buruensis*
Final hosts	Raccoon (*Procyon lotor*), human, fish-eating animals
References	Chieffi *et al*. 1990; Hamir *et al*. 1993; Toledo *et al*. 2006; Athur and Lumanlan-Mayo 1997

***Procerovum calderoni* (Africa and Garcia, 1935) Price, 1940**

Distribution	Africa, China, Philippines
Infection in people	Human infections reported in Africa, China, Philippines
1st int. host	Brackish water snails, *Sermyla riqueti* (=*Thiara riquetii*)
2nd int. host	Fishes: *Ophiocephalus striatus*, *Glossogobius giurus*, *Creisson validus*, *Mollienesia latipinna*, *Mugil* sp.
Final hosts	Cat, dog, human
References	Chai 2007; Chai *et al*. 2009; Toledo *et al*. 2006; Yu and Mott 1994

***Procerovum varium* Onji and Nishio, 1916**

Distribution	Australia, China, Korea, India, Philippines
Infection in people	Human infection reported in Japan
1st int. host	Snail: *Thiara riquetii*
2nd int. host	Fish: *Mugil affinis*
Final hosts	Cat, dog, human
References	Chai *et al*. 2009; Sohn and Chai 2005; Yu and Mott 1994

***Pygidiopsis summa* Onji and Nishio, 1916**

Distribution	Japan, Korea
Infection in people	Human infection reported in Japan in 1965; in two coastal areas of Korea 18 and 5 people were found positive with this fluke.
1st int. host	Brackish water snails: *Cerithidea* sp., *Tympanotonus* sp.
2nd int. host	Fishes: *Mugil cephalus*, *Liza menada*, *Acanthogobius flavimanus*
Final hosts	Dog, cat, rat, human
References	Chai *et al*. 2009; Chai and Lee 2002; Sohn and Chai 2005; Toledo *et al*. 2006; Yu and Mott 1994

***Stellantchasmus falcatus* Onji and Nishio, 1916**

Distribution	Hawaii, Japan, Korea, Palestine, Philippines, Thailand, Vietnam
Infection in people	Human infection reported in Hawaii, Japan, Korea, Palestine, Philippines, Thailand, and Vietnam. In Nam Dinh province (Vietnam) 2 of 610 examined people were found infected with this species.
1st int. host	Snails: *Stenomelania newcombi*, *Tarebia granifera*
2nd int. host	Fishes: mullet *Mugil cephalus* and half-beaked fish *Dermogenus pusillus*
Final hosts	Dog, cat, rat, human
References	Chai *et al*. 2009; Chai and Lee 2000, 2002; Le 2000; Sohn and Chai 2005; Toledo *et al*. 2006; Yu and Mott 1994

***Stellantchasmus formosanum* (Katsuta, 1932)**

Distribution	Taiwan
Infection in people	An experimental human infection was reported in Taiwan
1st int. host	Snail

2nd int. host	Fish: *Mugil cephalus*
Final hosts	Cat, rat, human
References	Chai *et al*. 2009

***Stellantchasmus pseudocirratum* (Witenberg, 1929) Yamaguti, 1958**

Synonyms	*S. amplicaecalis* Katsuta, 1932
Distribution	Hawaii, Palestine, Philippines, Taiwan
Infection in people	Human infection reported in Hawaii, Philippines
1st int. host	Snail
2nd int. host	Fish: *Mugil cephalus*
Final hosts	Dog, cat, human
References	Chai *et al*. 2009; Fahmy and Selim 1959; Toledo *et al*. 2006

***Stictodora fuscatum* (Onji and Nishio, 1916) Yamaguti, 1958**

Distribution	Japan, Korea
Infection in people	First human case was found in a young Korean man; 13 additional human cases were detected in this village in the south western coastal area.
1st int. host	Brackish water snails
2nd int. host	Fishes: mullet *Mugil cephalus*, goby *Acanthogobius flavimanus*, *Pseudorasbora parva*, *Liza macrolepis*, *Gobio gobio*
Final hosts	Cat, human
References	Chai V, 2009; Chai and Lee 1990; Toledo *et al*., 2006; Yu and Mott 1994

***Stictodora lari* Yamaguti, 1939**

Distribution	Korea, Japan
Infection in people	In 2 southern coastal villages, 6 Korean people were detected with this species.
1st int. host	Blackish water snail: *Velacumantus australis*
2nd int. host	Estuarine fish, including goby *Acanthogobius flavimanus*
Final hosts	Dog, cat, human
References	Chai *et al*. 2002, 2009

Nanophyetidae

***Nanophyetus salmincola* (Chapin, 1927)**

Synonyms	*Nanophyes salmincola* Chapin, 1926; *Troglotrema salmincola* (Chapin, 1926) Witenberg, 1932
Distribution	Russia, United States
Infection in people	The infection prevalence in Amur and in Ussuri valleys of Khabarovsk territory (Russia) was 5%, and some localities, the average prevalence was 20% and reached up to 60%.
1st int. host	Snail: *Oxytrema silicula*
2nd int. host	Salmon fishes: *Salmo* sp., *Oncorhynchus* sp., *Brachymystax* sp., *Coregonus* sp. and some non-salmonid fish species
Final hosts	Human
References	Chai *et al*. 2005a; Yu and Mott 1994

Opisthorchiidae

***Amphimerus noverca* (Braun, 1902) Barker, 1911**

Synonyms	*Distoma conjunctum* Lewis et Cunningham, 1872; *Opisthorchis noverca* Braun, 1902
Distribution	Indian
Infection in people	Two cases have been reported in India
1st int. host	Aquatic snails
2nd int. host	Fishes
Final hosts	Dog, fox, pig, human
References	Kassirsky and Plotikov 1969; Mas-Coma and Bargues 1997; Yamaguti 1971

***Amphimerus pseudofelineus* (Ward, 1901) Barker, 1911**

Synonyms	*Amphimerus guayaquilensis* (Ward, 1901) (Artigas and Perez, 1964; Thatcher 1970); *Opisthorchis guayaquilensis* Rodríguez, Gómez Lince and Montalvan, 1949

Distribution	Brazil, Canada, Colombia, Ecuador, Panama, United States, Venezuela
Infection in people	Reported from Ecuador, 245 persons in lowland area were examined; 18 of them passed eggs of this fluke
1st int. host	Aquatic snails
2nd int. host	Fish: white sucker *Catostomus commersoni*
Final hosts	Dog, coyote, cat, marsupial (*Didelphis marsupialis*, *Philander opossum*), human
References	Chai *et al*. 2005a; MacLean *et al*. 2006; Mas-Coma and Bargues 1997

***Clonorchis sinensis* (Cobbold, 1875) Looss, 1907**

Distribution	China, Far East of Russia, Japan, Korea, North Vietnam, Taiwan
Infection in people	About 7-10 million people are infected, and 290 million people are at risk.
1st int. host	Freshwater snails: *Parafossarulus manchoricus*, *P. anomalospiralis*, *P. sinensis*, *Bithynia fuchsiana*, *B. chaperi* (Bithynidae), *Allocinma longicornis* (Hydrobiidae), *Melanoides tuberculata*, *Tarebia granifera* (Thiaridae), *Assiminea lutea* (Assimineidae), *Semisulcospira libertine* (Pleuroceridae)
2nd int. host	Cyprinid fish: *Macropodus opercularis*, *Hypophthalmichthys molitrix*, top mouth minnow: *Pseudo rasbora parva*, grass carp: *Ctenopharyngodon idella*, common carp: *Cyprinus carpio*, Crucian carp: *Carassius auratus*, long nose barbel: *Hemibarbus longirostris*, goby minnow *Pseudogobio esocinus*, black striped gudgeon: *Pungtungia herzi*, *Zacco* spp., etc.
Final hosts	Cat, dog, pigs, rats, hog, wild cat, marten, badger, mink, weasel, fish-eating animals, rat (*Rattus norvergicus*), human
References	Bray *et al*. 2008; Chai *et al*. 2005a; Choi 1976; De *et al*. 2003; IARC 1994; Keiser and Utzinger 2009; Le 2000; Mas-Coma and Bargues 1997; Traub *et al*. 2009; Yu and Mott 1994, Zhang *et al*. 2007

***Metorchis albidus* (Braun, 1983) Looss, 1899**

Distribution	Denmark, France, Germany, England; Russia
Infection in people	No information in human, this species have been found in cat
1st int. host	Snails: *Amnicola limosa*, *Bithynia troscheli* (=*Codiella troscheli*)
2nd int. host	Freshwater cyprinoid fishes
Final hosts	Cat, fox, gray seal, birds, human
References	Bray *et al*. 2008; Bowman *et al*. 2012; Serbina and Iurlova 2002; Sherrard-Smith *et al*. 2009

Metorchis bilis

Distribution	Europe
Infection in people	Human infections have reported from the Ob River basin (West Siberia)
1st int. host	Snail: *Bithynia* spp.
2nd int. host	Freshwater fish
Final hosts	Fox, dog, cat, seal, raccoon
References	Eckert *et al*. 2005; II'inskikh *et al*. 2007; Schuster *et al*. 2007; Taylor *et al*. 2007; Mordvinov *et al*. 2012

***Metorchis conjunctus* (Cobbold, 1860) Looss, 1899**

Synonyms	*Distoma conjunctum* Cobbold, 1860; *Parametorchis canadensis* Price, 1929; *P. intermedius* Price, 1929; *P. manitobensis* Allen and Wardle, 1934; *P. noveboracensis* Hung, 1926
Distribution	Canada, North United States
Infection in people	Human infection reported from an Indian patient in Canada
1st int. host	Freshwater snail: *Amnicola limosa porata*
2nd int. host	Fish: common sucker *Catostomus commersonii*
Final hosts	Fish eating mammals, dog, cat, wolf, fox, raccoon, mink, fish-eating mammals, human
References	Axelson 1962; Bowman *et al*. 2012; Chai *et al*. 2005a; Mas-Coma and Bargues 1997; Taylor *et al*. 2007

***Metorchis orientalis* Tanabe, 1919**

Synonyms	*Metorchis albidus* Hsü, 1934
Distribution	China, Japan
Infection in people	In Ping Yuan country of Guangdong province (China), the infection rate was 4.2%
1st int. host	Freshwater snail: *Parafossarulus striatulus*
2nd int. host	Freshwater cyprinoid fishes
Final hosts	Dog, cat
References	Bowman *et al*. 2012; Lin *et al*. 2001

***Opisthorchis felineus* (Rivolta, 1884) Blanchard, 1895**

Synonyms	*Campula feline* Cholodkowshy, 1898; *Dicrocoelium felineus* Moniez, 1896; *Distoma conus* Gurlt, 1831; *D. felineum* Rivolta, 1884; *D. lanceolatum felis cati* Siebold, 1836; *D. lanceolatum canis familiaris* Tright, 1889; *D. sibiricum* Winogradoff, 1892; *D. winogradoffi* Jaksch, 1897; *Opisthorchis tenuicollis felineus* Erhardt, 1935; *O. wardi* Wharton, 1921
Distribution	France, Germany, Greece, Italy, Russia, Spain, Poland
Infection in people	The global infection is estimated at about 1.6 million
1st int. host	Freshwater snails: *Bithynia inflata (=Codiella inflata*), *Bithynia troscheli* (=*Codiella troscheli*), *Bithynia tentaculata* (=*Codiella tentaculata*), *B. leachi* (=*Codiella leachi*), *B. fuchsiana*, *Parafos sarulus manchouricus*, *Allocinma longicornis*, *Hua ningpoensis*, *Opisthorchophorus hispanicus*
2nd int. host	Freshwater fishes: *Abramis balerus*, *A. bramae*, *A. sapa*, *Alburnus alburnus*, *Aspius aspius*, *Barbus barbus borysthenicus*, *Blicca bjoerkna*, *Carassius carassius*, *Chondrostoma nasus*, *Cobitis taenia*, *Cyprinus carpio*, *Gobio gobio*, *Leucaspius cephalus*, *L. delineates*, *Leuciscus idus*, *L. leuciscus*, *L. rutilis*, *Phoxinus chekanowskii*, *P. phoxinus*, *Polecus cultratus*, *Rutilus rutilus*, *Scardinius erythrophthalmus*, *Tinca tinca*, *Idus melanotus*
Final hosts	Dog, red-, silver- and polar foxes, cat, wolverine, domestic and wild hogs, maren, beaver, common otter (*Lutra lutra*), European (*Mustela putorius*), Siberian weasel (*Mustela sibirica*), sable (*Martes zebellina*), rat (*Rattus norvegicus*), water vole (*Arvicola terrestris*), lagomorphs (*Oryctolagus cuniculus*), grey seal (*Halichoerus grypus*), Caspian seal (*Phoca caspica*), bearded seal (*Erignathus barbatus*), lion (*Felis leo*), pig, human
References	Armignacco *et al*. 2008; Chai *et al*. 2005a; Dawes 1956; Eckert *et al*. 2005; Le 2000; Mas-Coma and Bargues 1997

***Opisthorchis tenuicollis* (Rudolphi, 1819) Stiles and Hassall, 1896**

Synonyms	*Distoma tenuicollis* Rudolphi, 1819; *D. viverrini* Poirier, 1886; *Opisthorchis viverrini* Stiles and Hassall, 1896; *O. tenuicollis-felineus* Looss, 1899 etc.
Distribution	Asia, Europe
Infection in people	Human infection was reported but the exact locality was unknown.
1st int. host	Snail
2nd int. host	Cyprinid fishes
Final hosts	Dog, cat, civet cat, bearded seal, grey seal, common porpoise, human
References	Dawes 1956; Bowman and Georgi 1963

***Opisthorchis viverrini* (Poirier, 1886) Stiles and Hassall, 1896**

Distribution	Cambodia, Laos, South Vietnam, Thailand
Infection in people	About 9 milion people globally are estimated to be infected with this fluke
1st int. host	Freshwater snails: *Bithynia siamensis goniomphalus*, *B. s. funiculata*, *B. s. siamensis*. *B. s. laevis*, *Melanoides tuberculata*
2nd int. host	Cyprinid fishes, mainly *Barbodes gonionotus*, *Carassius auvatus*, *Cyclocheilichthys apagon*, *C. repasson*, *C. siaja*, *Puntius brevis*, *P. leiacanthus*, *P. partipentazona*, *P. orphoides*, *Esomus metallicus*, *Hampala dispar*, *H. macrolepidora*, *Osteochilus* sp.
Final hosts	Cat, rabbits, guinea pigs, albino rats, dog, rat, civet cat, fish-eating mammals, human
References	Chai *et al*. 2005a; De *et al*. 2003; IARC 1994; Keiser and Utzinger 2009; Kumar 1999; Le 2000; Mas-Coma and Bargues 1997; Yu and Mott 1997

***Pseudamphistomum aethiopicum* Pierantoni, 1942**

Distribution	Ethiopia
Infection in people	Human infection reported in Ethiopia
1st int. host	Snail
2nd int. host	Fish
Final hosts	Mammals, human
References	Mas-Coma and Bargues 1997; Yamaguti 1971

***Pseudamphistomum truncatum* (Rudolphi, 1819) Lühe, 1908**

Distribution	Europe (France, Germany, Hungary, Italy, Russia, etc.) and North America
Infection in people	Human infection reported in River Kama (USSR) where this species was found in 31 patients.
1st int. host	Snail
2nd int. host	Cyprinoid fishes
Final hosts	Cat, dog, fox, seal, skunk, mink, otter, human
References	Bray *et al*. 2008; Bowman *et al*. 2012; Mas-Coma and Bargues 1997

ond intermediate hosts of some minute intestinal trematodes (Chai *et al.* 2005a; Yu and Mott 1994; Toledo *et al.* 2006).

Fish-borne zoonotic trematodes in aquaculture

Aquaculture plays an important role in providing food for domestic consumption and generating foreign currency through export of aquaculture products (General Directorate of Statistics of Vietnam 2012). The aquaculture systems include marine, brackish water and freshwater aquaculture. The freshwater aquaculture environments include ponds, canals, cages, net enclosures and pens in reservoirs, lakes, rivers, canals, and paddy fields (Phan *et al*. 2010a). Depending on the production mode and the cultivation area, they can be divided into commercial fish culture system and small-scale poly- or monoculture farming systems (Thien 2011).

Aquaculture practices are similar throughout Asia (Guo 2001) and in endemic areas these practices may directly impact prevalence and persistence of FZTs (Phan *et al.* 2010a, b; Chi *et al*. 2008). Particularly in northern Vietnam where small-scale family-based systems are mainly practiced (Phan *et al.* 2010b). Cultured fish is a main protein source for the households and consumed by the families at any time of the year (Thien 2011). This system is named the VAC system in Vietnam and is considered as an ecological way of using farm products in natural cycles (Tai *et al*. 2004). In the traditional form, the system has three functional units, including a garden (Vuon in Vietnamese), a fish pond (Ao), and an animal shed (Chuong). Manure from the husbandry is used to fertilize ponds, so as to stimulate algal growth and subsequently fish growth, and remnants from garden products and fish remains can be fed to dogs, cats or pigs. Mud from fish ponds is used to fertilize gardens or fields (Dung *et al.* 2010). The recirculation of waste material including human and animal manure is conducive for the life cycle of FZT. Eggs of trematodes will go with feces of their host into the pond, where snails and fishes are available as the first and the second intermediate hosts.

Fishborne zoonotic liver flukes

The human liver flukes are a closely related group of trematodes belonging to the family Opisthorchiidae, and have similar life cycles and epidemiologies (Chai *et al*. 2005a). Almost all of them have in common the hepatic location (bile ducts, gall bladder) of the adult stage of the parasite at the level of the definitive host. The most important species are *Clonorchis sinensis*, *Opisthorchis viverrini* and *O. felineus* but nine other species have been reported to infect humans.

Clonorchis sinensis

Clonorchis sinensis is the most important species of FZT in East Asia (Rim 1990; Chen *et al*. 1994; Hong 2003). It is widely distributed in this region (Table I). In Japan, this parasite was formerly quite prevalent, but has been successfully controlled since the 1960s (Chen *et al*. 1994; Hong 2003). Current endemic areas of clonorchiasis include China, South Korea, North Vietnam, Taiwan, and the Far East of Russia (Mas-Coma and Bargues 1997). In this wide geographical zone, the incidence of clonorchiasis varies considerably from one district to another, even within small regions (Rim 1982a). Infections with *C. sinensis* have been reported in Thailand, Malaysia, Singapore, Laos and Philippines (Cross and Basaca-Sevilla 1984) but these were among immigrants or acquired from fish imported from endemic countries.

In China, clonorchiasis has been detected in 24 provinces, municipalities and autonomous regions (Chen *et al.* 1994). Southern regions, such as Guangdong, Guangxi, Zhuangzu, and northern regions, such as Heilongjiang, Jilin and Liaoning appear to be the zones with highest infection with prevalence ranging from 1 to 57% (Li 1991).

In Taiwan, clonorchiasis was formerly endemic in three areas, Mei-Nung in the south, Sun-Moon Lake in the center and Miao-Li in the north (Cross 1984). The disease continues to be found in almost every city/county, with prevalence in the range 0 and 57%; prevalence over 20% was considered as heavy endemic areas (Chen 1991; Cross 1984; Rim 1986). That disease is extending to new endemic localities in which human prevalence of up to 10–20% are found (Chen 1991).

In Korea, endemic areas are scattered over the country and the most extensive and intensive endemic regions are found mainly along Nakdong River and lower reaches of other rivers (Rim 1982a, 2005), with prevalence of up to 40% (Rim 2005). According to Rim (1990, 2005), Joo and Hong (1991) and Maurice (1994) the overall prevalence slowly decreases due to mass treatment programmes from 4.6% in 1971 to 2.4% in 2004.

In Vietnam, the most heavily infected area is found in the northern parts of the country, in the Red River delta e.g. Nam Dinh, Ninh Binh, Thai Binh, etc. provinces and some provinces in the center e.g. Thanh Hoa, Nghe An (Hop *et al.* 2007; Le 2000; Rim 1986).

In Russia, human cases have been reported in the far eastern part, namely in the Amur River Territory and Khabarovsk Territory (Korablev and Koltsov 1992; Posokhov 1982; Posokhov *et al.* 1987).

The distribution of *C. sinensis* is partly dependent on the distribution of the first intermediate host snails. Nine species of fresh water snails have been reported as first intermediate host for *C. sinensis*, including *Parafossarulus manchouricus* (Syn. *P. striatulus*), *P. anomalospiralis*, *P. sinensis*, *Bithynia fuchsiana*, *B. chaperi*, *Allocinma longicornis* (Family: Bithyniidae), *Tarebia granifera* (Syn. *Thiara granifera*), *Melanoides tuberculata* (Family: Thiaridae), *Assiminea lutea* (Family: Assimineidae) and *Semisulcospira libertina* (Family: Pleuroceridae) (Mas-Coma and Bargues 1997). The status of the thiarid species, *Tarebia granifera* and *Melanoides tuberculata*, however, is questionable (Dung *et al.* 2010). Bithynid snail species are the main first intermediate hosts in all the endemic regions where transmission of the parasite is accomplished, such as in China, Taiwan, Korea, Japan, Vietnam and Far East of Russia (Mas-Coma and Bargues 1997). Generally the prevalence of *C. sinensis* in snails is low (Mas-Coma and Bargues 1997; Zhang *et al.* 2007). The release of cercariae from snails is high and occurs over a fairly long period thus ensuring propagation (Keiser and Utzinger 2009; Mas-Coma and Bargues 1997).

A crude estimate of the global number of people infected with *C. sinensis* was about 19 million (Stoll 1947), while Lun *et al*. (2005) and Fang *et al*. (2008) mentioned that 35 million people are infected globally, and 15 million of these are from China. However, according to several documents, it has been estimated to be about 7–10 million (World Health Organization 1995; Crompton 1999) and 290 million people are at risk (Rim *et al*. 1994).

Mas-Coma and Bargues (1997) mentioned that parasites lodge and mature in the medium and large intrahepatic ducts in the liver, especially those of the left liver lobe. Early changes seen in the biliary ducts are excessive mucin formation, desquamation, and adenomatous hyperplasia of the duct epithelium with goblet cell metaplasia (Markell and Goldsmith 1984). In the chronic stage, progressive bile duct thickening dilatation, ductal, and periductal fibrosis are noted. Biliary stasis results in secondary infection leading to pericholangitis, pyelophlebitis, cholangiohepatitis, and multiple abscesses (Markell and Goldsmith 1984). Fibrosis rarely appears in the portal tracts, and portal cirrhosis has been described only infrequently. The flukes may cause dilation and fibrosis (Markell and Goldsmith 1984). The organ may be enlarged to 2 or 3 times normal size in massive infection cases (Dooley and Naefie 1976). The external surface of the liver may show pale cystic areas and linear whitish streaks corresponding to dilated bile ducts may be observed (Dooley and Naefie 1976). The cut surface reveals a normal parenchyma punctuated by bile ducts with walls 2 to 3 times their normal thickness (Dooley and Naefie 1976).

The infection may persist up to 26 years in human hosts (Attwood and Chou 1978). Lightly infected persons (<100 flukes) usually show no symptoms, but in moderate or progressive cases the clinical symptoms show loss of appetite, indigestion, fullness of abdomen, epigastric distress unrelated to meals, discomfort in the right upper quadrant, diarrhea, edema and some hepatomegaly (Belding 1965; Keiser and Utzinger 2009). In heavily infected cases (101 to 1,000 flukes) the symptoms are weakness and lassitude, epigastric discomfort, paresthesia, loss of weight, palpitation of heart and tachycardia, diarrhea, vertigo, tetanic cramps and tremors, and toxemia from liver impairment (Belding 1965; Keiser and Utzinger 2009). In patients with a very heavy worm burden (up to 25,000 flukes) the symptoms include acute pain in the right upper quadrant, marked gastrointestinal disturbances, with a syndrome associated with portal cirrhosis, splenomegaly, ascites and edema (Keiser and Utzinger 2009; Mas-Coma and Bargues 1997).

Opisthorchis viverrini

Opisthorchis viverrini is a particularly serious liver fluke (Rim 1982b; Kaewkes 2003) and is highly prevalent in Southeast Asia, including Thailand, Laos, Cambodia and South Vietnam (IARC 1994; Keiser and Utzinger 2009; Le 2000; Mas-Coma and Bargues 1997; Yu and Mott 1994). Fish-eating mammals such as cat, rat, dog, and civet cat are definitive hosts other than humans, and they are often found infected with *O. viverrini*, even in regions where the infection is not known to occur in humans (Mas-Coma and Bargues 1997). In Malaysia and southern China, reports on human infection by *O. viverrini* are limited; however, it has been found in cats (Mas-Coma and Bargues 1997; Bisseru and Chong 1969). Worth mentioning is the frequency of *O. viverrini* infection as reported in studies on human emigrants from these endemic countries and carried out in other parts of the world, such as Thais in Japan; Laotians and Thais in the United States; Laotians in Germany; Laotians, Vietnamese and Cambodians in France; Thais, Laotians and Vietnamese in Czech Republic or Thais in Kuwait (Mas-Coma and Bargues 1997). About 9 million people are estimated to be infected globally (Yossepowich *et al*. 2004).

The transmission of the parasite to the fresh-water snail hosts is related to the defecating habits of the definitive hosts, mainly human but also other fish-eating mammals, especially cats and dogs (Mas-Coma and Bargues 1997; Yu and Mott 1994; IARC 1994). In highly endemic areas of Thailand, *Bithynia* spp. snails are normally present in water bodies. The absence of latrines and disposal of untreated faeces into the environment around villages constitutes an important factor responsible for the propagation of the parasite (Forrer *et al*. 2012; Nithikethkul *et al*. 2004; Sayasone *et al*. 2007). The habit of people defecating on the ground in the bush not far from their houses, many of which are situated around the lakes, ponds, streams, etc., results in contamination of the water by the faeces containing *O. viverrini* eggs during the rainy season (Mas-Coma and Bargues 1997). Human and other animals acquire the infection by ingestion of fish, primarily cyprinoid fishes, containing metacercariae. The transmission of *O. viverrini* from humans to fish via snails is the net result of complex interplay between hosts and parasites that is invariably regulated by seasonal environmental conditions, especially water temperature and duration and amount of rainfall (Brockelman *et al*. 1986).

Thailand is the most endemic country for opisthorchiasis due to *O. viverrini* (Chai 2005; IARC 1994; Mas-Coma and Bargues 1997; Kaewpitoon *et al*. 2008; Sripa *et al*. 2003; Sithithaworn *et al*. 1997). It is widespread in the north and northeastern regions. The number of infected people in the northeastern region alone was estimated in the 1960s to be over 3.5 million (Wykoff *et al*. 1965 in Chai *et al*. 2005a). The estimated number of infected people is currently about 6 million (Jongsuksuntigul and Imsomboon 2003; Sripa *et al*. 2003).

It was estimated that 1.7 million people were infected with *O. viverrini* in Laos in 1992 (Rim *et al*. 1994; World Health Oganization 1995). The Mekong River basin is the most heavily infected area in Laos (Chai *et al*. 2005a) and the parasite is widespread because of geographical location and similar eating habits of people. Detailed investigations on *O. viverrini*, however, are scarce in this country (Sayasone *et al*. 2007). Most surveys have been done in the Vientiane province (Chai *et al*. 2005b) and its immediate surrounding areas (Chai *et al*. 2005b, 2007; Forrer *et al*. 2012; Sayasone *et al*. 2007). Sayasone *et al*. (2007) found a prevalence of 58.5% of people infected with *O. viverrini* in a southern rural district, while Chai *et al*. (2007) found 67.1% people in Savannakhet province infected with both small liver fluke and intestinal flukes. An exact knowledge on the distribution of human infection by *O. viverrini* in the interior of Laos is still lacking (Mas-Coma and Bargues 1997), although Forrer *et al*. (2012) presented the risk map of *O. viverrini* in Champasack province, and found 61.1% people infected with this parasite.

Only few official reports or published data on *O. viverrini* infection in Cambodia prior to 1997 are available (Mas-Coma and Bargues 1997). A small survey in primary schoolchildren from Kampongcham province showed a prevalence of *Opisthorchis* spp. of 4% from 251 fecal specimens in 2002 (Lee *et al*. 2002). Current studies have confirmed high prevalence of *O. viverrini* in several provinces of this country, e.g. Takeo province with average prevalence of *O. viverrini* infection in human was 47.5% (Yong *et al*. 2012) and Kratie province 4.6% (Sohn *et al*. 2012).

In Vietnam, several southern provinces such as Phu Yen, Binh Dinh, Dak Lak have reported infections with *O. viverrini* and with prevalence about 10% (De *et al*. 2003; De 2004b).

The life span of *O. viverrini* is over 10 years (Harinasuta and Harinasuta 1984; International Agency for Research on Cancer 1994). Patients infected with *O. viverrini* were found to have pathological changes in the extra- and intrahepatic bile ducts and gall bladder (Mas-Coma and Bargues 1997). The movement of flukes along the biliary ducts results in adenomatous hyperplasia of the biliary epithelium and thickening of their walls with the fibrous connective tissue, bile ducts becoming hypertrophied and dilated (Kim 1984). Enlargement of the liver is observed in most cases, particularly in massive infections. The gross hepatic pathology in heavy infection is characterized by subcapsular bile duct dilatation on the liver surface (Pairojkul *et al*. 1991a, b). In early infection, there is no hyperplasia of epithelium, no proliferation of fibrous connective tissues, and the ducts are lined by a single layer of columnar epithelium. Suppurative cholangitis occurs, and the infection may extend into the parenchyma of the liver tissue, causing hepatitis with the formation of micro and macroabscesses (Pairojkul *et al*. 1991a; Mas-Coma and Bargues 1997; Rim 1982b).

Morbidity in *O. viverrini* infection is not clear. Few infected people, even among those with heavy infection, suffer detectable signs or symptom by physical examination, but this does not mean that the parasite is non-pathogenic (Mas-Coma and Bargues 1997; International Agency for Research on Cancer 1994). Unfortunately, the asymptomaticity of *O. viverrini* infections becomes extremely dangerous since it contributes to enhancement of carcinogenesis, a leading cause of death among northeast Thais (Mas-Coma and Bargues 1997). The frequency of hepatobiliary abnormalities, e.g. gall bladder enlargement and poor function and simultaneously the odds of cholangiocarcinoma, rise sharply with intensity of infection (Khuhaprema and Srivatanakul 2007; Sithithaworn *et al*. 1994; Sripa and Pairojkul 2008; Sriamporn *et al*. 2004). This risk is clearly the highest incidence of liver cancer in the world (Sithithaworn *et al*. 1994).

Opisthorchis felineus

Opisthorchis felineus is a species very close to *O. viverrini* from the morphological point of view; however, several differences have been distinguished e.g. body size, oesophagus, distance between the anterior testis and ovary (Mas-Coma and Bargues 1997).

This species infects several species of fish-eating mammals, including humans in southern, central and eastern Europe, i.e. Italy, Albania, Greece, Switzerland, Holland, Germany, Poland, Ukraine, Russia and in Asia it is present in Turkey (Zavoikin 1991; World Health Oganization 1995). The distribution of *O. felineus* in freshwater fish and human opisthorchiasis do not coincide; human infection occurs at some distance from the main endemic areas because of the natural fish migration patterns and transport of fish for sale (World Health Organization 1995).

Although humans may be considered an accidental host, this liver fluke is now known to infect approximately 1.2 million people in Russia and 1.5 million in the former Union of Soviet Socialist Republics (Rim *et al*. 1994). The global number of cases is estimated to be about 1.6 million (Yossepowitch *et al*. 2004). The largest number of registered infections (over 900,000 extrapolated cases) were reported from the two districts of T'umen' and Tomsk in the Russian Federation (IARC 1994; Mas-Coma and Bargues 1997). High prevalences were also observed in areas along the Volga-Kama river basin, along river basin in the Novosibirsk, Krasnojarsk, Kurgan, Kemerovo, Serdlovsk, Omsk and Tomsk districts and the Altaj territory (Iarotski and Be'er 1993; IARC 1994).

Infections also occur in Ukraine and Kazakhstan (Iarotski and Be'er 1993; IARC 1994). Reports from Ukraine indicate that infection is found in the Sumy, Poltava and Černigov districts within the Dnepr River basin, with prevalences of 5–40%. In Kazakhstan, the average prevalence in six endemic districts was less than 10% (Iarotski and Be'er 1993). In Germany, 8% of the population of one rural area was reported to be infected in 1929, but more recent surveys on parasitic zoonosis in this region indicated that the infection no longer persists (Hinz 1991).

Hepatic lesions produced by *O. felineus* are similar to those caused by *O. viverrini* (IARC 1994; Mas-Coma and Bargues 1997). During the course of their development, they initiate inflammatory and proliferative changes of the biliary epithelium, which continue after the worms have matured and are accompanied by fibrosis of the distal biliary ducts. If the infection is intensified by continued exposure, the pathological process may extend to the bile ducts and gall-bladder and result in cirrhosis (IARC 1994). The degree of pathogenicity and clinical involvement depends largely on the number of parasites and the duration of infection (IARC 1994). Normally, small numbers of worms do not cause serious damage and do not give rise to clinical signs. In the Russian Federation, many apparently healthy people have been found to be infected. However, their worm burden was light, with average of no more than 200 eggs/g faeces (Bronshtein *et al*. 1991). When several hundred or thousand worms are present, severe damage to the liver and pancreas can occur (Rim 1982b).

Other fishborne zoonotic liver flukes

Amphimerus pseudofelineus has apparently a wide geographic range and low specificity for its definitive hosts. It is a parasite of the bile-ducts of dogs, coyotes, domestic cats and marsupials (*Didelphis marsupialis*, *Philander opossum*) in the USA, Panama, Colombia, Venezuela, Ecuador and Brazil. Rodriguez *et al*. (1949) made fecal examinations of 245 persons in a lowland area of Ecuador and found 18 of them infected with this species. Restrepo (1962) reported finding 6 cases out of 176 persons residing on the Amazon River, in Colombia. No additional human report and the pathology, symptom of this species appears in the literature (Mas-Coma and Bargues 1997).

Amphimerus noverca has been reported in the gall bladder at autopsy of two people in India (McConnell 1876 quoted in Mas-Coma and Bargues 1997). Proliferative changes in pancreatic duct epithelium and some epithelial desquamation and periductal fibrosis have been observed in pigs, in case of heavy infection in the pancreas (Sinha 1968).

Metorchis conjunctus was reported in the stool from an Indian patient in Saskatchewan, Canada (Cameron 1945 in Mas-Coma and Bargues 1997). Eggs of this species have also been reported in stools of humans native of Greenland (Babboti *et al*. 1961). The life cycle of this species is similar to that of species of *Clonorchis* and *Opisthorchis*. At the level of the bile ducts, adult worms may cause lesions similar to those produced by *Clonorchis sinensis* and *Opisthorchis felineus*: proliferation of biliary epithelium, biliary congestion and some degree of cirrhosis (Mills and Hirth 1968).

Metorchis albidus affects carnivorous mammals, but they are considered as a potential source of infection to humans, at least in Kazakhstan (Sidorov and Belyakova 1972) and Lithuania (Linnik 1983).

Metorchis bilis infections have occurred in people living in several regions of the Ob River basin in the West Siberia. The infection of this species was more common in many of the serologically tested people than *Opisthorchis felineus* (II'inskikh *et al*. 2007). The disease caused by *M. bilis*, is very close to opisthorchiasis in symptomatology.

Metorchis orientalis was originally described from a dog and cat in Japan and China (Bowman *et al*. 2012). Lin *et al*. (2001) reported a prevalence of infection of this species of 4.2% in human populations in Ping Yuan County of Guangdong Province, China. The infection rate of ducks, cats, and dogs are available 66.7%, 78.6% and 23.5%, respectively.

Opisthorchis tenuicollis is very similar to *O. felineus* (Dawes 1956). Infections in people have been reported (Bowman and Georgi 1963). There are few reports about its prevalence of infection in cats and pigs in India (Gatne *et al*. 2008; Chakrabarty and Sinha 1960).

Pseudamphistomum truncatum parasitizes bile ducts of various mammals, including humans. Instances of human infection are relatively few (Bittner 1928; Petrov 1940; Delianova 1957 in Mas-Coma and Bargues 1997). In a district near the River Kama (USSR), *P. truncatum* was found in bile of up to 31 patients (Khamidullin *et al*. 1991). Vinograidov (1892) reported young stages of a fluke from a human source in Russia. There are no studies on the pathology caused in humans, but liver pathological effects are known in seals.

Pseudamphistomum aethiopicum has been found in humans in Ethiopia and caused cyst-like nodules in the internal wall of the small intestine (Cacciapuoti 1947 in Mas-Coma and Bargues 1997).

Intestinal flukes

Among 47 fishborne zoonotic intestinal fluke species of 3 families which have been detected in humans, Nanophyetidae has only one species, while Echinostomatidae has 10 species (Table I). The family Heterophyidae has the highest number, with 36 species. In this section, we only review material at the family level.

Heterophyidae

The species of Heterophyidae are considered minute intestinal flukes because of their small sizes, i.e. typically less than 0.5 mm in length. Adult worms are found in fish-eating birds and mammals in addition to humans (Chai 2005a; Yu and Mott 1994). Although generally not considered of significant clinical importance compared to the liver flukes, several species, including *Stellantchasmus falcatus*, *Haplorchis* spp. and *Procerovum* spp., can cause significant occasionally fatal pathology, i.e. diarrhea, mucus-rich faeces, abdominal pain, dyspepsia, anorexia nausea, and vomiting (MacLean *et al*. 2006; Toledo *et al*. 2006, 2011; World Health Oganization 1995; Yu and Mott 1994). In one case, an adult heterophyid was found in the epicardium of the heart (Yu and Mott 1994), and sometime eggs were found in the brain and in sections of the spinal cord of humans (MacLean *et al*. 2006; World Health Oganization 1995; Yu and Mott 1994). The exact mechanisms of pathogenesis responsible are not clear but may be related to invasion of the circulatory system by trematode eggs (Chai *et al*. 2005a). Disease is usually related to worm burden which in some cases can be very heavy (MacLean *et al*. 2006). Another very important issue related to heterophyids is the difficulty of differentiating eggs from those of the liver flukes in human fecal examinations, which may cause inaccurate estimates of the prevalence of both trematode groups (Chai and Lee 1991, 2002; Johansen *et al*. 2010).

Chai and Lee (2002) listed 12 species of heterophyids that parasitize humans in Korea, including a single species in the genera *Heterophydosis*, *Pygidiopsis*, *Stellantchasmus* and *Centrocestus*, two species of *Stictodora*, three species of *Metagonimus*, and three species of *Heterophyes*. In humans, heterophyiases and metagonimiasis are the best known diseases associated with heterophyid parasitism (Fried *et al*. 2004). The two most prevalent species of human heterophyids are *Heterophyes heterophyes* and *Metagonimus yokogawai* (Toledo *et al*. 2011). The former species has been reported in humans from Egypt, Sudan, Iran, Turkey, Tunisia, Siberia, Europe, Russia, China, Taiwan, Philippines, Indonesia, India and Vietnam (Yu and Mott 1994). Kumar (1999) estimated that 10,000 people were affected by heterophyiases in Egypt in 1992 and reported a high prevalence of heterophyiasis in China with estimates of 230,000 infected individuals (Fried *et al*. 2004).

Adult flukes inhabit the mucosa of the middle part of the small intestine, and eggs released by the worms may penetrate the gut and travel to vital organs via the circulatory/ lymphatic system (MacLean *et al*. 2006). Eggs of different heterophyid species have been recovered from capillaries of the brain, heart, lungs, spleen and liver, where space-occupying granulomatous lesions may induce clinical pathology (MacLean *et al*. 2006). The flukes appear to live for less than a year. In light infections, fatigue and mild gastrointestinal concerns such as epigastric pain, diarrhea and anorexia are present; in heavy infections, abdominal cramps, malabsorption and weight loss may occur (MacLean *et al*. 2006). The diagnosis is made by recovery of the eggs in fecal examinations (Chai *et al*. 2005a).

Echinostomatidae

The Echinostomatidae flukes are small, typically 3–10 mm in length and 1–3 mm in width (Fried *et al*. 2004). At least 30 genera and more than 200 species of this family are known in the world, 15 species are reported to infect humans (Chai *et al*. 2005a; Huffman and Fried 1990). Among them, 10 species were reported as fish-borne echinostome species (Table I). Human echinostomiasis is endemic to Southeast Asia and the Far East, i.e. mainland China, Taiwan, India, Korea, Malaysia, Philippines, Indonesia, Thailand and Vietnam (Bandyopathy and Nandy 1986; Le 2000), but infections probably occur also in Africa (Yu and Mott 1994). *Echinostoma hortense* and *Echinochasmus japonicus* are the most important species because of their wide distribution and high prevalence in endemic areas (Chai *et al*. 2005a). Two separate life cycles for several different species of echinostomes were demonstrated to occur in endemic areas, i.e., the "human cycle" and the "sylvatic cycle", which has a zoonotic potential (Fried *et al*. 2004). In endemic areas, the disease occurs focally and is associated with common socio-cultural practices (Carney 1991). The prevalence of infection ranges from 65% in Taiwan and 44% in the Philippines to 5% in mainland China and from 50% in northern Thailand to 22% in Korea (Fried *et al*. 2004). However, the disease is under-reported in the endemic areas and is most prevalent in remote rural places among the low-wage earning population and among women of child-bearing age (Fried *et al*. 2004). In many countries, echinostomiasis is aggravated by socio-economic factors such as poverty, malnutrition and an explosively growing free-food market; and lack of food inspection, poor sanitation, other helminthiasis and declining economic conditions also contribute (Carney 1991; Fried *et al*. 2004).

Chai and Lee (1990) mentioned that morbidity and mortality due to echinostomiasis are difficult to assess. It is because of a prolonged latent phase, asymptomatic presentations, a short acute phase, and similarity of clinical symptoms to other intestinal helminthiases. Clinical symptoms are related to parasite load (Chai *et al*. 1994; MacLean *et al*. 2006). In light to moderate infections, patients have been observed to have anemia, headache, dizziness, stomach ache, gastric pain, and loose stools (Bundy *et al*. 1991; Chattopadyay *et al*. 1990; Field *et al*. 2004). Other synptoms such as eosinophilia, abdominal pain, profuse watery diarrhea, anemia, edema, and anorexia are associated with heavy infections (Chattopadyay *et al*. 1990). Pathologically echinostomes damage the intestinal mucosa, causing extensive intestinal and duodenal erosions and catarrhal inflammation (Fried *et al*. 2004).

Nanophyetidae

These are small (about 1 mm or less) flukes and the most important species is *Nanophyetus salmicola* (Fried et al. 2004). A subspecies of this digenean, also considered as a geographic variant by some researchers, is *N. s. schikhobalowi*, a human parasite in Siberia (Kumar 1999).

Nanophyetiasis is endemic in the far-eastern part of Russia, including Amur and Ussuri valleys of Khabarovsk territory and north Sakhalin (Yu and Mott 1994). In local ethnic minorities, the prevalence is 20%, and reaches up to 60% in some localities. In the USA 20 human cases have been reported since 1974 (Eastburn *et al*. 1987). Infected people may experience mild diarrhea, abdominal discomfort, and eosinophilia. In animals such as dogs, foxes, and coyotes, however, the fluke has been shown to be the vector of a rickettsia, *Neorickettsia helmintheca*, which causes a serious and often fatal systemic infection known as "salmon poisoning" (Fried *et al*. 2004; Yu and Mott 1994). The *Neorickettsia* bacteria is not pathogenic in humans, but mortality in dogs may reach 90% (Schell 1985).

The major risk factors in human infections

In some cultures, raw animals and plants are eaten for medicinal as well as nutritional purposes and this is associated with various diseases, including FZT. Raw crayfish is used to treat measles and transmits paragonimiasis. In Cameroon, raw crab is thought to increase fertility and in Ecuador macerated crab supernatant is given to sick children (Huss *et al*. 2004). Transmission of fish-borne trematodes is associated with behavioral patterns determined by socio-economic and cultural conditions in endemic areas. Consumption of raw fish and shellfish occurs most often around lakes, streams and ponds. Throughout Asia, up to 750 million people are at risk of infection by fish-borne liver flukes (Lima dos Santos and Howgate 2011; Kaiser and Utzinger 2009; World Health Oganization 2004). Food safety education may be the most expedient way to control the spread of infections because prevalence is inherently linked to human behavior (Ziegler *et al*. 2011). However, eating habits are deeply rooted in cultures and are resistant to changes.

In Japan, sushi and sashimi are traditional dishes known world-wide. They are prepared from relatively expensive marine fish such as tuna, red snapper, salmon, etc. in the restaurants or sushi bars (Nawa *et al*. 2005). Although various marine fish species may harbor *Anisakis* larvae, fish that are preferentially served in these restaurants are less contaminated or free from *Anisakis* larvae (Nawa *et al*. 2005). Other popular and cheaper marine fish, such as cod, herring, mackerel, etc. tend to be heavily infected with *Anisakis* larvae and are mainly consumed at home or at local restaurants. In rural areas, freshwater or brackish-water fish are consumed as sushi and sashimi (Nawa *et al*. 2005). Various wild animals e.g. frogs, land snails, snakes, backyard chicken, and wild boar are also served as sushi and sashimi, especially in the mountainous areas. They are also consumed raw or undercooked in a variety of ethnic dishes in many Asian countries as well. Because of this, zoonotic parasites are transmitted to humans. Thus, travelers dining in local restaurants or street shops can be expected to have much higher risks of infections with various parasites (Nawa *et al*. 2005). Nowadays, there are several remarkable parasitic diseases associated with eating raw fish in Japan, i.e. (1) anisakiasis, an acute gastrointestinal disease caused by infection with herring worm, *Anisakis* species or the cod worm – *Pseudoterranova decipiens*), (2) diphyllobothriasis (an intestinal infection caused by the fish tapeworm *Diphyllobothriasis latum*), (3) gnathostomiasis, primarily a disease of the skin caused by migration of the larvae of a *Gnasthostoma* sp. nematode, (4) paragonimiasis, caused by infection with *Paragonimus* spp. (lung flukes), (5) clonorchiasis/opisthorchiasis, (6) minute intestinal flukes. Infection with *Metagonimus yokogawai*, are still prevalent because people prefer to eat sushi and sashimi prepared from a locally famous freshwater fish “Ayu” – *Plecoglossus altivelis* (Nawa *et al*. 2005). Examination of stool samples for parasite eggs at Mitsui Memorial Hospital in Tokyo showed that 10–20% of samples were infected with *M. yokogawai*, angiostrongyliasis, an acute or subacute infectious disease of the central nervous system caused by the larval stage of the nematode *Angiostrongylus cantonensis*, and sparganosis, caused by larva of tape worm *Sparganum mansoni* (Nawa *et al*. 2005). Approximately 500 cases of people infected with *Sparganum mansoni* have been reported in Japan but realistic figures are certainly higher (Nawa *et al*. 2005).

Korean cuisine has various raw food dishes e.g. <u>Saengseon hoe</u> or <u>hwal-eo hoe</u> which is thinly sliced raw fish or other raw sea food (similar to Japanese sashimi); <u>yukhoe</u> is raw food made with raw beef and seasoned with soy sauce, sesame oil, and rice wine; <u>gan hoe</u> is raw beef liver with a sauce of sesame oil and salt. Chu (1970) estimated that in South Korea 4.5 million people are infected with *Clonorchis sinensis* and 1.5 million with *Paragonimus westermani*, and both fluke species infect humans through consumption of raw food. Prevalences of these trematodes, however, are slowly decreasing due to mass treatment programmers (Joo and Hong 1991; Maurice 1994).

In South China and Hong Kong, people like to eat congee (rice gruel) with slices of raw fish (Chai *et al*. 2005a; Fried *et al*. 2004). Half roasted or undercooked fish in Guangdong province and raw shrimps in Fujian province are other dishes commonly servered in daily meal in China (Chai *et al*. 2005a; Chen *et al*. 1994). Paragonimiasis is acquired by eating wine soaked ‘drunken’ crabs in parts of China. And in Thailand and the Philippines crab juice is used for medicinal purposes as well as using it in food preparations (Huss *et al*. 2004). Echinostome infections are contracted from eating undercooked snails and raw fish in Northern Luzon in the Philippines and in Korea.

In Southeast Asia, the most important of the parasitic diseases is opisthorchiasis, which is distributed throughout the Lower Mekong sub-region, including Northeast of Thailand, West of Laos, central of Cambodia and in the South of Vietnam (Chai *et al*. 2005; Fried *et al*. 2004; Lima dos Santos and Howgate 2011; MacLean *et al*. 2006; Mas-Coma and Bargues 1997; Sripa *et al*. 2003; World Health Oganization 1995). The Lower Mekong Basin has numerous rivers, streams, human-made water diversion, irrigation ditches, reservoirs, natural lakes, aquaculture pond, and paddy fields (Grundy-Warr *et al*. 2012) and fisheries are a key source of livelihood, providing the major source of animal protein to large populations. Fishing is occupation by which many farmers supplement their incomes and family diets through small-scale fishing activities (Friend 2007; Gregory and Guttman 1996; Hortle 2008; Poulsen 2003).

In Laos, many rural areas in the Mekong River basin, sticky rice, fermented and raw fish locally known as “pla ra”, “som fak”, and “pla som” are regularly consumed, sometimes on a daily basis (Chai and Hongvanthong 1998; Chai *et al*. 2005a; Rangsin *et al*. 2009). Other traditional raw food is “koi pla" (a dish made from finely chopped raw fish mixed with chili, lemon-juice, vegetables, and spices) eaten on special occasions (Chai *et al*. 2005a; Grundy-Warr *et al*. 2012). Consumption of koi pla is popular in the fishing and farming villages of northeast Thailand and Lao PDR as a cheap form of protein for local people. Koi pla is relatively quick and easy to prepare, taking approximately 20 minutes, and therefore it is very convenient for fishers and farmers who may be preparing the dish at some distance from their homes (Grundy-Warr *et al*. 2012). High consumption (92%) of raw or partially cooked fish in local dishes, such as koi pla, as well as "pla som" (moderately fermented fish) and "pla ra" or "pa dek" (Laos) (long-term fermented and highly salted fish) undoubtedly help the spread of liver fluke infections in human populations (Grundy-Warr *et al*. 2012). Research in Laos indicates that mostly men eat raw fish dishes and men are resistant to any alteration in their habits (Chai *et al*. 2005; Grundy-Warr *et al*. 2012). However, the same study also notes that women are still at risk because they often taste food, including raw fish dishes, during preparation.

Research in Thailand has indicated that alcohol was portrayed as having the ability to strengthen the body and prevent illness, as a means of pain relief, and a mood enhancer (Grundy-Warr *et al*. 2012). Local fishermen believe that strong alcohol kills germs and worms. There are also associated beliefs that plenti of lime juice on raw fish (nam manao) removes parasites (Grundy-Warr *et al*. 2012). Some women fish-traders consume lao-kao with the men (Fordham 1995). Nevertheless, it is a common practice mostly amongst fishermen, partly due to the fact that after a night's fishing activity, they are able to consume koi pla and whiskey before they go to sleep in the late morning, whereas, the women still have many activities to do relating to fish processing, marketing, and helping with their families (Grundy-Warr *et al*. 2012).

Cambodia is potential hot-spot for multiple water-borne and food-borne parasitic infections. Average fish dependence of Cambodians is the highest of all countries in the Mekong Basin, and Mekong River and Tonle Sap Lake receive many migratory cyprinid species that are also found in Thailand and Laos (Grundy-Warr *et al*. 2012). Unlike Lao PDR and Thailand, eating "raw fish" is less common in Cambodia while the consumption of the hugely popular "prahoc" (Khmer fermented fish paste) which is popular in both urban and rural contexts (Grundy-Warr *et al*. 2012). However, there has yet to be a systematic study of whether *Opisthorchis viverrini* metacercariae can survive in prahoc made from small cyprinid fishes (Grundy-Warr *et al*. 2012).

Vietnam has two big river systems, the Red River in the North and the Mekong River in the South. In northern Vietnam, common fish species used to prepare raw fish dish, also called "gỏi cá", are silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idellus*), rohu (*Labeo rohita*), and mrigal (*Cirrhinus mrigala*) (Chi *et al*. 2009; Phan *et al*. 2011). In the rural areas, slices of raw fish are soaked twice in a mild saline (1–3% NaCl) solution, before mixed with rice powder and eaten with herbs and sauce (Chi *et al*. 2009; Phan *et al*. 2011). Mostly adult men eat raw fish, whereas women mainly eat herbs dipped into the sauce. Children also have meals together with those eating raw fish, but the children consumed other types of food. In these places 32.2% of fish farm household members were infected with FZT (Phan *et al*. 2011). In restaurants, raw fish is prepared in two different ways, i.e. (1) fillets placed on ice and eaten wrapped in vegetables and dipped in various sauces e.g. mustard or wasabi, or (2) fillets served in a sauce of lemon or vinegar (Chi *et al*. 2009). Chi *et al*. (2009) found that 11.8% dishes from Nam Dinh restaurants were infected with heterophyids, while 3.1% of dishes from Hanoi restaurants were infected. Chi *et al*. (2009) also compared metacercariae density in fish meat served raw with that in the remainder of the same fish and found that density in the meat was very low compared to the density in the remainder and it appears that heterophyids are located rather superficially in the fish, i.e. in the skin. This, however, may not be the case for *C. sinensis*. In the mountain areas, local people consume lightly fried crabs and this constitutes a high risk of infection with lung fluke of *Paragonimus* spp. Doanh *et al*. (2007, 2008, 2012) and Le *et al*. (2006) isolated metacercariae of several *Paragonimus* species in crab and experimentally infected cats. The recovered flukes were collected and identified and two of these species were new. The prevalence of paragonimiasis in humans detected by Kato-Katz method ranged from 0.3% in Lang Son, 0.6% in Nghe An province to 0.9–10.9% in Yen Bai and 3.3–11.3% in Hoa Binh province (De 2004a). Doanh *et al*. (2011) used ELISA method for diagnosing infections and they found a prevalence of 12.7% among people in Sinho district of Lai Chau province and 3.3% in Lucyen district of Yenbai province. In parts of southern Vietnam, people eat live fish with raw vegetables, chili and this is always accompanied by intake of strong alcohol, for example rice vodka (De 2009). De (2009), however, did not identify the fish used, nor did he determine the prevalence of metacercaria in these fish nor the prevalence of people infected with FZT. According to the reports from national hospitals and public communication, some patients were reported to be infected with taeniasis/cysticercosis, gnathostomiasis, anisakiasis when they consumed undercooked meat of mammals, frogs, snakes and fishes (De 2009).

Options for FZT control

With the primary purpose to develop a control strategy against FZT infections in aquaculture and thus providing safe food, several approaches have been developed to intervene at various stages of the trematodes' transmission cycle, i.e. interventions against the adult parasites, preventing eggs from reaching aquaculture ponds, control of the intermediate host snails so as to reduce infection risks in fish, and preventing metacercariae reaching the final host. Due to the complexity of the dynamics of transmission, integration of most of these options should probably be the optimal strategy for control.

Education

In endemic areas, health programs and hygiene instructions may have an important role in the promotion of a safe environment. Instructions cover topics such as hygienic excreta disposal, use of latrines, and the relationship between aquaculture practices and the life cycle of the parasites. Farmers should be provided with guidelines on how to improve their ponds. This could include removal of the top 3–5 cm of mud from the pond bottom and letting the pond dry out for several days before restocking, removal of all aquatic vegetation from the pond to reduce snails and their habitat (Clausen *et al*. 2012). The banks of ponds could be lined with concrete to help control vegetation and possibly thereby reduce snail density (Clausen *et al*. 2012). Furthermore, the inlet tube could be fitted with a mesh filter to help reduce snail entry into the pond; if the mesh size is small the mesh filter must be long, otherwise it could be clogged by mud, vegetation or waste and eventually break due to water pressure (Clausen *et al*. 2012). Reduction of FZT egg contamination of ponds could perhaps be achieved by constructing a 10–15 cm elevated cement barrier all along the pond bank to prevent surface runoff water from entering the pond. Furthermore, the pond could be completely fenced by a 50 cm high fine meshed net placed very close to the pond edge to keep dogs and cats out (Clausen *et al*. 2012). Also farmers should not utilize liquid waste from pigpens and human latrines as fertilizer of ponds and this could be achieved by blocking drains with cement and bricks to prevent fecal contamination from surface runoff water (Clausen *et al*. 2012). In addition, the habit of eating raw or inadequately cooked fish should be changed through propaganda and education.

Treatment

Humans in endemic areas should be examined for FZT eggs and infected humans with clonorchiasis and opisthorchiasis should be treated with specific drugs e.g. praziquantel (Biltricide) at a dose of 40mg/kg body weight in a single administration or three times daily at 25 mg/kg body weight for 3 consecutive days (World Health Oganization 2011, 2012). For treatment of infected people with intestinal flukes, single dose of 10–20 mg/kg is satisfactory (Chai and Lee 2002). According to the recommended strategy of World Health Oganization (2012), in districts where the prevalence of infection is more than 20%, mass treatment of all residents should be done every 12 months. When the infection rate is less than 20%, all residents should be treated every 24 months or alternatively just treat those individuals reporting the habit of eating raw fish every 12 month (World Health Oganization 2012). In Vietnam about 100,000 Vietnamese people were treated in 2008–2009 (World Health Oganization 2011). It should be noted that the Ministry of Health recommended 75 mg praziquantel/kg body weight, given in three equivalent doses in one day, but now they adopted a standard regimen of praziquantel 50 mg/kg body weight, administered as two doses in one day (World Health Oganization 2011).

In hospitals or health centres in communities, the doctors or technicians are using Kato-Katz smear method to diagnose the liver flukes (Chai and Lee 2002; Dung *et al*. 2007). But eggs from liver flukes are very similar to eggs of intestinal flukes and this can cause inaccurate estimates of prevalence of both trematode groups (Chai and Lee 2002). Thus some of the areas reported to have very high prevalences in Vietnam (De 2004b) could be partly due to misdiagnosis, although *Clonorchis sinensis* also is present (Dung *et al*. 2007). Hence new methods for accurate diagnosis and easily applicable in the field should be developed. Similarly, high prevalences of infections in the snail hosts in Vietnam (De 2004b) based on cercariae morphology alone could be misleading (Dung *et al*. 2010).

In addition, in the endemic areas, mass treatment should also be applied for domestic animals (dogs, cats, pigs, chicken etc.) (World Health Oganization 2011). It is also highly desirable that the anthelminthic is active against both larval and adult parasitic stages. Especially, treatment of animals is difficult for various reasons, i.e. dog and cats can be difficult to catch; the cycle production of breeding animals is non-stop, so there is rapid exchange of animals (Clausen *et al*. 2012).

Snail control

One method to control FZT is to disrupt the life cycle of the snails. Snails can be controlled indirectly by reducing the suitability of their habitat or directly by removing them through chemical, physical, or biological control (Hoffman 1970; Sturrock 1995; Terhune *et al*. 2003). For chemical control, molluscicides such as niclosamide, copper compounds, hydrated lime, sodium chloride and calcium cyanamide could be used in ponds (Hoffman 1970; Rondelaud and Dreyfuss 1996; Sturrock 1995; Khallaayoune *et al*. 1998; Terhune *et al*. 2003; Wada 2004; Mostafa *et al*. 2005; Campbell *et al*. 2002; Wui and Engle 2007). Most molluscicides, however, are toxic to fish as well and therefore their use in aquaculture ponds may be limited to ponds with out fish. Physical alteration of culture ponds by draining or scraping of the banks can affect snail density through destruction or removal of snails along the periphery of ponds. Removal of aquatic vegetation may have some effect on snail density, although intermediate host snails for FZT do not show a strong association with aquatic plants (Dung *et al*. 2010). Flushing of drained ponds by washing with high pressure water hoses may reduce snail populations (Hoffman 1970). Many natural enemies of snails may have the potential to reduce snail density, but emphasis has been on competitor snails or predators (Madsen 1983). Biological control of snails may be achieved by the introduction of competitor snails, and there have been examples of the natural displacement of snails transmitting schistosomes in the field (Pointier and McCullough 1989; Pointier *et al*. 1989; Pointier and Jourdane 2000; Pointier 2001; Giovanelli *et al*. 2005).

With varying success, species of mollusk-eating fishes have been tested as snail control agents (Shelton *et al*. 1995; Venable *et al*. 2000; Rothbard and Rubinshtein 2000; Ben-Ami and Heller 2001; Terhune *et al*. 2003; El-Deeb and Ismail 2004; Ledford and Kelly 2007; Wui and Engle 2007), e.g. the Haplochromine cichlid *Astatoreochromis alluaudi*, Reader Sunfish *Lepomis microlophus*, Blue Catfish *Ictalurus furcatus* etc., especially, Black Carp, *Mylopharyngodon piceus*, stands out as an efficient predator of snails.

References

Adam A.M., Murrell K.D., Cross J.H. 1997. Parasites of fish and risks to public health. *Revue Scientifique et Technique-Office Interational Des Epizooties*, 16, 652–660.

Armignacco O., Caterini L., Marucci G., Ferri F., Bernardini G., Raponi G.N., Ludovisi A., Bossù T., Morales M.A.G., Pozio E. 2008. Human illnesses caused by *Opisthorchis felineus* flukes, Italy. *Emerging Infectious Diseases*, 14, 1902–1905. DOI: 10.3201/eid1412.080782.

Athur J.R., Lumanlan-Mayo S. 1997. Checklist of the parasites of fishes of the Philippines. *FAO Fisheries Technical Paper*, Issue 369.

Attwood H.D., Chou S.T. 1978. The longevity of *Clonorchis sinensis*. *Pathology*, 10, 153–156. DOI: 10.3109/003130278090 63494.

Axelson R.D. 1962. Case report: *Metorchis conjunctus* liver fluke infestation in a cat. *Canadian Veterinary Journal*, 3, 359–360. DOI: 10.1139/z2012-070.

Babboti F.L.Jr., Erye W.W., Gordon J.E. 1961. Intestinal parasites of man in Arctic Greenland. *American Journal of Tropical Medicine and Hygiene*, 10, 185–190.

Bandyopathy A.K., Nandy A. 1986. A preliminary observation on the prevalence of echinostomes in a tribal community near Calcutta. *Annals of Tropical Medicine and Parasitology*, 80, 3016–3034.

Bargues M.D., González L.C., Artigas P., Mas-Coma S. 2011. A new baseline for fascioliasis in Venuzuela: lymnaeid vectors ascertained by DNA sequencing and analysis of their relationships with human and animal infection. Parasites & Vectors, 4, 200. DOI: 10.1186/1756-3305-4-200.

Belding D.L. 1965. Text book of Parasitology. 4th Edition Appelton Century Crofus. NewYork, 1374 pp.

Ben-Ami F., Heller J. 2001. Biological control of aquatic pest snails by the Black Carp *Mylopharyngodon piceus*. *Biological Control*, 22, 131–138. DOI: 10.1006/bcon.2001.0967.

Bisseru B., Chong L.K. 1969. *Opisthorchis viverrini* (Poirier, 1886) a trematode parasite of man in West Malaysia. *Tropical and Geographical Medicine*, 21, 138–146.

Bittner H., Sprehn C.E.W. 1928. Trematodes. Saugwiirmer. *Biologie der Tiere Deeutschlands*, 27, 1–133.

Bowman D.D., Georgi J.R. 1963. Georgis' parasitology for veterinarians – 9th edit. Saunders Elsevier, 11830 Westline Industrial driver, St. Louis, Missouri, 451 pp.

Bowman D.D., Hendrix C.M., Lindsay D.S., Barr S.C. 2012. Feline clinical parasitology. Iowa State University Press, 460 pp.

Bray R.A., Gibson D.I., Jones A. 2008. Key to the trematoda. Volume 3. CABI and Natural History Museum, 825 pp.

Brockelman W.Y., Upatham E.S., Viyanant V., Ardsungnoen S., Chantanawat R. 1986. Field studies on the transmission of the human liver fluke *Opisthorchis viverrini*, in northeast Thailand: population changes of the snail intermediate host. *International Journal for Parasitology*, 16, 545–552. DOI: 10.1016/0020-7519(86)90091-3.

Bronshtein A.M., Zolotukhin V.A., Gitsu G.A., Sabgaida T.P., Parfenov S.B. 1991. The clinic-epidemiological characteristics of opisthorchiasis foci in the Yamalo-Nenetz Autonomous district and the treatment results with praziquantel. *Meditsinskaya Parazitologiya i Parazitarnye Bolezni*, 5, 12–16 (in Russian).

Bundy D.A., Chandiwana S.K., Homeida M.M., Yoon S., Mott K.E. 1991. The epidemiological implications of a multiple-infection approach to the control of human helminth infections. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 85, 274–276. DOI: 10.1016/0035-9203(91)90054-3.

Cacciapuoti R. 1947. Su di una nuova distomatosi umana en Ethiopia. *Rivista di Biologia Coloniale*, 8, 111–116 (in Mas-Coma and Bargues 1997).

Cameron T.W.M. 1945. Fish-carried parasites in Canada. *Canadian Journal of Comparative Medicine*, 9, 245–254; 283–286; 302–311.

Campbell K.C.M., Meech R.P., Klemens J.J., Gerberi M.T. 2007. Prevention of noise- and drug-induced hearing loss with D-methionine. *Hearing Research*, 226, 92–103. DOI: 10.1016/j.heares.2006.11.012.

Carney W.P. 1991. Echinostomiasis – a snail-borne intestinal trematode zoonosis. *The Southeast Asian Journal of Tropical Medicine and Public Health*, 22, 206–221.

Chai J.Y. 2007. Intestinal flukes. In: (Eds. K.D. Murrell, B. Fried) Food-borne Parasitic Zoonoses: Fish and plant-borne parasites. Vol. 11. New York, USA: Springer, 53–115 (World Class Parasites).

Chai J.Y., Han E.T., Guk S.M., Shin E.H., Sohn W.M., Yong T.S., Eom K.S., Lee K.H., Yeong H.G., Ryang Y.S., Hoang E.H., Phommasack B., Insisiengmay B., Lee S.H., Rim H.J. 2007. High prevalence of liver and intestinal fluke infections among residents of Savannakhet province in Laos. *Korean Journal of Parasitology*, 45, 213–218. DOI: 10.3347%2Fkjp.2007.45.3.213.

Chai J.Y., Han E.T., Park Y.K., Guk S.M., Park J.H., Lee S.H. 2002. *Stictodora lari* (Digenea: Heterophyidae): The discovery of the first human infection. *Journal of Parasitology*, 88, 627–629. DOI: 10.1645/00223395(2002)088[0627:SLDHTD]2.0.CO;2.

Chai J.Y., Hong S.T., Lee S.H., Lee G.C., Min Y.I. 1994. A case of echinostomiasis with ulcerative lesions in the duodenum. *Korean Journal for Parasitology*, 32, 201–204. DOI: 10.3347%2Fkjp.1994.32.3.201.

Chai J.Y., Hongvanthong B. 1998. A small-scale survey of intestinal helminthic infections among the residents near Pakse, Laos. *Korean Journal of Parasitology*, 36, 55–58. DOI: 10.3347%2Fkjp.1998.36.1.55.

Chai J.Y., Lee S.H. 1990. Intestinal trematodes of humans in Korea: *Metagonimus*, Heterophids and Echinostomes. *Korean Journal of Parasitology*, 28, 103–122. DOI: 10.3347%2Fkjp.1990.28.Suppl.103.

Chai J.Y., Lee S.H. 1991. Intestinal trematodes infecting humans in Korea. *Southeast Asian Journal of Tropical Medicine and Public Health*, 22, 163–170.

Chai J.Y., Lee S.H. 2002. Food-borne intestinal trematode infections in the Republic of Korea. *Parasitology International*, 51, 129–154. DOI: 10.1016/S1383-5769(02)00008-9.

Chai J.Y., Murrell K.D., Lymbery A.J. 2005a. Fish-borne parasitic zoonoses: status and issues. *International Journal for Parasitology*, 35, 1233–1254. DOI: 10.1016/j.ijpara.2005.07.013.

Chai J.Y., Park J.H., Han E.T., Guk S.M., Shin E.H., Lin A., Kim J.L., Sohn W.M., Yong T.S., Eom K.S., Min D.Y., Hwang

E.H., Phommasack B., Insisienqmay B., Rim H.J. 2005b. Mixed infection with *Opisthorchis viverrini* and intestinal flukes in residents of Vientiane municipality and Saravane province in Laos. *Journal of Helminthology*, 79, 283–289. DOI: 10.1079/JOH2005302.

Chai J.Y., Shin E.H., Lee S.H., Rim H.J. 2009. Foodborne intestinal flukes in Southeast Asia. *Korean Journal of Parasitology*, 47, 69–102. DOI: 10.3347%2Fkjp.2009.47.S.S69.

Chakrabarty M., Sinha P.K. 1960. On the occurrence of *Opisthorchis tenuicollis* (Rudolphi, 1819) Stiles and Hassall, 1896 (syn. *O. viverrini* (Poirier, 1886) Stiles and Hassal, 1896) in domestic cat in India. *Indian Veterinary Journal*, 37, 17–18.

Chattopadyay U.K., Das M.S., Pal D., Das S., Mukherjee A. 1990. A case of echinostomiasis in a tribal community in Bengal. *Annals of Tropical Medicine and Parasitology*, 84, 193.

Chen E.R. 1991. Clonorchiasis in Taiwan. *Southeast Asian Journal of Tropical Medicine and Public Health*, 22, 184–185.

Chen M.G., Lu Y., Hua X., Mott K.E. 1994. Progress in assessment of morbidity due to *Clonorchis sinensis* infection: a review of recent literarute. *Tropical Diseases Bulletin*, 91, R7-R56.

Cheng Y.Z., Lin J.X., Chen B.J., Fang Y.Y., Guo Z.F., Xu G.F., Wu Z.Y. 1992. A new species of *Echinochasmus* parasitic in man and observation of its experimental infection. *Wuyi Science Journal*, 9, 43–48.

Chi T.T.K., Dalgaard A., Turbull J.F., Tuan P.A., Murrell K.D. 2008. Prevalence of zoonotic trematodes in fish from a Vietnamese fish-farming community. *Journal of Parasitology*, 94, 423–428. DOI: 10.1645/GE-1389.1.

Chi T.T.K., Murrell K.D., Madsen H., Khue N.V., Dalsgaad A. 2009. Fishborne zoonotic trematodes in raw fish dishes served in restaurants in Nam Dinh province and Hanoi, Vietnam. *Journal of Food Protection*, 72, 2394–2399.

Chieffi P.P., Leite O.H., Dias R.M.D., Torres D.M.A.V., Mangini A.C.S. 1990. Human parasitism by *Phagicola* sp. (Trematoda, Heterophyidae) in Cananesia, São Paulo State, Brazil. *Revista do Instituto Medicina Tropical de São Paulo*, 32, 285–288. DOI: 10.1590/S0036-46651990000400008.

Choi D.W. 1976. *Clonorchis sinensis* in Kyungpook Province, Korea. Demonstration of metacercaria of *Clonorchis sinensis* from fresh-water fish. *Korean Journal of Parasitology*, 14, 10–16. DOI: 10.3347%2Fkjp.1976.14.1.10.

Chu I. 1970. Trematode infection in Korea. *Official journal of Research Institute of Medical Science of Korea*, 2, 33–40.

Clausen J.H., Madsen H., Murrell K.D., Van P.T., Ha N.T.T., Dung D.T., Anh N.T.L., Hung N.M., Dalsgaard A. 2012. Prevention and control of fish-borne zoonotic trematodes in fish nurseries, Vietnam. *Emerging Infectious Diseases*, 18, 1438–1445. DOI: 10.3201/eid1809.111076.

Crompton D.W.T. 1999. How much human helminthiasis is there in the world? *Journal of Parasitology*, 85, 397–403. DOI: 10.2307/3285768.

Cross J.H. 1984. Changing patterns of some trematode infections in Asia. *Arzneimittelforschung/Drug Research*, 34, 1224–1226.

Cross J.H., Basaca-Sevilla V. 1984. Biomedica Survey in the Philippines. NAMRU- SP-47, 119 pp.

Dawes B 1956. The trematoda – with special reference to British and other European forms. Cambridge at the university press, 644 p.

De N.V. 2004a. Epidemiology, pathology and treatment of Paragonimiasis in Vietnam. *Southeast Asian Journal of Tropical Medicine and Public Health*, 35, 331–336.

De N.V. 2004b. Fish-borne trematodes in Vietnam. *Southeast Asian Journal of Tropical Medicine and Public Health*, 35, 229–231.

De N.V. 2009. Assessment of fish-borne trematode infection in human and freshwater fishes in the community of Namdinh province and identification of the causative agents by morphology and molecular methods. In: 6th Seminar on Food and Water-borne Parasitic Zoonoses (FBPZ6) incorporating 3rd International Meeting on Gnasthostomiasis, 2–4 December, 2009, Thailand, p. 49.

De N.V., Murrell K.D., Cong L.D., Cam P.D., Chau L.V., Toan N.D., Dalsgaard A. 2003. The food-borne trematode zoonoses of Vietnam. *Southeast Asian Journal of Tropical Medicine and Public Health*, 34, 12–34.

Delianova R.S. 1957. Distribution of helminthiasis of dogs in different geographica zones of SSSR. *Doklady Academii Nank Uzbek SSR*, 10, 65–71 (in Russian).

Derraik J.G.B. 2008. The potential significance to human health associated with the establishment of the snail *Melanoides tuberculata* in New Zealand. *New Zealand Medical Journal*, 121, 25–32.

Doanh P.N., Dung D.T., Thach D.T., Horii Y., Shinohara A., Nawa Y. 2011. Human paragonimiasis in Viet Nam: epidemiological survey and identification of the responsible species by DNA sequencing of eggs in patients' sputum. *Parasitology International*, 60, 534–537. DOI: 10.1016/j.parint.2011.09.001.

Doanh P.N., Hien H.V., Nonaka N., Horii Y., Nawa Y. 2012. Discovery of *Paragonimus skrjabini* in Vietnam and its phylogenetic status in the *Paragonimus skrjabini* complex. *Journal of Helminthology*, 16, 1–7. DOI: 10.1017/S0022149X1200065X.

Doanh P.N., LE N.T., Minh N.T., Ha N.V. 2006. Prevalent infection of *Paragonimus* larvae in Yenbai province. *Journal of Biology*, 28, 1–4 (in Vietnamese).

Doanh P.N., Shinohara A., Horii Y., Habe S., Nawa Y., Le N.T. 2007. Description of a new lung fluke species, *Paragonimus vietnamensis* sp. nov. (Trematoda: Paragonimidae), found in Northern Vietnam. *Parasitology Research*, 101, 1495–1501. DOI: 10.1007/s00436-007-0666-9.

Doanh P.N., Shinohara A., Horii Y., Habe S., Nawa Y., Le N.T. 2008. Discovery of *Paragonimus proliferus* in Northern Vietnam and their molecular phylogenetic status among genus *Paragonimus*. *Parasitology Research*, 102, 677–683. DOI: 10.1007/s00436-007-0811-5.

Dooley J.R., Naefie R.C. 1976. Clonorchiasis and Opisthorchiasis. In: (Eds. C.H. Binford, D.H. Connor) Pathology of Tropical and Extraordinare Diseases. Armed Forces Institute of Pathology, Washington D.C., 509–516.

Dung B.T., Madsen H., The D.T. 2010. Distribution of freshwater snails in family-based VAC ponds and associated waterbodies with special reference to intermediate hosts of fish-borne zoonotic trematodes in Nam Dinh province, Vietnam. *Acta Tropica*, 116, 15–23. DOI: 10.1016/j.actatropica.2010.04.016.

Dung D.T., De N.V., Waikagul J., Dalsgaard A., Chai J.Y., Sohn W.M., Murrell K.D. 2007. Fishborne Intestinal Trematodiasis: An Emerging Zoonosis in Vietnam. *Emerging Infectious Diseases*, 13, 1828–1833. DOI: 10.3201/eid1312.070554.

Eastburn R.L., Tritsche T.R., Terhune Jr.C.A. 1987. Human intestinal infection with *Nanophyetus salmincola* from salmonid fishes. *American Journal of Tropical Medicine and Hygiene*, 36, 586–591.

Eckert J., Freidhoff K.T., Zahner H., Deplazes P. 2005. Stamm Plathelmintha. In: Lehrbuch der Parasitologie fur die Tiermedizin. Enke, Germany, 132–159.

El-Deeb F.A., Ismail N.M. 2004. Feeding ecology and food composition of the Black Carp *Mylopharyngodon piceus* and the grass carp *Ctenopharyngodon idella* inhabiting the fish pond of Al-abbassa fish hatchery with emphasis given to vector snails. *Journal of the Egyptian Society of Parasitology*, 34, 643–657.

Fahmy M.A.M., Selim M.K. 1959. Studies on some trematode parasites of dogs in Egypt with special reference to the role played by fish in their transmission. *Zeitschrift für Parasitenkunde*, 19, 3–13. DOI: 10.1007/BF00260314.

Fan S.Q., Sun M.F. 1989. *Echinostoma hortense*. *Bulletin of Harbin Medical University*, 23, 161 (in Chinese).

Fang Y.Y., Chen Y.D., Li X.M., Wu J., Zhang Q.M., Ruan C.W. 2008. Current prevalence of *Clonorchis sinensis* infection in endemic areas of China. *Chinese Journal of Parasitology and Parasitic Diseases*, 26, 81–86.

Fordham G. 1995. Whisky, wine, women and song: Men, alcohol and AIDS in northern Thailand. *Australian Journal of Anthropology*, 6, 154–177.

Forrer A., Sayasone S., Vounatsou P., Vonghachack Y., Bouakhasith D., Vogt S., Glaser R., Utzinger J., Akkhavong K., Odermatt P. 2012. Spatial distribution of, and risk factors for, *Opisthorchis viverrini* infection in Southern Lao PDR. *PLoS Neglected Tropical Desease*, 6, e1481. DOI: 10.1371/journal.pntd.0001481.

Fried B., Graczyk T.K., Tamang L. 2004. Food-borne intestinal trematodiases in humans. *Parasitology Research*, 93, 159–170. DOI: 10.1007/s00436-004-1112-x.

Friend R.M. 2007. Securing sustainable livelihoods through wetland management: Reflections on experience under the Mekong Wetlands Biodiversity and Sustainable Use Program (MWBP). ICN/MWBP, Vientiane, Lao PDR: Technical Report.

Gatne M.L., Gaurat R.P., Pednekar R.P., Patil S.B., Savant S.K., Ugalmugle S.S. 2008. Infestation of *Opisthorchis tenuicollis* in a pig – An abattoir report. *Journal of Veterinary Parasitology*, 22, 69–70.

General directorate of Statistics of Vietnam, 2012. Summary of statistical yearbook of Vietnam in 2011. Statistical publishing houre, available in http://www.gso.gov.vn/default_en.aspx?tabid=515&idmid=5&ItemID=12576.

Giovanelli A., Coelho da Silva C.L.P.A., Leal G.B.E., Baptista D.F. 2005. Habitat preference of freshwater snails in relation to environmental factors and the presence of the competitor snail *Melanoides tuberculatus* (Müller, 1774). *Memórias do Instituto Oswaldo Cruz*, 100, 169–176.

Gregory R., Guttman H. 1996. Poor in all but fish: a study of the collection of rice-field foods from three villages in Svay Teap district, Svay Rieng. Working paper 5, Asian Institute of Technology, AIT Aquaculture Outreach Project, Bangkok, Thailand.

Grundy-Warr C., Andrews R.H., Sithithaworn P., Petney T.N., Sripa B., Laithavewat L., Ziegler A.D. 2012. Raw attitudes, wetland cultures, life-cycles: Socio-cultural dynamics relating to *Opisthorchis viverrini* in the Mekong Basin. *Parasitology International*, 61, 65–70. DOI: 10.1016/j.parint.2011.06.015.

Guo Y. 2001. Integrated agriculture-aquaculture: a primer. FAO Fisheries Technical Paper, 149 pp. (http://www.fao.org/docrep/005/Y1187E/y1187e21.htm).

Hamir A.N., Snyder D.E., Hanlon C.A., Rupprecht C.E. 1993. A trematode (*Phagicola* sp.) – induced mesenteric lymphadenitis and enteritis in Raccons (*Procyon lotor*). *Veterinary Pathology*, 30, 373–376. DOI: 10.1177/030098589303000407.

Harinasuta C., Harinasuta T. 1984. *Opisthorchis viverrini*: life cycle, intermediate hosts, transmission to man and geographical distribution in Thailand. *Arzneimitteforschung*, 34, 1164–1167 (abstract).

Hinz E. 1991. Current status of food-borne parasitic zoonoses in Germany. *Southeast Asian Journal of Tropical Medicine and Public Health*, 22, 78–84.

Hoffman G.L. 1970. Control methods for snail-borne zoonoses. *Journal of Wildlife Diseases*, 6, 262–265.

Hong S.T. 2003. *Clonorchis sinensis*. In: (Eds. M.D. Miliotis MD, J.W. Bier JW (Eds.). International Handbook of Foodborne Pathogens, Marcel Dekker, Inc, NewYork, Basel, 581–592 pp.

Hong S.T., Yoon K., Lee M., Seo M., Choi M.H., Sim J.S., Choi B.I., Yun C.K., Lee S.H. 1988. Control of clonorchiasis by repeated praziquantel treatment and low diagnostic efficacy of sonography. *Korean Journal of Parasitology*, 36, 249–254. DOI: 10.3347/kjp.1998.36.4.249.

Hop T.N., De V.N., Murrell D., Dalsgaard A. 2007. Occurrence and species distribution of fishborne zoonotic trematodes in wastewater-fed aquaculture in northern Vietnam. *Tropical Medicine and International Health*, 12, 66–72. DOI: 10.1111/j.1365-3156.2007.01943.x.

Hortle K.G. 2008. Liver and intestinal flukes: an underrated health risk in the Mekong Basin. *Catch Culture*, 14, 14–18.

Howgate P. 1998. Review of the public health safety of products from aquaculture. *International Journal of Food Science and Technology*, 33, 99–125.

Huffman J.E., Fried B. 1990. *Echinostoma* and echinostomiasis. *Advances in Parasitology*, 29, 215–269. DOI: 10.1016/S0065-308X(08)60107-4.

Hung N.M. 2013. Use of black carp, *Mylopharyngodon piceus* (Cyprinidae), for control of intermediate host snails for fishborne zoonotic trematodes in Vietnamese aquaculture ponds. Ph.D. thesis, Faculty of Health and Medical Sciences, University of Copenhagen.

Huss H.H., Ababouch L., Gram L. 2004. Assessment and management of seafood safety and quality. In FAO Fisheries Technical Paper, No. 444. Rome, 230 pp.

Iarotski L.S., Be'er S.A. 1993. Epidemiology and control of Opisthorchiasis in the Former USSR, Geneva, World Health Organization.

II'inskikh E.N., Novitskii V.V., II'inskikh N.N., Lepekhin A.V. 2007. *Opisthorchis felineus* (Rivolta, 1884) and *Metorchis bilis* (Braun, 1890) infections in population of some regions of the Ob River Basin. *Parazitologiya*, 41, 55–64 (in Russian).

International Agency for Research on Cancer 1994. IARC Monographs volume 61. Chapter: Infection with liver flukes (*Opisthorchis viverrini*, *Opisthorchis felineus* and *Clonorchis sinensis*), 121–175.

Johansen M.V., Sithithaworn P., Bergquist R., Utzinger J. 2010. Towards improved diagnosis of zoonotic trematode infections in Southeast Asia. *Advances in Parasitology*, 73, 171–195. DOI: 10.1016/S0065-308X(10)73007-4.

Jongsuksuntigul P., Imsomboon T. 2003. Opisthorchiasis control in Thailand. *Acta Tropica*, 88, 229–232. DOI: 10.1016/j.actatropica.2003.01.002.

Joo C.Y., Hong Y.A. 1991. Epidemiological studies of *Clonorchis sinensis* in the vicinity of River Ahnseong, Kyung-pook Province, Korea. *Japanese Journal of Parasitogy*, 40, 542–552.

Jordan P., Webbe G., Sturrock R.F. 1993. Human schistosomiasis, 3rd ed. Oxford, CAB International, 212 pp.

Kaewkes S. 2003. Taxonomy and biology of liver flukes. *Acta Tropica*, 88, 177–186. DOI: 10.1016/j.actatropica.2003.05.001.

Kaewpitoon N., Kaewpitoon S.J., Pengsaa P. 2008. Opisthorchiasis in Thailand: Review and current status. *World Journal of Gastroenterology*, 14, 2297–2302. DOI: 10.3748/wjg.14.2297.

Kassirsky I.A., Plotnikov N.N. 1969. Diseases of Warm Lands: A clinical manual. The University of Michigan press, 566 pp.

Keiser J., Utzinger J. 2005. Emerging foodborne trematodiasis. *Emerging Infectious Diseases*, 11, 1507–1514. DOI: 10.3201%2Feid1110.050614.

Keiser J., Utzinger J. 2009. Food-borne trematodiases. *Clinical Microbiology Review*, 22, 466–483. DOI: 10.1128/CMR.00012-09.

Khallaayoune K., Madsen H., Laamrani H. 1998. Evaluation of three methods to control *Bulinus truncatus*, the intermediate host of *Schistosoma haematobium* in an irrigation scheme, Tessaout-Amont, Morocco. *Acta Tropica*, 69, 51–63. DOI: 10.1016/S0001-706X(97)00119-8.

Khamidullin R.I., Lyubina V.S., Khamidullin I.R., Medinskii B.L. 1991. Trematode infections in Tataria. *Meditsinskaya Parazitologiya i Parazitarnye Bolezni*, 2, 60–61 (in Russian).

Khuhaprema T., Srivatanakul P. 2007. Cancer incidence in Thailand: Liver and bile duct. In: (Eds. T. Khuhaprema, P. Srivatanakul, H. Sriplung *et al*.) Cancer in Thailand, vol. IV, 1998–2000. Bangkok: Ministry of Public Health, 2, 33–38.

Kim Y. 1984. Liver carcinoma and liver fluke infection. *Arzneimittelforschung/Drug Research*, 34, 1121–1126.

Korablev V.N., Koltsov I.P. 1992. Clinical and immunological characteristics of mixed infection with tuberculosis and *Clonorchis* in endemic regions of the Khabarovsk Territory. *Meditsinskaya Parazitologiya i Parazitarnye Bolezni*, 2, 61–66.

Kumar V. 1999. Trematode infections and diseases of man and animals. Kluwer Academic Publishers, 368 pp. (printed in the Netherlands).

Le N.T. 1998. General of Parasiotogy. Science and Technical Publishing hourse, Hanoi, 80 pp. (by Vietnamese).

Le N.T. 2000. Trematoda in human and animals. In: Fauna of Vietnam, vol. 8. Science and Technology Publishing House, 388 pp.

Le N.T., The D.T., Ngo H.D. 1993. The larvae of trematode in the species of snail belonging to families Pilidae and Vivipalidae in Ha Tay and Hoa Binh provinces. In: Selected collection of scientific reports on ecology and biological resources (1990–1992). Science and Technical Publishing House, Hanoi, 318–323 (by Vietnamese with English abstract).

Le T.H., Nguyen V.D., Blair D., McManus D.P., Kino H., Agatsuma T. 2006. *Paragonimus heterotremus* Chen and Hsia (1964), in Vietnam: a molecular identification and relationships of isolates from different hosts and geographical origins. *Acta Tropica*, 98, 25–33. DOI: 10.1016/j.actatropica.2006.01.008.

Ledford J.J., Kelly A.M. 2006. A comparison of Black Carp, Redear Sunfish, and Blue Catfish as biological controls of snail populations. *North American Journal of Aquaculture*, 68, 339–347. DOI: 10.1577/A05-062.1.

Lee K.J., Bae Y.T., Kim D.H., Deung Y.K., Ryang Y.S., Kim H.J., Im K.I., Young T.S. 2002. Status of intestinal parasites infection among primary school children in Kampongcham, Cambodia. *Korean Journal of Parasitology*, 40, 153–155. DOI: 10.3347/kjp.2004.42.4.201.

Lemly A.D., Esch G.W. 1983. Differential survival of metacercariae of *Uvulifer ambloptilis* (Hughes, 1927) in juvenile centrarchids. *Journal of Parasitology*, 69, 746–749.

Li X.P. 1991. Food-borne parasitic zoonoses in the People's Republic of China. *Southeast Asian Journal of Tropical Medicine and Public Health*, 22, 31–35.

Lima dos Santos C.A.M., Howgate P. 2011. Fishborne zoonotic parasites and aquaculture: A review. *Aquaculture*, 318, 253–261. DOI: 10.1016/j.aquaculture.2011.05.046.

Lin J., Chen Y., Li Y., Lin J., Chen Y.Y. 2001. The discovery of natural infection of human with *Metorchis orientalis* and the investigation of its focus. *Chinese Journal of Zoonoses*, 17, 19–20.

Lin J.X., Chen Y.Z., Liang C.Z., Yang L.B., Zhuang H.J. 1985. Epidemiological investigation and experimental infection of *Echinochasmus japonicus*. *Chinese Journal of Parasitology and Parasitic Diseases*, 3, 89–91 (in Chinese).

Linnik V.Y. 1983. Helminth zoonoses and other fish parasites in Lake Bobrovichskoe. *Veterinarnaya Nauka Proizvodstvu*, 21, 94–96.

Lun Z.R., Gasser R.B., Lai D.H., Li A.X., Zhu X.Q., Yu X.B., Fang Y.Y. 2005. Clonorchiasis: a key foodborne zoonosis in China. *Lancet Infectious Disease*, 5, 31–41. DOI: 10.1016/S1473-3099(04)01252-6.

MacLean J.D., Cross J.H., Mahanty S. 2006. Liver, lung and intestinal fluke infections. In: (Eds. R.L. Guerran, D.H. Walker, P.F. Weller) Tropical Infectious Diseases, vol. II. Churchill Livingston, Philadelphia, 1039–1057.

Madsen H. 1983. Distribution of *Helisoma duryi*, an introduced competitor of intermediate hosts of schistosomiasis, in an irrigation scheme in northern Tanzania. *Acta Tropica*, 40, 297–306.

Markell E.K., Goldsmith R. 1984. Trematode infections exclusive of Schistosomiasis. Diseases caused by liver flukes: Clonorchiasis. In: Hunter's Tropical Medicine, 6th Edition, W.B. Saunders Company, Philadelphia, 740–755.

Mas-Coma S., Bargues M.D. 1997. Human liver flukes: a review. *Research and Reviews in Parasitology*, 57, 145–218.

Mas-Coma S., Esteban J.G., Bargues M.D. 1999. Epidemiology of human fascioliasis: a review and proposed new classification. *Bulletin of World Health Organization*, 77, 340–346.

Maurice J. 1994. Is something lurking in your liver? *New Scientist*, 141, 25–31.

McConnell J.F.P. 1876. On the *Distoma conjunctum* as a human entozoon. *Lancet*, 1, 343–344.

Mills J.H.L., Hirth R.S. 1968. Lesion caused by the hepatic trematode, *Metorchis conjunctus* Cobbold, 1860. A comparative study in carnivore. *Journal of Small Animal Practice*, 9, 1–6. DOI: 10.1111/j.1748-5827.1968.tb04678.x.

Mordvinov V.A., Yurlova N.I., Ogorodova L.M., Katokhin A.V. 2012. *Opisthorchis felineus* and *Metorchis bilis* are the main agents of liver fluke infection of humans in Russia. *Parasitology International*, 61, 25–31. DOI: 10.1016/j.parint.2011.07.021.

Mostafa B.B., El-Khayat H.M.M., Ragab F.M.A., Tantawy A.A. 2005. Semi-field trials to control *B. alexandrina* by different modes of exposure to certain plant and chemical molluscicides. *Journal of the Egyptian Society of Parasitology*, 35, 925–940.

Murrell K.D., Fried B. 2007. Food-borne parasitic zoonoses: Fish and plant-borne parasites. World class parasites: Volume 11. Springer Science and Bisiness Media, 233 Spring Street, NewYork, 429 pp.

Nawa Y., Hatz C., Blum J. 2005. Sushi delights and parasites: the risk of fishborne and foodborne parasitic zoonoses in Asia. Travel Medicine, 41, 1297–1303. DOI: 10.1086/496920.

Niemi D.R., Macy R.W. 1974. The life cycle and infectivity to man of *Appophallus donicus* (Skrjabin and Lindtrop, 1919) (Trematoda: Heterophyidae) in Oregon. *Proceedings of Helminthological Society of Washington*, 41, 223–229.

Nithikethkul C., Wichman O., Polseela P., Wongsawad C., Akarachantachote N., Wananpinyosheep S., Boonprakob M. 2004. Health behavior associated with *Opisthorchis viverrini* infection in Khukan district, Sisaket province, Thailand. *Southeast Asian Journal of Tropical Medicine and Public Health*, 35, 309–312.

Pairojkul C., Shirai T., Hirohashi S., Thamavit W., Bhudhisawat W., Uttaravicien T., Itoh M., Ito N. 1991a. Multistage carcinogenesis of liver-fluke-associated cholangiocarcinoma in Thailand. *Princess Takamatsu Symposium*, 22, 77–86.

Pairojkul C., Sithithaworn P., Sripa B., Thamawit W., Ito N., Shirai T., Itoh M. 1991b. Risk group for Opisthorchiasis-associated cholangiocarcinoma. *Kan-Tan-Sui*, 22, 393–402.

Paz R.J., Watanabe T., Dijck M.P.M., Abilio F.J.P. 1995. First record of *Melanoides tuberculata* (Müller, 1774) (Gastropoda: Prosobranchia: Thiaridae) in the state of Paraiba (Brazil) and its possible ecological implications. *Revista Nordestina de Biologia*, 10, 79–84.

Petrov A.M. 1940. Parasitic worms of Mustelidae of the Moscow Zoological gardens. *Trudy Moskovsk Zooparka*, I, 200–213 (in Russian).

Phan T.V., Ersbøll A.K., Te B.Q., Hang N.T., Murrell K.D., Dalsgaard A. 2010a. Fish-borne zoonotic trematodes in cultured and wild-caught freshwater fish from the Red river delta, Vietnam. *Vector-borne and Zoonotic Diseases*, 10, 861–866. DOI: 10.1089/vbz.2009.0134.

Phan V.T., Ersbøll A.K., Do D.T., Dalsgaard A. 2011. Raw-fish-eating behavior and fishborne zoonotic trematode infection in people of Northen Vietnam. *Foodborne Pathogens and Disease*, 8, 255–260. DOI: 10.1089/fpd.2010.0670.

Phan V.T., Ersbøll A.K., Thanh N.T., Khue V.N., Ha T.N., Murrell D., Dalsgaard A., 2010b. Freshwater aquaculture nurseries and infection of fish with zoonotic trematodes, Vietnam. *Emerging Infectious Diseases*, 16, 1905–1909. DOI: 10.3201/eid1612.100422.

Pointier J.P. 2001. Invading freshwater snails and biological control in Martinique Island, French West Indies. *Memórias do Instituto Oswaldo Cruz*, 96, 67–74.

Pointier J.P., Guyard A., Mosser A. 1989. Biological control of *Biomphalaria glabrata* and *B. straminea* by the competitor snail *Thiara tuberculata* in a transmission site of schistosomiasis in Martinique, French West Indies. *Annals of Tropical Medicine and Parasitology*, 83, 263–269.

Pointier J.P., Jourdane J. 2000. Biological control of the snail hosts of schistosomiasis in areas of low transmission: the example of the Caribbean area. *Acta Tropica*, 77, 53–60. DOI: 10.1016/S0001-706X(00)00123-6.

Pointier J.P., McCullough F. 1989. Biological control of the snail hosts of *Schistosoma mansoni* in Caribbean area using *Thiara* spp. *Acta Tropica*, 46, 147–155.

Posokhov P.S, Dovgalev A.S., Briunetkina N.M. 1987. Case of clonorchiasis indiagnosed during life. *Medical Parasitology and Parasitic Diseases (Moscow)*, 5, 45–46 (in Russian).

Posokhov P.S. 1982. Biology of Far Eastern trematodes and the epidemiology of the diseases they cause. V. Natural factors dictating the limits of the nosogeographic range of clonorchiasis in Amur River region. *Medical Parasitology and Parasitic Diseases (Moscow)*, 2, 32–35 (in Russian).

Poulsen A. 2003. Floods are vital for fisheries. *Catch Culture*, 9, 7–11.

Proctor E.M., Gregory M.A. 1974. An ultrastructural study of ova of *Paragonimus* species from human and cat faeces. *South African Medical Journal*, 48, 1947–1948.

Radomyos P., Charoenlarp P., Radomyos B. 1991. Human *Episthmium caninum* (Digenea, Echinostomatidae) infection: Report of two more cases. *Journal of Tropical Medicine and Parasitology*, 14, 48–50.

Rangsin R., Mungthin M., Taamasri P., Mongklon S., Aimpun P., Naaglor J., Leelayooya S. 2009. Incidence and risk factors of *Opisthorchis viverrini* infections in a rural community in Thailand. *American Journal of Tropical Medicine and Hygiene*, 81, 152–155.

Restrepo M. 1962. Estudio parasitológico de una Región del Amazonas Coombiano. *Antioquia Medicine*, 12, 462–484.

Rim H.J. 1982a. Clonorchiasis. In: (Eds. J.H. Steele) CRC Handbook series in Zoonoses. Section C: (Eds. G.V. Hillyer, C.E. Hopla) Parasite Zoonoses, Vol. III CRC Press Inc., Boca Raton, 17–32.

Rim H.J. 1982b. Opisthorchiasis. In: (Eds. J.H. Steele) CRC Handbook series in zoonoses, Section C: (Eds. G.V. Hillyer, C.E. Hopla) Parasitic Zoonoses (Trematode Zoonoses), vol. III. CRC Press, Boca Raton, Florida, 109–121.

Rim H.J. 1986. The current pathobiology and chemotherapy of clonorchiasis. *Korean Journal of Parasitology*, 24, 1–141. DOI: 10.3347/kjp.1986.24.Suppl.1.

Rim H.J. 1990. Clonorchiasis in Korea. *Korean Journal of Parasitology*, 28, 63–78. DOI: 10.3347/kjp.1990.28.Suppl.63.

Rim H.J. 2005. Clonorchiasis: an update. *Journal of Helminthology*, 79, 269–281. DOI: 10.1079/JOH2005300.

Rim H.J., Farag H.F., Sornmani S., Cross J.H. 1994. Food-borne Trematodes: Ignored or Emerging? *Parasitology Today*, 10, 207–209. DOI: 10.1016/0169-4758(94)90111-2.

Rodriguez J.D., Gomez L.F., Montalvan J.A. 1949. El *Opisthorchis quayaquilensis* una nueva especie de *Opisthorchis encontrada* en el Ecuador. *Revista Ecuatoriana de Higiene y Medicina Tropical*, 6, 11–24.

Rohela M., Johari S., Jamaiah I., Init I., Lee S.H. 2006. Case report: acute cholecystitis caused by *Clonorchis sinensis*. *Southeast Asian Journal of Tropical Medicine and Public Health*, 37, 648–651.

Rondelaud D., Dreyfuss G. 1996. The development of tissue lesions in the snail *Lymnaea stagnalis* exposed to a subletal dose of molluscicide. *Veterinary Research*, 27, 79–86.

Rothbard S., Rubinshtein I. 2000. The Black Carp, a potential biocontrol of mollusks. *Israeli Journal of Aquaculture – Bemidgeh*, 51, 74–83.

Saeed I., Maddox-Hyttel C., Monrad J., Kapel C.M. 2006. Helminths of red foxes (*Vulpes vulpes*) in Denmark. *Veterinary Parasitology*, 139, 168–179. DOI: 10.1016/j.vetpar.2006.02.015.

Sayasone S., Odermatt P., Phoumindr N., Vongsaravane X., Sensombath V., Phetsouvanh R., Choulamany X., Strobel M. 2007. Epidemiology of *Opisthorchis viverrini* in a rural district of southern Lao PDR. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 101, 40–47.

Schell S.C. 1985. Trematodes of North America, north of Mexico. University Press Idaho, Moscow.

Scholtz T., Salgado-Maldonado G. 1999. The introduction and dispersal of *Centrocestus formosanus* (Nishigori, 1924) (Digenea: Heterophyidae) in Mexico: a review. *American Midland Naturalist*, 143, 185–200. DOI: 10.1674/0003-0031(2000)143[0185:TIADOC]2.0.CO;2.

Serbina E.N., Iurlova N.I. 2002. Participation of *Codiella troscheli* (Mollusca: Prosobranchia) in the *Metorchis albidus* (Trematoda; Opisthorchiidae) life cycle. *Meditsinskaya Parazitologiya* i Parazitarnye Bolezni, 3, 21–23 (in Russian).

Shelton W.L., Soliman A., Rothbard S. 1995. Experimental observations on feeding biology of black carp (*Mylogpharyngodon piceus*). *Israeli Journal of Aquaculture-Bamiddgeh*, 47, 59–67.

Sherrard-Smith E., Cable J., Chadwick E.A. 2009. Distribution of Eurasian otter biliary parasites, *Pseudamphistomum truncatum* and *Metorchis albidus* (Family Opisthorchiidae), in England and Wales. *Parasitology*, 136, 1015–1022. DOI: 10.1017/S0031182009006362.

Sidorov E.G., Belyakova Y.V. 1972. Natural focus of *Metorchis* and its biology. Voprosy Prirodnoi Ochagovosti Boleznei Alma-Ata. *Akademiya Nauk Kazakhskoi SSR*, 5, 133–150 (in Russian).

Simões S.B.E., Barbosa H.S., Santos C.P. 2010. The life cycle of *Ascocotyle* (*Phagicola*) *longa* (Digenea: Heterophyidae), a causative agent of fish-borne trematodosis. *Acta Tropica*, 113, 226–233. DOI: 10.1016/j.actatropica.2009.10.020.

Sinha B.K. 1968. *Opisthorchis noverca* Braun, 1902 in the pancreas of domestic pig (*Sus scrofa domestica*) in Bihaar. *Current Science*, 37, 22–23.

Sithithaworn P., Hasweli-Elikins M.R., Mariang P., Satarung S., Mariang E., Vatanasapt V., Elkins D.B. 1994. Parasite-associated morbidity: liver fluke infection and bile duct cancer in northeast Thailand. *International Journal of Parasitology*, 24, 833–843. DOI: 10.1016/0020-7519(94)90009-4.

Sithithaworn P., Pipithgool V., Srisawangwong T., Elkins D.B., Haswell-Elkins M.R. 1997. Seasonal variation of *Opistho-*

rchis viverrini infection in cyprinoid fish in north-east Thailand: implication for parasite control and food safety. *Bulletin of the World Health Organization*, 75, 125–131.

Sohn W.M. 2009. Fish-borne zoonotic trematode metacercariaae in the Republic of Korea. *Korean Journal of Parasitology*, 47, 103-113. DOI: 10.3347/kjp.2009.47.S.S103.

Sohn W.M., Chai J.Y. 2005. Infection status with helminthes in feral cats purchased from market in Busan, Republic of Korea. *Korean Journal of Parasitology*, 43, 93–100. DOI: 10.3347%2Fkjp.2005.43.3.93.

Sohn W.M., Yong T.S., Eom K.S., Pyo K.H., Lee M.Y., Lim H., Choe S., Jeong H.G., Sinuon M., Socheat D., Chai J.Y. 2012. Prevalence of *Opisthorchis viverrini* infection in humans and fish in Kratie Province, Cambodia. *Acta Tropica*, 124, 215–220. DOI: 10.1016/j.actatropica.2012.08.011.

Sriamporn S., Pisani P., Pipitgool V., Suwanrugruang K., Kamsaard S., Parkin D.M. 2004. Prevalence of *Opisthorchis viverrini* infection and incidence of cholangiocarcinoma in Khon Kaen, Northeast Thailand. *Tropical Medicine and Intenational Health*, 9, 588–594. DOI: 10.1111/j.1365-3156.2004.01234.x.

Sripa B., Kawekes S., Sithithaworn P., Mairiang E., Laha T., Smount M., Pairojkul C., Bhudhisawasdi V., Tesana S., Thinkamrop B., Bethony J.M., Loukas A., Brindley P.J. 2007. Liver fluke induces cholangiocarcinoma. *PLoS Medicine*, 4, e201. DOI: 10.1371/journal.pmed.0040201.

Sripa B., Pairojkul C. 2008. Cholangiocarcinoma: lessions from Thailand. *Current Opinion in Gastroenterology*, 24, 349–356. DOI: 10.1097/MOG.0b013e3282fbf9b3.

Sripa B., Sithithaworn P., Sirisinha S. 2003. *Opisthorchis viverrini* and opisthorchiasis. The 21st century review. *Acta Tropica*, 88, 169–170. DOI: 10.3201%2Feid1012.040410.

Stoll N.R. 1947. This wormy world. *Journal of Parasitology*, 33, 1–18.

Sturrock R.F. 1995. Current concepts of snail control. *Memórias Instituto Oswaldo Cruz*, 90, 241-248.

Tai M.V., Thuyet B.D., Nam T.H., Binh N.D., Chuong N.Q. 2004. Aquaculture practices in Nam Dinh province. Report from FIBOZOPA Project. Research Institute of Aquaculture No. 1, TuSon, BacNinh.

Taraschewski H., Nicolaidou A. 1987. *Heterophyes* species in Greece: record of *H. heterophyes*, *H. aequalis* and *H. dispar* from the first intermediate host, *Pirenella conica*. *Journal of Helminthology*, 61, 28–32. DOI: 10.1017/S0022149X00009676.

Taylor M.A., Coop R.L., Wall R.L. 2007. Parasites of dogs and cats. In: *Veterinary Parasitology* (third edition). Oxford: Blackwell., 356–454.

Terhune J.S., Wise D.J., Avery J.L., Khoo L.H., Goodwin A.E. 2003. Infestations of the trematode *Bolbophorus* sp. in channel catfish. *Southern Regional Aquaculture Center Publication* No. 1801.

Thien P.C. 2011. Occurrence and risk factors of fishborne zoonotic trematodes in major freshwater fish species cultured in Mekong Delta of Vietnam. PhD thesis. Printed by SL grafik, Frederiksberg C, Denmark.

Toledo R., Esteban J.G., Fried B. 2006. Immunology and Pathology of Intestinal Trematodes in their definitive hosts. *Advances in Parasitology*, 63, 285–365. DOI: 10.1016/S0065-308X(06)63004-2.

Toledo R., Bernal D.M., Marcilla A. 2011. Proteomics of foodborne trematodes. *Journal of Proteomics*, 74, 1485–1503. DOI: 10.1016/j.jprot.2011.03.029.

Traub R.J., Macaranas J., Mungthin M., Leelayoova S., Cribb T., Murrell K.D., Thompson R.C.A. 2009. A new PCR-based approach indicates the range of *Clonorchis sinensis* now extends to Central Thailand. *PLoS Neglected Tropical Diseases*, 3, e367. DOI: 10.1371/journal.pntd.0000367.

Tropmed Technical Group 1986. Snails of medical importance in Southeast Asia. *Southeast Asian Journal of Tropical Medicine and Public Health*, 17, 292–322.

Venable D.L., Gaude A.P., Klerks P.L. 2000. Control of the trematode *Bolbophorus confusus* in channel catfish *Ictalurus punctatus* ponds using salinity manipulation and polyculture with black carp *Mylopharyngodon piceus*. *Journal of the World Aquaculture Society*, 31, 158–166. DOI: 10.1111/j.1749-7345.2000.tb00349.x.

Vinograidov K.N. 1892. On a new species of distome (*Distomum sibiricum*) in the human liver. *Izvestiya Imperatorskoi Tomsk University,* 4, 116–160 (in Russian).

Wada T. 2004. Strategies for controlling the Apple snail *Pomacea canaliculata* (Lamarck) (Gastropoda: Ampullariidae) in Japanese Direct-Sown Paddy Fields. *JARQ*, 38, 75–80.

Waikagul J., Wongsaroj T., Radomyos P., Meesomboon V., Praewanich R., Jongsuksuntikul P. 1997. Human infection of *Centrocestus caninus* in Thailand. *Southeast Asian Journal of Tropical Medicine and Public Health*, 28, 831–835.

World Health Organization 1995. Control of foodborne trematode infections. *WHO Technical Report Series Number* 849, 1–157.

World Health Organization 2004. The World Health Report: changing history 170 pp.

World Health Organization 2011. Report of the WHO Expert Consultation on Foodborne Trematode infection and Taeniasis/Cysticercosis. *Vientiane, Lao People's Democratic Republic*. (http://www.who.int/neglected_diseases/preventive_chemotherapy/WHO_HTM_NTD_PCT_2011.3.pdf).

World Health Organization. 2012. Foodborne trematode infections. (http://www.who.int/mediacentre/factsheets/fs368/en/).

Wui Y.S., Engle C.R. 2007. The economic impact of restricting use of Black Carp for snail control on hybrid striped bass farms. *North American Journal of Aquaculture*, 69, 127–138.

Wykoff D.E., Harinasuta C., Juttijudata P., Winn M.M. 1965. *Opisthorchis viverrini* in Thailand – The life cycle and comparison with *O. felineus*. *Journal of Parasitology*, 51, 207–214.

Yamaguti S. 1971. Synopsis of Digenetic Trematodes of Vertebrates. Vol. I and II. Keigaku Publishing Co., Tokyo, 1074 pp.

Yamaguti S. 1958. Part I. The digenetic trematodes of vertebrate. In: Systema Helminthum, Vol. I. NewYork: Interscience Publishers Inc.

Yong T.S., Shin E.H., Chai J.Y., Sohn W.M., Eom K.S., Lee D.M., Park K., Jeoung H.G., Hoang E.H., Lee Y.H., Woo H.J., Lee J.H., Kang S.I., Cha J.K., Lee K.H., Yoon C.H., Sinuon M., Socheat D. 2012. High prevalence of *Opisthorchis viverrini* infection in a riparian population in Takeo province, Cambodia. *Korean Journal of Parasitology*, 50, 173–176. DOI: 10.3347%2Fkjp.2012.50.2.173.

Yossepowitch O., Gotesman T., Assous M., Marva E., Zimlichman R., Dan M. 2004. Opisthorchiasis from imported raw fish. *Emerging Infectious Diseases*, 10, 2122–2126. DOI: 10.3201%2Feid1012.040410.

Yu S.H., Mott K.E. 1994. Epidemiology and morbidity of Food-borne intestinal trematode infections. Report of World Health Organization [WHO], Schistosomiasis Control Unit, Division of Control of Tropical Diseases.

Zhang R., Gao S., Geng Y., Huang D., Yu L., Zhang S., Cheng J., Fu Y. 2007. Epidemiological study on *Clonorchis sinensis* infection in Shenzhen area of Zhujiang delta in China. *Parasitological Research*, 101, 179–183. DOI: 10.1007/s00436-006-0441-3.

Zavoikin V.D. 1991. Structure of the territorial range of opisthorchiasis and problem of control. *Medicinskaya Parazitologiya i Parazitarnye Bolezni*, 3, 26–30 (in Russian).

Ziegler A.D., Andrews R.H., Grundy-Warr C., Sithithaworn P., Petney T.N. 2011. Fighting liver flukes with food safety education. *Science*, 331, 282–283. DOI: 10.1126/science.331.6015.282-b.

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