Asian Fisheries Science **31** (2018):209–217
©Asian Fisheries Society
ISSN 0116-6514
E-ISSN 2073-3720
https://doi.org/10.33997/j.afs.2018.31.3.003

Performance of Domesticated (Vietnamese) versus Non-domesticated (Cambodian) Snakehead, *Channa striata* (Bloch 1793) with Regard to Weaning onto Pellet Feed

PHANNA NEN[1], PHEN CHHENG[1], NAM SO[1], TRAN THI THANH HIEN[2], BUI MINH TAM[2], HILLARY EGNA[3] and DAVID A. BENGTSON[4*]

[1]Inland Fisheries Research and Development Institute, Phnom Penh, Cambodia
[2]College of Aquaculture and Fisheries, Can Tho University, Can Tho, Vietnam
[3]Aquafish Innovation Laboratory, Oregon State University, Corvallis, OR, USA
[4]Department of Fisheries, Animal and Veterinary Sciences, University of Rhode Island, Kingston, RI, USA 02881

Abstract

The Cambodian government banned snakehead, *Channa striata* (Bloch 1793) aquaculture in 2004 due to the unsustainable practices. Recent research in Vietnam led to increased sustainability with regard to hatchery practices and feeds. As part of a project to transfer technology from Vietnam to Cambodia, a study was conducted to compare survival and growth of domesticated snakehead from Vietnam with those of non-domesticated snakehead from Cambodia. Cambodian broodstock fish were collected from Mekong River and Tonle Sap, and F1 Cambodian fish from previous breeding were also used. Domesticated broodstock were purchased from Vietnam. Larvae from spawns of the four broodstocks (Vietnam, Mekong River, Tonle Sap and F1 Cambodian fish) were subjected to a weaning protocol developed in Vietnam in a 60-d hatchery phase, followed by a 6-month grow-out in ponds. The experimental results showed that Vietnamese fish (10.88 $g.fish^{-1}$) grew significantly faster than Cambodian fish (3.24 to 4.96 $g.fish^{-1}$) in the hatchery, followed by continued rapid growth in the grow-out phase (324.2 $g.fish^{-1}$for Vietnamese fish versus 132.9 to 148.1 $g.fish^{-1}$ for Cambodian fish), largely due to increased feed consumption. Cannibalism rates ranged from 40–42 % in the hatchery phase except for Mekong River fish (significantly higher at 57 %) and 12–45 % in the grow-out phase (Vietnamese and F1 fish significantly lower than the other two treatments). It is not known whether differences were due to inherent genetic differences between wild Vietnamese and Cambodian fish, or to selective breeding (intentional or not) in Vietnam. Results will be useful information for Cambodian aquaculture policy to develop snakehead hatcheries and feed mills, following the lifting of the ban in 2016.

Keywords: snakehead, *Channa striata*, weaning, grow-out, cannibalism, domesticated

*Corresponding author. E-mail: dbengtson@uri.edu

Introduction

In Cambodia snakehead *Channa striata* (Bloch 1793) collected as wild juveniles have traditionally been cultured in small cages and ponds. Feed represents more than 70 % of the total operational cost and the main type of feed for *C. striata* culture is small-sized or low-value fish (SS fish), representing 60 to 100 % of the total feed used depending on feeding strategies adopted by different farmers (So et al. 2005). During the dry season (October to May), the most important source of feed is freshwater SS fish, whereas more marine SS fish species are used during the rainy season (June to September) (So et al. 2005). Importantly, snakehead production contributes more than 70 % of total aquaculture production in Cambodia due to its popularity as food and subsequent high market and trade demand in Cambodia as well as in Vietnam (So et al. 2005). Furthermore, snakehead is found in Cambodian and Vietnamese dishes at all social class levels (i.e. from poor, medium to rich people). The government of Cambodia banned snakehead farming in September 2004, due to the potential negative impacts on wild fish populations from snakehead seed collection and on SS fish species diversity, along with potential negative effects on consumers due to decreased availability of SS fish (So et al. 2007). To remove this ban, the Cambodian government required the development and application of successful technologies for domesticated snakehead breeding, weaning and rearing of the fish using formulated diets.

Nearly 200 freshwater SS fish species were detected in the Mekong River Basin of Cambodia and Vietnam, and these species, including juveniles of commercially important fish species, which contribute more than 70 % to total freshwater capture fisheries production (So et al. 2009; Hien et al. 2015a). After the ban on snakehead culture in Cambodia, snakehead were imported illegally from the neighbouring countries, particularly from Vietnam, to supply high local market demand in Cambodia. Furthermore, freshwater SS fish were illegally exported to Vietnam for feeding the commercially developed snakehead aquaculture (So et al. 2009).

Fish farmers chose snakehead over other fish species as snakehead generates more than 10 times profit than other fish species. The ban on snakehead culture affected the livelihood of farmers as this was their main source of income. Moreover, the ban did not show positive effect on snakehead wild stocks, because in recent years there has been an increase of fishing pressure on wild snakehead using illegal and destructive fishing gears, particularly electro-fishing (So et al. 2009).

Wild *C. striata* broodstocks have been successfully developed and matured, and semi-artificially induced spawned using the hormone HCG at a research station in Cambodia (So et al. 2011). Although Haniffa et al. (1999) had difficulty developing weaning diets for *C. striata*, Hien et al. (2017) found that the optimal weaning strategy for domesticated *C. striata* in Vietnam was for 17 days after hatch (DAH) larvae to be weaned by replacement of minced SS fish at the rate of 10 $\%.d^{-1}$ for 10 d.

Since the Cambodian broodstock fish was not domesticated, the opportunity arose to determine the weaning capabilities of larvae from wild vs domesticated broodstock and subsequent grow-out of the weaned fish. Thus, specific objectives of this investigation were to evaluate the survival and growth of the domesticated and non-domesticated snakehead during weaning and grow-out phases.

Materials and Methods

The experiment, consisting of weaning and grow-out phases, was conducted at the Freshwater Aquaculture Research and Development Center (FARDeC), Prey Veng province, Cambodia, under the direct supervision of the Inland Fisheries Research and Development Institute (IFReDI). In addition to available breeders at FARDeC (referred to here as F1, the offspring of Cambodian wild-caught fish), adult wild *C. striata* from different natural water bodies of Cambodia (Tonle Sap and Mekong River) were collected and conditioned for spawning at FARDeC. Domesticated snakehead were also purchased from a hatchery in Can Tho, Vietnam, and conditioned at FARDeC for induced spawning to produce larvae for the experiment. Snakehead at the Vietnamese hatchery have been reared for several generations, without a formal selective breeding program. All fish, regardless of Cambodian or Vietnamese origin, required 5–6 h of transportation to FARDeC in 30-L containers with two water exchanges during the trip and all fish arrived in good condition.

Snakehead broodstock were fed a combination of pellet diets (45 % crude protein) and SS fish. They were checked monthly for egg maturation using a cannula based on the method of Nikolsky (1963). Broodstock fish with matured eggs were selected for induced spawning with HCG hormone to produce larvae for the weaning experiment. Male brooders were given two intraperitoneal injections (IP): the first injection with dosage of 500 IU HCG + 1 mg pituitary gland (PG).kg^{-1} and 24 h later a second injection of 2000–3000 IU HCG.kg^{-1}. Female brooders were given a single IP injection of 1000 IU HCG.kg^{-1} simultaneously with the second injection of males. The fish spawned 24 h after the injection, producing approximately 20,000–30,000 eggs with 90–95 % hatching rate.

The spawned fish were used for the weaning experiment to compare their growth performance and survival rate when fed on pellet feed using the optimum weaning protocol for *C. striata* (So et al. 2011; Hien et al. 2017). The fish were weaned from live *Moina* sp. to formulated feed, as follows. After yolk absorption at 3 DAH, larvae were fed live *Moina* for 7 d until 10 DAH, and then fed a mixture of dead *Moina* and ground SS fish (replacing *Moina* by 20 %.day^{-1}) for 7 d until 17 DAH. The weaning experiment began at 17 DAH with replacement of SS fish with formulated feed at 10 %.day^{-1} until complete replacement by commercial feed. The formulated feed was made at Can Tho University, Vietnam for consistency with the diet used by Hien et al. (2017) and reproduced by the IFReDI and FARDeC research team in Cambodia (So et al. 2011). The formulated feed (45 % protein, 9 % lipid, 4.2 kcal.g^{-1}) consisted of fish meal (35.8 %), soybean meal (33.4 %), cassava meal (8.26 %), rice bran (15.0 %), mineral premix (2 %), oil (3 %), carboxymethylcellulose (0.4 %), lysine (0.4 %), methionine (0.28 %), fish solution (1.5 %) and phytase (0.02 %).

The experiment consisted of four treatments with six replicates each, with larvae originating from the four broodstock groups: F1 (broodstock were offspring of wild-caught Cambodian fish), Mekong (broodstock were wild-caught from the Mekong River in Cambodia), Tonle Sap (broodstock were wild-caught from the Tonle Sap in Cambodia), Vietnam (broodstock were purchased from a Vietnamese hatchery after several generations of domestication there). All treatments were subjected to the same weaning protocol, as mentioned above. Larvae were stocked in 100-L tanks with stocking density of 5 fish.L^{-1}. The fish were fed to satiation by hand twice daily. Any uneaten feed and faeces were siphoned out before feeding. Fish mortality, feed consumption and water quality were recorded daily. Temperature and dissolved oxygen were determined with a Quantong Instruments AZ8403 DO meter, while pH was determined with an API Freshwater Master Test Kit. Larvae were weighed and measured at biweekly intervals. At the end of the weaning period, final wet body weight (FBW, mg), wet weight gain (WWG, mg) and survival rate were determined. Percentage of cannibalism was calculated from the number of fish stocked into each tank, minus number of known mortalities, minus number of fish remaining at the end of the experiment, divided by the number of fish initially stocked, and multiplied by 100 to obtain percentage.

Immediately following the weaning phase, fish from each treatment and replicates were transferred to corresponding ponds at FARDeC for the 6-month study on the grow-out phase. Each replicate was contained in a 3 m × 1 m × 1.5 m hapa net. Fish were fed commercial pelleted feed (Super Floating Feed, NAFATSCO, Binh Duong, Vietnam, 40 % crude protein) to satiation by hand twice daily at 09:00 h and 16:00 h. The amount of feed consumed by fish and fish mortality were recorded daily. Water quality (temperature, pH, dissolved oxygen, NH_3 and NO_2) was monitored weekly. Temperature and dissolved oxygen were determined with the AZ 8403 meter as described above, while pH, ammonia and nitrite were determined with the API test kit described above. Fish growth was measured monthly based on subsamples of 30 fish on each sampling date. The survival rate and cannibalism rate were determined at the end of experiment as described above. Data were subjected to analysis of variance, followed by Tukey's HSD test to determine treatment differences using SPSS 16.0 and differences were considered significant at $P \leq 0.05$.

Results

Hatchery phase

Snakehead larvae from the domesticated Vietnamese broodstock showed significantly higher growth than larvae from the other three treatments, which did not differ among themselves (Fig. 1a; Table 1). The greatest difference in growth between the Vietnamese fish and the Cambodian fish happened between days 40 and 60 of the experiment, although Vietnamese fish were already significantly larger than the Cambodian fish by day 40 (Fig. 1a).

The better growth of the Vietnamese fish appeared to stem primarily from greater feed intake (Fig. 1b), but their FCR was not significantly different from that of the Tonle Sap or F1 fish; only the Mekong fish FCR was significantly higher (Table 1). Survival rates of Tonle Sap and F1 fish were significantly higher than those of Mekong and Vietnamese fish (Table 1). Cannibalism was by far the largest cause of mortality and Mekong fish had a significantly higher cannibalism rate than the other three treatments, which did not differ among themselves (Table 1). Mortality from "natural causes" (i.e. fish found dead and removed from tanks during the experiment) was rare.

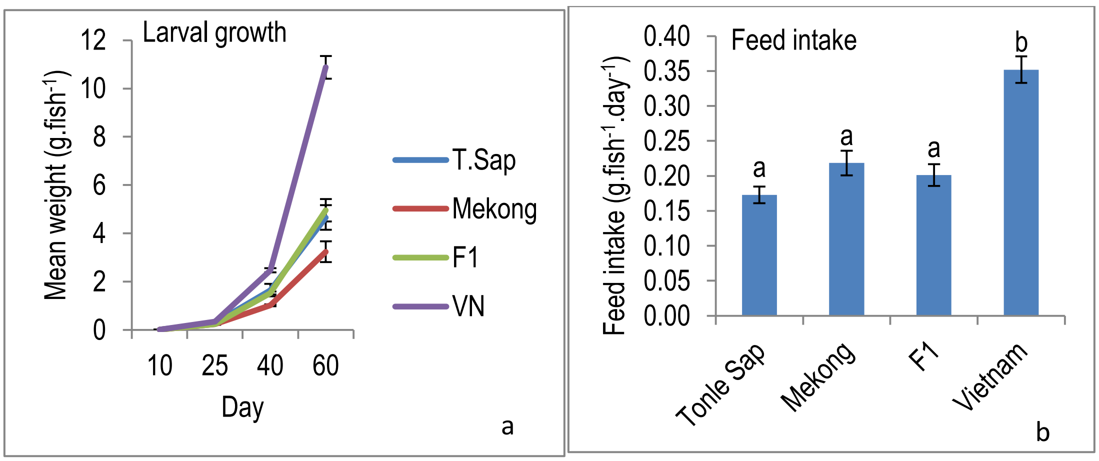

Fig. 1. Weight gain (panel a) and feed intake (panel b) of larvae spawned from *Channa striata* broodstock of Vietnamese and Cambodian origin and subjected to the same weaning and rearing protocol from 10 to 60 d after hatching.

Grow-out phase

Vietnamese fish continued to show significantly higher growth in the grow-out phase, reaching a weight of about 340 g after 6 months, compared to 140–150 g for all the Cambodian treatment groups (Fig. 2a, Table 1). Survival was significantly higher for the Vietnamese and F1 treatments than the Mekong treatment (Tonle Sap treatment), with cannibalism contributing to high mortality more than non-cannibalism causes (Table 1). FCR was not significantly different among treatments (Table 1), although feed intake of the Vietnamese fish was significantly higher (Fig. 2b). Yield.hapa^{-1} was significantly higher for the Vietnamese fish than any of the Cambodian fish (Table 1).

Discussion

This is the first report demonstrating the differences in weaning performance based on larvae from wild-caught broodstock vs larvae from domesticated broodstock. Fish from the Vietnamese broodstock showed higher growth while maintaining an acceptable FCR, although their cannibalism rate was the same as larvae of most of the wild-caught strains.

Table 1. Survival and growth of *Channa striata* of Vietnamese and Cambodian origin during weaning (hatchery phase) and grow-out phases of production. Both survival rate and cannibalism rate represent percentages of all the fish stocked in a given treatment. FCR is feed conversion rate. Values (mean ± SE) in a column followed by the same letter are not significantly different.

	Survival rate (%)	Cannibalism rate (%)	Weight gain (g.fish^{-1})	FCR	Yield.hapa^{-1} (kg)
Hatchery phase					
Vietnam	41.6 ± 3.4^{a}	41.1 ± 3.1^{b}	10.88 ± 0.47^{a}	1.63 ± 0.11^{a}	-
Tonle Sap	55.8 ± 2.9^{a}	42.0 ± 3.0^{b}	4.66 ± 0.50^{b}	1.91 ± 0.11^{a}	-
Mekong	39.0 ± 3.8^{b}	57.2 ± 4.0^{a}	3.24 ± 0.43^{b}	3.82 ± 0.86^{b}	-
F1	53.8 ± 3.6^{a}	40.2 ± 3.2^{b}	4.96 ± 0.46^{b}	2.06 ± 0.09^{b}	-
Grow-out phase					
Vietnam	80.8 ± 4.4^{a}	12.3 ± 4.0^{a}	324.2 ± 8.0^{a}	1.57 ± 0.06^{a}	81.0 ± 3.6^{a}
Tonle Sap	67.0 ± 5.6^{a,b}	27.4 ± 5.3^{b}	148.1 ± 16.4^{b}	1.90 ± 0.08^{a}	27.3 ± 1.9^{b}
Mekong	50.7 ± 9.4^{b}	45.1 ± 8.8^{b}	132.9 ± 19.0^{b}	2.08 ± 0.24^{a}	17.4 ± 2.9^{b}
F1	77.6 ± 5.0^{a}	21.0 ± 4.7^{a}	147.2 ± 17.7^{b}	1.59 ± 0.05^{a}	35.0 ± 3.4^{b}

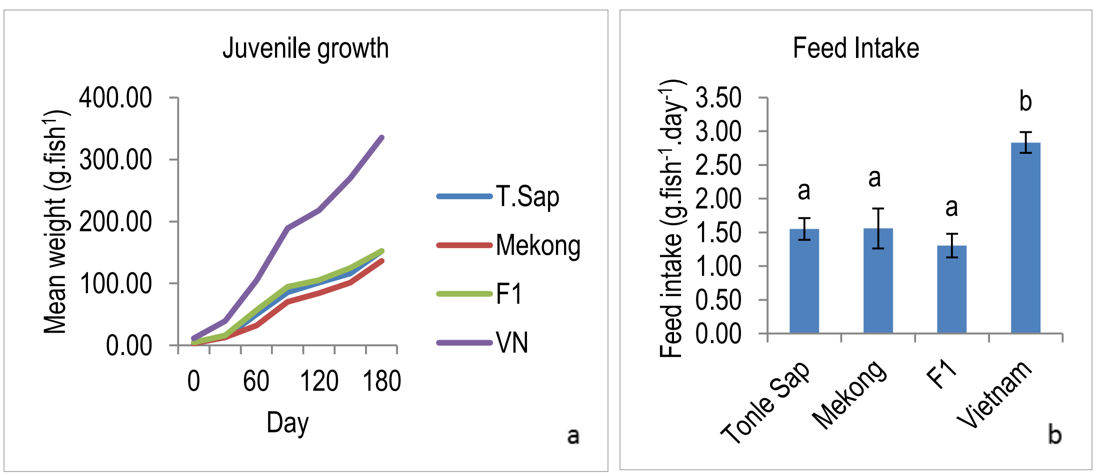

Fig. 2. Weight gain (panel a) and feed intake (panel b) of weaned *Channa striata* of Vietnamese and Cambodian origin subjected to the grow-out rearing protocol for 6 months beginning at 60 d after hatching.

The differences seen in the growth performance of the weaned fish from different origin could be due to various possibilities. The most obvious possible reason is the domestication of *C. striata* in Vietnam that has produced a line of fish selected over several generations (not necessarily intentionally by the hatchery managers) for greater feed consumption and growth. Given the high rates of cannibalism seen in all the treatments of our experiment, one can assume that maximization of feed consumption and growth would be a trait for which selection occurs in a hatchery (Hecht and Pienaar 1993; Kubitza and Lovshin 1999; Folkvord et al. 2010).

Another explanation is that, even prior to domestication, wild fish in Vietnam were genetically different from those in Cambodia and could inherently grow faster, regardless of domestication. For example, Imsland et al. (2004) and Chiba et al. (2007) found that genetically different populations of Atlantic cod, *Gadus morhua* Linnaeus 1758, and Atlantic silversides, *Menidia menidia* (Linnaeus 1766), respectively, grew at different rates. Genetic analysis of Vietnamese and Cambodian populations of snakehead is ongoing (D.T. Yen, personal communication), so some information on the possibility of genetic differences between these populations may be forthcoming. The finding that the fish in the F1 treatment in our experiment were similar to fish in the other treatments derived directly from Cambodian wild-caught fish suggests that selection for increased growth requires more than one generation.

Based on the results of the weaning phase, it is not surprising that the Vietnamese fish continued to show rapid growth during the grow-out phase. Presumably, the same arguments made above for growth differences between Vietnamese and Cambodian fish apply to grow-out as well. Further examination of genetic differences would help elucidate the basis for growth differences. Selective breeding programs for increased growth have greatly benefitted the finfish aquaculture industry, especially for Atlantic salmon (*Salmo salar* Linnaeus 1758), but for many other species as well (Gjedrem et al. 2012). Thus, domestication and breeding of Cambodian *C. striata* may over several generations result in production of fish strains with similar performance to that seen for Vietnamese fish.

Based on research and development of aquaculture in Vietnam, feeding of *C. striata* was changed from SS fish-based to pellet feed-based (Hien et al. 2015b, 2016). Furthermore, with the transfer of breeding and feed technology from Vietnamese to Cambodian scientists, the Cambodian government lifted the ban on snakehead in 2016. More research and policy development will be required before the Cambodian snakehead aquaculture industry achieves performance similar to that seen in Vietnam. To further enhance the development of aquaculture in Cambodia, there is a need to develop more hatcheries, feed mills, and improve processing and distribution facilities.

Conclusion

Domesticated snakehead *Channa striata* from Vietnam grew faster to market size, through weaning and grow-out phases, than non-domesticated Cambodian *C. striata*. This result appears to be directly attributable to increased feed consumption by the domesticated fish. Unfortunately, cannibalism rates remain high, especially in the hatchery phase, even after domestication. These findings can be used as guideline by the policy makers on the needs to consider the use of Cambodian-origin fish in re-starting the snakehead industry.

Acknowledgments

This research was funded by the AquaFish Innovation Lab under USAID CA/LWA No. EPP-A-00-06-00012-00 and by US and Host Country partners. The AquaFish accession number is 1469. The opinions expressed herein are those of the author(s) and do not necessarily reflect the views of the AquaFish Innovation Lab or the US Agency for International Development.

References

Allison, E.H., A.L. Perry, M.C. Badjeck, W.N. Adger, K. Brown, D. Conway, A.S. Halls, G.M. Pilling, J.D. Reynolds, N.L. Andrew and N.K. Dulvy. 2009. Vulnerability of national economies to the impacts of climate change on fisheries. Fish and Fisheries 10:173–196.

Chiba, S., S.A. Arnott and D.O. Conover. 2007. Coevolution of foraging behavior with intrinsic growth rate: risk-taking in naturally and artificially selected growth genotypes of *Menidia menidia*. Oecologia 154:237–246.

Folkvord, A., R.M. Koedijk, V. Lokøy and A.K. Imsland. 2010. Timing and selectivity of mortality in reared Atlantic cod revealed by otolith analysis. Environmental Biology of Fishes 89:513–519.

Gjedrem, T., N. Robinson and M. Rye. 2012. The importance of selective breeding in aquaculture to meet future demands for animal protein: A review. Aquaculture 350–353:117–129.

Halls, A.S., P. Chheng, N. So and N. Thuok. 2012. Food and nutrition security vulnerability to mainstream hydropower dam development in Cambodia: Impacts of mainstream dams on fish yield and consumption in Cambodia. Report, Inland Fisheries Research and Development Institute (IFReDI), Fisheries Administration, March 2012. 90 pp.

Haniffa, M.A., A.J.A. Raj and S. Sridhar. 1999. Weaning diet for striped murrel, *Channa striatus*. Fishery Technology 36:116–119.

Hecht, T. and A.G. Pienaar. 1993. A review of cannibalism and its implications in fish larviculture. Journal of the World Aquaculture Society 24:246–261.

Hien, T.T.T., T.D. Dinh, T.M. Phu and D.A. Bengtson. 2015a. Assessment of the trash-fish diet for snakehead aquaculture in Vietnam: species composition and chemical characterization. Asian Fisheries Science 28:165–173.

Hien, T.T.T., T.T. Be, C.M. Lee and D.A. Bengtson. 2015b. Development of formulated diets for snakehead (*Channa striata* and *Channa micropeltes*): can phytase and taurine supplementation increase use of soybean meal to replace fish meal? Aquaculture 448:334–340.

Hien, T.T.T., N.H.D. Trung, B.M. Tam, V.M.Q. Chau, N.H. Huy, C.M. Lee and D.A. Bengtson. 2016. Replacing freshwater small-size fish by formulated feed in snakehead (*Channa striata*) aquaculture: experimental and commercial-scale pond trials, with economic analysis. Aquaculture Reports 4:42–47.

Hien, T.T.T., B.M Tam, T.L.C. Tu and D.A. Bengtson. 2017. Weaning methods using formulated feeds for snakehead (*Channa striata* and *Channa micropeltes*) larvae. Aquaculture Research 48:4774–4782.

Imsland, A.K., A. Foss, G. Naevdal, T. Johansen, A. Folkvord, S.O. Stefansson and T.M. Jonassen. 2004. Variations in growth in haemoglobin genotypes of Atlantic cod. Fish Physiology and Biochemistry 30:47–55.

Kubitza, F. and L.L. Lovshin. 1999. Formulated diets, feeding strategies, and cannibalism control during intensive culture of juvenile carnivorous fishes. Reviews in Fisheries Science 7:1–22.

Nikolsky, G.V. 1963. The ecology of fishes. Academic Press, London and New York. 352 pp.

So, N., E. Tong, S. Norng and K. Hortle. 2005. Use of freshwater low value fish for aquaculture development in the Cambodia's Mekong basin. Consultancy report for Mekong River Commission - Assessment of Mekong Capture Fisheries Project. Inland Fisheries Research and Development Institute, Department of Fisheries, Phnom Penh, Cambodia. 31 pp.

So, N., S.V. Leng and Y. Kura. 2007. Study of the catch and market chain of low value fish along Tonle Sap River, Cambodia - Implications for management of their fisheries (A preliminary study). Report, Inland Fisheries Research and Development Institute, Phnom Penh, Cambodia. 26 pp.

So, N., S.V. Leng, S. Prum, L.X. Sinh and R. Pomeroy. 2009. Assessment of diversity and bioecological characteristics of low value/small-sized fish in the Lower Mekong basin of Cambodia and Vietnam. Report to AquaFish CRSP, Oregon State University, Corvallis, OR, USA. 19 pp.

So, N., S. Narith, B.M. Tam, T.T.T. Hien and R. Pomeroy. 2011. Sustainable snakehead aquaculture development in the Lower Mekong River Basin of Cambodia and Vietnam-Part 1: Breeding and Weaning of striped snakehead (*Channa striata*) in Cambodia. Report, Inland Fisheries Research and Development Institute (IFReDI), Fisheries Administration, Phnom Penh, Cambodia. 57 pp.

WorldFish Center. 2007. Fisheries and aquaculture can provide solutions to cope with climate change. Issues brief. WorldFish Center, Penang, Malaysia. 4 pp.

Received: 21/10/2017; Accepted: 31/07/2018; (AFSJ-2017-0119)