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Population Dynamics of the Black Shark-minnow *Morulius chrysophekadion* (Bleeker): Cyprinidae, in a "Run-of-the-River" Reservoir in Thailand

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Abstract

Black shark-minnow, *Morulius chrysophekadion* (Bleeker): Cyprinidae, was the species that had the highest index of relative importance during the trial opening of all the Pak Mun Dam sluice gates from July 2001 to June 2002. Its growth was conformed as having an isometric pattern with a 53.54 cm asymptotic length and a 0.61 yr^{-1} curvature parameter. Total-, natural- and fishing- mortality rates were 2.88, 1.12 and 1.76 yr^{-1}, respectively. Exploiting at the $E_{0.1}$ level (E-value = 0.406) of the relative yield per recruit analysis of the current length at first capture 10.2 cm is recommended.

Introduction

The Mun River is the longest river in the northeast of Thailand, 641 km from its origin to the Mekong confluence, with a 117,000 km^2 catchment area (Duangswasdi and Chookajorn 1991). Schouten et al. (2000) reported that there were 265 fish species recorded in the Mun watershed before 1994 and about 10 species were introduced. In 1990, construction commenced in the "run-of-the-river" Pak Mun Dam across the Mun River, 6 km upstream from the Mun confluence to the Mekong River (Fig. 1) and started to operate in 1994 for the purpose of hydropower (Jutagate et al. 2001). After the construction, the fishers protested the blockage of the dam on potamodromous activity of the riverine fishes. The Royal Thai Government decided to allow the opening of all dam sluice gates to study the changes of the fisheries and other aspects, such as agricultures and irrigation, from July 2001 to June 2002.

During the trial, the cyprinid: black shark-minnow *Morulius chrysophekadion* (Bleeker), which some taxonomists classified as *Labeo chrysophekadion* (Froese and Pauly 2000), was the species that had the highest index of relative importance (Fig. 2; Ubon Ratchathani University 2002). This fish is a marketable species and is a delicacy for the local people in the north-east region, where the Mun River runs across. *M. chrysophekadion* distributes throughout the lower Mekong River basin, from the northernmost part in the Lao PDR and Thailand to the southernmost part in Bassac, Cambodia, and the Mekong delta in Vietnam (Poulsen and Jørgensen 2001). *M. chrysophekadion* is a planktivorous and detritivorous carp, which can grow as large as 60 cm (Rainboth 1996). Poulsen and Jørgensen (2001) stated that *M. chrysophekadion* has a relatively long spawning season with the highest number of small juveniles (2 to 4 cm) from October to November. Gravid females are found between February and October and peak from April to July (Poulsen and Jørgensen 2001). Recently, from the success of the "Thai Indigenous Fishes Project" of the Royal Thai Department of Fisheries, *M. chrysophekadion* can be artificially bred but the stocking program of this species to the natural water body has still not yet been reported.

Like most of other riverine species in the Mekong basin, a population dynamics of *M. chrysophekadion* is not yet clearly studied. This paper attempts to study the population parameters and the relative yield per recruit of this species, by using the length-based method.

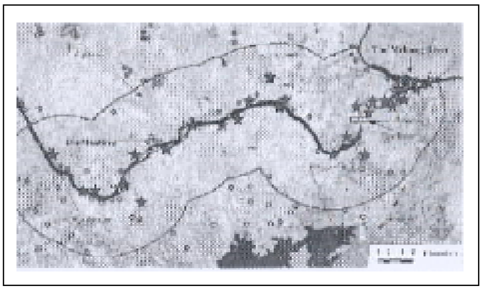

Fig. 1. Map of the Pak Mun Reservoir and sampling sites

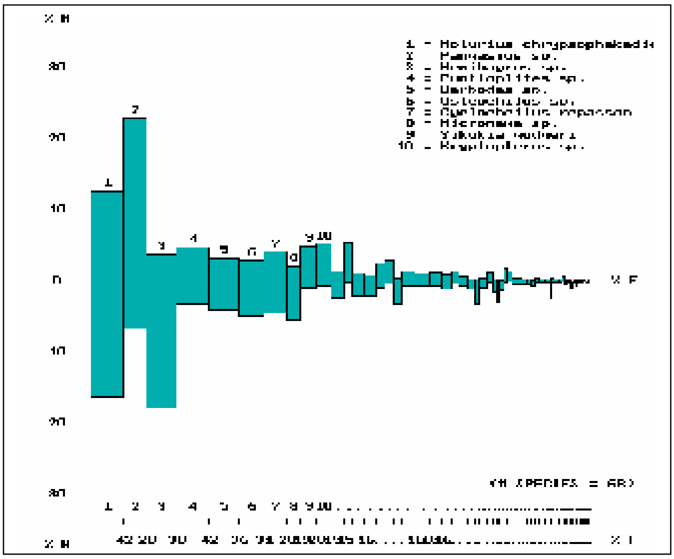

Fig. 2. Composition of fishes during the one year trial of Pak Mun Dam sluice gates opening where%N = percent in number,%W = percent weight and%F = percent frequency

Materials and Methods

Sampling sites

The sampling sites were divided into two main areas, a downstream site (from Mun confluence to the dam) and an upstream site (from dam to Pibun Mungsaharn District about 35 km upstream), where the water level increased during the sluice gate closing period. Sampling was carried out in 28 sites in upstream and downstream areas (Fig. 1).

Sampling of fish

Each station had its own data collector. Fishers were free to decide when they want to fish as well as what fishing gears, mostly gillnets, should be operated in their response area but the sampling dates were appointed by the project. Two project field-staff went to meet the data collectors fortnightly, to check the data collecting and take samples back. Fish samples were packed *in situ* with 10% formalin and taken to Ubon Ratchathani University (70 km from the Pak Mun Dam). Species of fish samples were identified and *M. chrysophekadion* species in the samples were measured in terms of total length (TL, nearest 0.1 cm) and 143 fish were also weighed (nearest 0.1 g).

Data analysis

Length data were classified into 1 cm interval for making a length frequency data (LFD). The "FiSAT" (FAO-ICLARM Stock Assessment Tool) software (Gayanilo et al. 1995) was used as a tool for expressing the von Bertalanffy growth formula (VBGF):

$$L_t = L_\infty \,[1\text{-exp}\ (\text{-}K\ (t\text{-}t_0))] \qquad (1)$$

where: L_t the predicted length at age t (cm), L_∞ the asymptotic length (cm), K the curvature parameter (yr^{-1}) and t_0 the "age" at which $L_t = 0$ (Gulland 1983). The estimations of L_∞ and K followed the steps, described by Amarasinghe and De Silva (1992).

Since t_0 cannot be easily determined when individual fish of a known age are unavailable, the value for t_0 was therefore obtained from the empirical equation (Pauly 1983):

$$\log_{10}(-t_0) = -0.3922 - 0.2752 \log_{10}(L_\infty) - 1.038 \log_{10}(K) \qquad (2)$$

Two more parameters were incorporated into VBGF, when a seasonality was taken into account (Somers 1988); *viz* C the value of which is between 0 and 1 indicates the magnitude of the seasonal growth pattern and WP the time of the year during which growth rate is minimum (Gayanilo et al. 1995).

Mattson (1997) stated that Roff's fish life history model (Roff 1986) is perhaps the most suitable successful model in predicting age and size at maturity in fish, which predicts that:

$$L_{á} = L_{\infty} [1/ (1+ (M/ 3K))] \quad (3)$$

where: $L_{á}$ is the length at 50% of maturity and M is the natural mortality rate.

M value was estimated from the empirical linear relationship model of Pauly (1980), using an average surface water temperature (T) = 29.38 ^{o}C (Ubon Ratchathani University 2002):

$$Log_{10}M = -0.0066 - 0.279log_{10} L_{\infty} + 0.6543 \log_{10}K + 0.463 \log_{10}T \quad (4)$$

The LFD were converted to age-frequency distribution via Eq (5):

$$t = [(1/K) \ln (L_{\infty} / (L_{\infty} - L_t))] + t_0 \quad (5)$$

The total mortality rate Z, was then estimated from the length-converted catch curve in which the natural logarithms of the numbers in each age class were plotted against age (Pauly 1990; Gayanilo and Pauly 1997). The fishing mortality rate (F) was calculated as Z – M.

Recruitment pattern was figured out through LFD and incorporated the parameters from VBGF (Gayanilo et al. 1995). Probabilities of capture were estimated from the detailed analysis of ascending part of the length-converted catch curve and incorporated in computing relative yield per recruit (Y'/R), which performed the analysis based on selection ogive (Pauly and Soriano 1986). The Y'/R analysis was performed for five levels of size at first capture (L_c) viz present size of 50% retention (L_{50}), two L_c values smaller than the present L_{50} and two L_c values greater than the present L_{50}.

Results

The length-weight relationship of *M. chrysophekadion* had high R^2 value (0.947) and the exponent was not significantly different from 3 (P > 0.05). Therefore, it is assumed that the growth of this species is "isometric" (Fig. 3).

$$W = 0.036TL^{2.931} \quad (7)$$

LFD ranged from 6 to 47 cm TL (Fig. 4). The growth parameters and curves superimposed on monthly LFD are shown in table 1 and figure 5, respectively. *M. chrysophekadion* takes about 4.5 yr to approach the L_{∞}. M-value was 1.12 yr^{-1} and, from this figure, the length at 50% of maturity, $L_{á}$, of *M. chrysophekadion* in the Mun River was 33.21 cm. From the length converted catch curve, Z-value was 2.88 yr^{-1}, with the R^2-value = 0.87 and the confident interval of Z-value were between 2.46 to 3.31 (Fig. 6). As a consequence, F-value was 1.76 yr^{-1} and the exploitation rate (E) was 0.61.

Peak of recruitment was found in the late rainy season between October and November (Fig. 7). From the probability of capture analysis, L_{50} of *M. chrysophekadion* in the Mun River was 10.21 cm. In the present fishing situation (L_c = L_{50}), the trend of over-exploitation was observed since E-value

Table 1. Demographical growth parameters status of *M. chrysophekadion* in Pak Mun Reservoir

Parameters							
L_∞ (cm)	K (yr^{-1})	t_0	f'	C	WP	R_n	Range of age
53.54	0.61	-0.22	3.243	0.6	0.4	0.124	1 – 4 yr

Note: Growth performance indices (f') = $\log_{10}K + 2\log_{10} L_\infty$ (Moreau et al. 1986); R_n is an index of goodness-of-fit of the growth come to the LFD in the ELEFAN (Electronic LEnght Frequency Analysis) method (Gayanilo et al. 1995)

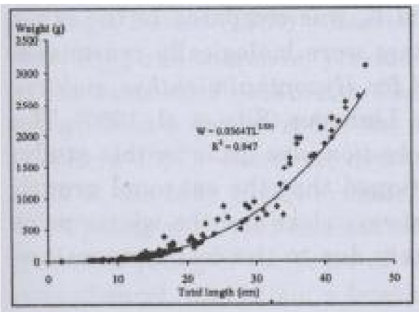

Fig. 3. Length-weight relationship of *M. chrysophekadion* in Pak Mun Reservoir

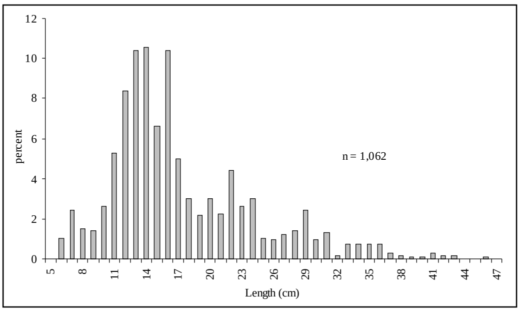

Fig. 4. Overall length frequency distribution of *M. chrysophekadion* in this study

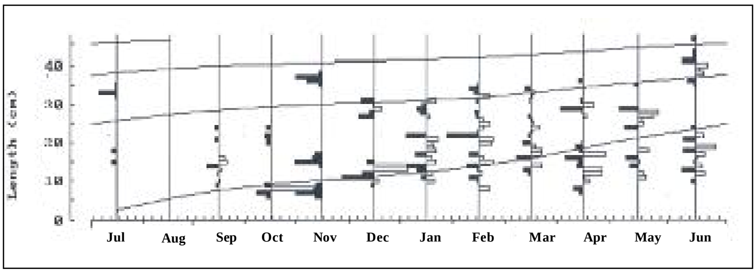

Fig. 5. Growth curves of *M. chrysophekadion*, superimposed on the length frequency distributions of the samples

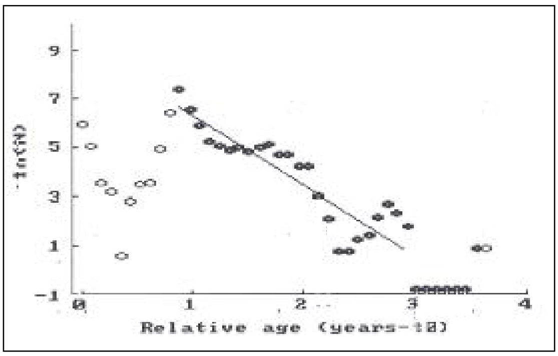

Fig. 6. Length converted catch curve of *M. chrysophekadion* in Pak Mun Reservoir

(0.61), is higher than the exploitation rate that yielded maximum Y'/R (E_{max} = 0.43; Table 2). By varying to five different L_c, in Y'/R analysis, they indicated that by increasing L_c, higher yield of *M. chrysophekadion* can be obtained (Fig. 8).

Table 2. Results from Y'/R analysis, showing the exploitation rate that yielded maximum Y'/R (E_{max}) and the exploitation rate corresponding to one tenth of the slope of Y'/R curve ($E_{0.1}$) of *M. chrysophekadion* in Pak Mun Reservoir

Level of L_c (cm)	Exploitation rate	
	E_{max}	$E_{0.1}$
6.2	0.401	0.368
8.2	0.421	0.401
10.2 (current L_c)	0.433	0.406
12.2	0.468	0.416
14.2	0.496	0.462

Discussion

The exponent value of length-weight relationship did not differ from three, hence the growth pattern of *M. chrysophekadion* is isometric, which means that the body proportion of fish is unchanged during growth. The growth performance indices (f'= 3.243), which were used to evaluate reliability of the estimated L_∞ and K, was compared to the other carps. It is seen that the growth parameters were biologically reasonable because f' was close to the values of 3.272 for *Hypopthalmichthys molitrix* Valenciennes and 3.210 for *Cyprinus carpio* Linnaeus (Sifa et al. 1990). The seasonality of the growth of *M. chrysophekadion* was clear in this study. Moreau and Sricharoendham (1999) mentioned that the seasonal growth pattern of many Thai freshwater fishes is always clear and the winter point takes place in early January and most likely due to the cool temperature during the period.

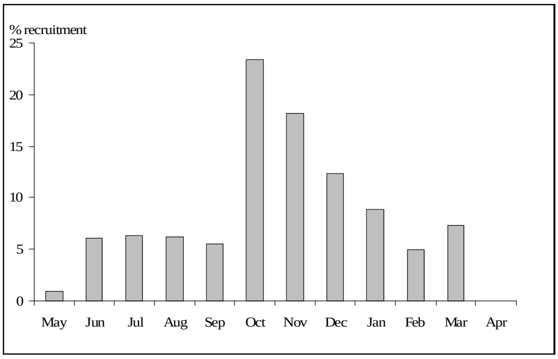

Fig. 7. The percentage monthly recruitment of *M. chrysophekadion*

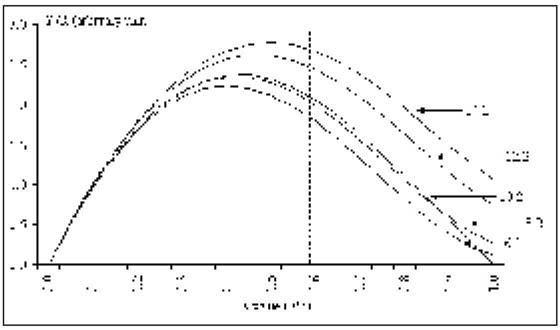

Fig. 8. Relative yield per recruit, Y'/R, (arbitrary unit) of *M. chrysophekadion* in Pak Mun Reservoir

The high value of exploitation rate (E = 0.61) and small asymptotic length (53.54 cm), instead of the reported maximum length of 90 cm in the Mekong mainstream (Poulsen and Jørgensen 2001), indicated that this fish is quite highly exploited in the Mun River. It is worthy to note that, although from 16th May to 15th September is the closed season, *M. chrysophekadion* are sometimes caught since some fishing gears are allowed *viz.* hooks, traps and any lift nets that are not larger than 2x2 m^2.

Recruitment of *M. chrysophekadion* appeared to be continuous throughout the year as mentioned by Poulsen and Jørgensen, (2001). Peak of recruitment from October to November complied with the hypothesis that *M. chrysophekadion* migrates upstream to the floodplain during the monsoon season and moves back to the river channel, along with young-of-the-year, when the water recedes (Rainboth 1996; Poulsen and Jørgensen 2001).

From Y'/R analysis, it is evident that *M. chrysophekadion* is heavily exploited. To lessen the fishing intensity, Amarasinghe (2002) mentioned that the E-value, which corresponds to 10% of the maximum rate of Y'/R increase with increasing E ($E_{0.1}$), is a good determinant of the optimum fishing strategy. Deriso (1987) observed that $E_{0.1}$ is desirable because it is lower than E_{max} and therefore, provides a buffer to avoid growth over-fishing but at the same time does not reduce the yield to any great extent nor does it bring about a severe reduction of the spawning biomass (Sissenwine and Shepherd 1987). Therefore, in attempting to sustain the *M. chrysophekadion* stock in the Mun River, exploitation rate at 0.406 is recommended.

Fishing at current smallest size (6.00 cm) is too dangerous, because at the time that young-of-the-years of *M. chrysophekadion* move back to the main river channel, they attain a length of about 10 cm (Rainboth 1996). Moreover, the important issue on *M. chrysophekadion* fishing, which has to be considered, is that the fishers categorize and recognize sub-adult and adult in different names. They call the sub-adult, which is darker than adult, as "Pla Ea-Kum" and the adult as "Pla Ea-Too" and exploit both fishes. This will be subjected to growth over-fishing because the individual small sizes are harvested before joining the usable stock (Jutagate et al. 2003).

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