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Original Article

Effects of temperature on growth performance and water quality in culture system of butter catfish *(Ompok bimaculatus)*

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Abstract

To evaluate water quality and growth performance of butter catfish under temperature manipulation, 15 fish were cultured in 16 fiberglass tanks for ten weeks in three temperatures of 29 °C, 31 °C, 33 °C, and in ambient temperature as control (25.1-29.5 °C). The growth performance and water quality parameters (temperature, DO, pH, TAN and NO_2-N) in culture were investigated. Water quality seemed not to be controlled by temperature but by feed consumption. DO concentration decreased (8.27±0.10 mg/l) in the 33 °C tank (P<0.05). Growth of catfish performed well in all treatments except fish in the 33 °C tank, in which the percentage weight and length gain declined (479.70±86.64% and 73.85±10.52%, respectively) (P<0.05), and both SGR and feed intake significantly decreased (2.55±0.26 %/day and 194.28±42.40 g, respectively) (P<0.01). FCR and survival were positive in every temperature exposure (P>0.05). Results reveal that the maximum thermal tolerance for growth is best in water temperature which does not exceed 31 °C.

Keywords: butter catfish, water quality, growth performance, water temperature

1. Introduction

Ompok bimaculatus is found in inland waters and widely distributed in South and Southeast Asia such as Cambodia, Thailand, Myanmar, India, Bangladesh, Pakistan, and Afghanistan (Ng, Tenzin, & Pal, 2010; Rainboth, 1996). It is a small catfish in the Siluridae family, weighing about 100 g to 300 g, and is usually 20 to 30 cms, long but has occasionally been found up to 50 cm in Thailand (Vorasayan, Chawpaknum, & Ranunon, 1989). Its preferred water temperature is from 20 to 26°C (Riehl & Baensch, 1991). According to the IUCN Red List of Threatened Species 2010, *Ompok bimaculatus* is in the Near Threatened (NT) category of freshwater species for several reasons including over-exploitation, anthropogenic threats, and disturbance from alien species (Ng *et al*., 2010). It is a pin-boneless-muscle fish with a good taste, extremely important in Indian traditions, and rich in nutrients such as proteins, lipids, and minerals (Gupta, 2015). The fish is a favorite that fetches a high price in Thailand and India (Gomonteir *et al*., 2012; Gupta, 2015). In the East and Northeast of India, it is an ornamental fish raised in fisheries and exported to international ornamental fish markets (Gupta, 2015).

Typically, aquatic animals are totally dependent on water resources. Thus, variations in their environment strongly affect their lives. More importantly, water temperature is already known to be the primary environmental parameter which is anomalous to all fish physiological functions, e.g. growth, metabolic rate, behavior, survival, and so on (Stickney, 1994; Suja, Phillips, Lochmann, & Chen, 2009).

The growth of the fish is a fundamental index which is affected by temperature; higher or lower than the thermal tolerance reduces growth rate (Stickney, 1994). The correlation of chemical constituents in fluctuating water temperatures and growth performance in culture is unpredictable and needs further research. Many researchers from Thailand and India have conducted many experiments on both wild and cultured butter catfish. Examples include research on stocking density (Debnath *et al*., 2016; Vongkhon, 2006), breeding (Chawpaknum, Khwandi, & Puang-in, 1990;

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Raizada *et al*., 2013), embryology (Chawpaknum, Vorasayan, & Ranunon, 1993b; Vorasayan *et al*., 1989), fry nursing (Chawpaknum, Vorasayan, & Puang-in, 1993a), dietary energy development (Chawpaknum & Bowonsupakijkul, 2003), reproductive biology in lotic water bodies (Malla & Banik, 2015), feeding habits and nutrition requirements (Pal, Verma, & Muzaddadi, 2017; Parihar, Chaturvedi, Saksena, & Rao, 2016), digestive tract development (Meesri & Sema, 2008) and diversity of its natural food (Sangpradub, Somnark, & Hanjavanit, 2014). Yet there is little information on this species in water temperature manipulation experiments. Interestingly, it was found that increases of water temperatures in hatchery stages can enhance the development of fish larvae and decrease time and feed for nursing fish larvae (Hallare, Schirling, Luckenbach, Köhler, & Triebskorn, 2005; Haylor & Mollah, 1995; Small & Bates, 2001). If increases of water temperature can enhance fish juvenile growth as well, it would give more benefit to fish farmers. Therefore, some interesting aspects about this study such as water quality in culture and growth performance under temperature manipulation were investigated in an attempt to understand the adaptation of butter catfish during the fingerling stage.

2. Materials and Methods

2.1 Location, experimental fish and design

The ten-week experiment was conducted at the Department of Aquatic Science, Faculty of Natural Resources, Prince of Songkla University, Thailand. Fish were supplied by Inland Aquaculture Research and Development Regional Center 12 (IARDRC 12), Songkhla Province. Using a completely randomized design comprising four treatments in four replications, 240 fingerlings were raised in 16 fiberglass tanks (40 X 50 X 110 cm^3) each with 150 L of freshwater (Chawpaknum & Bowonsupakijkul, 2003). Fish weighing 1.52-4.71 g and 6.1-8.8 cm total length were randomly selected for the experiments. Water temperatures of 29, 31, 33 °C and a control treatment with ambient water temperature (25.1-29.5 °C) were run through independent recirculation systems with individual biological filtrations, and aerations with two air stones in each tank. They were also equipped with a separate heater to maintain constant water temperature except for the control treatment, which fluctuated by day and night. The acclimation of the fish to the water temperatures was begun from ambient water temperature by increasing 1 °C per day to accomplish experimental treatments.

2.2 Fish culture

All fish were released into fiberglass tanks a week before the onset of the experiments. Fish were fed twice a day (at 9:30 a.m. and 4 p.m.) with the same floating pelleted, commercial frog feed (Charoen Pokphand Foods PCL., Thailand) as recommended by a fisheries biologist at IARDRC 12 who bred this catfish. Nutritive value of feed consisted of protein not less than 40%, lipids not less than 4%, moisture not more than 12%, and crude fiber not more than 4%. The uneaten feed was removed after satiation and was kept until finishing the experiments, then dried and weighed to find out their feed intake. Waste from fish tanks was siphoned as necessary, and all bio-filters were cleaned after 4 weeks. Dead fish were observed and removed from the tanks. Fish mortality was recorded regularly. After 10 weeks, fish were starved for 24 hrs to empty the gut then weighed individually.

Final fish length and weight were recorded. Percentage of weight and length gained, specific growth rate (SGR), feed conversion ratio (FCR), and survival rate were calculated as:

Percentage length gained (%) = (TL_f – TL_i) X 100/TL_i, where TL_f and TL_i are the final and initial total length, respectively.

Percentage weight gained (%) = (W_f – W_i) X 100/W_i, where W_f and W_i are the final and initial weights

SGR (%/d) = ($\ln W_f$ – $\ln W_i$) X 100/d, where "d" are the days of cultivation.

FCR = Total feed intake/Weight gain

Survival Rate (SR %) = Number of surviving fish X 100/Number of stocked fish

2.3 Water sample

Water samples were collected weekly for laboratory analysis of pH, total ammonia nitrogen (TAN), nitrite (NO_2-N) and dissolved oxygen (DO) according to the Boyd and Tucker (1992) method. In addition, water temperatures were monitored daily with a thermometer between 12:30 p.m. and 1:00 p.m.

2.4 Data analysis

The results of fish growth performance and water quality parameters were statistically analyzed with the SPSS program version 23.0, by using one-way analysis of variance (ANOVA) and comparing means by Duncan's Multiple Range test.

3. Results

3.1 Water quality parameters

Water quality parameters in all treatments fluctuated in a similar pattern during the 10-week-experiment. The temperature fluctuation in the control tank was higher than treatment tanks with temperature manipulation (Figure 1A), because the experiment was undertaken in open-air conditions. Overall water quality parameters differed among treatments (P<0.05), except for pH which ranged from 6.4 to 6.7 (Figure 1B). The average DO concentration (8.27–8.80 mg/l) tended to decrease with rising temperatures. The lowest DO concentration was noticed in the treatment with 33°C (Figure 1C). Furthermore, high average TAN concentration in the control was similar to treatment tanks with 29 °C and 31 °C (0.729, 0.805 and 0.765 mg N/l, respectively) and the treatment with 33°C obtained the lowest value of TAN (0.389 mg N/l) (Figure 1D). The lowest value of NO_2-N was in the treatment with 33 °C water (0.103 mg N/l) and the highest value was in the control treatment (0.164 mg N/l) (Figure 1E).

3.2 Growth performance of butter catfish

The average initial and final total lengths and percentage of total length gained differed among treatments (P<0.05). Moreover, the highest total length gain percentage

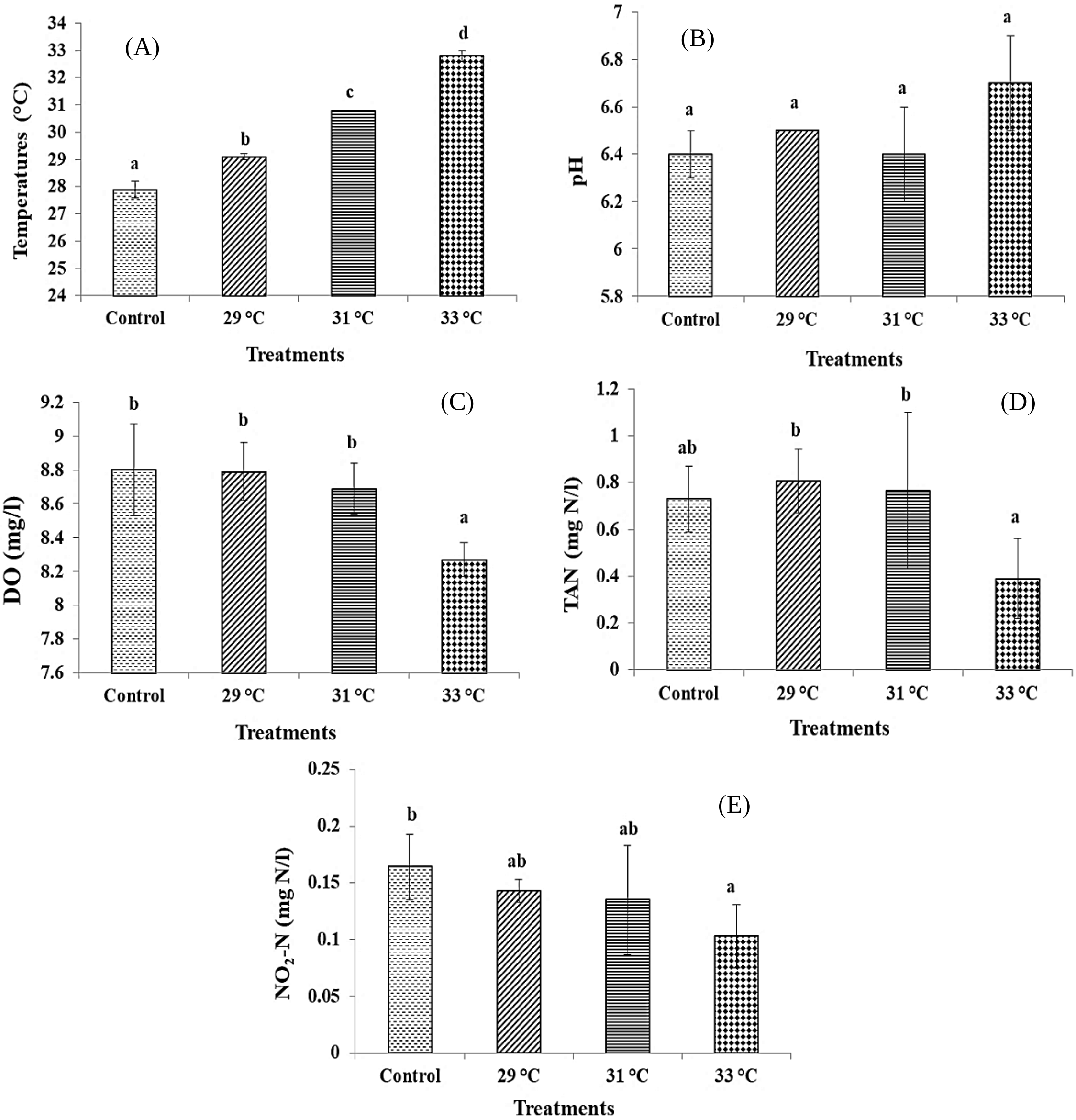

Figure 1. Water quality (A: Temperatures; B: pH; C: DO; D: TAN; E: NO_2-N) in 10 weeks culture under temperature manipulation (control tanks without heater unit). The values are averaged from four replications, except for the treatment with 29 °C water, which had only three replications because of the malfunction of one heater. Means sharing the same superscripts are not significantly different (P>0.05).

was obtained in the control tank (94.32%) and the lowest percentage was in the treatment with 33°C water (73.85%). The average percentages of weight gain also differed among treatments and tended to decrease with increased temperature (839.22–479.70%; control–33°C, respectively). Significant dropping of the average SGR and feed intake were also observed in fish cultured under 33°C (P<0.01). In addition, the average FCR and survival rate were not significantly different among treatment groups (P>0.05) (Table 1).

4. Discussion

As shown in Figure 1, water quality parameters in all treatments were not influenced by water temperature, except that DO was low. This finding is consistent with Boyd (1990), who reported that higher temperature causes lower soluble gases in water and triggers a decrease in DO concentration. Furthermore, the increased temperature leads to doubling the increased oxygen demand for the fishes' digestion, and the metabolism of amino acids and other nutrients (Wedemeyer, 1996). Wedemeyer (1996) added that salmonids in intensive culture inclined the oxygen consumption to support the metabolism and the digestion at temperatures above 27 °C. Nevertheless, the DO concentrations in this study were high compared to the saturated DO concentration in freshwater at 25-35°C (8.24-6.93 mg/l, respectively) (Colt, 1984). It may be due to the high rate of aeration from the two air stones in each tank, since there was a virulent movement of air bubbles in the experimental tanks.

Low pH resulted in all treatments, thus lime (calcium hydroxide) was added weekly. Boyd (1990) found that fish died in water at pH lower than 4 and higher than 11. Sapkale, Singh, and Desai (2011) added that the effect of pH is based on fish age and developmental stage. Most pH levels in the trial period were in the acceptable range for butter catfish according to Riede (2004), who identified the appropriate pH range for butter catfish of 6.0-8.0. In the ammonia cycle, various bacteria also produce hydrogen ions. Since water receives a strong effect from hydrogen ions in the process, pH begins to decrease. Boyd (1990) reported that ammonium ion is relatively nontoxic and predominates at low pH levels.

Correspondingly, the desirable range of TAN is 0-2 mg N/l, and NO_2-N is 0-1 mg N/l (Stone & Thomforde, 2004). Reduced feed intake and less feeding activity resulted in decreased waste products from fish (Stickney, 1994). As feed intake of butter catfish dropped in culture at 33 °C (Table 1), the concentrations of TAN and NO_2-N were lower than other treatments (Figure 1D and 1E). Moreover, it may be that the conversion bacteria worked properly in this culture system, while the proportion of TAN fell and the proportion of NO_2-N rose, and persisted to further conversion simultaneously.

The results of this study indicated that growth performance of butter catfish was negatively impacted by elevated water temperatures. Percentage of length gain, percentage of weight gain, SGR, and feed intake of butter catfish reared at 33 °C water temperature fell severely (Table 1). Similarly, reduced feed intake and lower growth were due to water temperature above or below the thermal limits (25-32 °C) (Stickney, 1994). Metabolic rate fell at low temperatures and fish started growing slowly. On the other way, the more metabolic rate rises at temperature above the optimum range, the less it can develop growing. A fish's feed consumption rate is just for maintenance of its body (Stickney, 1994). Consequently, butter catfish rearing in ambient water temperature, and 29°C and 31 °C water, exhibited better growth performance than fish cultured in 33 °C water (Table 1).
FCR was the same in all treatments and was a positive result for culture (Table 1). Phuc (2015) stated that FCR of tra catfish (*Pangasianodon hypophthalmus*) had a good outcome when cultured at water temperatures of 27 °C, 30 °C, 32 °C, 34 °C and 36 °C, compared to the lowest temperature, 24 °C. In addition, Suja *et al*. (2009) recorded that considerable FCR of channel catfish occurred at 27 °C, compared to 32 °C water and slightly below optimal temperature of 22 °C. The survival rates of butter catfish were of non-significant difference among treatments (Table 1) and were consistent with the results of Phuc (2015) and Suja *et al*. (2009). In addition, Wedemeyer (1996) reported that the effective utilization of food consumption for metabolic processes, conversion of food into new tissue, and excretion as waste depends on the temperature of the ingested food: high temperature reduces the formulated ration of food nutrients that fish can absorb. Also, feeding rate typically decreases if the water temperature is higher or lower than the optimal level of aquatic organisms (Stickney, 1994). In channel catfish culture, a temperature range of 21 to 32 °C required 3% of body weight daily for living, less than 21 °C reduced body weight by 2%, and in less than 7 °C, no feed was accepted, and in more than 32 °C, just 1% was required (Stickney, 1994). Furthermore, Phuc (2015) recommended that at 36 °C (thermal limit), the catfish's energy from metabolic activities shifted from growth to coping with temperature stress with consequential decreases in growth, survival, and FCR. Conversely, in this study, temperatures up to 33 °C did not result in increased FCR, low survival rates, which they may not be the stress conditions yet in butter catfish culture except for declining growth rate. However, higher water temperature is beneficial in culture systems during the early life stages of warm water fish species. The optimal temperature range (26-33 °C) produced desirable results, e.g. good embryo development, hatching rate, survival rate and a shortened hatching period (Hallare *et al*., 2005; Haylor & Mollah, 1995; Small & Bates, 2001).

5. Conclusions

To conclude, water quality parameters in culture were not directly impacted by water temperature, except DO. The butter catfish fingerlings performed extremely well in ambient water temperatures (25.1–29.5 °C). Even though water quality was better, water temperature higher than 31 °C reduced fish growth performance such as weight, length, SGR, and feed intake. Therefore, fish farmers would benefit by being aware of this species thermal limit during its fingerling stage, because growth deteriorates at elevated temperatures.

Table 1. Growth performance of butter catfish cultured under temperature manipulation for 10 weeks (mean±SD)*.

Parameter	Control	29°C	31°C	33°C
Initial total length (cm)	7.3 ± 0.5^{b}	7.3 ± 0.0^{b}	7.2 ± 0.6^{ab}	7.2 ± 0.0^{a}
Final total length (cm)	14.1 ± 0.5^{b}	13.8 ± 0.1^{b}	13.5 ± 0.8^{ab}	12.5 ± 0.8^{a}
Percentage total length Gained (%)	94.32 ± 6.63^{b}	87.83 ± 1.90^{ab}	86.35 ± 12.21^{ab}	73.85 ± 10.52^{a}
Initial weight (g)	2.72 ± 0.01^{a}	2.72 ± 0.00^{a}	2.72 ± 0.00^{a}	2.71 ± 0.01^{a}
Final weight (g)	26.95 ± 4.21^{b}	$25.30+1.84^{b}$	22.62 ± 4.69^{b}	16.34 ± 2.91^{a}
Percentage weight gained (%)	839.22 ± 132.74^{b}	787.34 ± 35.21^{b}	716.44 ± 161.60^{b}	479.70 ± 86.64^{a}
Specific growth rate (%/day)	3.26 ± 0.21^{b}	3.18 ± 0.11^{b}	3.00 ± 0.33^{b}	2.55 ± 0.26^{a}
Feed intake (g)	336.24 ± 51.69^{b}	315.94 ± 49.15^{b}	305.53 ± 69.86^{b}	194.28 ± 42.40^{a}
FCR	1.0 ± 0.0^{a}	1.0 ± 0.1^{a}	1.0 ± 0.0^{a}	1.0 ± 0.1^{a}
Survival rate (%)	95.0 ± 3.3^{a}	95.6 ± 3.85^{a}	98.3 ± 3.3^{a}	96.7 ± 6.7^{a}

* Values are averaged from four replications, except for the treatment with 29 °C water, which had only three replications because of the malfunction of one heater. In the same row, means sharing the same superscript are not significantly different (P>0.05).

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References

Boyd, C. E. (1990). *Water quality in ponds for aquaculture*. Alabama: Alabama Agricultural Experiment Station, Auburn University.

Boyd, C. E., & Tucker, C. S. (1992). *Water quality and pond soil analyses*. Alabama: Alabama Agricultural Experiment Station, Auburn University.

Chawpaknum, C., & Bowonsupakijkul, S. (2003). Dietary energy requirement for *Ompok bimaculatus* (Bloch). *Proceedings of 41th Kasetsart University Annual Conference on Fisheries*, 163-170.

Chawpaknum, C., Khwandi, V., & Puang-in, S. (1990). *Breeding of two-spot glass catfish (Ompok bimaculatus)* (Technical Paper No. 1). Chonburi, Thailand, Inland Fisheries Development Center.

Chawpaknum, C., Vorasayan, P., & Puang-in, S. (1993a). *Fry nursing of two-spot glass catfish Ompok bimaculatus (Bloch)* (Technical Paper No. 6). Chon-buri, Thailand, Inland Fisheries Development Center.

Chawpaknum, C., Vorasayan, P., & Ranunon, N. (1993b). *Embryonic development of egg larvae of two-spot glass catfish Ompok bimaculatus (Bloch)* (Technical Paper No. 37). Chonburi, Thailand, Inland Fisheries Development Center.

Colt, J. (1984). *Computation of dissolved gas concentrations in water as functions of temperature, salinity, and pressure*. Bethesda, MD: American Fisheries Society, Special Publication No. 14.

Debnath, C., Dube, K., Saharan, N., Tiwari, V. K., Datta, M., Sahoo, L., . . . Das, P. (2016). Growth and production of endangered Indian butter catfish, *Ompok bimaculatus* (Bloch) at different stocking densities in earthen ponds. *Aquaculture Research*, *47*, 3265–3275. doi:10.1111/are.12780

Gomonteir, B., Tanomtong, A., Supiwong, W., Sikhruadong, S., Neeratanaphan, L., & Sanoamuang, L. (2012). Standardized karyotype and idiogram of two-spot glass catfish, *Ompok bimaculatus* (Siluriformes, Siluridae) in Thailand by conventional and Ag-NOR staining techniques. *Cytologia*, *77*(4), 459–464. doi:10.1508/cytologia.77.459

Gupta, S. (2015). An overview on feeding habit, reproductive biology and induced breeding of *Ompok bimaculatus* (Bloch, 1794). *European Journal of Biological Sciences*, *7*(4), 147-153. doi:10.5829/idosi.ejbs.2015.7.04.95163

Hallare, A. V., Schirling, M., Luckenbach, T., Köhler, H. R., & Triebskorn, R. (2005). Combined effects of temperature and cadmium on developmental parameters and biomarker responses in zebrafish (*Danio rerio*) embryos. *Journal of Thermal Biology*, *30*(1), 7-17. doi:10.1016/j.jtherbio.2004. 06.002

Haylor, G. S., & Mollah, M. F. (1995). Controlled hatchery production of African catfish, *Clarias gariepinus*: The influence of temperature on early develop-ment. *Aquatic Living Resources*, *8*(4), 431-438. doi:10. 1051/alr:1995051

Malla, S., & Banik, S. (2015). Reproductive biology of an endangered catfish, *Ompok bimaculatus* (Bloch, 1794) in the lotic waterbodies of Tripura, North-East India. *International Journal of Fisheries and Aquatic Studies*, *2*(4), 251-260.

Meesri, J., & Sema, S. (2008). Development of digestive tract in two-spot glass catfish, *Ompok bimaculatus* (Bloch, 1797) larvae. Retrieved from http://elib.fisheries.go.th/libcab/drawers/article/0007/00007820.pdf.

Ng, H. H., Tenzin, K., & Pal, M. (2010). *Ompok bimaculatus*. The IUCN Red List of Threatened Species 2010: e.T166616A6248140. Retrieved from https://www.iucnredlist.org/species/166616/6248140

Pal, J., Verma, H. O., & Muzaddadi, A. U. (2017). Comparative study of seasonal variation in proximate composition and nutritional quality of farmed and wild Indian butter catfish (*Ompok bimaculatus*) in Tripura India. *Journal of Entomology and Zoology Studies*, *5*(5), 787-790.

Parihar, D., Chaturvedi, J., Saksena, D. N., & Rao, R. J. (20 16). Food and feeding habits of freshwater teleost: *Ompok bimaculatus, Xenentodon cancila, Puntius sarana* and *Labeo boggut* from Tighra reservoir, Gwalior (M.P.). *International Journal of Scientific Research and Growth*, *1*(1), 1-8.

Phuc, N. T. H. (2015). *Effects of temperature and salinity on growth performance in cultured tra catfish* (*Pangasianodon hypophthalmus*) *in Vietnam* (Doctoral thesis, Queensland University of Technology, Brisbane, Australia). Retrieved from https://eprints.qut.edu.au/86693/4/Phuc_Nguyen_Trong_Hong_Thesis.pdf

Rainboth, W. J. (1996). *Fishes of the Cambodian Mekong. FAO species identification field guide for fishery purposes*. Rome, Italy: FAO.

Raizada, S., Lal, K. K., Sarkar, U. K., Varshney, P. K., Sahu, V., Yadav, K. C., . . . Jena, J. K. (2013). Captive breeding and embryonic development of butter catfish (*Ompok bimaculatus*, Bloch 1794), a threatened fish of Indian Sub-continent in Northern India. *Proceedings of the National Academy of Sciences, India, Section B, Biological Sciences* *83*(3), 333–339. doi:10.1007/s40011-013 -01

Riede, K. (2004). *Global register of migratory species - from global to regional scales* (Final Report of the R&D-Projekt 808 05 081). Bonn, Germany, Federal Agency for Nature Conservation.

Riehl, R., & Baensch, H. A. (1991). *Aquarien atlas. Band 1*. Melle, Germany, Mergus, Verlag für Natur-und Heimtierkunde.

Sangpradub, N., Somnark, R., & Hanjavanit, C. (2014). Food of *Anematichthys repasson* and *Ompok bima-culatus* from Kaeng Lawa, Thailand. *AACL Bioflux*, *7*(5), 419-429.

Sapkale, P. H., Singh, R. K., & Desai, A. S. (2011). Optimal water temperature and pH for development of eggs and growth of spawn of common carp (*Cyprinus carpio*). *Journal of Applied Animal Research*, *39*(4), 339-345. doi:10.1080/09712119. 2011.620269

Small, B. C., & Bates, T. D. (2001). Effect of low temperature incubation of channel catfish Ictalurus punctatus eggs on development, survival, and growth. *Journal of the World Aquaculture Society, 32*(2), 189-194. doi:10.1111/j.1749-7345.2001.tb01094.x

Stickney, R. R. (1994). *Principles of aquaculture*. New York, NY: John Wiley and Sons.

Stone, N. M., & Thomforde, H. K. (2004). *Understanding your fish pond water analysis report*. Cooperative Extension Program, University of Arkansas at Pine Bluff.

Suja, B., Phillips, H., Lochmann, R., & Chen, R. (2009). Effect of temperature on growth, feed utilization, and immune status of channel catfish in recir-culating system. *North American Journal of Aqua-culture*, *71*(1), 64-72. doi:10.1577/A07-101.1

Vongkhon, A. (2006). *Optimum stocking density for nursing of two-spot glass catfish Ompok bimaculatus (Bloch, 1797) fry* (Technical Paper No. 23). Chon-buri, Thailand, Inland Fisheries Development Center. Retrieved from http://www.inlandfisheries.go.th/ research/files/full/F232549.pdf

Vorasayan, P., Chawpaknum, C., & Ranunon, N. (1989). *Em-bryology of two-spot glass catfish* (*Ompok bima-culatus*) (Technical Paper No. 1). Chonburi, Thai-land, Inland Fisheries Development Center.

Wedemeyer, G. A. (1996). *Physiology of fish in intensive cul-ture systems*. London, England: Chapman and Hall.