CHAPTER 1
GENERAL INTRODUCTION

1.1 Importance of diseases and parasites in aquaculture

Fish is an important source of protein in Southeast Asia. Until recently the main source of fish has been the natural aquatic systems (Table 1.1). However natural fish resources are rapidly declining due to overfishing and destructions of aquatic habitats (Table 1.2). To supplement declining catches from the wild and to ensure constant fish supply to meet the demand from the increasing human population, many countries have turned to aquaculture. This is especially true in Asian countries (see Table 1.3).

There are numerous problems in fish culture especially in seed production, water management and health management. Fish health is an important **consideration** since intensive culture, the purpose of which is to increase yield per unit area, tends to enhance infections resulting in production losses. Fish is host to a wide spectrum of bacteria, viruses and parasites such as protozoans, helminths, acanthocephalans, mollusc (Glochidia) and crustaceans (see Kabata, 1985). Many of these organisms do not normally cause fish mortality in natural systems unless there is a sudden change in the environmental factors. This was probably what had happened during the outbreak of epizootic ulcerative syndrome diseases (EUS) in Southeast Asia which affected both wild and cultured fishes (Tonguthai, 1985; Chinabut, 1995) causing massive mortalities (Chinabut, Roberts, Willoughby & Pearson, 1995; Lilley, Phillips & Tonguthai, 1992; Roberts, Willoughby & Chinabut, 1993; Tonguthai, 1985; Willoughby, Roberts & Chinabut, 1995). The causative agent is a fungus, *Aphanomyces invadans* (see Thompson, Lilley, Miles, Chinabut & Adams, 1998).

Bacterial diseases are the main cause of fish losses in aquaculture systems in many countries. For instance, in China, 70 % of grass carp fingerlings were lost because of haemorrhagic disease (Yulin, 1995). In Thailand, bacterial diseases are also the main cause of mortality in cultured fishes (clariids, cyprinids, pangasiids, channids and eleotrids) (Chinabut, pers. com.).

Parasitic organisms also play an important role directly or indirectly in causing mortality in fish (see Lim, 1992a; Woo, 1995). Diseases caused by

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Table 1.1 Fisheries production of Thailand during 1985-1994 (quantity (Q) in 1,000 tons, Value (V) in million baht)

Year	Capture				Culture				Total	
	Marine		Inland		Coastal		freshwater			
	Q	V	Q	V	Q	V	Q	V	Q	V
1985	1,997.2	14,077.3	92.2	2,569.7	60.6	1,573.3	75.2	1,565.2	2,225.2	19,785.5
1986	2,309.5	16,987.3	98.4	2,069.9	39.1	1,890.1	89.3	1,935.0	2,536.3	22,882.3
1987	2,540.0	19,357.1	87.4	2,113.1	61.9	3,726.1	89.8	2,445.3	2,779.1	27,641.6
1988	2,337.2	19,823.0	81.5	1,784.7	108.9	8,216.9	102.1	2,597.9	2,629.7	32,422.5
1989	2,370.5	19,935.2	109.1	2,228.2	168.7	11,493.6	91.7	2,213.0	2,740.0	35,870.0
1990	2,362.2	20,738.4	127.2	3,301.7	193.2	14,753.6	103.8	2,602.0	2,786.4	41,395.7
1991	2,478.6	26,403.7	136.0	3,290.8	230.4	20,362.1	122.7	2,969.2	2,967.7	53,025.8
1992	2,736.4	32,833.0	132.0	2,998.8	229.3	26,234.5	142.1	3,478.2	3,239.8	65,544.5
1993	2,752.5	36,224.1	175.4	4,489.5	295.6	33,603.5	161.6	4,089.6	3,385.1	78,406.7
1994	2,804.4	36,337.2	202.6	4,805.6	345.8	40,961.8	170.4	4,896.6	3,523.2	87,001.2

(Fisheries Statistics of Thailand, 1994: Department of Fisheries, Thailand (1996))

Table 1.2 Production of capture fisheries from natural inland waters of Thailand (1985-1994)

Fish species	Quantity (1,000 tons)									
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Clariidae:										
Clarias spp.	11.6	3.0	2.9	4.6	6.8	7.9	6.9	6.7	8.1	7.1
Cyprinidae:										
Puntius spp.	8.7	13.0	5.7	8.9	22.3	26.0	23.1	22.4	23.1	22.5
Anabantidae:										
Trichogaster pectoralis	6.5	6.9	5.9	2.6	0.7	0.8	0.5	0.5	0.8	0.2
Channidae:										
Channa striata	14.5	17.6	16.3	11.8	11.2	13.0	14.4	14.0	18.6	21.4
Other fishes	38.3	50.0	49.9	47.9	68.0	79.4	91.0	88.3	124.6	148.3

(Department of Fisheries, 1996)

Table 1.3 Production from aquaculture in Asian countries (1988-1993) (Quantity (Q) in metric tons; Value (V) in million us$)

Countries	Year											
	1988		1989		1990		1991		1992		1993	
	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V
Bangladesh	155	213	163	238	170	293	178	292	230	365	248	424
China	5,077	6,540	5,429	6,808	5,804	7,273	6,134	7,747	7,210	8,658	8,880	9,584
India	894	1,024	1,005	1,257	1,013	1,600	1,223	1,439	1,392	1,564	1,439	1,640
Indonesia	415	943	442	1,331	500	1,477	518	1,713	550	1,812	592	1,948
Iran	29	251	31	299	45	447	20	208	42	425	22	203
Japan	807	3,246	785	3,147	804	3,108	803	3,487	818	3,495	833	3,609
Laos	7	10	8	12	10	20	12	24	14	35	12	30
Malaysia	47	37	55	43	48	34	60	48	79	80	105	114
Myanmar	6	13	7	21	7	28	4	21	4	27	7	51
Nepal	5	7	7	9	9	10	10	11	10	10	9	9
Pakistan	7	7	10	9	10	9	13	11	13	12	13	14
Phllippines	343	696	361	682	381	799	409	791	391	969	392	1,055
Thailand	219	501	260	533	292	776	353	1,098	371	1,169	414	1,478
Vietnam	142	235	149	327	153	349	175	414	185	464	192	497

(summarised from FAO, 1995)

monogeneans have affected fish production adversely (Cone, 1995; Egusa, 1992; Leong, 1994; Leong & Wong, 1988, 1990, 1992, 1995; Ogawa & Inouye, 1997a; Ogawa, Chung, Kou & Imada, 1985; Wada & Hatai, 1995).

Parasites have been dispersed along with their fish hosts when the fish are translocated to new places. In the Philippines, for instance, 28 of the 41 fish species imported from nine countries were infected with many groups of parasites (see Lumanlan, Albaladejo, Bondad-Reantaso & Arthur, 1992). Monogeneans have been known to be translocated along with their hosts. For examples, *Pseudodactylogyrus bini* (Kikuchi, 1929) Gussev, 1965 and *P. anguillae* (Yin & Sproston, 1948) Gussev, 1965 were transported on the Japanese eel (*Anguilla japonica*) from Japan to Europe. These monogeneans subsequently infected the European eel (*Anguilla anguilla*) causing mass mortalities (see Buchmann, Mellergaard & Koie, 1987; Molnar, 1984). The lack of enforcement in quarantine measures further enhanced the translocation of parasitic diseases. In fact, parasitic diseases have been reported on the catfish species imported from Thailand to Malaysia for culture purposes. *Ichthyophthirius multifiliis* (Protozoa) had been recorded on the *Clarias macrocephalus* imported from Thailand (see Leong, Tan, Wong, Ahyaudin & Kwan, 1987), while the monogeneans *Thaparocleidus caecus* (Mizelle & Kritsky, 1969) Lim, 1996 and *T. siamensis* (Lim, 1990) Lim, 1996 were found on *Pangasianodon hypophthalmus* (syn. *Pangasius sutchi*) cultured in Peninsular Malaysia (see Lim, 1990b).

Despite the importance of parasites as pathogens and potential pathogens under intensive culture conditions there are very few studies on diseases caused by parasites in this part of the world. A recent bibliographic compilation on fish health research in the Southeast Asian region prior to 1992 yielded a total of 847 references with 212 references dealing with fish health studies in Thailand (Arthur, 1992). This figure is low considering the importance of aquaculture activities in this region.

From the ecological and parasitological perspectives a total parasitofaunal investigation of a particular group of fish is desirable for a better understanding of the role of parasites in affecting wild and cultured fish population. However such an approach is not always possible in a dissertation owing to time, technical and financial constraints. This present study is designed to focus on the distribution and diversity of the monogenean fauna on freshwater siluriforms of Thailand (Section 1.5).

1.2 The monogeneans

Monogenea is one of the most diverse class of Platyhelminthes. Gussev (1967) estimated there are about 1,340 described monogenean species in the world. Monogeneans are obligate parasites of aquatic and semi-aquatic organisms because they are unable to withstand desiccation (Bychowsky, 1957). Fish forms the main host for the majority of the known monogeneans (Euzet & Combes, 1998; Lim, 1998). In fact 95 % of the monogeneans are found on the gills of fish. Monogeneans are also found on amphibians, aquatic reptiles (turtles), cephalopods (squids) and on the hippopotamus (on the eyes) (see Bychowsky, 1957; du Preez, 1997; Llewellyn, 1984; Thurston, 1965).

While the majority of the monogeneans are ectoparasites, a few are endoparasites and found in sites which are connected to the exterior. Monogeneans are found on the gills, fins, skin, pharyngeal region (*Diplectanotrema*), nostril (*Paraquadriacanthus*) of fish (see Bychowsky, 1957; Ergens, 1988) and also on the eyes of turtles (see Rohde & Pearson, 1980). Monogeneans are also found internally in the olfactory capsule (examples *Merizocotyle*, *Squalotrema*) (see Kearn, 1994), esophagus (examples *Neodiplectanotrema* and *Paradiplectanotrema*) (see Kearn, 1994), stomach and intestine (examples *Enterogyrus* and *Montchadskyella*) (see Gussev & Fernando, 1973; Kearn, 1994; Paperna, 1963b, 1996; Pariselle, Lambert & Euzet, 1991), ureter and urinary bladder (examples *Acolpenteron*, *Kritskyia* and *Urogyrus*) (see Euzet & Combes, 1998; Kohn, 1990; Malmberg, 1990; Paperna, 1996), cloaca and rectal gland (*Calicotyle*) (see Williams & Jones, 1994; Euzet & Combes, 1998), female ducts (*Gymmocalicotyle*) (see Kearn, 1998), body cavity (*Dictyocotyle*) (see Williams & Jones, 1994) and heart (*Amphibdella*) (see Euzet & Combes, 1998). Monogeneans of the family Polystomatidae are found in pharynx, lung, kidney, urinary bladder and cloaca of frogs and turtles (see du Preeze & Kok, 1995; Lim, 1998; Kearn, 1998; Yamaguti, 1963).

1.2.1 Monogenean as pathogens

Monogeneans are important pathogens on cultured fishes (see Buchmann, 1997; Kabata, 1985; Leong, 1994; Paperna, 1996). There have been reports of etiology and damages due to *Gyrodactylus* spp. on the salmonids (see Bakke, Harris, Jansen & Hansen, 1992; Cone & Odense, 1984; Malmberg, 1993). *Gyrodactylus salaris* Malmberg, 1957 was introduced from Sweden to Norway with the smolt of *Salmo salar* causing severe mortalities in the fish stocks in almost 40 Norwegian rivers reducing the natural production of smolt to 2-4 % of the original population (see Malmberg, 1993). *G. salaris* is transmitted horizontally by direct contact between fish and fish or fish and bottom substrate (see Bruno & Poppe, 1996). Cone and Odense (1984) showed that the wounds caused by the pharynx are much larger than that of marginal hooks. Malmberg (1993) also suggested that the wounds on the skin and fins of fish caused by the monogeneans may cause mortality directly or indirectly through secondary bacterial invasion of the open wounds. Monogeneans are also regarded as the mechanical vectors of bacteria and virus (see Cusack & Cone, 1986) although this has not been shown conclusively.

Under intensive culture system, monogeneans have been shown to be the main parasitic pathogens which lower fish production in both freshwater and brackish water fish farming. In Israel the heavy infestation of *Dactylogyrus vastator* Nybelin, 1924 on gills of carp fry (<35 mm. in length) in nursery ponds during spring to early summer caused mass mortality by inducing severe hyperplasia of gill epithelium interfering with respiratory functions (Paperna, 1963a). On the other hand, *Dactylogyrus extensus* Mueller & Van Cleave, 1932 causes only focal cellular damage at its attachment sites (Sarig, Lahav & Shilo, 1965). In Hungary, *Thaparocleidus vistulensis* (Sivak, 1932) Lim, 1996 (syn. *Ancylodiscoides vistulensis* (Sivak, 1932) Yamaguti, 1963) was reported as the pathogen causing the death of *Silurus glanis* (see Molnar, 1980). The outbreak of dactylogyrosis due to *Dactylogyrus* species had caused loss of common carp and crucian carp cultured in Russia (Musselius, 1987). *Dactylogyrus* spp. caused haemorrhaging along the basal membrane of the gills of carps (due to collapse of the capillaries), thickening (swelling), deformation and fusion of the gill lamella as well as inflammation and epithelial proliferation of parasitised regions (Egusa, 1992).

In Thailand monogeneans also caused mass mortality of *Clarias* spp. fry and have been found in every stage of rearing (Tonguthai, Chinabut, Limsuwan, Somsiri, Chanratchakool, Kanchanakhan & MacRae, 1993). The monogeneans on the gills and body surface of the moribund *Clarias* spp. were found to be *Quadriacanthus* spp. (two species) and *Gyrodactylus* (one speices) (see Kumlerd, 1992; Primpol, 1990).

In marine or brackish water fish culture, monogeneans have been shown to cause serious damages. Heavy infection of the capsalids, *Benedenia epinepheli* (Yamaguti, 1937) Meserve, 1938 on fin, skin and eyes of at least 25 cultured fish host species (five orders) resulted in massive fish kills in Japan (Ogawa, Bondad-Reantaso & Wakabayashi, 1995). The benedineans also caused excessive production of skin mucus resulting in anemia and emaciation of the fish (see Egusa, 1992). The massive fish kill in Singapore in 1995 was due to an outbreak of benedineans (Lim, pers. com.).

The tiger puffer (*Takifugu rubripes*) cultured in Japan was infested by a number of species of parasitic organisms: *Heterobothrium okamotoi* Okamoto, 1963 was found on gills *and Gyrodactylus rubripedis* Ogawa & Inouye, 1997 and *G. pardalidis* Ogawa & Inouye, 1997 were observed on body surface of the same host species (see Ogawa & Inouye, 1997a, 1997b).

In Peninsular Malaysia, nine species of monogeneans were recorded from cultured marine fishes in net cages: *Pseudorhabdosynochus* (three species), *Diplectanum* (one species), *Benedenia* (two species) and *Megalocotyloides* (one species) from sea bass (*Lates calcarifer*) and grouper (*Epinephelus malabaricus* and *E. suillus*) and two species of *Haliotrema* from golden snapper (*Lutjanus johni*). These monogeneans caused lesions on skin and gills resulting in death of severely infected fishes (Balasuriya & Leong, 1995; Liang & Leong, 1991; Leong, 1994; Leong & Wong, 1995).

Gyrodactylus is capable of infecting both freshwater and marine fishes. There have been reports of *Gyrodactylus* spp. in marine fish species, for example, *Gyrodactylus unicopula* Glukhova, 1955 on plaice (*Pleuronectes platessa*) cultured in Britain (see MacKenzie, 1970), *G. anguillae* Ergens, 1960 on the eels, *Anguilla rostrata* and *A. anguilla* (see Cone, 1995).

1.2.2 Monogeneans as ecological indicators

Besides being economically important as disease-causing agents, monogeneans could be used as indicators of host relationships (Arthur, 1997; Lim, 1990a; Williams, MacKenzie & McCarthy, 1992). The ability of monogeneans to function as indicators is due to their host specificity. Most of the known monogenean species are host-specific. This is supported by the fact that the majority of the monogenean species on the marine ariids are limited to one host species (see Lim, 1994, 1995a, 1996a). Rohde (1993) has shown that 78 % of marine monogenean species from various seas are restricted to one host species and 89 % to one host genus. Parasites that infect a single host taxon or related taxa are said to exhibit phylogenetic host specificity (Rohde, 1993). Narrow host-specificity could also provide clues to hosts' evolution and original habitats (see Brooks, 1986).

The host-specificity of monogeneans also allows monogeneans to be used as indicators of the fish identity, fish phylogenetic relationships as well as their evolutionary and geological history (Lim, 1997). For examples, the presence of *Notopterodiscoides* species on *Notopterus chitala* and *Malayanodiscoides* species on *Notopterus notopterus* (see Lim, 1996b; Lim & Furtado, 1986) suggest that the two hosts species could be different. Based on morphological characteristics, *N. chitala* was later re-assigned to new genus, *Chitala* and re-named *Chitala lopis* (see Roberts, 1992b). The presence of the same monogenean genera or species on freshwater anabantoids, clariids, channids in India, South China, Indo-China, Thailand, Peninsular Malaysia and Africa suggests that these regions were once connected with Gondwana (Lim, 1997).

Monogeneans have been used to identify fish stock and timing of fish recruitment (see Arthur, 1997; Arthur & Albert, 1996; Humphreys, Crossier & Rowland, 1993). Stanley, Lee and Whittaker (1992) found that the monogeneans could be used as biological tags for the identification of marine fish stocks in North America. Stanley *et al.* (1992) noted that *Microcotyle sebastis* Goto, 1894 which parasitized the yellowtail rockfish (*Sebastes flavidus* Ayres) is abundant with 80 - 100 % prevalence in high latitudes and declining gradually towards the lower latitudes.

Monogeneans can also be used as the indicators of behavior of the fish host. Zharikova and Kasyanov (1997) documented five species of *Dactylogyrus* on deep water *Rutilus rutilus* (mollusc feeder forms), viz., *Dactylogyrus micracanthus*, *D. nanus*, *D. sphyrna*, *D. crusifer* and *D. succinus*. Of these five *Dactylogyrus* species, only three (*D. micracanthus*, *D. nanus* and *D. sphyrna*) were found on near-shore fish group which were littoral plant feeder forms.

1.3 Review of monogenean studies in Thailand

The status of monogenean studies in Southeast Asia has been discussed by Lim (1998). Despite the increase in aquaculture activities in Thailand, there have been few parasitological investigations conducted in this country as indicated by the 212 references on fish health (see Arthur, 1992) (Section 1.1). The same is true for the monogenean parasites. Lim (1998) noted that between 1930 - 1997 only 30 species of monogeneans had been described from 14 fish species in Thailand. And of these, 27 species of monogeneans were from 12 freshwater fish. A literature search (including literature written in the Thai language) reveals that to date only 20 freshwater fish species in Thailand had been examined for monogeneans (see Areerat, 1978a, 1978b; Boonyaratapalin, Kasornchandra & Nutchmon, 1984; Chinabut, 1981; Chinabut & Lim, 1991, 1993, 1994; Chinabut & Soonthornsatit, 1983; Kumlerd, 1992; Lerssutthichawal & Lim, 1997; Lim & Lerssutthichawal, 1996; Pavaputanon & Chinabut, 1983; Primplol, 1991; Sirikanchana, 1982, 1991; Tangtrongpiros & Koeipudsa, 1986; Tonguthai, 1996). Monogeneans have been recorded from one cichlids, seven clariids, seven cyprinids, one eleotrids; one notopterids; one pangasiids and two silurids (Table 1.4). However in many cases the monogenean species identified in these previous investigations were incorrect. For example: the *Dactylogyrus* species reported from *Clarias batrachus* and *C. macrocephalus* (see Pavaputanon & Chinabut, 1983; Sirikanchana, 1982) is most likely either *Quadriacanthus* or *Bychowskyella* species (see Lerssutthichawal & Lim, 1997), while the *Dactylogyrus* species on *Oxyeleotris marmorata* (see Sirikanchana, 1982) is probably *Pseudodactylogyroides* (see Lim, 1995b). There is thus a need to rectify the present situation.

Table 1.4 Monogenean genera of Thai freshwater fish species

(* dubious identification with comment species should be found; ** published in Thai)

Fish host species	Monogenean genera (No. of species)	Authors	Comments
Cichlidae:			
Oreochromis niloticus	**Dactylogyrus* (1)	Tonguthai, 1996**	*Cichlidogyrus*
	Gyrodactylus (1)	Tonguthai, 1996**	
Clariidae:			
Clarias batrachus	*Quadriacanthus* (1)	Lerssutthichawal & Lim, 1997	
	Bychowskyella (2)	Lerssutthichawal & Lim, 1997	
	**Dactylogyrus* (1)	Pavaputanon & Chinabut, 1983**	*Quadriacanthus* or *Bychowskyella*
	**Dactylogyrus* (1)	Sirikanchana, 1982	*Quadriacanthus* or *Bychowskyella*
	Gyrodactylus (1)	Pavaputanon & Chinabut, 1983**	
	Gyrodactylus (1)	Areerat, 1978b**	
	Gyrodactylus (1)	Tangtrongpiros & Koeipudsa, 1986**	
C. cataractus	*Quadriacanthus* (1)	Lerssutthichawal & Lim, 1997	
C. gariepinus	*Quadriacanthus* (1)	Lerssutthichawal & Lim, 1997	
C. macrocephalus	*Quadriacanthus* (1)	Lerssutthichawal & Lim, 1997	
	Bychowskyella (1)	Lerssutthichawal & Lim, 1997	
	Quadriacanthus (2)	Primpol, 1990**	
	**Dactylogyrus* (1)	Pavaputanon & Chinabut, 1983**	*Quadriacanthus* or *Bychowskyella*
	Gyrodactylus (1)	Pavaputanon & Chinabut, 1983**	
C. meladerma	*Bychowskyella* (2)	Lerssutthichawal & Lim, 1997	
C. nieuhofi	*Bychowskyella* (3)	Lerssutthichawal & Lim, 1997	
Clarias hybrid	*Quadriacanthus* (1)	Lerssutthichawal & Lim, 1997	
	Quadriacanthus (1)	Kumlerd, 1992**	
Cyprinidae:			
Cirrhinus jullienii	*Dactylogyrus* (3)	Chinabut & Lim, 1991	
	Thaparogyrus (1)	Chinabut & Lim, 1991	
Puntius altus	*Dactylogyrus* (3)	Chinabut & Lim, 1993	
P. daruphani	*Dactylogyrus* (2)	Chinabut & Lim, 1993	
P. gonionotus	*Dactylogyrus* (1)	Chinabut & Soonthornsatit, 1993**	
	Dactylogyrus (7)	Chinabut & Lim, 1993	
P. orphoides	*Dactylogyrus* (2)	Chinabut & Lim, 1993	

Table 1.4 cont'd

Fish host species	Monogenean genera (No. of species)	Authors	Comments
P. schwanenfeldii	*Dactylogyrus* (4)	Chinabut & Lim, 1993	
Puntioplites protozysron	*Dactylogyrus* (5)	Chinabut & Lim, 1994	
Eleotridae:			
Oxyeleotris marmorata	**Dactylogyrus* (1)	Sirikanchana, 1982	*Pseudodactylogyroides*
Notopteridae:			
Notopterus notopterus	**Ancylodiscoides* (1)	Sirikanchana, 1991**	*Malayanodiscoides* or *Thaparocleidus*
Pangasiidae:			
Pangasius sutchi	*Dactylogyrus* (1)	Areerat, 1978a**	*Thaparocleidus*
	Dactylogyrus (1)	Boonyaratapalin, Kasornchandra & Nutchmon, 1984**	*Thaparocleidus*
	Dactylogyrus (1)	Pavaputanon & Chinabut, 1983**	*Thaparocleidus*
	Gyrodactylus (1)	Pavaputanon & Chinabut, 1983**	
Siluridae:			
Kryptopterus apogon	*Ancylodiscoides* (2)	Chinabut, 1981**	*Thaparocleidus*
Wallago attu	*Mizelleus* (1)	Lim & Lerssutthichawal, 1996	
	Thaparocleidus (2)	Lim & Lerssutthichawal, 1996	

1.4 Importance of siluriform fish

Although the major fish groups cultured in Asia are cyprinids and cichlids (FAO, 1995), siluriforms (pangasiids and clariids) are beginning to play an important role in the culture systems in Thailand (Department of Fisheries, 1996) (Table 1.5) and also in India (Tripathi, 1990), Bangladesh (Hasan, 1990) and Vietnam (Singh, 1990). The siluriforms are favored because of their relative lack of scales and delicate flesh. Siluriforms are currently the most important fish cultured in Thailand. About 25 % of the fish cultured in Thailand are clariids and pangasiids

(Department of Fisheries, 1996). The artificial propagation of 16 freshwater catfish species have been successfully done in Thailand (Table 1.6). Some species of freshwater catfish are ornamental fish which are exported into at least 15 countries (Table 1.7).

Taxonomically, Siluriformes is considered a primitive fish group (Fink & Fink, 1981). Knowledge of the monogenean parasites would form the baseline data for monogenean fauna on the Siluriformes of Thailand.

Table 1.5 Production of freshwater fish culture in Thailand (1985-1994)

Freshwater fish	Quantity (1,000 tons)									
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Claridae:										
Clarias spp.	6.4	15.8	13.9	12.6	12.4	17.9	29.1	23.8	31.1	34.6
Pangasiidae										
Pangasius sutchi	13.8	12.6	11.8	20.4	13.5	13.3	14.5	14.2	12.0	8.2
Cyprinidae:										
Puntius gonionotus	7.3	8.8	11.1	13.0	13.4	14.6	16.3	23.8	21.9	27.2
Cyprinus carpio	1.5	1.9	2.1	2.5	2.0	2.1	2.5	2.3	3.1	2.8
Cichlidae:										
Tilapia nilotica	15.1	18.4	17.0	18.8	21.1	22.8	28.1	43.9	54.0	55.7
Anabantidae:										
Trichogaster pectoralis	16.6	16.1	14.3	14.9	13.2	12.8	13.3	13.0	15.4	19.3
Channidae:										
Channa striata	7.4	6.0	3.3	4.0	3.7	3.8	5.6	4.7	5.9	5.6
Other fish	4.7	5.2	4.5	5.0	4.5	10.0	5.5	5.9	8.6	6.3
Total	72.8	84.8	78.0	91.2	83.8	97.3	114.9	131.6	152.0	159.7

(Department of Fisheries, Thailand, 1996)

Table 1.6 Freshwater catfish species in the breeding programme (*non-indigenous species)

Fish species	**Authors**
Clariidae:	
Clarias batrachus	Sukphan, Sriwattana & Kuanpitak, 1990
*Clarias gariepinus**	Tungtrongpairos, Luanpreda, Nu-kwan, Lawanyawut & Keawlaeard, 1989
Clarias macrocephalus	Tamchalanukit, Chuarpohak, Suraneeranart & Na-nakorn, 1982
	Tavarutmaneegul, Nu-kwan & Watcharakornyothin, 1995
Clarias nieuhofi	Promkaew, 1995
Clarias hybrid*	Tonguthai, Chinabut, Limsuwan, Somsiri, Chanratchakool, Kanchanakhan & MacRae, 1993
Bagridae:	
Hemibagrus nemurus (syn. *Mystus nemurus*)	Tanthong & Sriwattana, 1982
	Chawpaknam & Kongrod, 1994
	Chatmalai, Rungsiyapirom & Keokliang, 1995
Hemibagrus wyckoides (syn *Mystus wyckoides*)	Ratanatrivong, Kunghrat, Taksin & Pennapaporn, 1994
Pangasiidae:	
Pangasianodon hypophthalmus	Varikul & Boonsom, 1968
Pangasianodon gigas	Pholprasith, 1983a
Pangasius conchophilus	Ratanataiwong, Kongtaratana, Laocham & Chantasuth, 1995a
	Ratanataiwong, Kongtaratana, Laocham & Chantasuth, 1995b
Pangasius larnaudii	Pholprasith, 1983b
Pangasius sanitwongsei	Chantasutra, Vivacharakosate, Leesa-nga, Pongchawee, Pimolbut & Ratanatrivong, 1990
Siluridae:	
Belodontichthys dinema	Tanthong, Sriwattana & Pasukdee, 1985
Ompok bimaculatus	Chawpaknam & Kongrod, 1995
	Chawpaknam, Kuandee & Puang-intra, 1992
Wallago attu	Vivacharakosate, 1983
Wallago leerii	Leesa-gna, Yoovechwattana & Damdas, 1994

Table 1.7 Freshwater catfish species exported as ornamental fishes in 1994 (AAHRI; unpublished data) (Ka = *Kryptopterus apogon*, Kb = *K. bicirrhis*, Mm = *Mystus mysticetus*, Ph = *Pangasianodon hypophthalmus*)

Countries	Fish species and values (US$)				Total (US$)
	Ka	Kb	Mm	Ph	
Canada	-	75.0	-	-	75.0
Finland	-	-	-	360.0	360.0
Germany	-	5,300.0	-	1,651.0	6,951.0
Greece	-	-	-	55.0	55.0
Hungary	-	221.0	50.0	24.0	295.0
Israel	-	260.0	-	608.0	868.0
Malaysia	-	-	400.0	14,240.0	14,640.0
Mexico	-	72.0	-	-	72.0
Netherland	-	-	-	544.0	544.0
North Ireland	-	-	-	30.0	30.0
South Africa	-	-	-	108.0	108.0
Spain	-	-	-	93.0	93.0
Switzerland	-	160.0	-	63.0	223.0
Taiwan	80.0	40.0	-	-	120.0
United Arab Emirates	-	-	-	240.0	240.0
Total	80.0	6,128.0	450.0	18,016.0	24,674.0

1.5 Objective of Study

Despite the large number of freshwater fish species (560 species; Smith, 1945) in Thailand, the government's effort to use local indigenous fish for future aquacultural production and the potential threat of parasites (see Section 1.2.1) to aquaculture, there has been little concerted effort to document the monogenean parasites or any other parasites (see Section 1.3) on the freshwater fish. The academic aspect of this study should not be overlooked (Section 1.4) especially in the face of rapid degradation of aquatic ecosystems. Although it is important to document the monogeneans on all the freshwater fish of Thailand, the large number of host species (560 species) and time constraint made it necessary to limit this study to the documentation and analysis of the monogeneans on one fish group.

This rather 'primitive' fish group has a global distribution which spans both the Old World and New World.

The main objective of the study is to document the monogenean species found on the Thai freshwater catfishes in order to determine the diversity (at different taxonomic levels) and distribution patterns (specificity and faunistic affinity) of the monogeneans. Since this study is pioneering in nature many of the monogenean species collected will be new requiring detailed descriptions.

1.6 Descriptions of the different Chapters

Although the identifications and descriptions of the monogeneans collected from the siluriforms form the basis of this study, the detailed descriptions of the species (especially the new species) are given in Appendices 3.1-3.8. This is to enable the analyses of the distribution and morphological data without the 'species descriptions taking central place. The research design and methodologies to achieve the objective of the study as set out in Section 1.5 are detailed in Chapter 2. Chapter 3 provides an account of what is known about the siluriform fish species of Thailand (distribution patterns, diversity and phylogenetic relationships). Such information might provide clues to the distribution patterns as well as phylogenetic relationships of the monogeneans. The distribution patterns (specificity) and diversity of monogeneans obtained as well as the faunistic affinity of the Thai catfish monogeneans are discussed in Chapter 4. The results of the cluster analysis which is to determine the degree of morphological similarities amongst the monogeneans in order to elucidate the morphological relationships of monogeneans especially congeners and to ascertain if host could influence morphological traits (by determining if there are any correlations of morphological traits to host groups) are given in Chapter 5. In Chapter 6, the information obtained in the previous Chapters will be summarised and an overview provided on the questions raised in Chapter 1 as well as issues pertinent to the distribution of the monogeneans.