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The Wet-Season Movements and General Biology of Some Important Fish Species at the Great Fault Line on the Lower Mekong River of the Lao P.D.R.

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Abstract

Nocturnal wet-season fish movements during the months of May and June have been studied in 1994, 1996, 1997 and 1998 in one rocky channel, *Hoo Som Yai* (HSY), traversing the Great Fault Line (GFL) on the Mekong River in Southern Lao P.D.R. The primary aim of the study was to obtain an overview of fish movements in relation to changes in local hydrological conditions and gather information on general biology of the species at the time of the migrations based on reproductive and dietary investigations. The studies were carried out in cooperation with local artisanal fishers using specialized bamboo wing traps set into rapids. Movements at the GFL are bi-directional, but mainly in an upstream direction. Upstream movements are dominated by catfishes (Pangasiidae and Siluridae) and downstream movements are anecdotally reported to be dominated by a group of mainly small Cyprinid species that also form an important fishery in some years. Two Pangasid catfishes, *Pangasius conchophilus* and *Pangasius larnaudiei* form the mainstay of the fishery in HSY. Hydrological conditions in HSY were recorded during all studies and related to standardized catch (CPUE). Length-weight relationships are provided for the most

important migratory species. Biological examination of migratory species from the study site and local markets has provided limited information regarding the nature of the migratory movements. Adult Pangasid catfishes are considered to be on their spawning migration, but destination habitats are unknown. Large numbers of juvenile *P. conchophilus* appear to be making a different type of migration, perhaps for dispersal and / or feeding. Based on anecdotal evidence, several small Cyprinid species make a downstream movement just after, or just before spawning. Movement at the GFL appears to be dependent on local hydrological conditions. Threshold flow-volumes may trigger the first large runs in May or early June, but further movements appear to be dependent on freshets and the numbers of fish waiting to move below the GFL. Standardized catch (CPUE) was found to be significantly related to flow volume passing down HSY in 1996 (P = 0.0002) and 1997 (P = 0.0000). No significant relationship was found in 1994 (P = 0.82) and 1998 (P = 0.16). Using correlation, Standardized catch (CPUE) was found to be significantly related to flow volume in 1996 (P = 0.0000), in 1997 (P=0.0000) and in 1998 (P = 0.0000). No significant relationship was found in 1994 (P = 0.20).

Introduction

The migratory movements of large-river fish faunas often provide opportunities for intensive exploitation by low-income riparian communities (Barthem and Goulding 1997, Hesse *et al*., 1989, Lelek 1989, Ochumba and Manyala 1992, and Rahman 2001). Migratory populations of fish moving into and out of floodplain areas in the Magdalena River Basin form the mainstay of a very important seasonal fishery in Columbia, South America (Barco and Villarreal, 1989). Lieng *et al*. (1995) report on an important bagnet fishery based on seasonal migrations in the Tonle Sap River connecting Cambodia's Great Lake with the Mekong River.

The upstream dry-season movements of mainly Cyprinid species are targeted by villagers for subsistence or semi-commercial purposes in Southern Lao PDR, such as at Hadsalao Village, near to Pakse, and at Hat Village at Muang Khong (Warren *et al*., 1998). However, the fishery associated with the upstream wet-season movements of catfishes is more commercially orientated, but an overlap in status is known to exist.

Wet-season conditions begin around early May each year with the arrival of the first flood-cycle rains. Water turbidity, velocity and volume increase rapidly, often precluding the use of many dry-season fishing gears in all but the most sheltered locations. The Great Fault Line (GFL), a unique geographical feature to the Mekong River, is located just upstream from the Lao PDR's southern border with Cambodia. Here the Mekong falls about 20 m through a series of rocky channels and waterfalls extending over a total river width of about 10 km. The GFL is perhaps the only mainstream site where catfishes (Pangasiidae and Siluridae) can be exploited in commercial quantities using specialized traps during their upstream, nocturnal migrations. This is because other more conventional type gears, such as gillnets, are difficult to set under wet-season conditions at most other locations in the mainstream. Bamboo-wing traps, known as lees, are set in appropriate channels and placed in position to intercept the nocturnal fish movements. Lee traps are mainly used in channels where total ascent is not possible, either due to natural (waterfalls) or man-made barriers (bamboo fences). Lee traps are placed directly in the current with half of the bamboo matting structure in the water, and half out of it (Fig. 2). The eventual forced return movement back downstream causes the fish to beach themselves in the open traps set in mid-stream (pers. obs.). There are thought to be an estimated 400 traps in the 18 major channels that traverse the GFL. Based on anecdotal evidence and personal observation, lee traps also intercept the downstream, post-spawning movements of a number of small Cyprinid species. Some species appearing in trap landings are not thought to be migratory, and may enter the channels to forage.

Fig. 2: Lee traps in Hoo Som Yai.

The fishery at the GFL begins around mid- to late May each year following trap construction or renovation in April, and lasts until about August or September. Physical destruction, or submergence of traps, and an eventual reduction in migratory activity effectively ends the fishing period during the wet-season months between May and October. There is some evidence that certain species preferentially select an ascent channel (Baird, pers. com.) and that the species composition of the migratory populations changes from May to September. However, the main movement of Pangasid and Silurid catfishes usually takes place in May and June in the HSY channel where this research was conducted. The two most important species by landing weight are *P. larnaudiei* and *P. conchophilus* (Table 2).

The main objective of the studies in HSY was to identify the main migratory species, the timing, duration, direction, purposes, main influencing factors and the change in magnitude of migratory activity between years. Standardized catch data (CPUE) from lee traps over specific time periods have been used as an index of migratory activity between years. Whilst the studies during the 1994 to 1998 period were orientated towards basic research, the results from these studies have provided baseline data against which to monitor changes in species compositions and numbers within the fishery in subsequent years.

Material and Methods

The Mekong River enters the Muang Khong area, where the GFL is located, at approximately 14° 80 N (Fig.1). It then divides up into a series of channels that eventually become rapids in proximity to the GFL. At about 13° 44 N the Mekong plunges over the GFL in a series of waterfalls, rocky channels and rapids (Khone Falls) just before entering Northern Cambodia (Fig.1).

Study site

Hoo Som Yai (HSY) is a rocky channel at the GFL, and is the second channel on the west side of Papeng Waterfall, the largest and most impressive fall at the GFL. Papeng is located close to the east bank of the Mekong River (Fig.1). Hoo Som Yai then flows down through a thickly forested gully for approximately 300 m in a series of rapids, small waterfalls and deeper pools before rejoining the mainstream channel below Papeng Waterfall. Lee traps are positioned at permanently fixed strategic points throughout the length of HSY. Although the number of lees in operation at any one time is dependent on prevailing hydrological conditions, approximately 20 traps are re-built at established sites each year in HSY.

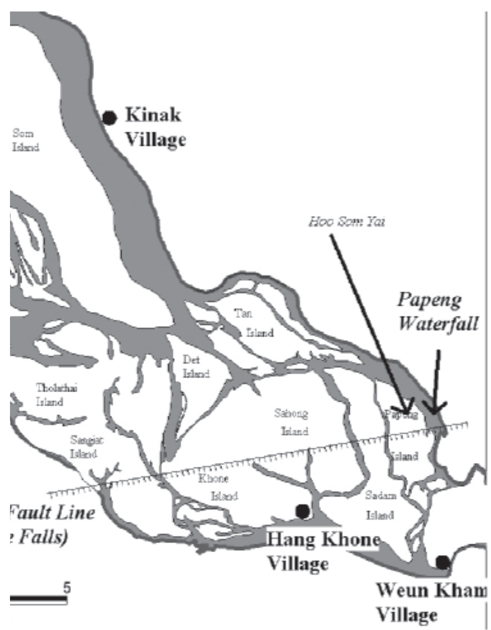

Fig. 1: Map of the Muang Khong area showing the Great Fault Line and Hoo Som Yai where the study was carried out.

Quantitative measure of migration

Standardized catch data (CPUE) from lee traps over specific time periods have been used as an index of migratory activity between years. Data were recorded from lee traps every two or three days on specific dates from May 24 to June 28 during each study year. Village meetings held prior to data collection ensured that all fishers operating lees in HSY provided data for the study. Data collection took place close to one trading point where most fishers passed at dawn each day.

The landings from each lee trap were separated by species, or in the case of a number of small Cyprinid species (Pba Soi), into groups. During early studies, individual weights and total lengths were recorded to obtain length-weight relationships in addition to CPUE data. In 1997 and 1998, landings were separated by species, counted and then batch weighed.

Following the weighing-in of all landings, a count was made of all operational traps (that is, those that were not flooded or damaged) in HSY on each sampling day at dawn. All-species mean CPUE (kg. Trap^{-1}. Night^{-1}.) was estimated by dividing the total weight of fish caught during the night in HSY by the total number of traps in operation. CPUE for individual species was estimated using the same method.

Biological and hydrological factors related to the movements

During the 1996 study, samples of migratory species were purchased daily at local markets and directly from fishers. For each specimen examined, the following data were recorded: body weight (g); total and fork lengths (cm); sex where this could be determined, gonadal maturation stage (after Ali, 1993) using a visual index (I - IV males, I - V females), gonad weight (g); viscera weight (g); viscera fat deposition using a visual index ((I) zero or negligible and (II) moderate to heavy); stomach / intestine fullness using a visual index ((I) zero or negligible and (II) moderate to full); and stomach contents using a visual index to estimate which dietary item was dominant. The purpose of this was to try to predict why fish were migrating during the particular months of study, and what the sex ratios were during the migratory period.

Mean flow volume (m^{3}s^{-1}) was estimated on each sampling day from empirical data gathered on water depth, velocity and channel width (Fig's 3 and 4).

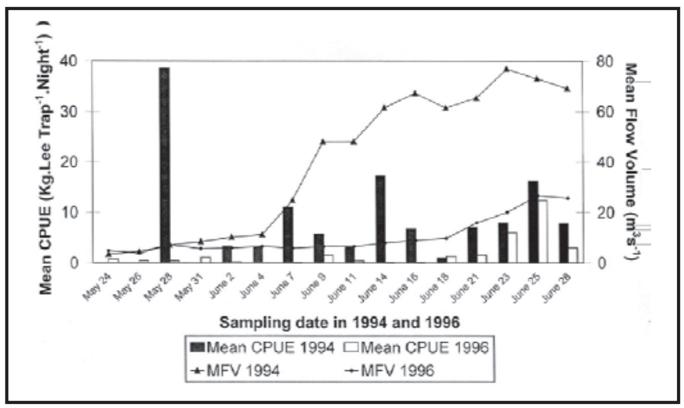

Fig. 3. Migratory activity as measured by CPUE in relation to flow volume in Hoo Som Yai during the studies in 1994 and 1996.

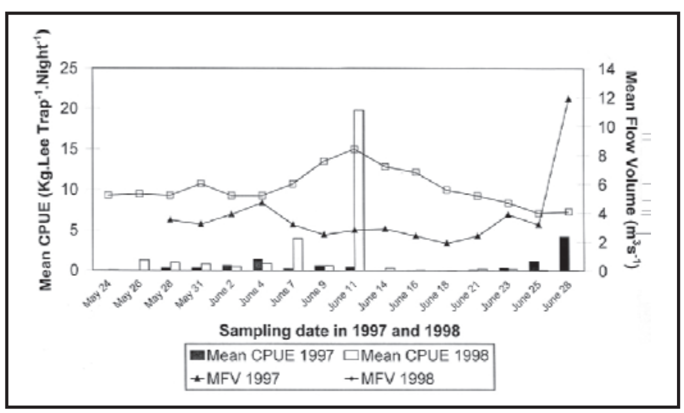

Fig. 4. Migratory activity as measured by CPUE in relation to flow volume in Hoo Som Yai during the studies in 1997 and 1998.

Water depth was measured by taking five separate measurements across the channel, and taking an average of the five measurements. Water velocity was measured using a floater and a ten-meter piece of light string. An average velocity of three "runs" was recorded after being timed. The channel width was recorded on each sampling day using a rope stretched across the channel with one meter-graduated markings. Surface water temperature (°C) was recorded at one point in the lower part of the channel. Simple linear regression (model 2) was used to examine the effect of mean flow volume on migratory activity as measured by CPUE.

Results

Migratory activity and hydrological factors

Based entirely on personal observation, at least one species of Pangasid catfish, *Pangasius conchophilus*, appears to make two or three major runs during May and June involving large numbers of individuals. Other Pangasids, such as *Pangasius larnaudiei*, engage in protracted movements over the whole migratory period. Based on anecdotal evidence and personal observation, a number of small Cyprinid fishes make a post spawning movement downstream during May and June each year.

The entire wet-season (May to October) movement at the GLF spans approximately five months from May to September involving perhaps 40 to 50 different fish species. However, the two most important species in terms of landing weight (*P. larnaudiei* and *P. conchophilus*) appear to make most of their movements during May and June. This is based on anecdotal evidence only. Unfortunately, conditions become too dangerous to sample after about the end of June, and also many of the traps are by then destroyed by the force of the current, or are totally submerged.

In 1994 and 1996, the initial flow volumes recorded on the first sampling day (May 24) at HSY were similar at 3.4 and 4.8 m^3s^{-1} respectively (Fig.3). An increase to 7.1 m^3s^{-1} on May 28 appeared to cause a major movement of fish in 1994 (Fig.3). A similar increase in 1996 did not appear to stimulate a large movement (Fig.3). In 1994, sudden increases in flow volume appeared to be accompanied by peaks in migratory activity throughout the duration of sampling. In 1994, flow volume in HSY was generally much higher than in 1996, peaking at an estimated 76.8 m^3s^{-1} on June 23 1994. Migratory activity was also much reduced in 1996 compared to 1994 (Fig.3). A gradual increase in flow volume from June 18 until June 25 1996 appeared to stimulate a modest increase in migratory activity (Fig.3).

In 1997, flow volume in HSY could not be estimated until May 28 and was recorded at 3.5 m^3s^{-1} on that date. In 1998, flow volume was estimated at 5.2 m^3s^{-1} on

May 24 (Fig.4). In 1997, flow volume and migratory activity remained low throughout most of the sampling period. On the last day of sampling on June 28, flow volume increased to approximately 12.0 m^3s^{-1}. This appeared to stimulate a slight increase in migratory activity (Fig.4). In 1998, flow volume remained relatively consistent until about June 7, and then peaked on June 11 at 8.4 m^3s^{-1}. The June 11 peak in flow volume was accompanied by a marked increase in migratory activity on that date (Fig.4). After June 11 until the end of sampling on June 28, flow volume gradually declined and migratory activity remained at a very low level (Fig.4). However, it may have increased again after this period, but sampling was not possible due to strong water currents.

Using simple regression (model 2), migratory activity was found to be significantly related to flow volume in 1996 (r^2 = 65.5, P = 0.0002) and in 1997 (r^2 = 91.2, P = 0.0000). No significant relationship was found in 1994 (r2 = 0.4, P = 0.82) and 1998 (r^2 = 14.9, P = 0.16). Using correlation, migratory activity (as measured by CPUE) was found to be significantly related to flow volume in 1996 (r^2 = 0.95, P = 0.0000, N = 17), in 1997 (r^2 = 0.99, P = 0.0000, N = 15) and in 1998 (r^2 = 0.99, P = 0.0000, N = 17). No significant relationship was found in 1994 (r^2 = 0.20, P = 0.07, N = 17). Surface water temperature was not found to be significantly related ($P < 0.05$) to CPUE during any of the studies.

Migratory species

Catch data, direct observation and biological examination were used to distinguish between migratory and non-migratory species. Nineteen known migratory species, in four different families, were targeted by lee trap fishers in HSY over the entire period of study (Table 1). A further 13 species in seven families occasionally appeared in lee trap landings in HSY, but were either not considered to be migrating at the time of sampling, or did not appear to select HSY as a main migratory route (Table 1).

By far the two most important species targeted by lee trap fishers in HSY by landing weight were *P. larnaudiei* and *P. conchophilus* (Table 2).

Typically, the runs of *P. conchophilus* were characterized by the arrival of groups of comparatively large individuals (> 1 kg) early on in the season, followed by what appeared to be groups of pre-adults, and quite likely yearling fish (< 0.12 kg). Some larger individuals from markets and HSY often showed signs of sexual maturation, at stage 3 and above (Table 3 and pers. obs.), and the groups appeared to be dominated by females. The pre-adult fish were sexually immature.

The weight of *P. larnaudiei* individuals caught in HSY was rarely outside the 0.8 to 2.7 kg range, and perhaps up to about 70% of individuals showed signs of sexual development, but mostly initial stages only (Table 3 and pers. obs.).

Considerable variation exists between annual sample landings (Table 2). In decreasing order of magnitude these were: 1994 (1662 kg), 1996 (523 kg), 1998 (472 kg) and in 1997 (197 kg) (Table 2).

Table 1. The main migratory species caught in Hoo Som Yai during the four-year study. The direction and likely purpose of the migration referred to in the table below is based on anecdotal evidence, personal observation and limited biological examination of migratory species over the four years of study.

Main Migratory Species	**Direction And Likely Purpose Of Migration**	**Other Species Caught Intermittently**
(BAGRIDAE)		(BAGRIDAE)
Mystus nemurus	Upstream / Reproductive	*Mystus wyckioides*
(CYPRINIDAE)		(COBITIDAE)
Crossocheilus reticulatus	Downstream / Reproductive	*Botia modesta*
Crossocheilus siamensis	Downstream / Reproductive	
Cyprinus carpio	Upstream / Trophic-Dispersal	(CYPRINIDAE)
Dangila sp. cf *cuvieri*	Downstream / Reproductive	
Henicorhynchus cryptopogon	Downstream / Reproductive	*Cosmochilus harmandi*
Henicorhynchus siamensis	Downstream / Reproductive	*Cyclocheilichthys enoplos*
Labeo erythropterus	Downstream / Reproductive	
Lobocheilos melanotaenia	Downstream / Reproductive	(PANGASIIDAE)
Paralaubuca sp.	Downstream / Reproductive	
(PANGASIIDAE)		*Pangasius krempfi* *
Helicophagus waandersi		(SCHILBEIDAE)
Adults	Upstream / Reproductive	
Juveniles	Upstream / Dispersal / Trophic ?	*Laides hexanema*
		Laides sinensis
Pangasius bocourti	Upstream / Reproductive	
Pangasius conchophilus		(SILURIDAE)
Adults	Upstream / Reproductive	
Juveniles	Upstream / Dispersal / Trophic ?	*Belodontichthys dinema*
		Kryptopterus cryptopterus
Pangasius larnaudiei	Upstream / Reproductive	*Ompok bimaculatus*
Pangasius pleurotaenia	Upstream / Reproductive	*Ompok hypopthalmus*
Pangasius siamensis	Upstream / Reproductive	
		(SISORIDAE)
(SILURIDAE)		
Hemisilurus mekongensis	Upstream / Reproductive ? / Dispersal ?	*Bagarius bagarius*
Kryptopterus hexapterus	Upstream / Reproductive / / Dispersal ?	*Bagarius yarrelli*
Micronema bleekeri		
Adults	Upstream / Reproductive	
Juveniles	Upstream / Dispersal / Trophic ?	

* NOTE: *Pangasius krempfi* is a very important commercial migratory species caught in other channels at the Great Fault Line during the upstream wet-season migration, but very rarely passes through Hoo Som Yai.

Table 2. Individual species contribution to total landings by weight and numbers in decreasing order of importance. Data are based on a total of 218 Trap-Nights in 1994, 265 in 1996, 263 in 1997 and 250 in 1998.

Year	Species or Group	Mean Weight (g)	Total Weight Landed (kg) (Percentage of Total)	Total Number Landed (n)
1994	*P. larnaudiei*	1347	552.3 (34.0)	410
	P. conchophilus	148	510.0 (31.4)	3457
	L. erythropterus	2546	173.1 (10.7)	68
	Pba Soi Group *	11	110.0 (6.8)	10015
	H. mekongensis	353	84.6 (5.2)	240
	M. wyckioides	3173	69.8 (4.3)	22
	P. bocourti	915	37.5 (2.3)	41
	C. carpio	147	26.6 (1.6)	181
	M. nemurus	732	22.7 (1.4)	31
	H. waandersi	259	21.0 (1.3)	81
	Other Species	-	14.6 (1.0)	100
			Total Weight = **(1622.2kg)**	
1996	*P. larnaudiei*	1111	300.0 (57.3)	270
	M. wyckioides	3333	70.0 (13.4)	21
	P. conchophilus	125	64.1 (12.3)	514
	B. dinema	689	38.6 (7.4)	56
	H. mekongensis	215	29.5 (5.6)	137
	Other Species	-	9.6 (1.8)	142
	M. bleekeri	348	7.3 (1.4)	21
	Pba Soi Group	9	4.2 (0.8)	471
			Total Weight = **(523.3kg)**	
1997	*P. larnaudiei*	1251		72
	P. conchophilus	213	90.1 (45.5)	160
	H. mekongensis	209	34.0 (17.2)	82
	Pba Soi Group	19	17.1 (8.6)	701
	B. dinema	743	13.1 (6.6)	16
	M. wyckioides	593	11.9 (6.0)	7
	M. bleekeri	348	11.8 (6.0)	29
	Other Species	-	10.1 (5.1)	108
			9.8 (5.0)	
			Total Weight = **(197.9kg)**	
1998	*P. larnaudiei*	1219		184
	P. conchophilus	130	222.8 (47.2)	1309
	P. siamensis	61	170.3 (36.0)	472
	Other Species	-	28.7 (6.1)	174
	M. wyckioides	1127	21.0 (4.5)	11
	Pba Soi Group	21	12.4 (2.6)	474
	M. nemurus	228	9.9 (2.1)	32
			7.3 (1.5)	
			Total Weight = **(472.4kg)**	

* NOTE: “Pba Soi” is a Lao vernacular name given to a number of small fish species mostly from the Cyprinidae family. In this table the term refers to the following species: *C. reticulatus*, *C. siamensis*, *Dangila* sp. cf *cuvieri*, *H. cryptopogon*, *H. siamensis*, *L. melanotaenia* and *Paralaubuca* sp. (Table 1).

Table 3. Results of the internal examination of some important migratory species from the HSY area during May and June 1996. Column 2 shows the sample size. Column 4 shows the number of individuals in either category I or II. Column 7 shows the number of individuals in either category I or II.

Species	n	Reproductive Stage And Fish Weights	Stomach Fullness	Dominant Food Item	Other Food Items	Viscera Fat Deposition
M. nemurus	10	(0-I) 5U (<1820g) (II-III) 5F (< 808g) (IV-V) -	(I) 10 (II) -	Freshwater Shrimp	None	(I) - (II) 10
H. cryptopogon	213	(0-I) 48U (< 34g) (II-III) 25M (< 34g) (IV-V) 140F (< 34g)	(I) 213 (II) -	Chlorophytes	None	(I) 213 (II) -
H. siamensis	16	(0-I) 5U (< 27g) (II-III) - (IV-V) 11F (< 38g)	(I) 16 (II) -	Chlorophytes	None	(I) 16 (II) -
L. melanotaenia	19	(0-I) 5U (< 26g) (II-III) 5M (< 47g) (IV-V) 9F (< 179g)	(I) 19 (II) -	Chlorophytes	None	(I) 17 (II) 2
H. waandersi	4	(0-I) 1U (574g) (II-III) 3F (< 1080g) (IV-V) -	(I) 2 (II) 2	Bivalve Molluscs	Gastropod Molluscs	(I) 4 (II) -
P. conchophilus	20	(0-I) 16U (<1080g) (II-III) 3F (< 3240g) 1M (1500g) (IV-V) -	(I) 4 (II) 16	Bivalve and Gastropod Molluscs Crabs	Leaves Fruits	(I) 7 (II) 13
P. larnaudiei	7	(0-I) 1F (814g) 3M (<2700g) (II-III) 3F (< 1320g) (IV-V) -	(I) 7 (II) -	Fruits	Paste Material	(I) - (II) 7
P. siamensis	2	(0-I) 1F (78g) 1M (79g) (II-III) - (IV-V) -	(I) 2 (II) -	No Food	-	(I) - (II) 2
P. pleurotaenia	9	(0-I) 9U (< 107g) (II-III) - (IV-V) -	(I) 1 (II) 8	Leaves Fruits Seeds	Insect Larvae	(I) 7 (II) 2
H. mekongensis	11	(0-I) 10U (< 290g) (II-III) 1F (730g) (IV-V) -	(I) 10 (II) 1	Shrimp	Fish	(I) 11 (II) -

* Note that M is used to designate male fish, F for female fish and U for those specimens where sex could not be determined.

Table 4. Length-Weight relationships and related statistics of some of the most important commercial species caught in lee traps in Hoo Som Yai. Data are based on fish landings during preliminary studies in 1993 and follow-up

Species	n	Mean Body Weight (g) (range)	Mean Total Length (cm)	a	b	r^2
C. carpio	55	183.0 + 48.5 (13.0-2520.0)	19.7 + 0.9 (9.5-52.0)	0.0123	3.088	97.3
M. wyckioides	37	2987.7 + 391.1 (343.0–13200.0)	68.1 + 2.6 (33.3–113.0)	0.0110	2.925	97.3
M. nemurus	17	651.1 + 98.5 (38.0–1300.0)	38.9 + 2.7 (17.0–50.0)	0.0036	3.243	99.3
H. waandersi	12	202.1 + 36.7 (50.0-556.0)	32.5 + 1.5 (23.7-45.0)	0.0008	3.550	97.1
P. conchophilus	269	138.7 + 5.9 (20.0-570.0)	26.9 + 0.3 (18.0-43.0)	0.0015	3.429	95.6
P. larnaudiei	194	1227.8 + 52.3 (305.0-5600.0)	48.8 + 0.5 (34.0-75.0)	0.0034	3.279	93.0
P. pleurotaenia	34	30.1 + 6.4 (3.0-132.0)	13.9 + 1.1 (7.2-27.0)	0.0137	2.575	98.0
B. dinema	22	874.5 + 74.0 (530.0-1760.0)	54.0 + 1.3 (47.0-69.0)	0.0031	3.137	92.9
H. mekongensis	147	306.7 + 14.0 (18.0-606.0)	38.5 + 0.7 (17.6-50.0)	0.0013	3.343	99.1
M. bleekeri	32	344.2 + 30.2 (130.0-1060.0)	41.6 + 1.0 (31.3-59.9)	0.0024	3.162	96.6

Biological data for the most important migratoryspecies caught at HSY

Summary results from the internal examination of selected migratory species in May and June 1996 are presented in Table 3.

For most of the species examined, the process of sexual maturation appeared to have begun, but only a few individuals had reached an advanced stage of development beyond about stage 3. Exceptions to this were *H. cryptopogon*, *H. siamensis* and *L. melanotaenia*, in which most individuals examined were sexually mature (Table 3). For some individuals of most species, sex could not be determined (Table 3).

In the majority of species examined, only a small amount of, or no, food was found in stomachs and intestines. This was particularly so in individuals where sexual development was advanced (Table 3). For the small Cyprinid species, the dominant food item was chlorophytes. For *P. larnaudiei*, where food was present in the stomach and intestines, it appeared to be mainly fruit. *P. conchophilus* were mostly feeding on bivalve and gastropod molluscs and crabs. *H. waandersi* were feeding on bivalve and gastropod molluscs. For *P. pleurotaenia*, the dominant food items were leaves, fruits and seeds. *H. mekongensis* appeared to be feeding on freshwater shrimp and fish (Table 3). Sexually mature individuals mostly appeared to lack deposits of fatty material around their intestines (Table 3).

Length-weight relationships, mean total length, mean weight and related statistics of some of the most important commercial species caught in lee traps in HSY in 1993, 1994 and 1996 are presented in table 4.

Discussion

This study at Hoo Som Yai channel confirms that the Great Fault Line in Southern Lao PDR does not represent a zoo-geographical barrier to the upstream movement of a number of important Mekong migratory species during the wet-season months. There is considerable anecdotal evidence that bi-directional movement is possible at any time of the year in the two largest of the channels that pass over the GLF; Hoo Sahong and Hoo Saddam (Roberts and Baird 1995). However, for all but perhaps the smallest of species, it appears unlikely that bi-directional migratory movements take place in HSY outside the wet-season months (May to October) based on anecdotal evidence and personal observation.

Bi-directional movements appear to be influenced by local hydrological conditions, but are also dependent on the numbers of fish waiting to move above and below the GFL. There appears to be a period of gathering below the GFL in April as fish arrive from Cambodian waters. A sudden increase in flow volume down through the channels may stimulate an upstream movement of catfishes, but only during the hours of darkness. The arrival of further freshets in May or June may stimulate more movements, particularly following periods of settled weather when flow volumes have been steadily decreasing.

The first major upstream runs of fish in HSY each year appear possible for some species (mainly *P. larnaudiei* and *P. conchophilus*) even when flows are modest and under 10 m^3s^{-1}. It appears that once a threshold volume for mass-movement is attained (approximately above 3 m^3s^{-1}), further increases in flow volume on subsequent nights may, or may not, immediately stimulate further movements, but this requires further research. This suggests that for some species, there may be a period of gathering in the waters below the fault line before a major run takes place, or that sometimes there are only small numbers of fish remaining from large runs on previous nights. In addition, there may be a delay effect whereby sudden increases in flow volume do not stimulate immediate movement up the channel. More research is required to verify any of the above theories.

To migrate in large numbers during the hours of darkness may represent an adaptation to predator avoidance in the comparatively shallow waters of HSY, especially for the large groups of pre-adult *P. conchophilus*. Nocturnal movements through environments where predation pressures are high have been cited by several authors (Hvidsten and Lund 1988, cited by Hvidsten *et al*. 1995; Hvidsten and Hansen 1988, cited by Hvidsten *et al*. 1995; Reitan *et al*. 1987, Strand *et al*. 1992, cited by Hvidsten *et al*. 1995). Although predatory populations of mammals, reptiles and birds are much reduced now, historically they were undoubtedly much greater. Alternatively, the mass movements may simply reflect a time when current speeds, and or, flow volumes are sufficient to enable the physical passage of fish up through the HSY channel, in which case, the fact that movements are exclusively nocturnal is difficult to account for. Alternatively still, perhaps both of the above hypotheses are relevant.

The fact that there may be other factors involved in regulating the size of the migration in any one-year may account for the non-significant relationship between flow volume and migratory activity in 1994 and 1998. Some of these other factors might include the level of recruitment in previous years, or perhaps fishing pressures further up and down stream. These additional factors may also partially explain why annual landings show considerable variation (Table 2). In a year such as 1994, flow volumes in HSY were much greater that in the other study years. Although migratory activity was greater also, the considerably larger flow volumes did not stimulate proportionally greater levels of migratory activity. These additional factors may partially account for the non-significant linear regression and correlation relationships between flow volume and migratory activity specifically in 1994.

Our personal observations that larger *P. conchophilus* arrive first in markets and fishers landings, before the pre-adult groups, may simply mean that they are stronger swimmers, or that they are destined for distant spawning grounds that may take some considerable time to reach. Although only limited quantitative data are available, anecdotal information gathered from fishers and observation in markets suggests that the groups of larger *P. conchophilus* are dominated by female fish. Similar observations were made on populations of *H. cryptopogon*, *H. siamensis*, *M. nemurus* and *L. melanotaenia*, but quantitative data are insufficient to be able to reach any firm conclusions. Roberts and Baird (1995) make reference to this phenomenon. They reached the tentative conclusion that *H. cryptopogon* might be an early-maturing protogynous hermaphrodite species. There may be advantages for female fish to undertake more distant migratory movements in order to reach quality feeding grounds before returning to their spawning habitat. This may be related to the advantages associated with increased body size, fecundity and egg size (McKeown, 1984).

Only very few *P. larnaudiei* were observed approaching full sexual maturation during this study. This suggests that either spawning habitats are relatively distant, or that spawning does not take place until much later in the wet-season, or perhaps that sexual maturation takes place comparatively quickly once the fish reach their spawning grounds. Goulding (1980) considered this latter scenario might account for why Siluroid catfishes, on their upstream spawning migration in the Madeira Basin in Brazil, showed limited sexual development. In addition, if spawning grounds are relatively distant, from an energy expenditure viewpoint, it may be disadvantageous for any species to undertake a long migration whilst sexually mature.

For those species that were mostly at an advanced stage of sexual maturation (*H. cryptopogon*, *H. siamensis* and *L. melanotaenia*), stomach and intestine fullness was either zero or negligible. Physical restriction created by gonadal development within the body cavity may account for this. Limited data on stomach content analysis for other species do not lead to clear findings concerning food consumption.

Our main conclusions from the studies at HSY, based on quantitative records and anecdotal information gathered from there and elsewhere, are as follows. It is mainly Pangasid and Silurid catfishes that form the mainstay of the fishery in HSY, and these groups arrive from Cambodian waters on their upstream wet-season migration. Large individuals of these families and other species are on their spawning migration, but destination habitats are unknown. Based on years of accumulated observation and interviewing with riparian communities up and down the mainstream, the Pangasid catfishes at least do not appear to enter the major tributaries for spawning. They may be mainstream spawners. The fish may undergo a period of gathering below the GLF before making their nocturnal ascent, but this requires verification by further research. Because the length of this gathering period is unknown, our observations and records do not necessarily reflect the true temporal nature of the main migration in the mainstream. If sampling were possible during the later months of the wet-season (July to October), the pattern may be different. If conditions are suitable, the main migration may pass the GLF quickly without much delay and within a few weeks. In a year when the flood-cycle arrives late, the timing of the migration through Southern Lao PDR may be distorted, and its true magnitude unknown because of our limited timeframe for sampling.

In addition to the upstream movement (mainly Pangasid and Silurid catfishes) mentioned above, there appears to be a group of about six small Cyprinid species that make a pre- and post-spawning downstream movement over the GLF early in the wet-season. They may be returning to the inundated areas of the Cambodia floodplains for a period of feeding and post-spawning recuperation.

This research has been carried out under field conditions with limited human and material resources. Future investigations should aim to separate landings into upstream and downstream components. However, since both components are actually moving downstream at the time of capture, the exact methodology required to make the separation is not immediately clear at present. In addition, other factors that might possibly reflect the size and duration of the fish movements over the GLF should be investigated. However, according to anecdotal sources, flow volume remains the key factor and to some extent, our findings support this.

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