

Technical achievements of indigenous fish aquaculture in rice-paddy and pond in rural areas of Lao PDR: summarized results obtained by the JIRCAS-LARReC project

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Abstract

Research achievements in aquaculture-related research techniques during the JIRCAS-NAFRI project with LARReC since 2007 are presented in this report. In particular, seed production of Laotian indigenous fishes and morphological development of several species are summarized. In addition, case studies of rice-paddy fish culture and pond fish culture that were conducted with farmers in rural areas are also presented. Based on the results we can propose practical applications for aquaculture using Laotian indigenous fishes by farmers in rural areas that can contribute to increase in fish production. In addition, information on morphological development of larval and juvenile stages of the concerned species is essential for consideration of their evolutionary ecologies and contribution to the conservation of indigenous species.

Introduction

Lao PDR is a country in which ca. 70 % of the population (total population 6.9 million) (Worldmeter 2019) is directly/indirectly engaged in the agricultural sector (Seo 2018). It is an inland country surrounded by China, Vietnam, Cambodia, Thailand, and Myanmar. The country is still categorized as a least developed country (LDC) as per economic status, although economic development has been accelerated in recent years (World Bank 2018). However, the national population of the country is growing at a high rate (ca. 1.45 % per year), and the further enhancement of food production for national food security is an important national subject. Moreover, the rate of malnutrition in the population, reported to be ca. 21 %, is much higher than that of Thailand (ca. 7 %), and animal protein intake of 14 g/day is much lower than that of Thailand (ca. 24 g/day) (FAOSTAT 2018). These nutritional deficiencies may cause high stunting rate (ca. 41.4 %) (WHO 2018) and shorter lifespan (ca. 67 years) (World Bank 2017) in the country, and, furthermore, such malnutrition was reported to be more serious in mountainous rural areas than in urban areas (WFP 2013). Hence, enhancement of animal protein intake for nutritional improvement is one of the important national aims.

Considering the above situation, the government of Lao PDR has attempted to promote aquaculture development, since capture fishery production has been stagnant at ca. 30,000 t/year

during the past few decades (Phonvisay 2013) suggesting it to have reached the upper limit of exploitation. Consequently, further increase in fish production is largely dependent on aquaculture development and has in fact, developed rapidly since the early 2000s and has reached ca. 100,000 t/year of production currently (Phonvisay 2013). However, at present, most aquaculture production depends on alien fishes, e.g., the Nile tilapia, Chinese carps, and African catfish (Welcomme and Vidthayanon 2003), and the production is mainly operated in/or near urban areas that have easy accessibility for commercial sales at markets. Thus, such an aquaculture system contributes less to the enhancement of protein intake in rural areas, and poor infrastructure of cold chains is another factor affecting market distribution of aquaculture products in rural areas.

To improve the above situation, technical development of aquaculture using Laotian indigenous fishes that are applicable in rural areas has been considered, and the Japan International Research Center for Agricultural Sciences (JIRCAS) and the National Agriculture & Forestry Research Institute (NAFRI) have conducted a joint project in cooperation with the Living Aquatic Resources Research Center (LARReC) since 2007. In this report, several technical developments useful for the aquaculture of Laotian indigenous fishes being established by the JIRCAS- NAFRI project with technical cooperation from the LARReC, are reviewed.

Technical development of seed production of indigenous fishes as potential targets for aquaculture

Seed production techniques have been established for nine Laotian indigenous fishes (Table 1) during the JIRCAS-NAFRI project with LARReC since 2007. Among these species, we evaluated the growth performance (slow, moderate, and rapid growth), for each species (Table 1). For all species, morphological development during larval and juvenile stages have been described as also behavioral features (e.g., Morioka et al. 2012b etc.) (Fig. 1). This information is helpful not only for stable seed production of the target species but also for consideration of evolutionary ecology contribution to species and biodiversity conservation of the target species.

Table 1. Laotian indigenous fishes for which seed production techniques were established by the JIRCAS-NAFRI project with LARReC.

Fish species	Max. size	Growth	Feeding	References
Cypriniformes				
Cyprinidae				
<i>Hypsibarbus malcolmi</i> / <i>Barbonymus gonionotus</i>	ca. 25 cm SL	moderate	omnivorous	Ogata et al. (2010)
<i>Cirrhinus microlepis</i>	> 70 cm SL	rapid	omnivorous	Morioka et al. (2012a)
Siluriformes				
Clariidae				
<i>Clarias macrocephalus</i>	ca. 30 cm SL	slow	carnivorous	Morioka et al. (2013a)
Bagridae				
<i>Hemibagrus filamentus</i>	ca. 30 cm SL	slow	carnivorous	Morioka & Vongvichith (2011)
Pangasiidae				
<i>Pangasianodon</i> <i>hypophthalmus</i>	> 100 cm SL	rapid	omnivorous	Morioka et al. (2010b)
Perciformes				
Anabantoidei				
Anabantidae				
<i>Anabas testudineus</i>	ca. 25 cm SL	moderate	carnivorous	Morioka et al. (2009)
Osphronemidae				
<i>Trichogaster pectoralis</i>	ca. 25 cm SL	slow	omnivorous	Morioka et al. (2010a)
<i>T. trichopterus</i>	ca. 15 cm SL	slow	omnivorous	Morioka et al. (2012b)
<i>Osphronemus gouramy</i> / <i>exodon</i>	> 70 cm SL	rapid	omnivorous	Morioka et al. (2013b)

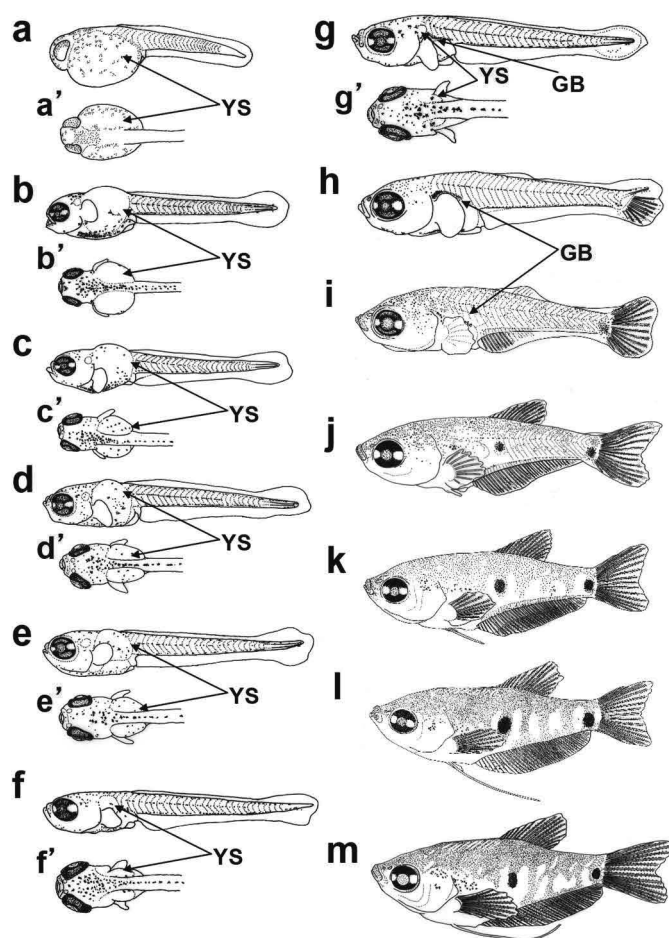


Fig. 1. Morphological development of *Trichogaster trichopterus*. **a** newly hatched larva (2.5 mm BL); **b** preflexion larva, day 1 (3.1 mm BL); **c** preflexion larva, day 2 (3.4 mm BL); **d** preflexion larva, day 3 (3.7 mm BL); **e** preflexion larva, day 5 (4.0 mm BL); **f** preflexion larva, day 7 (4.2 mm BL); **g** preflexion larva, day 9 (4.4 mm BL); **h** flexion larva, day 11 (5.5 mm BL); **i** postflexion larva, day 13 (6.7 mm BL); **j** postflexion larva, day 19 (8.6 mm BL); **k** postflexion larva, day 25 (10.6 mm BL); **l** juvenile, day 30 (12.5 mm BL); **m** juvenile, day 35 (14.0 mm BL). **a'** **b'**, **c'**, **d'** anterior dorsal view. YS yolk sac, GB gas bladder [Figure modified from Morioka et al. (2012b)].

Applicable facilities of fish aquaculture and target species in rural areas

In rural areas, aquaculture operators (the farmers) are relatively economically disadvantaged in general and are not capable of building new facilities for aquaculture (e.g., cages and ponds). However, using existing agricultural water masses (i.e., rice-paddies and irrigation reservoirs), fish aquaculture is practically possible. In our trials, the basic design of a rice paddy for fish culture with the establishment of refuge canals in paddies is shown in Fig. 2.

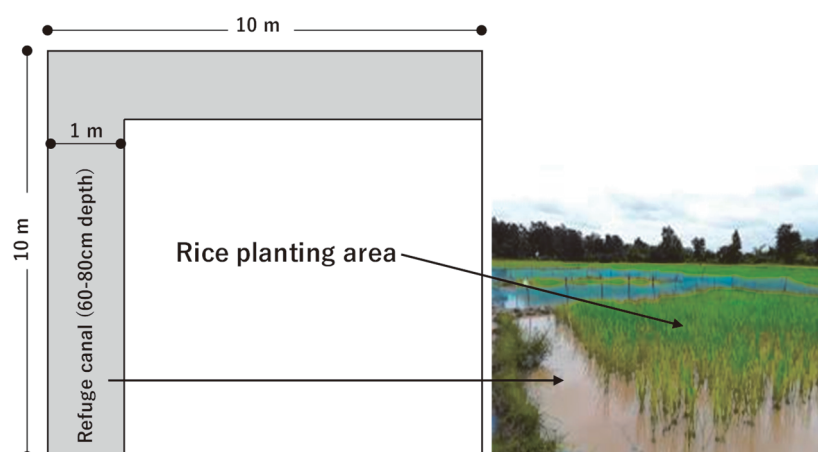


Fig. 2. Basic design of rice paddy for fish culture (left) and rice-paddy fish culture trial in Savannakhet Province, Lao PDR (right).

As suitable fishes for rice-paddy fish culture and pond fish culture, we selected four species (*Anabas testudineus*, *Barbonymus gonionotus*, *Pangasianodon hypophthalmus*, and *Osphronemus exodon*) from the species listed in Table 1 as shown in Table 2 and Fig. 3. As selection criteria, we considered the following aspects indicating suitability to rice-paddy and pond fish culture: 1) adaptability to rice-paddy and pond environment, 2) moderate and/or rapid growth, and 3) acceptable marketable values. All the species in Table 2 more or less satisfy the aspects 1) and 2), and three species, except *B. gonionotus*, have relatively higher market value among the fishes sold in the local market and satisfy aspect 3). The marketable value of *B. gonionotus* is indeed not as high as the other three species, but we identified this species as being ecologically well suited to the rice-paddy/pond culture system owing to ease of seed production and large fecundity that enables constant seed production and supply.

Table 2. Four indigenous fishes selected as applicable species for rice-paddy and pond fish culture.

Fish species	Seed production technique	Water mass
<i>Anabas testudineus</i>	semi-artificial propagation	rice-paddy / pond
<i>Barbonymus gonionotus</i>	semi-artificial propagation	rice-paddy / pond
<i>Pangasianodon hypophthalmus</i>	artificial propagation	rice-paddy
<i>Osphronemus gouramy / exodon</i>	natural propagation	rice-paddy

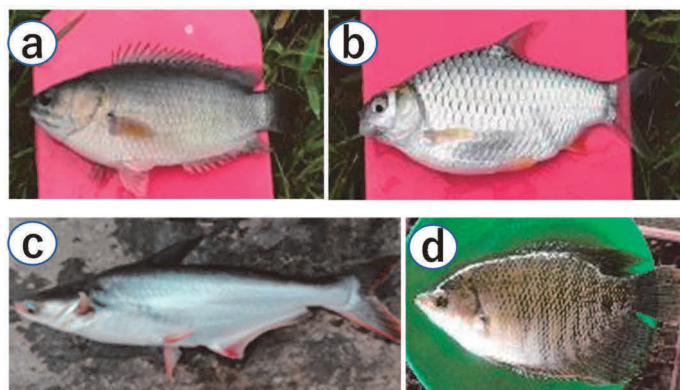


Fig. 3. Fishes applied for aquaculture in rural areas. a: *Anabas testudineus* (Pa kheng), b: *Barbonymus gonionotus* (Pa pak), c: *Pangasianodon hypophthalmus* (Pa sooai), d: *Osphronemus exodon* (Pa meng).

Productivity of rice-paddy fish and pond fish culture

We aimed to establish fish culture system(s) with low input (less input of artificial feeds) both in the rice-paddy and in pond. Rice-paddy fish culture trials were conducted in two sites of the Vientiane Province during 2013–2016 (Vongvichith et al. 2018). The results obtained indicate that low stocking density (< 0.5 fish/m²) could lead to a high biomass gain index (BGI = weight of stocked fish/weight of harvested fish) of 15–20 even without providing artificial feed. This BGI is considered acceptable for self-sufficiency of fish to the farmer's household.

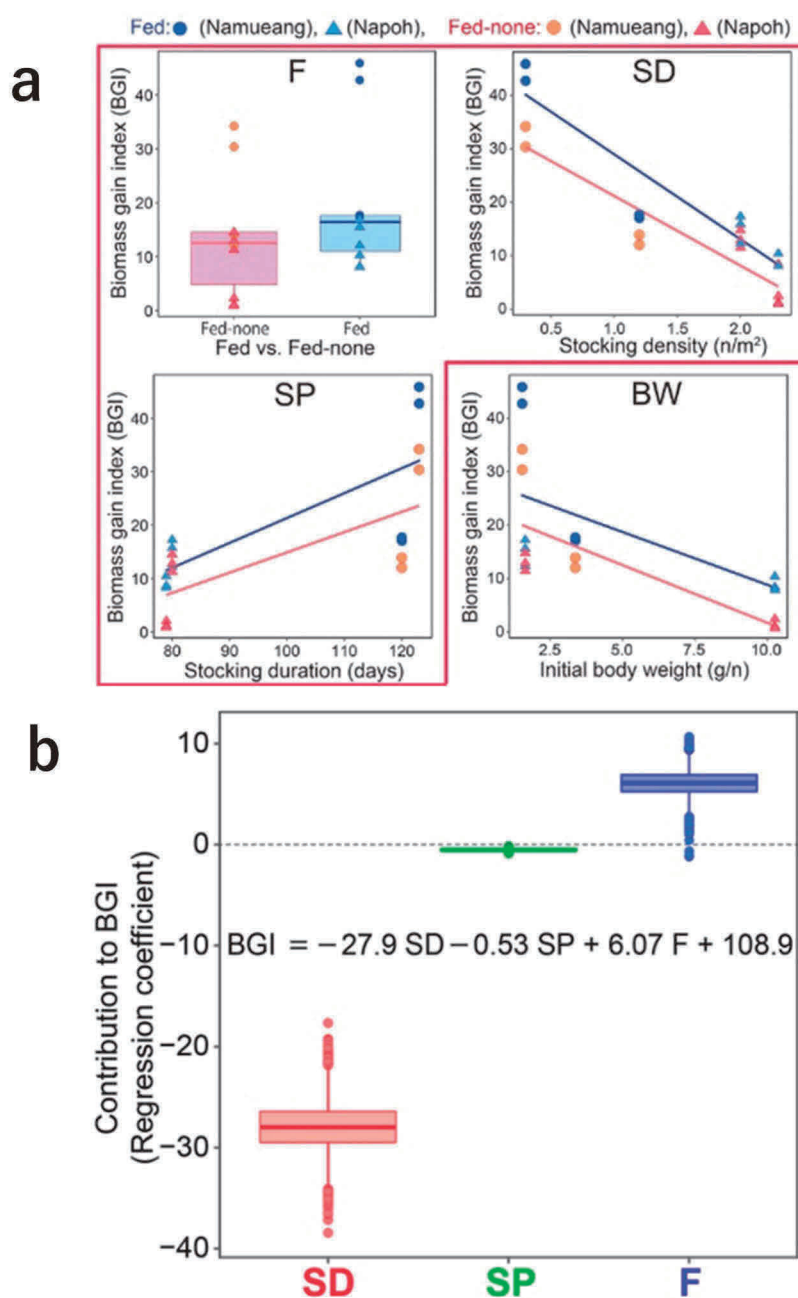


Fig. 4. Potential factors relevant to fish productivity (BGI) in rice paddy. [F: feeding or non-feeding, SD: stocking density of fingerlings, SP: stocking period, BW: weight of fingerling at stocking. F, SD & SP were selected as influential parameters by linear regression analyses, while BW was not selected] (a) and evaluation of contribution of selected parameters of stocking density (SD), stocking period (SP) and feeding condition (F) to fish productivity (BGI). [Figure modified from Vongvichith et al. (2018)] (b).

For pond fish culture, two trials were conducted during 2017–2018 in a village in Savannakhet Province to examine fish productivity, using an existing earthen pond of ca. 1,500 m² (ca. 1.5 m maximum depth). Applied fishes for pond culture were the four indigenous fish species as shown in Table 2 and Fig. 3.



Fig. 5. Pond fish culture trial in Savannakhet Province.

In the trial conducted in 2017, *A. testudineus* (2,000 juveniles) and *B. gonionotus* (4,000 juveniles) were stocked on June 18, 2017, and *P. hypophthalmus* (100 juveniles) and *O. exodon* (100 juveniles) were stocked on August 18, 2017 (overall stocking density was ca. 4 fish/m²). All fishes were harvested on February 22, 2018 (249 days of stocking for the former two species, and 188 days for the latter two). In the trial conducted in 2018, *A. testudineus* (1,200 juveniles), *B. gonionotus* (2,300 juveniles), and *P. hypophthalmus* (200 juveniles) were stocked on June 28, 2018 (ca. 2.5 fish/m²), and they were harvested on February 18, 2019. For the trial conducted in 2017, fish were provided commercial pellet feed intensively (ca. 4–5 % of biomass per day), whereas fish were fed agricultural byproducts (mainly rice bran with occasionally termite larvae) on an irregular basis by farmers for the trial in 2018.

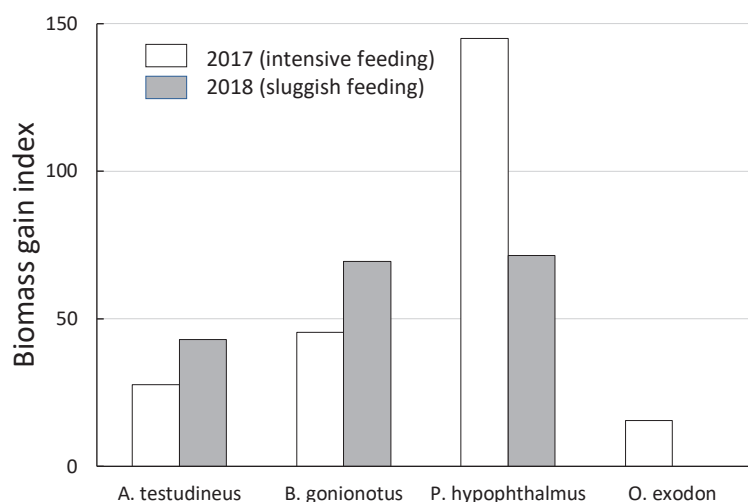


Fig. 6. Comparisons of biomass gain indices (BGI) of four indigenous fishes cultured in earthen pond in Savannakhet Province.

The results showed a remarkably high BGI in *P. hypophthalmus* observed in 2017; this high BGI probably being caused by its greater swimming ability than the others, leading to its

monopolistic feeding on commercial pellet feed. In contrast, distinctively low BGI of *O. exodon* was observed in 2017 and this is probably because of its inferior swimming ability with difficulty in feeding on commercial pellet feed. Considering this low BGI for *O. exodon*, polyculture of this species with the others having better swimming ability is probably not recommendable.

For *A. testudineus* and *B. gonionotus*, the BGIs were higher in 2018 than in 2017 indicating better productivities in 2018 regardless of the more limited feed condition in 2018, while the BGI for *P. hypophthalmus* was remarkably lower in 2018 than in 2017 (Fig. 6). Lower BGI in 2018 for *P. hypophthalmus* can be explained by the absence of artificial feed in 2018, but the higher BGIs for *A. testudineus* and *B. gonionotus* in 2018 were probably because of lower stocking densities in that year.

Future prospects for indigenous fish aquaculture in Lao PDR

In the present report, fish aquaculture using indigenous species, i.e., Pa kheng *Anabas testudineus*, Pa pak *Barbonymus gonionotus*, and Pa soai *Pangasianodon hypophthalmus* (rice-paddy fish culture for the first two species and pond fish culture for all three species), was mostly confirmed as a feasible system. Considering the BGIs in each system, the rice-paddy fish culture is more suitable for consumption at the household level because of its relatively lower BGI. However, the pond fish culture is considered to have more potential for commercial production of fishes because of higher BGIs even under limited artificial feeding conditions (Fig. 6). Currently, the major target for aquaculture in Lao PDR is the Nile tilapia *Oreochromis niloticus*, but the prices of many of the indigenous fishes are in general higher than the price of the Nile tilapia (B. Vongvichith pers. comm.). This situation also indicates that the culture of indigenous fish in ponds has a commercial potential.

However, we have found several serious problems that have affected the promotion of aquaculture across the country, including in rural areas of Lao PDR. These problems need to be urgently addressed for broad extension of fish culture techniques, as follows:

- 1) High dependency of imported fish feeds that are too expensive in economically disadvantaged areas of Lao PDR,
- 2) Insufficient seed production capacity and limited seed supply,
- 3) Quantitative and qualitative insufficiency of technical staff for seed production.

Concerning problem 1), we have been conducting trials in the use of the black soldier fly (BSF) larvae (Fig. 7) as fish feed. Nakamura et al. (2016) demonstrated a production system of the BSF larvae that is feasible for small-scale farmers and the associated reduction in feed cost has mostly become realizable.



Fig. 7. Larvae of the black soldier fly produced in the LARReC.

For problems 2) and 3), infrastructural enhancement for seed production facilities as well as further capacity building of human resources are further required.

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