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Estimation of Desirable Gillnet Mesh Size for an Exploited Population of a Pangasiid *Pangasius bocourti* in Thailand's Fishing Ground of the Mekong Mainstem

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Abstract

The mesh selectivity of gillnets for pangasiid *Pangasius bocourti* was investigated using four different stretched mesh sizes (4, 7, 9 and 14 cm). Fishing experiments were conducted in Nongkhai Province, Thailand, between September 2007 and July 2008. A total of 2,673 *P. bocourti* was caught with the size range (total length) of 9.3-55.5 cm. Length at 50% maturity estimated as 23.3 cm, was used as the criterion for selecting desirable mesh size. The optimal retention length was estimated for each mesh size employing Baranov-Holt method using the model for various mesh sizes. The optimal retention lengths of *P. bocourti* were estimated as 11.6, 20.3, 26.1 and 40.6 cm for the stretched mesh sizes of 4, 7, 9 and 14 cm respectively. Accordingly, the desirable gillnet mesh size for *P. bocourti* corresponding to length at 50% maturity was determined to be 9.0 cm. The asymptotic total length and the curvature parameter estimated by length-based stock assessment methods were 57.6 cm, and 0.56 yr^{-1}, respectively. Meanwhile, the natural mortality rate was 1.04 yr^{-1}. The relative yield per recruit was used to analyze long-term biological effect, which was based on different length at first capture of each studied mesh size.

Introduction

Members of family Pangasiidae are important counterparts in the fish communities of the Lower Mekong Basin (LMB) (Nam and Baran, 2008; Vu et al. 2009). They are known as long migratory species and have a high market price (Poulsen et al. 2004). There is intensive fishing pressure on this group, which represented about 10% of total harvest in the LMB (Nam and Baran, 2008; Hortle, 2009). Appropriate fisheries management strategies for this fish group are therefore very important. Since they occur in huge numbers during the rainy and flood season in the middle Mekong area (Grudpan and Grudpan, 2008), fishing is concentrated during rainy season. Fishing is conducted regardless of their sizes to maximize the yield and then processing (i.e., smoking and salt drying) helps to smooth out oversupply (Hortle, 2009), which also results in overexploitation. In LMB, more than 50% of catches of medium to large sized pangasids are from gillnets, while the small pangasiids, such as *Pangasius macronema* and *Pseudolais pleurotaenia* are targeted by traps (Jutagate and Mattson, 2003; Grudpan and Grudpan, 2008).

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Gillnets are recognized as a very selective type of fishing gear for a given mesh size (Hamley, 1975) and a well-managed gillnet fishery is expected to use the gillnet that catch most of the available sizes that do not undermine the sustainability (Ajith Kumara et al. 2009). In the pangasiid-fisheries of LMB, so far, gillnet mesh regulation of 5 cm has been recommended only for shark catfish, *Helicophagus waandersii* (Thapanand, 2006). Among the pangasiids, Bocourti's catfish, *Pagasius bocourti* Sauvage, 1880 is another heavily exploited species in LMB area using gillnets. In addition to commercial exploitation of adults, fingerlings are also caught for aquaculture purposes (Cacot et al. 2002; Holland, 2007). Knowledge about gillnet selectivity of *P. bocourti* is therefore important for defining management strategies for the fishery of this species. In the present paper, an attempt is made to estimate gillnet selectivity for *P. bocourti* in LMB.

Materials and Methods

Source of data

The study was carried out on a monthly basis during September 2007 to July 2008 in the Mekong mainstem at Nongkhai Province. There were four stations along the river (Fig. 1). The distance from one station to another was about 55 km. Experimental gillnet fishing was conducted using four different mesh sizes, stretched mesh, i.e. 4 cm (M4), 7 cm (M7), 9 cm (M9) and 14 cm (M14). The dimension of each net was 100 m long and 1.2 m wide and they were attached altogether in one set. The experimental fishing was carried out by five fishers$\cdot$station^{-1}. They were free to decide on the fishing ground in the area of sampling station, and on operation time. Catches of *P. bocourti*, in each mesh-size gillnet, were packed and stored in -4 ºC refrigerators until they were taken to the laboratory. The total length (TL, nearest 0.1 cm) and weight (nearest 0.01 g) of individual specimens were measured, and the fish were then sexed. A proportion of mature females was classified by examining the ovary development. The mature females had ovaries covered with thick blood vessels with clearly visible eggs. Length frequency data (LFD) were recorded separately by mesh-sizes and monthly LFD samples were pooled.

Data analyses

Estimation of length at 50% maturity

Length at 50% maturity (L_{50}) was employed as the principal criterion to investigate the desirable mesh size, which should be worthwhile for assuring the large spawning biomass (Amarasinghe, 1988a; Amarasinghe and Pushpalatha, 1997). Thus, the optimum length caught by the desirable mesh size should be above L_{50}. The logistic function between the proportions of mature to immature fish (P_L) in each length class (L) at 1 cm interval was applied to estimate L_{50} as shown in Equation 1 (Sparre and Venema, 1998).

$$P_L = \frac{1}{1+e^{(S_1 - S_2 L)}} \qquad (1)$$

where S_1 and S_2 are the equation coefficients. This equation was further used to estimate L_{50} by setting P_L at 0.5.

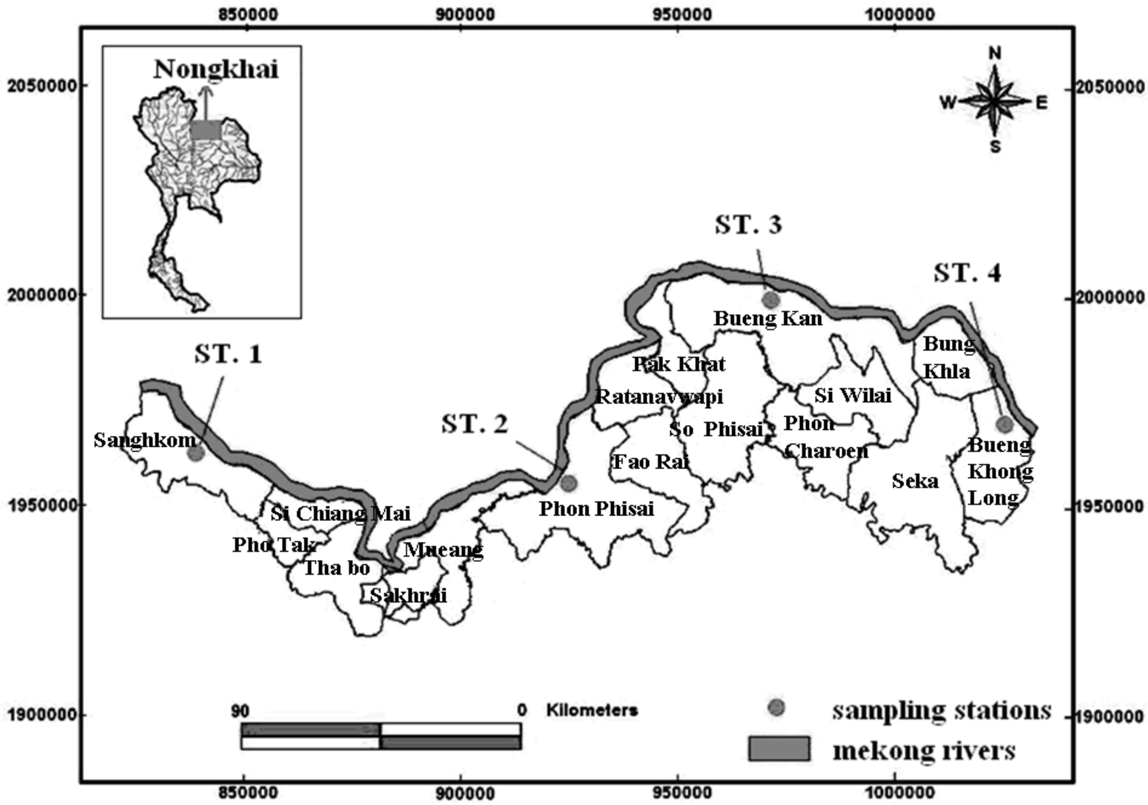


Fig. 1. Location of Nong Khai Province and map of the sampling stations

Estimation of gillnet selection

For the gillnets of different mesh sizes, the model for various mesh sizes (Sparre and Venema, 1998) was used. Estimate of an overall selection factor and a common standard deviation can be obtained from the results of an analysis of each pair of successive mesh sizes as in Baravov-Holt method (Holt, 1963), by relating the catches in terms of logarithmic ratios of two contiguous mesh sizes to fish length using linear regression (Holt, 1963; Amarasinghe, 1988a). The regression coefficients were estimated to calculate the common selection factor (*SF*) as shown in Equation 2 (Sparre and Venema, 1998) and if the number of the slightly different mesh sizes used is *n*, then there will be *n-1* pairs of estimations

$$SF = \frac{-2 * \sum_{i=1}^{n-1} (m_i + m_{i+1}) * \left(\frac{a_i}{b_i}\right)}{\sum_{i=1}^{n=1} (m_i + m_{i+1})} \qquad (2)$$

where a_i and b_i, are the intercept and slope, respectively, of the regression derived from two successive mesh sizes m_i and m_{i+1}. The common standard deviation (SD_{common}) was estimated as the mean value of the individual estimates for each consecutive pair of mesh sizes as

$$SD_{common} = \sqrt{\frac{1}{n-1} * \sum_{i=1}^{n-1} \frac{-2 * a_i * (m_{i+1} - m_i)}{b_i^2 * (m_i + m_{i+1})}} \quad (3)$$

and the optimum length for mesh size *i* (L_{m_i}) was then estimated as

$$L_{m_i} = SF * m_i \quad (4)$$

Estimation of relative yield per recruit (Y'/R)

The relative yield per recruit (*Y'/R*) model (Beverton and Holt, 1966; Pauly and Soriano, 1986) was used to estimate the *Y'/R* and relative biomass-per-recruit (*B'/R*), assuming a knife edge recruitment to determine the mesh size that afforded the best yields. It is the simplest method to make an understanding of the impact of the differences of level of fishing (i.e. exploitation ratio, *E*) and the length at first capture (L_c) on fish stock. In this study, L_c was varied according to the optimum length of each mesh size (L_{m_i}). Analyses of the *Y'/R* were performed by the FiSAT II program (Gayanilo et al. 2006). The input parameters of *Y'/R* model are the asymptotic length (L_∞), the curvulture parameter (*K*) and natural mortality rate (*M*),

L_∞ was estimated by the length of the largest fish in the sample, L_{max} (Equation 5, Froese and Binohlan, 2000),

$$\log_{10} L_\infty = 0.044 + 0.9841 * \log_{10} L_{\max} \quad (5)$$

Munro's phi prime, ϕ' (Munro and Pauly, 1983), which is quite constant within a family, was used to estimate *K* as $K = 10^{\phi'} / L_\infty{}^2$ and the ϕ' value was taken from FishBase (Froese and Pauly, 2010). *M* was estimated using Pauly's empirical equation (Pauly, 1980) as

$$\log_{10} M = -0.0066 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} K + 0.4634 \log_{10} T \quad (6)$$

where T is annual mean water temperature (ºC).

Results

A total of 14 experimental trips were conducted and the number of the *P. bocourti* sampled was 2,673, which ranged between 9.3 and 55.5 cm TL. The highest number of catch was caught by the smallest mesh size (M4). Except for the bi-modal distribution found in M9, the length frequency distribution of the mesh sizes (Fig. 2) showed the unimodal distribution and the probability of capture of the large individual increased with mesh size from M4 to M14. Of the 806 females, the length at 50% maturity (L_{50}) of the samples, according to the proportion of mature fish at each length class, was estimated at 23.3 cm (Fig. 3). The results also indicated that the proportion of mature females caught during the whole study period was 30%.

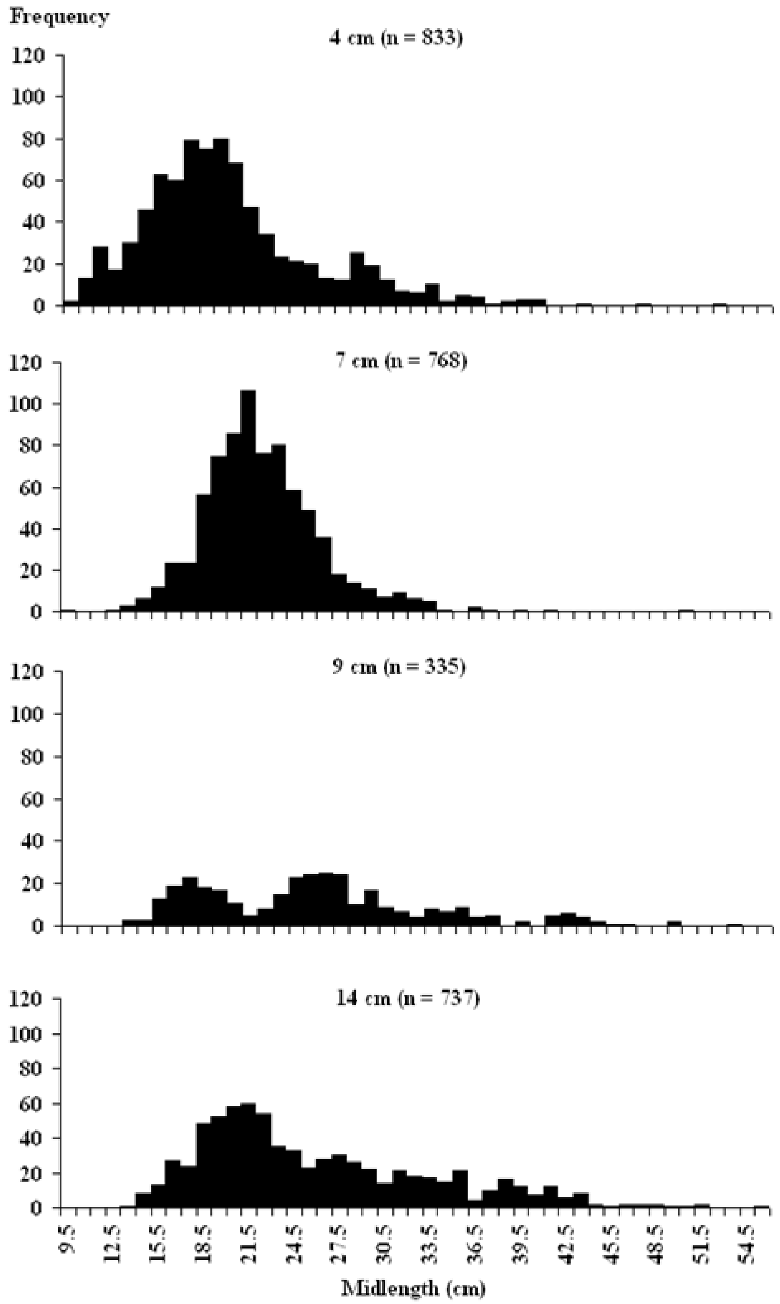


Fig. 2. Length frequency distributions and numbers of *P. bocourti* samples, caught by each mesh sizes.

The selection curves for *P. bocourti* caught in the group of four mesh sizes are presented in Fig. 4. Selection factor (*SF*) and SD_{common} estimated using the regression coefficients of each pair were 2.90 and 5.88 respectively. The optimum lengths estimated for individual mesh sizes (L_{m_i}) are presented in Table 1. Empirical relationship between the mesh size and L_{m_i} was found to be linear and described by the equation

$$L_{m_i} = -0.00028 + 2.90M \text{ ; } R^2 = 0.98 \; p < 0.01 \qquad (7)$$

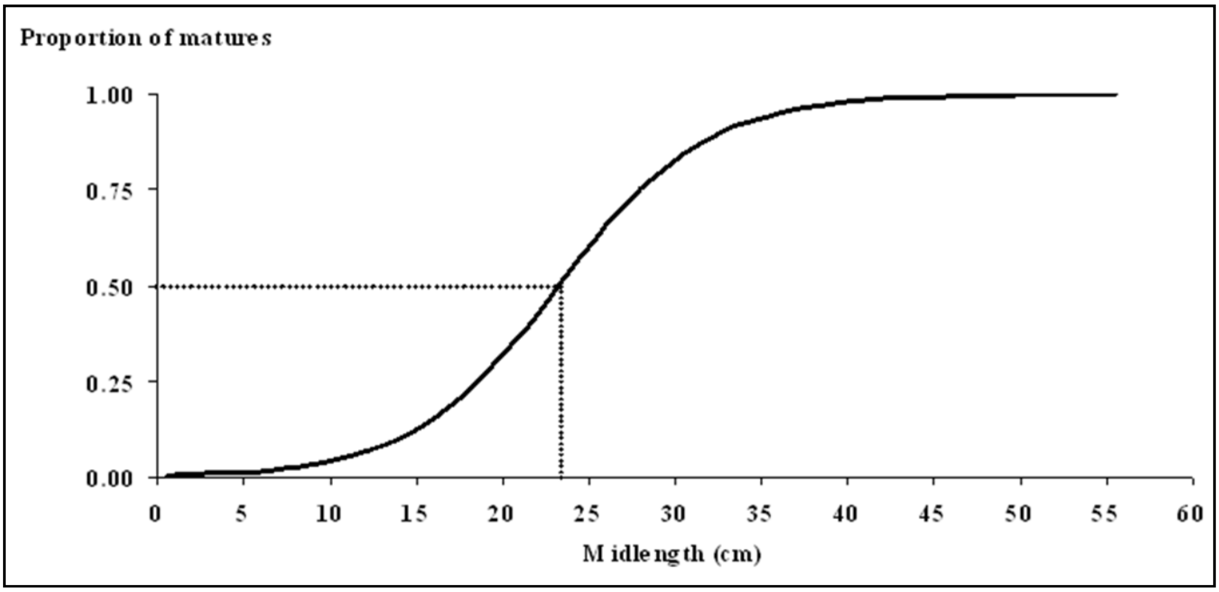


Fig. 3. The proportion of mature female *P. bocourti* in each length class (1 cm interval).

According to results of L_{m_i} and the estimated L_{50}, the M9 (i.e. mesh size = 9 cm stretched mesh) was recommended to be a desirable mesh size for this species.

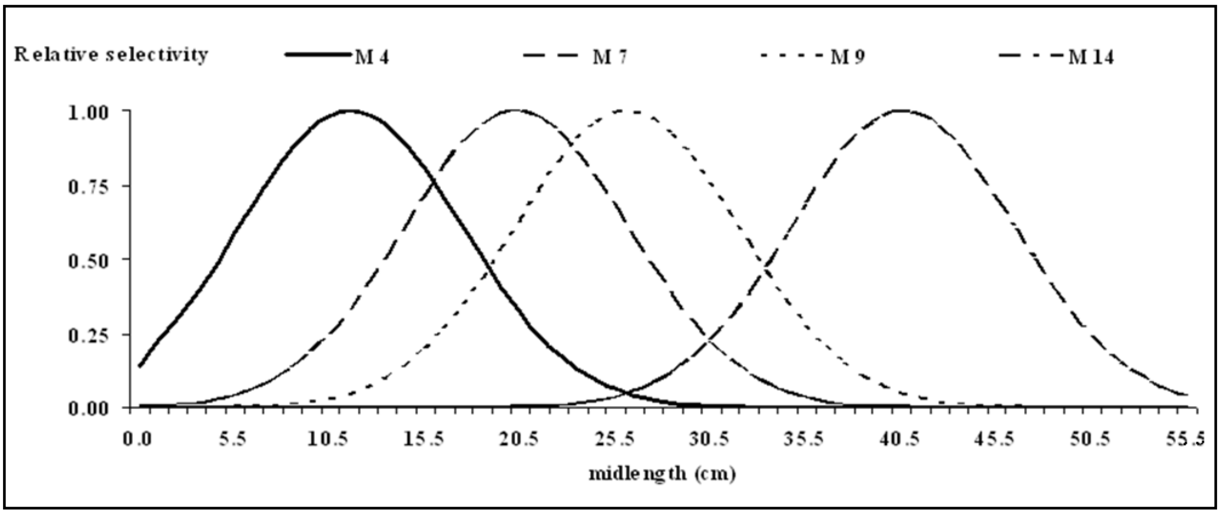


Fig. 4. Selection curves of *P. bocourti* using the multi-mesh model.

Table 1. The optimum length (L_{mi}) of *P. bocourti* at each mesh size of gillnet.

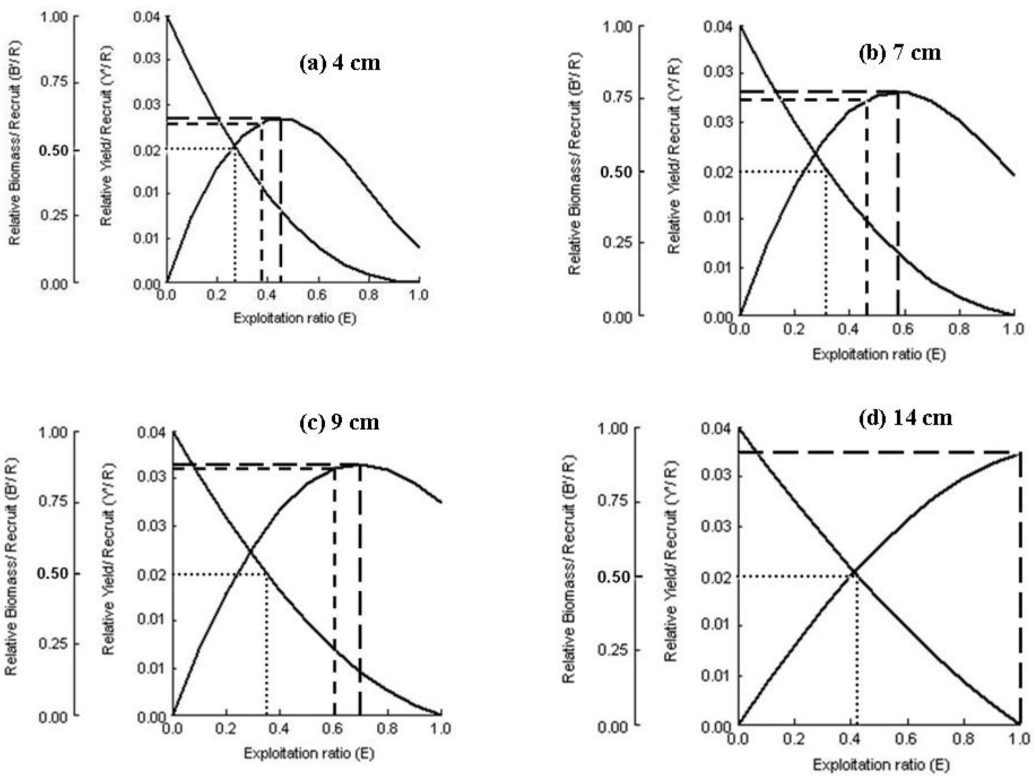
Parameters	Mesh size (cm)			
	4	**7**	**9**	**14**
The optimum length (L_{mi}; cm)	11.60	20.29	26.09	40.59
Age at optimum length (yr^{-1})	0.40	0.77	1.07	2.17

The L_∞ value was estimated from the maximum length in LFD as 57.62 cm TL and ϕ' value of Pangasiid fishes was 3.27 (Ramakrishniah, 1986), which consequently made the K value of $0.56 \cdot yr^{-1}$. The M value of $1.04 \cdot yr^{-1}$ was estimated at the mean annual temperature during this study, i.e. 29.5 ºC. Hence the M/K, as the input for the Y'/R model, for *P. bocourti* in this study is 1.86. The Y'/R of each mesh size was calculated for the array of E. In the Y'/R model, the ratios of L_c/L_∞ represented varying scenarios equivalent to changes in mesh size, meanwhile E corresponds to changing levels of fishing. The results (Table 2 and Fig. 5) showed that the exploitation rate that gives maximum Y'/R (E_{max}) was getting higher as the mesh size gets larger. The highest Y'/R was obtained by the gillnet M14 at E_{max} = 1.000. However, imposing extremely high levels of exploitation is harmful to the stock. This can be seen from Fig. 5 which indicates decrease of relative biomass per recruit (B'/R) to zero at high levels of E. Therefore, the gillnet mesh size of M9 is determined to be desirable for *P. bocourti* in LMB.

Table 2. The estimated relative yield per recruit (Y'/R) values at 3 reference-points of each mesh size of gillnet.

Reference-point	Mesh size (cm)			
	4	**7**	**9**	**14**
$E_{0.1}$	0.371	0.458	0.601	1.000
$E_{0.5}$	0.275	0.317	0.348	0.426
E_{max}	0.449	0.574	0.695	1.000

Note: $E_{0.1}$: the value of E at which marginal increase in Y'/R is 10% of its value at E = 0,
$E_{0.5}$: the value of E at 50% of the unexploited B'/R, E_{max}: the value of exploitation rate giving maximum relative Y'/R.



Note: The dash-lines: — — — , - - - - - - and .... indicate the exploitation rates at E_{max}, $E_{0.1}$ and $E_{0.5}$, respectively.

Fig. 5. Relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) of each mesh size of gillnet to *P. bocourti* as functions of the exploitation rates.

Discussion

The experimental gillnet fishing for *P. bocourti* in the middle part of LMB (i.e. Nongkhai Province, Thailand) was conducted to find out the desirable mesh size, which prevents growth overfishing (Dinçer and Bahar, 2008). Skewness in length frequency distribution of catch in M9 and M14 (Fig. 1), could be interpreted that some fish were entangled in these mesh sizes (Sparre and Venema, 1998), whereas the unimodal distribution found in M4 and M7 implied that most fish were caught in the nets by wedged or gilled (Hamley, 1975; Pet et al. 1995; Dos Santos et al. 2003). Although estimation of optimum length of gillnet mesh by Baranov-Holt method is considered to be appropriate for non-tangled fish (Pet et al. 1995), the various mesh size model, which was applied in this study, can cope up with this disadvantage because the L_m of each selection curve are summed and then normalized to a maximum of one and cover all the length groups of samples (Sparre and Venema, 1998).

A study of gillnet selectivity would not be complete without the simultaneous use of nets with different mesh sizes (Grégoire and Lefebvre, 2003). Employing M4 and M7 gillnets resulted in low *Y'/R*, at any given exploitation rate, which was not appropriate to the high fishing intensity in the area. Moreover, the increased efforts in M4- and M7- mesh sizes might also bring about growth over-fishing (Amarasinghe, 1988b) because the small sized fish would be heavily harvested. Amarasinghe (1988b) also mentioned that the decline in harvest could occur when employing a large mesh size (>10 cm) with slightly increase in *B'/R*.

Conclusion

In the area that fishing intensity is high, regulatory measures on input control (e.g. mesh size regulation) should be the option to sustain the resources. Knowledge of the size-selectivity of gillnet is crucial for management of the fishery for optimizing yield (Wileman et al. 1996). In the present analysis, 9 cm (M9) mesh size was recommended to be desirable for *P. bocourti* fishery in the middle area of the Lower Mekong mainstem. It is also beyond the legal size of 4 cm stretched mesh, declared by the Department of Fisheries of Thailand. As such, the desirable mesh size for *P. bocourti* recommended by the present study helps its differential exploitation. The effective mesh sizes of gillnets for many small to medium sized cyprinids were found to range from 2-6 cm stretched mesh (Jutagate et al. 2001; Ajith Kumara et al. 2009) making it possible for their differential exploitation.

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References

Ajith Kumara, P.A.D., U.S. Amarasinghe, F. Schiemer, G. Winkler and M. Schabuss. 2009. Gillnet selectivity of small cyprinids in three Sri Lankan Reservoirs. Asian Fisheries Science 22:885-900.

Amarasinghe, U.S. 1988a. Empirical determination of a desirable mesh size for the gill-net fishery of *Oreochromis mossambicus* (Peters) in a man-made lake in Sri Lanka. Asian Fisheries Science 2:59-69.

Amarasinghe, U.S. 1988b. Growth overfishing: a potential danger in the Sri Lankan reservoir fishery. In: Reservoir Fishery Management and Development in Asia (ed. S.S. De Silva), pp. 105-112. IDRC, Ottawa.

Amarasinghe, U.S. and K.B.C. Pushpalatha. 1997. Gillnet selectivity of *Ompok bimaculatus* (Siluridae) and *Puntius dorsalis* (Cyprinidae) in a small-scale riverine fishery. Journal of National Science Council of Sri Lanka 25:169-184.

Beverton, R.J.H. and S.J. Holt. 1966. Manual of methods for fish stock assessment. Part 2. Table of yield function. FAO Fisheries Technical Paper No. 38 (Rev.1). 67 pp.

Cacot, P., M. Legendre, T.Q. Dan, L.T. Tung, P.T. Liem, C. Mariojouls and J. Lazard. 2002. Induced ovulation of *Pangasius bocourti* (Sauvage, 1880) with a progressive CG treatment. Aquaculture 213:199-206.

Dinçer, A.C. and M. Bahar. 2008. Multifilament gillnet selectivity for the red mullet (*Mullus barbatus*) in the Eastern Black Sea Coast of Turkey, Trabzon. Turkish Journal of Fisheries and Aquatic Science 8:355-359.

Dos Santos, M.N., M. Gaspar, C.C. Monteiro and K. Erzini. 2003. Gillnet selectivity for European hake *Merluccius merluccius* from southern Portugal: implications for fishery management. Fisheries Science 69:873-882.

Froese, R. and C. Binohlan. 2000. Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fish, with a simple method to evaluate length frequency data. Journal of Fish Biology 56:758-773.

Froese, R. and D. Pauly. (eds). 2010. FishBase-electronic publication. www.fishbase.org, version (02/2010).

Gayanilo, F.C. Jr., P. Sparre and D. Pauly. 2006. The FAO-ICLARM Stock Assessment Tools II Revised version, User's guide. FAO, Rome. 124 pp.

Grégoire, F. and L. Lefebvre. 2003. Estimation of gillnet selectivity for Atlantic herring (*Clupea harengus harengus*) from the west coast of Newfoundland, 1997-2001. Maurice Lamontagne Institute, Québec. Canadian Industry Report of Fisheries and Aquatic Science No. 272. 22 pp.

Grudpan, C. and J. Grudpan. 2008. Traditional fisheries and biodiversity of Pangasiid catfishes (Family Pangasiidae) in Ubon Ratchathani Province, Thailand. Paper presented at the International Symposium "Sustaining Fish Diversity, Fisheries and Aquacultures in the Mekong Basin" Ubon Ratchathani, 3-5 September 2008.

Hamley, J.M. 1975. Review of gillnet selectivity. Journal of Fisheries Research Board of Canada 2:1954-1969.

Holland, J. 2007. Pangasius 2007: Growth on shaky ground. Seafood International 22:27-31.

Holt, S.J. 1963. A method for determining gear selectivity and its application. ICNAF Special Publication 5:106-115.

Hortle, K.G. 2009. Fisheries of the Mekong River Basin In: The Mekong: biophysical environment of an international river basin (ed. I. Campbell), pp. 199-251. Elsevier Publishers, Amsterdam.

Jutagate, T., N.S. Mattson, M. Kumsri and R. Panjun. 2001. Gillnet selectivity as a fisheries management proposal at Sirindhorn Reservoir, Thailand. Paper presented at the 39th Kasetsart University Annual Conference, February 2001. Bangkok, Thailand.

Jutagate, T. and N.S. Mattson. 2003. Optimizing fishing gear operation in Sirinthorn Reservoir, Thailand. Natural History Bulletin of the Siam Society 51**:**105-122.

Munro, J.L. and D. Pauly. 1983. A simple method for comparing growth of fishes and invertebrates. ICLARM Studies and Reviews 7:15-25.

Nam, S. and E. Baran. 2008. Pangasiid catfish in Cambodia: a taxonomy update. Paper presented at the International Symposium "Sustaining fish diversity, fisheries and aquacultures in the Mekong Basin" Ubon Ratchathani, 3-5 September 2008.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameter, and mean environmental temperature in 175 fish stocks. Journal du Conseil 39:175-192.

Pauly, D. and M.L. Soriano. 1986. Some practical extensions to Beverton and Holt's relative yield -per-recruit model. In: The First Asian Fisheries Forum (eds. J.L. Maclean, L.B. Dizon and L.V. Hosillos), pp. 491-496. Asian Fisheries Society, Manila.

Pet, J.S., C. Pet-Soede and W.L.T. van Densen. 1995. Comparison of methods for the estimation of gillnet selectivity to tilapia, cyprinids and other fish species in a Sri Lankan reservoir. Fisheries Research 24:141-164.

Poulsen, A.F., K.G. Hortle, J. Valbo-Jorgensen, S. Chan, C.K. Chhuon, S. Viravong, K. Boukhamvongsa, U. Suntornratana, N. Yoorong, T.T. Nguyen and B.Q. Tran. 2004. Distribution and ecology of some important riverine fish species of the Mekong River Basin. MRC Technical paper No. 10. Mekong River Commission, Vientiane. 116 pp.

Ramakrishniah, N. 1986. Studies on the fishery and biology of *Pangasius pangasius* (Hamilton) of the Nagarjunasagar reservoir in Andrha Pradesh. Indian Journal Fisheries 33:320-335.

Sparre, P. and S.C. Venema. 1998. Introduction to fish stock assessment. Part 1: Manual. FAO Fisheries Technical Paper 306/1 Rev. 2. FAO, Rome. 376 pp.

Thapanand, T. 2006. Shark catfish (*Helicophagus waandersii* Bleeker, 1858) gillnetting in the Mun River, Thailand. Kasetsart Journal (Natural Science) 40:229-234.

Wileman, D.A., R.S.T. Ferro, R. Fonteyne and R.B. Millar. 1996. Manual of methods of measuring the selectivity of towed fishing gears. ICES Cooperative Res. Rep. No 214. 126 pp.

Vu, V.A., N.D. Nguyen, E. Hidas and M.N. Nguyen. 2009. Vam Nao Deep Pools: a critical habitat for *Pangasius krempfi* and other valuable species in the Mekong Delta, Vietnam. Asian Fisheries Science 22:631-639.

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