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The Upstream Dry-Season Migrations of Some Important Fish Species in the Lower Mekong River Of Laos

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Abstract

Dry-season migration patterns at selected sites on the section of the Lower Mekong River which flows through Southern Lao PDR were investigated. The study was carried out from 1995 to 1997, following exploratory studies in 1994, in cooperation with local artisanal fishers at a key fishing site in Muang Khong district, specifically, to compare variations in migratory patterns between years. In 1996, the study was expanded to include an important fishing village near the town of Pakse, some 130 km upstream from the Muang Khong site, which provided a spatial dimension to the investigation. Lunar cycles and hydrological conditions were monitored and related to standardized catch (CPUE). Bio-logical examination of migratory species revealed important information regarding the na-ture of the migrations. Dry-season, upstream potamodromous migrations, dominated by cyprinids and exhibiting marked periodicity, were found to be directly linked to the new moon phase of lunar cycles. Lunar-orientated migration patterns appear to be affected by changes in the local hydrological conditions.

Introduction

Vast numbers of riparian villagers along the Lower Mekong River in Southern Lao PDR and Cambodia exploit fish stocks undertaking large-scale upstream movements during dry-season months to support their subsistence-level livelihoods. Current information on Mekong mainstream migrations is fragmentary and based mostly on anecdotal reports and observation (Roberts 1993; Roberts and Warren 1994; Roberts and Baird 1995). The taxonomy of many Mekong fish species is currently in a marked revisionary phase, further confusing documentation (Roberts 1993; Rainboth 1996).

Chanthepha (1972), cited by Welcomme (1985), refers to an upstream migration of cyprinids at Khone Falls from November to February. Roberts and

Warren (1994) report on an association between the lunar-dependent Chinese New Year and large-scale upstream movements of cyprinid fishes. Roberts and Baird (1995) consider the upstream dry-season migration to originate in Cambodian waters and state that it is a daytime, non-reproductive migration dominated by cyprinids. They describe the migrations as occurring in waves, strongest of which takes place on or about the Chinese New Year.

We define migration as any purposeful, seasonally regular type of movement of individuals from one ecologically distinct zone to another. Catch (CPUE) was used as an index of the intensity of migratory activity at specific locations and we consider it the product of both localized fish abundance and degree of fish movement.

Specifically, the objectives of these studies were to identify the main migratory species, the timing, duration, direction, purposes, main influencing factors and the change in magnitude of migration between years.

Materials and Methods

The Mekong River in Southern Lao PDR enters the Muang Khong area at approximately 14° 80 N and then divides into many large channels separated by hundreds of mainstream islands (Fig. 1). This area supports some of the most productive fisheries in the country and is widely acknowledged as an important site for feeding and reproduction of many lower Mekong fish species (Roberts 1993; Roberts and Warren 1994). At about 13° 44 N, the Mekong passes over the Khone Waterfalls just before entering Northern Cambodia (Fig. 1).

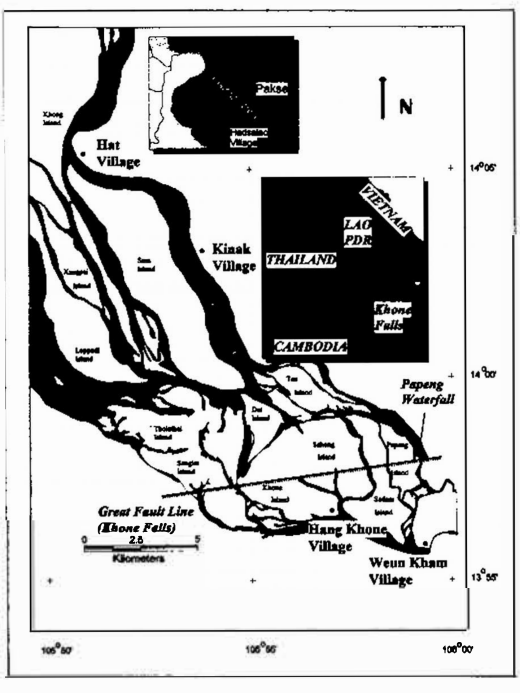

Fig.1 Map of the study areas in Southern Lao PDR. The main map showing the various mainstream islands and the Great Fault Line at Khone Falls is an enlargement of the smaller inset showing the countries of S.E. Asia. The other inset at the top of Fig. 1 shows the position of Hadsalao Village relative to the town of Pakse, 130km upstream from Khone Falls.

Study Sites

Dry-season migration studies were conducted at Hat Village, Muang Khong district, and at Hadsalao Village, Pakse. Dry-season fish landings at Hat Village are among the highest reported for any village in the Muang Khong area. The fishing grounds are located over a depression in the riverbed directly in front of the village. A daytime drift-gillnet fishery begins around December and continues until approximately April, but operates most intensively around the new moon phase of each lunar month. Monofilament nets in use range between 60m and 120m long. Mesh sizes are 5cm, 6cm or 7cm and vary from 5m to 7m deep.

Hadsalao Village is located at approximately latitude15°N on the west bank of the Mekong River, 2 km below the town of Pakse in Southern Lao PDR. At this point, the river is confined to a single channel less than one km in width. A daytime drift-gillnet fishery operates during the dry-season, mainly targeting migratory species moving upstream from the lower reaches of the river. Net dimensions are similar to those in use at Hat Village.

Quantitative Measure of Migration

CPUE data were recorded from 1995 to 1997 from fishers at Hat Village around the time of the second new moon phase after the winter solstice, which is associated with the Chinese New Year. This period marks the onset of the large-scale movements of fishes referred to throughout this paper as the Chinese New Year (CNY) migrations. In 1996, CPUE data were also gathered around the time of the first new moon phase after the winter solstice and are referred to here as the Early Dry-Season (EDS) migrations.

Data were gathered from five randomly selected fishers in 1995 and ten in 1996 and 1997.

Data collection began four days before the new moon phase and continued for 15 days after it. Migratory activity was measured as CPUE every two or three days over all three CNY periods, but on almost every day immediately prior to, and just after, the lunar-dependent Chinese New Year's day itself. During the EDS study, sampling took place twice weekly from 17 days before new moon until six days after it, and thereafter three times per week until the end of the study at 23 days after the new moon, just prior to the CNY period.

Catch was standardized to numbers of fish per $100m^2$ of gillnet per hour, to provide an index of migratory activity on each sampling day. Mean overall and individual species CPUE were estimated by adding all daily CPUE records and dividing them by the number of fishers from whom the data were collected.

In 1996, at Hadsalao Village, catch and effort data were collected from five randomly selected fishers around the time of the CNY new moon using the same methods and sampling dates as at Hat Village, Muang Khong, some 130 km downstream. The migration at Hadsalao Village is referred to throughout this paper as the Dry-Season Comparative (DSC) migration.

Biological and Hydrological Factors Related to Migration

During the 1996 EDS and CNY studies, samples of migratory species were purchased daily at local markets and directly from fishers. The following data were recorded for each specimen: body weight (g), total and fork lengths (cm), sex (where this could be determined), gonadal maturation stage using a visual index (I - IV males, I - V females), gonad weight (g), viscera weight (g), viscera fat deposition using a visual index (I - II), stomach/intestine fullness using a visual index (I - II) and stomach contents using a visual index to estimate percentages of dietary items. Macroscopic characteristics used to identify gonadal maturation stages are after Ali (1993).

Lunar phase, surface water temperature (°C) and the change in relative water depth (m) were recorded during all migration studies at Hat Village.

Results

Migratory Activity, Lunar Cycles and Hydrological Factors

All lunar phases in Figs. 2 to 4 are shown according to calendars based on Eastern Standard Time.

In 1995, apart from brief periods of stabilization, water level decreased gradually over the whole study period (Fig. 2). Migratory activity intensified rapidly from four days before new moon and peaked three days later. It then decreased gradually and was at a low level by full moon phase (Fig. 2). Using

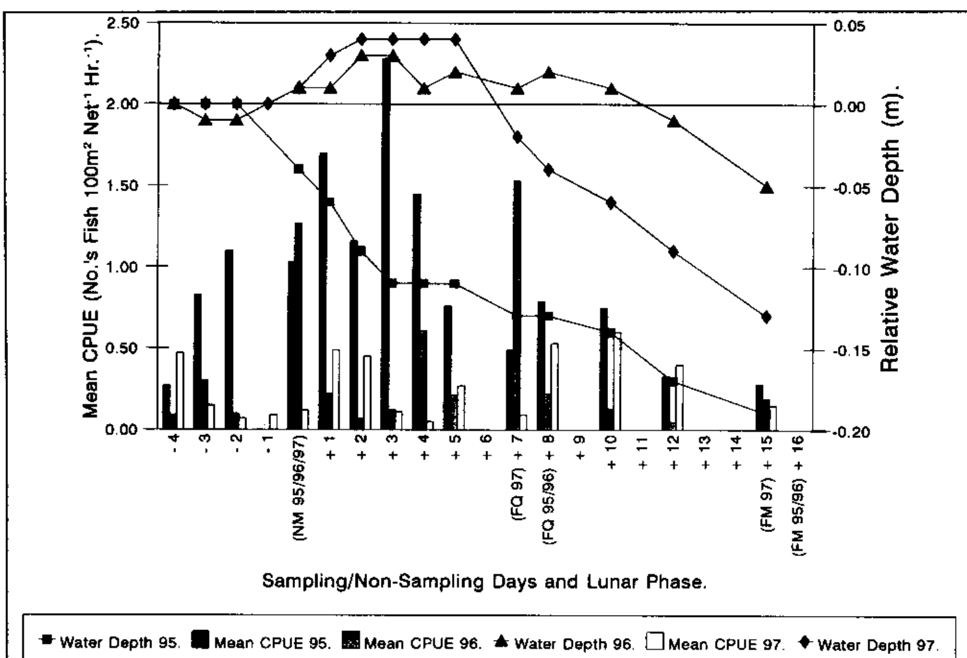

Fig. 2 Migratory activity for all species together during CNY studies at Hat Village, Muang Khong, 1995-1997. Data were recorded on every sampling day in each year and non-sampling days are indicated where no data entry exists. (FM = Full Moon, NM = New Moon, FQ = First Quarter).

a multiple regression model, migratory activity was found to be significantly related to lunar phase (P=0.006) and water depth (P=0.049).

In 1996 and 1997, apart from minor fluctuations and periods of stabilization, water level increased at, or just prior to, new moon. During these periods of increasing water level, or the periods of stabilization that followed, migratory activity decreased temporarily but intensified again when water levels began declining (Fig. 2). However, neither 1996 and 1997 showed a significant relationship between migratory activity and lunar phase or water depth.

During the EDS study, water depth decreased continuously from the first sampling day at two days before the first full moon to the last sampling day at eight days after the second full moon without stabilizing or increasing at any time (Fig. 3). Migratory activity gradually increased over the same period until three days after new moon, when it peaked and then decreased again, returning to a very low level at the end of the study (Fig. 3). Migratory activity was significantly related to lunar phase (P=0.027), but not to water depth.

At Hadsalao Village during the DSC study in 1996, migratory activity was most intense towards the end of the study, seven and twelve days after the new moon, respectively (Fig. 4). At Hat Village, migratory activity showed two main peaks; the first at new moon and the second seven days after the new moon.

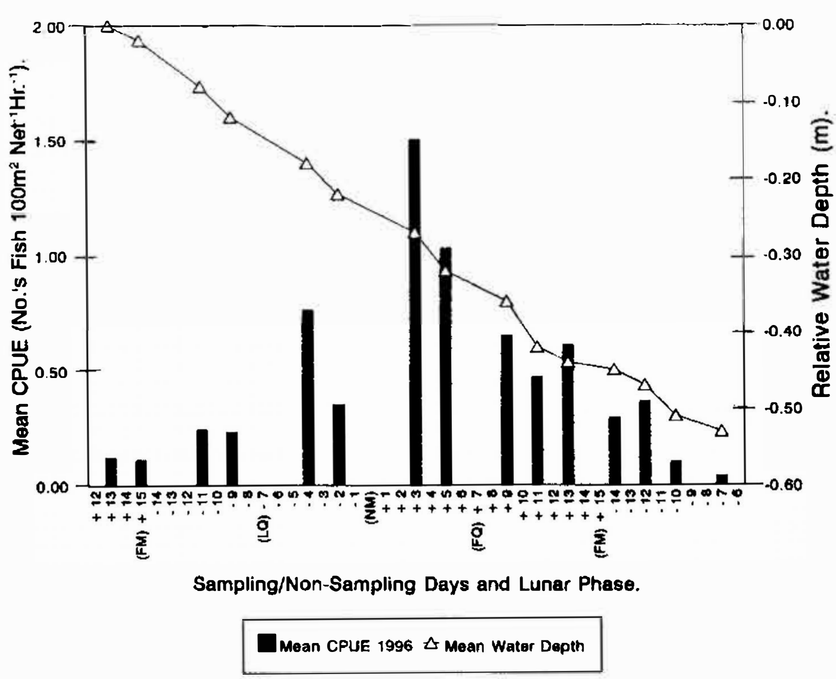

Fig. 3 Migratory activity for all species together during EDS study at Hat Village, Muang Khong in 1996. Data were recorded on every sampling day and non-sampling days are indicated where no data entry exists. (FM = Full Moon, LQ = Last Quarter, NM = New Moon, FQ = First Quarter).

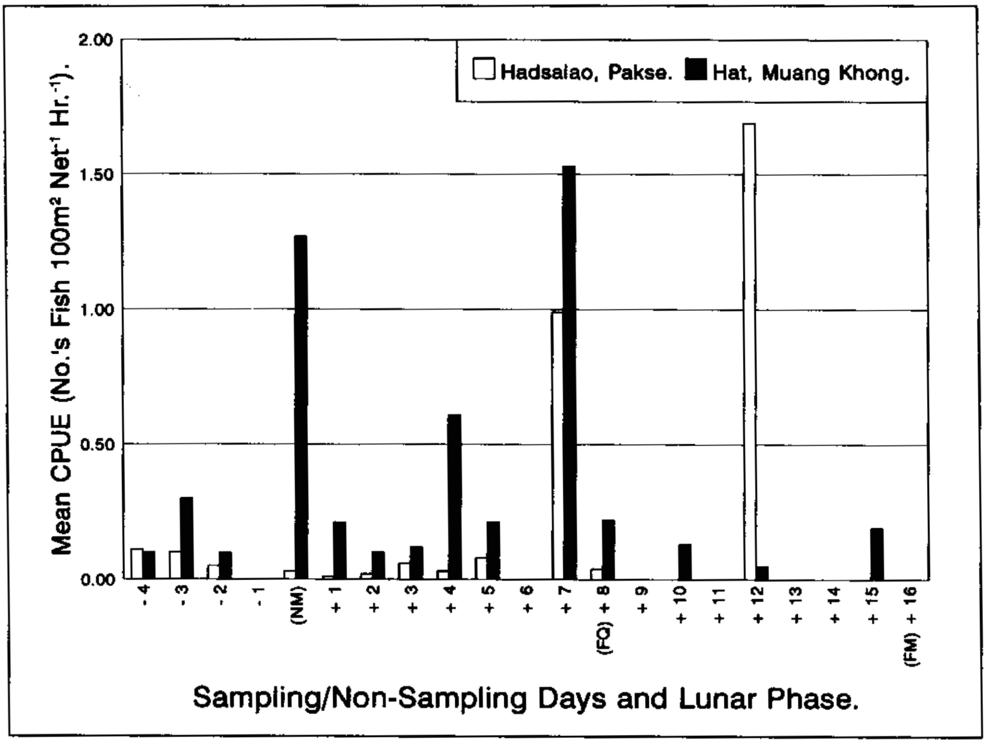

Fig. 4 Migratory activity for all species during DSC study at Hat Village, Muang Khong and Hadsalao Village, Pakse in 1996. Data were recorded on every sampling day in at least one site and non-sampling days are indicated where no data entry exists. (FM = Full Moon, NM = New Moon, FQ = First Quarter).

Migratory Species

Catch data, direct observation and biological examination were used to distinguish between migratory and non-migratory species. Nine migratory species were targeted by drift-gillnet fishers at Hat Village (Table 1).

Intense migratory activity occurs over a short period of only seven to ten days past Hat Village and involves mainly cyprinid fishes, many of which are in non-reproductive condition, and some fishes likely of age 1+. However, two migratory species, *H. malcolmi* and *S. stejnegeri*, are in full reproductive condition from late December until late January or early February. If the Chinese New Year is early in the calendar year, then these species may appear in reproductive condition in fish landings. Otherwise, they will likely appear as immature or spent individuals.

A large-scale upstream migration of cyprinid fishes past Hat Village begins around late December (EDS migration), which is similar to the CNY migration above. Migratory activity of most species is concentrated around the time of new moon, although in this case it is the first lunar cycle after the winter solstice. *H. malcolmi* and *S. stejnegeri* are in full reproductive condition at this time. In most other respects, the pattern of the EDS and CNY migrations are generally similar.

Landings at Hat Village are highly variable between years with an estimated 7.8 t of fish caught during the sampling period in 1995 compared to fifteen times less in 1997.

Table 1. Migratory and non-migratory species caught at Hat Village, Muang Khong, using 5, 6 and 7cm drift-gillnets during the CNY and EDS migrations.

Migratory Species	Likely Purpose Of Migration	Other Species Caught Intermittently
(Cyprinidae)		(Bagridae)
Bangana behri	Trophic/Dispersal	*Bagrichthys macracanthus*
Cirrhinus microlepis	Trophic/Dispersal	*Mystus nemurus*
Cirrhinus molitorella	Trophic/Dispersal	*Mystus wyckioides*
Hypsibarbus malcolmi	Reproductive/Trophic/Dispersal	
Labeo erythropterus	Trophic/Dispersal	(Cyprinidae)
Mekongina erythrospila	Trophic/Dispersal	
Scaphognathops bandanensis	Trophic/Dispersal	*Barbodes altus*
Scaphognathops stejnegeri	Reproductive/Trophic/Dispersal	*Cosmochilus harmandi*
		Cyclocheilichthys enoplos
(Gyrinocheilidae)		*Hampala macrolepidota*
		Morulius chrysophekadion
Gyrinocheilus pennocki	Trophic/Dispersal	*Osteochilus hasselti*
		Poropuntius deauratus
		Sikukia stejnegeri
		Thynnichthys thynnoides
		(Lobotidae)
		Datnioides sp.
		(Notopteridae)
		Chitala blanci
		(Pangasidae)
		Helicophagus waandersi
		Pangasius conchophilus
		(Pristolepididae)
		Pristolepis fasciata

In terms of total landings by weight, the overall four most important species targeted by fishers in decreasing order of magnitude during CNY were *S. bandanensis*, *C. microlepis*, *M. erythrospila* and *B. behri*; during EDS, *S. bandanensis*, *B. behri*, *H. malcolmi*, and *M. erythrospila*; and during DSC, *S. bandanensis*, *M. erythrospila*, *C. microlepis* and *L. erythropterus* (Table 2).

Biological Data for the Most Important Migratory Species Caught at Hat Village

Pooled biological data from the 1996 EDS and CNY studies are presented in Table 3.

Many individuals of the nine migratory species examined were sexually immature. Also, the sex of many could not be determined. Notable exceptions were *H. malcolmi* and *S. stejnegeri*, many of which were were sexually mature (Table 3). Stomachs and intestines of most individuals in most species

Table 2. Individual species contribution to total landings by weight and number percentages recorded on sampling days during the EDS, DSC and all CNY studies combined from 1994 to 1997. Species are shown in decreasing order of importance by weight percentage contribution.

Migratory Species	Percentage by Weight	Percentage by Numbers
1. EDS Study		
S. bandanensis	30.9	62
B. behri	30.4	1.6
H. malcolmi	16.7	16.5
M. erythrospila	9.7	9
L. erythropterus	5.5	3.4
S. stejnegeri	4.8	6.2
C. molitorella	1.7	0.9
C. microlepis	0.2	0.2
G. pennocki	0.1	0.3
2. DSC Study		
S. bandanensis	65.4	81.2
M. erythrospila	15.1	8.7
C. microlepis	7.1	4.9
L. erythropterus	4.3	1.6
C. molitorella	3.2	1.1
B. behri	2.5	0.8
H. malcolmi	2.0	1.2
G. pennocki	0.3	0.4
S. stejnegeri	0.0	0.0
3. CNY Studies		
S. bandanensis	31.2	51.1
C. microlepis	17.4	15.7
M. erythrospila	16.4	12.3
B. behri	11.5	4.9
L. erythropterus	10.9	5.4
H. malcolmi	6.9	5.2
S. stejnegeri	2.3	2.3
C. molitorella	2.3	1.2
G. pennocki	1.1	1.9

Table 3. Results of the internal examination of some important migratory species targeted by fishers in the Muang Khong area during the 1996 dry season.

Species	n	Reproductive Stage and Fish Weights	Stomach fullness	Dominant Food Item	Other Food Items	Viscera Fat Deposition
C. molitorella	9	(0-I) 7U(<377g) (II-III) 2F(>580g) (IV-V) -	(I) 9 (II) -	Chlorophytes	Substrate deposits	(I) - (II) 9
M. erythrospila	13	(0-I) 13U(<312g) (II-III) - (IV-V) -	(I) 9 (II) 4	Chlorophytes	Substrate deposits	(I) 3 (II)10
L. erythropterus	14	(0-I) 11U(<655g) (II-III) 3F(>802g) (IV-V) -	(I) 10 (II) 4	Chlorophytes		(I) 5 (II) 9
B. behri	10	(0-I) 8U(<1401g) (II-III) 1M(383g) (IV-V) 1F(1039g)	(I) 7 (II) 3	Chlorophytes	Substrate deposits	(I) 2 (II) 8
G. pennocki	14	(0-I) 12U(<274g) (II-III) 1M(275g) (IV-V) 1F(325g)	(I) 2 (II)12	Chlorophytes		(I) 2 (II) 12
C. microlepis	11	(0-I) 11U(<134g) (II-III) - (IV-V) -	(I) 9 (II) 2	Chlorophytes	Substrate deposits	(I) - (II) 11
S. stejnegeri	25	(0-I) 2U(<134g) (II-III) 14F(>77g) 4M(>93g) (IV-V) 5F(>102g)	(I) 24 (II) 1	Chlorophytes	Gastropod molluscs	(I) 22 (II) 3
S. bandanensis	20	(0-I) 14U(<425g) (II-III) 3F(>157g) (IV-V) 3M(>144g)	(I) 17 (II) 3	Chlorophytes	Substrate deposits	(I) 5 (II) 9
H. malcolmi	47	(0-I) 28U(<308g) (II-III) 13M(>147g) 1F(260g) (IV-V) 5F(>588g)	(I) 31 (II) 16	Chlorophytes	Plant matter	(I) 21 (II) 26

contained either little food, or were empty. The predominant food item for all nine species was a filamentous chlorophyte. *S. stejnegeri* was also apparently feeding on small gastropod molluscs (Table 3). Most individuals of most species examined had moderate to heavy deposits of lipid around their viscera. Exceptions were *G. pennocki* and *S. stejnegeri*. Approximately half the *H. malcolmi* examined contained moderate to heavy lipid deposits (Table 3).

Length-weight relationships and related statistics of the most important migratory species landed at Hat Village during dry-season studies from 1994 to 1996 are presented in Table 4.

Discussion

Our studies suggest that upstream dry-season migrations of certain fish species past Hat Village, Muang Khong, take place during the darkest periods of at least the first and second lunar cycles following the winter solstice. Welcomme (1985) states that whitefish migrations in the Mekong take place only during the second quarter to the full moon phase each month, and Lieng *et al.* (1995) report movements in the Tonle Sap River during the full moon phase in January and February, as fish move out of Cambodia's Great Lake.

Limited data do not link movements to lunar cycles at Pakse. Movements during the monthly dark period at Muang Khong may be specific to that area and might represent an adaptation to predator avoidance. Nocturnal

Table 4. Length-weight relationships and related statistics of the most important migratory species landed at Hat Village, Muang Khong, during dry season studies from 1994 to 1996.

Species	n	Mean B.Wt(g)	Mean TL(cm)	a	b	r^2
C. molitorella	24	257.3±32.2 (83.0-808.0)	28.6±1.0 (20.8-41.5)	0.0062	3.141	98.6
M. erythrospila	256	155.5±3.0 (60.0-302.0)	24.9±0.2 (18.7-32.6)	0.0160	2.847	89.3
L. erythropterus	136	236.2±10.1 (21.0-644.0)	26.8±0.4 (12.2-40.6)	0.0181	2.854	97.4
B. behri	93	275.1±40.7 (65.0-2640.0)	24.4±0.8 (15.9-55.0)	0.0091	3.113	98.2
G. pennocki	28	67.7±4.9 (25.0-119.0)	18.3±0.4 (13.3-22.8)	0.0113	2.975	94.3
C. microlepis	181	130.4±3.4 (78.0-454.0)	24.3±0.2 (20.7-37.0)	0.0137	2.861	91.8
S. stejnegeri	133	111.2±5.0 (27.0-249.0)	19.9±0.3 (13.0-27.6)	0.0205	2.843	97.1
S. bandanensis	348	72.0±2.3 (27.0-378.0)	17.9±0.2 (11.9-32.0)	0.0172	2.863	95.0
H. malcolmi	297	146.4±4.0 (40.0-464.0)	23.3+0.2 (17.0-36.4)	0.0124	2.959	95.9

Note: Means are shown with standard errors and ranges are given in parentheses.

movements in environments where predation pressures are high have been cited by several authors as a means of reducing vulnerability to attack (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).

Overall, water depth decreased continuously during the 1995 CNY and 1996 EDS studies and the migratory pattern appeared to be led by the lunar cycle, peaking when nights were dark just after new moon. A fitted multiple regression model suggests that migratory activity was significantly related to lunar phase during both studies, but not significantly related to water depth in the case of the 1996 EDS study, and only just so during the 1995 CNY study.

During the 1996 and 1997 CNY studies, increase in water depth around the new moon was accompanied by reduced migratory activity. As water depth decreased again, migratory activity intensified. The non-significant relationship between migratory activity and lunar phase and water depth during both these studies was possible due to hydrological and lunar factors conflicting with each other, producing large daily variations in migratory activity. It is postulated that had there been no increase in water depth around new moon, perhaps a more lunar-orientated migratory activity pattern similar to that observed in the 1996 EDS and 1995 CNY studies may have occurred. Hydrological factors overriding otherwise lunar-orientated movements are discussed by Benech and Quensiere (1982, 1983 and 1984), cited by Welcomme (1985). However, our results are inconclusive and this subject requires a separate research effort.

Two large peaks in migratory activity at Hadsalao Village, Pakse, were not centered around the moon, and were separated from the large ones at Hat Village, Muang Khong, by periods of seven and five days, respectively. If the peaks at Hadsalao and Hat represent the same groups of fishes moving upstream, average swimming speeds would vary between approximately 19 km and 26 km day^{-1} or 0.79 km and 1.08 km hr^{-1} over the periods in question. These ranges are consistent with estimates for other migratory species elsewhere (Daget 1952, cited by Welcomme 1985; Buckley and Kynard 1985; Hall *et al.* 1991). One possible explanation for the extra time involved between the first peak at Muang Khong and the first arrival peak at Pakse is that the increase in water depth, and presumably current speed, may have affected swimming speed. Increased current speed has been cited as a likely cause of upstream migratory delay by several authors (Bayley 1973; Jellyman and Ryan 1983; Sorensen and Bianchini 1986). Conversely, peaks at Muang Khong and Pakse may not be unrelated. The fact that large peaks occurred at both Muang Khong and Pakse at seven days after new moon may indicate that groups of migrating fishes were geographically separated and that, for whatever reason, there was greater migratory activity at both locations on that particular day; perhaps because the water depth and current speed had decreased.

H. malcolmi and *S. stejnegeri* of both sexes were sexually mature during the early dry-season, and were spent by late February and early March. Roberts and Baird (1995) make reference to one species of *Hypsibarbus* found in reproductive condition during the low water season. The presence of sexually mature individuals has been used by others to identify proximity to reproductive habitats (O'Herron *et al.* 1993). Their low numbers (*H. malcolmi*), or total absence (*S. stejnegeri*), in landings at Pakse suggest that their reproductive migrations terminate between Pakse, and close to Muang Khong.

Large beds of filamentous chlorophyte begin developing in the Muang Khong area during the January to February period, forming an important dietary item for most species. For non-juveniles of some species (*G. pennocki, M. erythrospila* and *S. bandanensis*), oily lipid accumulation was generally accompanied by further gonadal development. In mature *H. malcolmi* and *S. stejnegeri*, many individuals lacked fatty reserves. Presumably energy reserves for these species had been mostly diverted to gonadal development and, or, utilized during the migratory journey to Muang Khong. Bayley (1973) noted that large quantities of fat stored alongside the intestines of migratory characins in the Pilcomayo River, South America, gradually diminished towards the end of the migratory season.

These migration studies have provided a primary overview of the nature and importance of some dry-season fish movements at selected sites along the Mekong River of Southern Lao PDR. By relating standardized catch to lunar phase and hydrological factors, we have attempted to demonstrate the dependence of the movements on external factors. The Mekong River Basin ecosystem generally has received little in the way of scientific study and remains for the most part very poorly known and described. A thorough understanding of mainstream and tributary fish movements within the basin, and the factors controlling them, will require a large-scale, regional research effort from all riparian countries of the Lower Mekong.

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