

Importance of resources of small-sized fishes as fundamental components of food resources and fish diversity in Lao PDR

Shinsuke Morioka¹, Bounsong Vongvichith²

¹ Japan International Research Center for Agricultural Sciences (JIRCAS), Tsukuba, Japan

² Living Aquatic Resources Research Center (LRReC), National Agriculture and Forestry Research Institute of (NAFRI), Vientiane, Lao PDR

Abstract

Growth, reproduction, and lifespan were reviewed in three indigenous small-sized fishes in Lao PDR belonging to different taxa, *Parambassis siamensis* (Ambassidae), *Rasbora rubrodorsalis* (Cyprinidae), and *Clupeichthys aesarnensis* (Clupeidae). All three species were estimated to have short lifespans (< one year) and breed throughout the year with plural generation alternations within a year. Environment in high temperature accelerated initial growth in all species. In *C. aesarnensis*, while higher temperature was considered to lead to earlier maturation and downsizing of maturation size, evolutionary downsizing owing to overfishing was of another concern. As the recent economic development and population growth within the country has led to an increase in fish demand and deterioration of the environment, all the species are considered to be in danger of stock decline. Therefore, in the present study, some ideas for stock managements for these species based on biological aspects are discussed.

Introduction

Lao PDR is a country with rich resources of indigenous fish species, particularly in the basins of the Mekong River and its tributaries. Estimates of the numbers of indigenous fish species in this region range from 700 to more than 1,200 (Kottelat 2001; Sverdrup-Jensen 2002). Among these, various indigenous small-sized fishes are distributed across the country regardless of taxa. These small-sized fishes are important as one of the major food sources for farmers in rural areas owing to easy access, as they are abundantly present in agricultural water masses (e.g., rice paddies, irrigation canals, and reservoirs) in which assured catch is expected using simple fishing gears. Some, such as a non-common miniature fish *Brachygobius mekongensis* (Gobiidae) with a maximum size of ca. 14 mm in standard length (SL) are not valuable as fishery resources (Morioka and Sano 2009). However, species that are larger than this and smaller than 70 mm SL with short lifespans, sometimes called “trash fishes”, are important members supporting the rich diversity of regional fauna as prey of carnivorous fishes, birds, mammals, and reptiles. However, the increasing population of Lao PDR and over-fishing of natural fish resources since the 20th century (FAO 2006) have led to the introduction of substantial numbers of alien fishes for aquaculture, particularly the Nile tilapia *Oreochromis niloticus*, common carp *Cyprinus carpio*, and Chinese carps (e.g., the grass carp *Ctenopharyngodon idella* and silver carp

Hypophthalmichthys molitrix) (Phillips 2002; Welcomme and Vidthayanon 2003). Consequently, more than 20 invasive alien species are now considered to have established natural breeding populations in the Mekong region, and their numbers are increasing even now through continuous un-official introduction of alien fishes (e.g., *Paramisgurnus dabryanus* of Cobitidae) (S. Morioka, unpubl. data). The presence of these alien fishes is of concern because of a potential for decline in the region's native and endemic fish diversity and their stock levels.

With the above context, ecological investigation on several small-sized fishes in Lao PDR have been made and some information helpful for stock management have so far been obtained. In this report, the summarized results of these investigations are presented for important food fishes of different taxa, i.e., *Parambassis siamensis* of Ambassidae, *Rasbora rubrodorsalis* of Cyprinidae, and *Clupeichthys aesarnensis* of Clupeidae.

Materials and methods

Three Laotian indigenous small-sized indigenous fishes (Fig. 1) are discussed in the present report. *Parambassis siamensis* (locally called *Pa kapkohn*) belonging to the family Ambassidae, is widely distributed in lakes, swamps, and small-scale rivers and is a source of dried fish. *Rasbora rubrodorsalis* (called *Pa sieu*) belonging to the family Cyprinidae is distributed in small-scale reservoirs and rivers and is eaten in the form of traditional fermented fish (called *Pa som noy*). *Clupeichthys aesarnensis* (locally called *Pa keo*) belonging to the family Clupeidae is distributed in mid/large-scale reservoirs and rivers and is eaten in dried and traditional fermented forms (*Pa deak*).



Fig. 1. Three Laotian small-sized fishes investigated and reviewed in this article., Morioka et al. (2014) and Morioka et al. (2019). a: *Parambassis siamensis* [Okutsu et al. (2011)], b: *Rasbora rubrodorsalis* [Morioka et al. (2014)], c: *Clupeichthys aesarnensis* [Morioka et al. (2019)].

Investigations on *P. siamensis* and *R. rubrodorsalis* were conducted in 2010 in Laos, and that on *C. aesarnensis* in 2016–2017 in Laos and in Thailand in 2012–2013. For all species, the daily ages were estimated using otolith daily increments, and the growth patterns and hatching periods of each species were then estimated. The sagittae were used for *P. siamensis* and *C. aesarnensis*, and the lapillus was used for *R. rubrodorsalis* for daily age determination (Fig. 2).

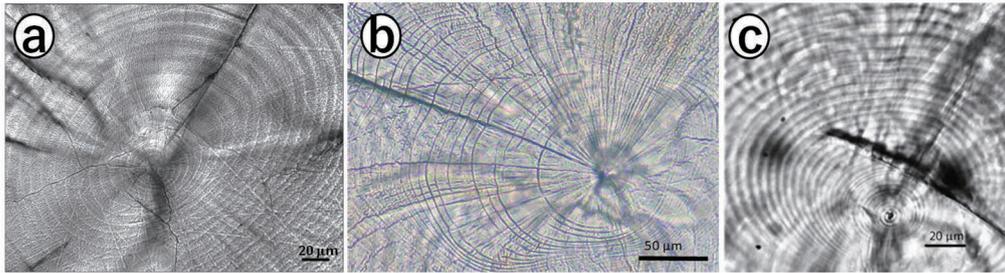


Fig. 2. Otoliths of *Parambassis siamensis* (a), *Rasbora rubrodorsalis* (b) and *Clupeichthys aesarnensis* (c).

In addition to the growth analyses, gonad development was also investigated with the application of gonadosomatic indices (GSI; weight of ovary or testis / body weight \times 100) for *R. rubrodorsalis* and *C. aesarnensis*, and histological observations of ovaries and testes for *P. siamensis*.

Results

Growth of each species was analyzed by seasons (warmer period from March to October (WP), cooler period from November to February (CP)) for *P. siamensis* and *R. rubrodorsalis*. In *P. siamensis*, growth (relationship between ages and standard length) was regressed using the logistic growth formulae for the specimens collected during the WP and CP as follows (Okutsu et al. 2011) (L_t and t in the formulae were the size at the age t and age in days, respectively):

$$\text{Warmer period: } L_t = 36.97 / (1 + \exp(-0.036 \cdot (t-47.09))) \quad (R^2 = 0.86, n = 85)$$

$$\text{Cooler period: } L_t = 40.98 / (1 + \exp(-0.026 \cdot (t-76.37))) \quad (R^2 = 0.91, n = 92)$$

The formulae were significantly different (F -test, $p < 0.01$), and growth during the WP was faster than that during the CP (Fig. 3). In this species, matured females appeared both during the WP and CP, and most of the matured females were > 30 mm SL (although a few females with < 30 mm SL seemed matured) (Fig. 4), indicating maturation age was estimated to be ca. 90 days in the WP and ca. 115 days in the CP (Fig. 3). These results suggest that *P. siamensis* breeds throughout the year and plural generation alternations within a year take place.

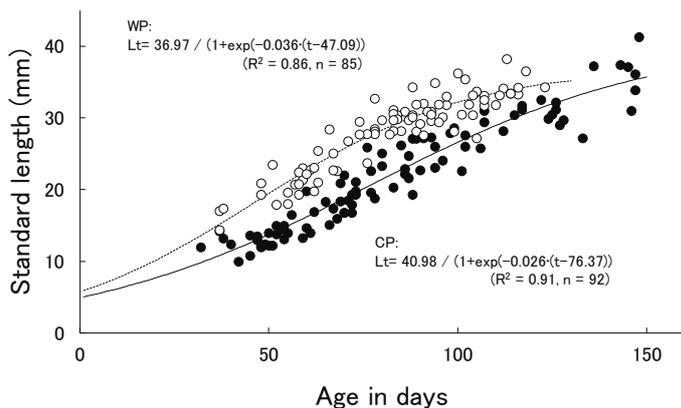


Fig. 3. Comparison in growths of *P. siamensis* collected during warmer period (open circles) and during cooler period (solid circles). [Figure cited from Okutsu et al. (2011) with modification].

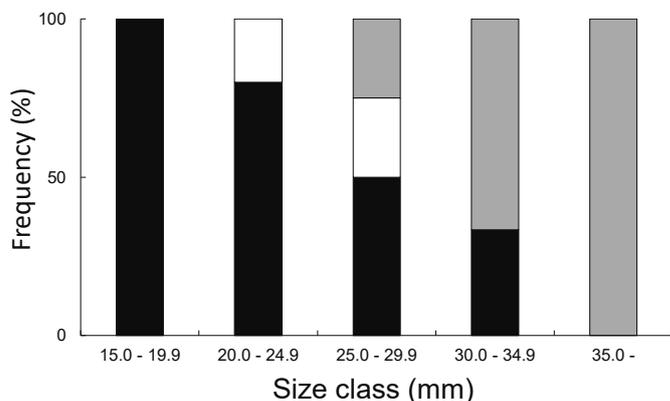


Fig. 4. Frequency distribution (%) of females with primary growth (black bar) previtellogenic (open bar) and vitellogenic oocytes (grey bar) observed in their ovaries in each size class. [Figure cited from Okutsu et al. (2011) with modification].

In *R. rubrodorsalis*, growth was analyzed separately by seasons and by sexes, because we identified that the females of this species grow larger than the males and the sex ratio was remarkably biased towards females (female : male = 1 : 0.43) (Fig. 5). Logistic growth formulae were used as follows (Morioka et al. 2014):

Warmer period

Females: $Lt = 29.38 / (1 + \exp(-0.050(t-38.40)))$ ($R^2 = 0.82, n = 185$)
 Males: $Lt = 24.91 / (1 + \exp(-0.054(t-31.61)))$ ($R^2 = 0.92, n = 80$)

Cooler period

Females: $Lt = 29.22 / (1 + \exp(-0.043(t-48.37)))$ ($R^2 = 0.87, n = 85$)
 Males: $Lt = 31.28 / (1 + \exp(-0.036(t-54.85)))$ ($R^2 = 0.95, n = 42$)

As observed in *P. siamensis*, growth in *R. rubrodorsalis* during the WP was also faster than that during the CP (Fig. 6). In addition, based on the GSI, this species also breeds during the CP in the females > ca. 20 mm SL (Fig. 7). Considering their short lifespan (< 150 days, Fig. 6), this species is considered to breed over a year and maturation age of ca. 50 days in the WP and ca. 60 days in the CP (Fig. 6).

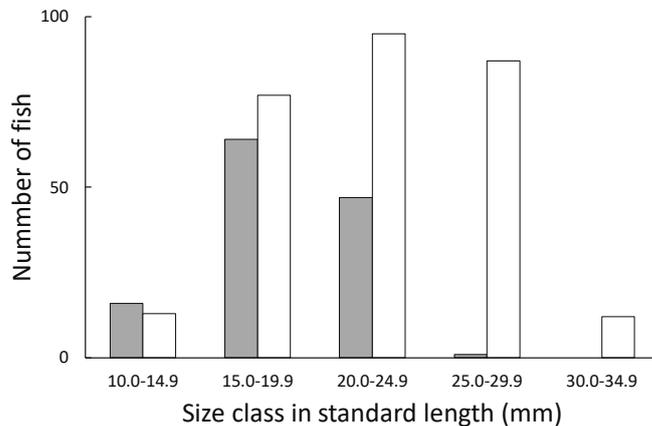


Fig. 5. Frequency distributions in standard length (mm) of *R. rubrodorsalis*. Open and solid bars indicate females and males. [Figure cited from Morioka et al. (2014) with modification].

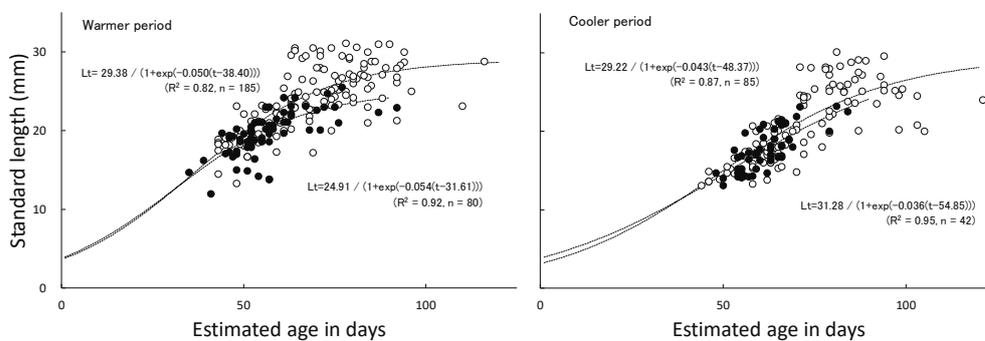


Fig. 6. Growths of *R. rubrodorsalis* collected during warmer period (left) and during cooler period (right). Open and solid circles are females and males. [Figure cited from Morioka et al. (2014) with modification].

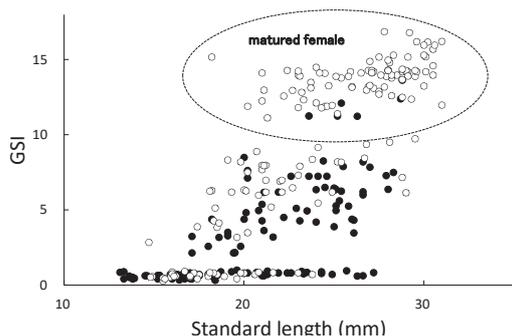


Fig. 7. Relationship between standard length (mm) and gonadosomatic index of female *R. rubrodorsalis*. Open and solid bars indicate females collected during the WP and CP, respectively. [Figure cited from Morioka et al. (2014) with modification].

In *C. aesarnensis*, growth of the populations in the Sirindhorn and Nam Ngum reservoirs was analyzed separately using the von Bertalanffy growth formula as follows (Morioka et al. 2019):

$$\begin{aligned} \text{Sirindhorn Reservoir: } Lt &= 36.72(-\exp(-0.02t)) & (R^2 = 0.85, n = 378) \\ \text{Nam Ngum Reservoir: } Lt &= 44.76(-\exp(-0.01t)) & (R^2 = 0.89, n = 486) \end{aligned}$$

The Sirindhorn population, chronically under higher temperature than that of the Nam Ngum Reservoir, tended to grow faster (Fig. 8). The GSI indicated that the gonads started to mature in the specimens ca. > 20 mm SL in the Sirindhorn population and > ca. 25 mm SL in the Nam Ngum population (Fig. 9). Furthermore, the growth models indicated the theoretical maximum size of the Sirindhorn population was smaller than that of the Nam Ngum population (Fig. 8).

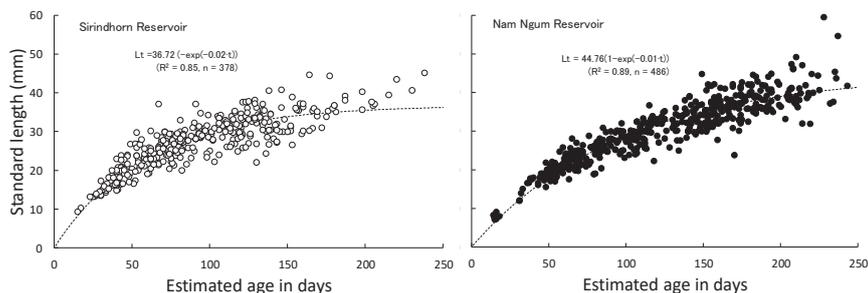


Fig. 8. Growths of *C. aesarnensis* collected from Sirindhorn Reservoir, Thailand (left) and from Nam Ngum Reservoir, Laos (right). [Figure cited from Morioka et al. (2019) with modification].

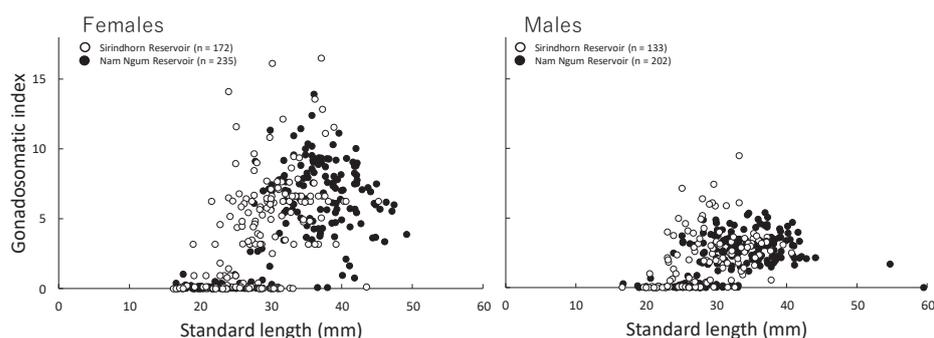


Fig. 9. Relationship between GSI and standard length (mm) of *C. aesarnensis* collected from Sirindhorn Reservoir, Thailand (open circles) and from Nam Ngum Reservoir, Laos (solid circles). [Figure cited from Morioka et al. (2019) with modification].

Discussion

The stocks of the three species, i.e., *Parambassis siamensis*, *Rasbora rubrodorsalis*, and *Clupeichthys aesarnensis*, have recently given cause for concern owing to a decline because of environmental changes (e.g., urbanization and land exploitation for cropping) and over-fishing. Accordingly, biological information on these species is required, with a view toward future stock assessment. Of additional concern, are the nearly 20 invasive exotic fish species (e.g., *Oreochromis niloticus*, *Clarias gariepinus*, and *Hypophthalmichthys molitrix*) that have recently been reported as having established breeding populations in the Mekong River basin (Phillips 2002; Welcomme and Vidthayanon 2003), emphasizing the need for conservation of the region's native/endemic fish species diversity. For fish diversity conservation as well as stock assessment, information on the life history of the targeted species, such as growth, sexual development, and generation time is a basic requirement. In this context, all the results presented here are useful information for future stock management leading to species conservation.

In the growth analyses for *P. siamensis*, *R. rubrodorsalis*, and *C. aesarnensis*, higher temperatures are considered to be one of the most important factors to accelerate growth of individual fish (Figs. 3, 6, 8) (Okutsu et al. 2011; Morioka et al. 2014; Morioka et al. 2019). Our results were consistent with previous reports illustrating that higher temperatures lead to faster growth in several fish species in semi-tropical areas (Morioka 2002; Morioka and Kaunda 2005). In addition, higher temperature can also cause earlier maturation (Dotsu 1982; Kon and Yoshino 2002) in the species led by faster growth. The earlier maturation under chronic higher temperature was typically observed in *C. aesarnensis* (Fig. 9), and the results from this species further indicate the downsizing by faster growth and earlier maturation (Figs. 8, 9) (Morioka et al. 2019).

In both the Sirindhorn and Nam Ngum reservoirs, the maximum sizes observed (45.2 mm SL during 2012-2013 and 59.5 mm SL during 2016-2017, respectively) tended to be smaller than those observed at the end of the 1990s (larger than 60 mm TL in the Sirindhorn reservoir and 70 mm SL in the Nam Ngum reservoir) (Baird et al. 1999; Jutagate et al. 2003). The decrease in maximum sizes may have been caused by overexploitation of each population leading to “evolutionary downsizing by overexploitation” as previously reported in several marine fish

species (Sharpe and Hendry 2009) in addition to the water temperature affecting maximum size in *C. aesarnensis*.

Considering the potential concerns of overexploitation and declines in stock levels of these species, appropriate methods of stock management should be proposed. Examples of classic methods for stock management in fishes are broadly summarized in Table 2.

Table 2. Examples of stock management manners for fishes.

Manner	Main target
1) Restriction / prohibition of fishing in spawning area	Adults (spawners)
2) Restriction / prohibition of fishing during breeding season	Adults (spawners)
3) Restriction / prohibition of fishing of small specimens	Larvae/juveniles, subadults
4) Restriction of annual catch amount	Whole population

For all the species presented in this report, spawning grounds are not known with breeding over a year, and hence the methods 1) and 2) described in Table 2 are not considered applicable. However, method 3) is applicable using mesh size control for restricting the catch of small specimens for future conservation of breeding specimens. Furthermore, to restrict the amount of annual catch as suggested by method 4), restriction in gear number is also considered practical. To realize these stock management strategies, related laws and/or ordinances by the central/local governments are to be ensured.

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