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ORIGINAL RESEARCH

Yolk utilization and growth during the early larval life of the Silver Perch, *Bidyanus bidyanus* (Mitchell, 1838)

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Abstract The aim of this research was to investigate the yolk sac and oil globule utilization by silver perch (*Bidyanus bidyanus)* larvae produced from domesticated broodfish. The larvae were kept unfed in the holding tank, sampled, and investigated by image analysis software to determine various characteristics, such as the diameters of ova, water-hardened eggs, yolk-sac, oil globules, and the total length of larvae. The research illustrated that, with the exception of oil globule diameter, all other morphometric parameters were significantly lower ($P < 0.05$) when compared to the larvae from the wild broodfish. The yolk sac was completely absorbed at 96 h post-hatching (hph) and the oil globule was visible until 240 hph. The larvae exhibited predatory movements and tried to catch rotifer at 4 days post hatching (dph). However, the onset of feeding took place at 5 dph, while 100% of feeding occurred at 6 dph. During the first 96 h (h), larvae grew significantly faster than the next 144 h. Larvae encountered low mortalities (<10%) during the first 96 hph, before increasing significantly in the next 24 h and no unfed larvae survived post 240 h. The results also suggested that the exogenous feed should be available at 96 hph, which is well after the yolk sac is completely depleted. In addition, although most of eggs and larval performance from domesticated broodfish were inferior compared to the wild one, it has larger oil globule that could make longer of its mixed feeding period and therefore could have better in viability.

Keywords Yolk utilization · Larvae · *Bidyanus bidyanus*

Introduction

The yolk stages (yolk-sac and oil globule) of most of the teleost with early-life planktonic stages and lack of parental care, are characterized by reduced capacities in swimming, vision, and feeding ability (Jug-Dujaković et al. 1995). The knowledge about the role of early fish ontogeny is particularly essential for better understanding of larval dynamics and mechanisms of adapting to variable environmental conditions. The essential events in larviculture are not only the period of these susceptible ontogenetic stages, but also a diversity of vital physical appearances such as the hatching size, onset of feeding, and the efficacy of yolk utilization

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(Koumoundouros et al. 2001; Polo et al. 1991). Some fish species are more highly prone to mass mortalities during the early feeding time than during the advanced development phase (Dou et al. 2005; Gisbert and Williot 1997; Kailasam et al. 2007; Mookerji and Rao 1999; Paperna 1978; Qin et al. 1997). Fish larvae are also highly vulnerable during the period of transition from consuming endogenous reserves of food to exogenous nutrient consumption. Failure to perform first feeding response immediately when the mouth has opened often causes morphological deformities, abnormal moving behaviour, and an inability to swim and feed (Gwak and Tanaka 2001; Kjørsvik et al. 1991), leading to high mortality (Dou et al. 2002; Houde 1974).

Generally, the rate of survival of fish larvae is poor during the early life stages (Bisbal and Bengtson 1995; Yang 2007). The availability of food at the right time is crucial because starvation can lead to high larval mortality (Bisbal and Bengtson 1995; Gisbert et al. 2004; Kohno et al. 1997; Peña and Dumas 2005). Some other factors such as larval size, yolk and oil quantity and absorption rate, feeding behaviour, and the time of initial feeding may also affect mortality (Blaxter 1974; Dou et al. 2000). In chinook salmon, *Oncorhynchus tshawytscha*, and rainbow trout, *Salmo gairdneri*, initial feeding starts after the swim-up stage (Heming et al. 1982; Twongo and MacCrimmon 1976), while in burbot, *Lota lota,* exogenous food needs to be given at 9–10 dph (Palińska-Żarska et al. 2014). The elapsed time from yolk sac depletion to irreversible starvation also differs between fish species (Bisbal and Bengtson 1995; Shan et al. 2008).

Silver perch, *Bidyanus bidyanus* (Mitchell, 1838), endemic to the Murray-Darling river system in New South Wales, is a native Australian freshwater fish, belonging to the Teraponidae family (Merrick and Schmida 1984). Also known as freshwater bream, silver bream and grunter, the silver perch occupies the northern and western rivers and upper reaches of the Murray-Darling river system (Rowland 1995). It is an important freshwater aquaculture species intensively cultured in Australia with production around 500 metric tons per year (Rowland 2009). It has also been cultured in China, Taiwan and Israel (Allan and Rowland 2002). Limited information on its morphogenesis and larval ontogeny originating from wild broodfish has been reported by Lake (1967b), but no detailed information has been published about domesticated broodfish. Since the life cycle of the silver perch can be closed in captivity (Rowland 2004), it is important to assess the ontogeny and morphogenesis of larvae from the domesticated broodfish and compare it with the larvae from the wild broodfish.

This paper delivers early life-history data on the silver perch larvae, obtained from the domesticated broodfish. The research details the information found during the early larval stages with respect to the yolk absorption rates, the onset of feeding, and the mortality response of the unfed larvae.

Materials and methods

Each experiment was accepted by the Animal Ethics Committee of Curtin University and the Australian Code of Practice for the care and use of animals for scientific purposes was also followed.

Fish and experimental setup

The second generation of domesticated silver perch broodfish (6 years old), reared in a farmer's pond at Gingin, Western Australia (31°20′0.5.53″S, 115°46′20.51″E), was used in this experiment. Eggs were obtained after human chorionic gonadotropin (hCG) hormone was injected into both male and female broodfish at a dosage of 200 IU/kg (Levavi-Sivan 2004; Rowland 1984, 2009). Following hormone injection, both males and females were kept together in a 3-tonne fiberglass tank filled with two tons of freshwater until they spawned. The spawning tank was placed in a hatchery hall at a room temperature of 20–25 °C, equipped with gentle aeration that was placed in the mid-bottom of the tank.

After spawning, the eggs were transported from Gingin to the Curtin Aquaculture Research Laboratory (CARL) for incubation and for the production of the fry used in the experiment. On arrival, about 5000 eggs were placed into two 200-L, conical-shaped, fiberglass incubator tanks filled with freshwater, with a flow-through system that had a flow rate of 500 mL/min. With this system, egg shells were retained in the incubation tank while larvae from the two incubation tanks were moved into the sump tank. Larvae from the sump tank were then transferred to the holding tank (200 L volume) at a stocking density of 50 larvae/L. The

holding tank was filled with 6 ppt saline water and gently aerated. The water temperature in the holding tank was preserved at 20 ± 0.5 °C by a thermostatically controlled heater (Sonpar, Model-Ha200). The newly hatched larvae were then haphazardly taken to perform morphometric measurements, age at first feeding, and mortality experiments. The rest of the larvae were kept unfed in this tank until the end of the experiment. The swimming behaviour of the larvae was observed simultaneously to identify the initial time of starvation characterized by a slow-moving swimming, hanging the head down into the water column, or almost no reaction to gentle probing.

Morphometric measurements

The hatching time was appointed at which 90% of the viable eggs were hatching (Shan et al. 2008). Meanwhile, morphometric measurements were performed at 6 h intervals, from hatching until 10 days post hatch (dph), using 7–53 larvae (average = 25) per sample. Yolk utilization (yolk sac and oil globule) was dignified based on the reduction in the volume of the yolk-sac and oil globule over time. The yolk utilization of the unfed larvae was studied using a stereoscopic microscope (Olympus-SZH) while morphometric characteristics were monitored using photographs taken with a digital camera (Olympus-SC30) attached to the microscope. On the photographs, five morphometric characteristics (TL: total length; YsH: yolk sac height; YsL: yolk sac length; OgD: oil globule diameter) were quantified to the nearest 0.001 mm (using Photoshop image software), while yolk sac volume (YsV) and oil globule volume (OgV) were estimated. The YsV was estimated using the formula introduced by Bagarinao (1986) for a prolate spheroid, $V = \pi/6\ l\ h^2$, where l is the length of yolk sac and h is the height of yolk sac. The volume of the oil globule in the larvae was computed from the formula $V = \pi/6\ d^3$, where d is the oil globule diameter. The specific growth rate (SGR) of the TL at different periods of their larval stage was calculated by the formula: SGR = (e.g. −1) × 100% (Árnason et al. 2009; Hopkins 1992), where $g = [\ln(l_2) - \ln(l_1)]/(t_2 - t_1)$, and l_2 and l_1 are the mean TL on day t_2 and t_1, respectively. All measurements were performed parallel to the body-length axis, and all depths and diameters were measured perpendicular to this axis (Fig. 1). The measurements for the diameter of ova, water-hardened egg, yolk sac, and oil globule, and the TL of each larva at hatching from domesticated broodfish in this study were then compared to the corresponding characteristic for larval performance from wild broodfish as reported by Lake (1967b). The data presented by Lake (1967b) were based on the wild broodfish of silver perch stocked in a pond and spawned naturally before eggs were collected for examination in accordance with the egg and larvae parameters.

Age at first feeding

To determine the age at first feeding, 10 one-day-old larvae were introduced into a beaker glass containing 1 L of water with rotifers (*Brachionus calyciflorus*) at a density of 10 ind/mL. Beakers were placed in the incubator tank, each equipped with a thermostat (Thermomix, B. Braun Biotech International) in order to maintain the water temperature at approximately 20 ± 0.1 °C. To facilitate prey contrast, the trough was covered with black plastic on the sides and bottom, and illuminated from above by a 36 W fluorescent light. The larvae were netted out after 45 min, lightly anaesthetized with AQUI-S (0.025 mg/L) and preserved in 8% buffered formalin for subsequent gut content observation. The incidence of feeding was expressed as the percentage of test fish ($n = 10$) with food (at least one food item) in their gut. The feeding trials were repeated every 24 h with unfed silver perch until they were 144 h or 6 days' old.

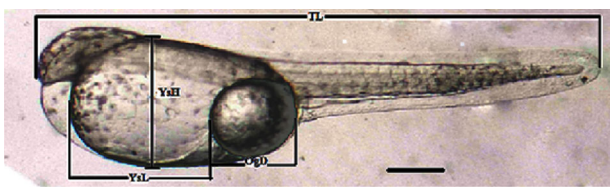

Fig. 1 Newly hatched silver perch, *Bidyanus bidyanus* larvae (eyes, jaws and gut not formed) showing morphometric measurements of total length (TL), yolk sac length (YsL), yolk sac height (YsH), and oil globule diameter (OgD), (*bar* = 250 μm)

Mortality

The experiment was conducted using three 2-L, conical-shaped glass containers placed in an incubator tank to determine the mortality of unfed larvae during their yolk stage. Fifty 1-dph larvae from the holding tank were transferred to the experimental glass container. Mild aeration was provided, along with illumination using 40 W fluorescent light regulated at about 200 lx. Dead fish were counted and removed along with bottom sediments before changing the water about 30% from the rearing volume every 24 h. Cumulative mortality was then calculated daily. Water temperature was maintained at 20 °C.

Data analysis

Statistical differences in egg and larva parameters (the TL, diameter of ova, diameter of water hardened egg, Ysh, and the Ogd) between domesticated and wild broodfish were analyzed by one sample *t* test. The comparison between TL and SGR at different stages were analyzed by an independent-sample *t* test between two periods of development i.e. from 0 to 96 hph and from 96 to 240 hph. Mortality rates at a different age of larvae were analyzed by one-way analysis of variance (ANOVA) followed by a post hoc test (Tukey's) with the level of significance below 5% ($P < 0.05$). The relationship between the mortality rate and the time after hatching was studied using regression analysis. Statistical analysis was performed using IBM SPSS Statistic-22 and regression analysis using Microsoft Excel 2013.

Results

Larval size, yolk reserves, and early growth

The eggs obtained from the pond-reared broodfish hatched about 32 h after fertilization, at 20 ± 1.0 °C. The newly-hatched silver perch larvae were transparent with a large yolk sac prolonging from the tip of the snout to about half of the ventrolateral of the body (Fig. 1) with an initial mean length of 1.35 ± 0.03 mm and a volume of 0.71 ± 0.07 mm^3. An oil globule (OG) of 0.64 ± 0.00 mm in diameter and 0.02 ± 0.00 mm^3 mean volume was present at the caudal tip of the yolk sac. The frontal part of the body was bent about the yolk sac and the border of finfold formed surrounded the body from the dorsal and ventral part of the body to the caudal part. The intestine was not fully formed, with anus and mouth sealed. Eye pigmentation was observed 12 h post-hatching (hph) and completed after 3 dph. The intestinal canal started formation at 2 dph, and a simple, straight, tubular gut was observed. Further development of the alimentary system was the formation of the intestinal loop at 3 dph and at the same time the lower jaw was completely formed.

At hatching, the silver perch larvae each measured 2.52 ± 0.05 mm in total length (TL). They grew to 4.12 ± 0.13 mm TL in about 96 h, by which time there was no more yolk sac left and about 45% of the oil globule remained (Fig. 2). After this stage, the TL growth subsequently slowed down and was significantly ($P < 0.05$) lower than the first 96-h period.

Yolk utilization rate

The yolk-sac utilization rates were much higher than the oil-globule exhaustion rate during the early life history of the silver perch larvae. Nearly 34 and 0.5% of the initial yolk sac and oil globule reserves, respectively, were utilized within 6 h. More than 50% of the silver perch larvae exhausted their yolk sac completely by the fourth day at 96 hph, whereas the oil globule traces (<1%) could still be seen up to 240 hph (Fig. 2). At the same time, the TL increased significantly ($P < 0.05$) as the SGR reached approximately 12% per day during the first 96 h, followed by a slow growth rate of 4.8% only from 96 to 240 hph.

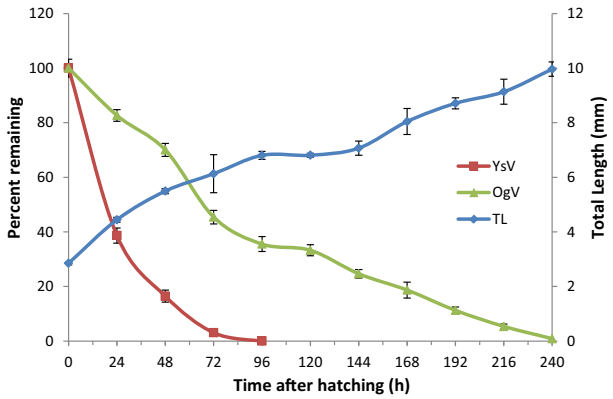

Fig. 2 Yolk sac volume (YsV) and oil globule volume (OgV) utilization and the total length (TL) development in relation to the time after hatching in hours (h) of the unfed silver perch, *Bidyanus bidyanus,* larvae. Data points are mean ± S.E. of 7–20 larvae per sample

Age at first feeding

Even before the yolk exhausted completely, the larvae of the silver perch have demonstrated a sign of food searching behaviour, comprising prey search, pursuit, and attempts to capture prey. The initial timing of first feeding was noticed at 5 dph. However, only about 5% of larvae could successfully initiate feeding instantly after the yolk sac was totally absorbed. The incidence of 100% of larvae feeding was observed at 6 dph; that is, one day after the yolk sac was fully absorbed. When silver perch larvae initiated first feeding, they already had functional mouths and active swimming behaviour, which indicated that most of the larvae needed some time to establish active feeding before and during the yolk exhaustion period. The symptoms of starvation of unfed larvae were observed at 5 dph.

Mortality

All silver perch larvae died no later than 240 hph. The daily cumulative mortality during the early life history of silver perch larvae increased with age (Fig. 3). The daily mortality rate underwent a rapid increase ($P < 0.05$) after the exhaustion of the yolk sac at 96 hph onward and 50% mortality was reached at 175 hph (Fig. 3). The correlation analysis between mortality and yolk sac-volume showed that mortality rate was significantly ($P < 0.05$) affected by the availability of the yolk sac.

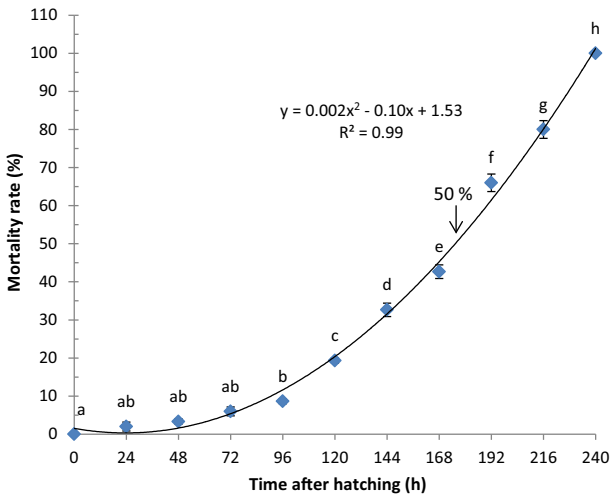

Fig. 3 The effect of starvation on mortality in silver perch, *Bidyanus bidyanus* larvae. Data points are mean ± S.E. of three replications. The *marker* with the same label indicates not significantly different ($P < 0.05$)

Discussion

Earlier research has shown that the silver perch would not spawn at a temperature below 24 °C in the natural environment and at a temperature below 23.3 °C under captive pond conditions (Lake 1967a). The domesticated broodfish of the silver perch does not spawn naturally under the Gingin (Western Australia) pond conditions in temperatures ranging between 11 and 34 °C. However, after a single injection of HCG, the domesticated broodfish in this experiment spawned at 21 °C. This is in the range of temperatures (21–24 °C) within which silver perch spawned in Israel (Levavi-Sivan 2004), which are both lower than the spawning temperature of 25 °C as reported by (Rowland 1984). Hence, no evidence of spawning deterioration was observed in this experiment. This may indicate that the domesticated silver perch could have adapted to spawn under different ranges of temperature after long time acclimation in pond conditions. This phenomenon has also been stated by Lam (1983) for the goldfish, *Cyprinus auratus*, where spawning temperature changed after acclimation to the new environmental condition.

Another interesting information here is the relationship between the incubation temperature and the hatching time (Table 1). The difference in incubation temperature did not make much different in hatching time. This may possible that the incubation period does not only depending on the temperature, but also depending on the broodstock and eggs quality (Mylonas et al. 2010). Therefore, the internal factor related to the eggs development stage at hatching may also affect the hatching time. On the other hand, the hCG injection before spawning may also contribute to influence the period of incubation. However, there is no detailed information to support this argument yet.

The measured TL of the newly-hatched larvae, egg's parameters and larvae morphometric of the domesticated silver perch were significantly lower than for the parameters derived from wild broodfish as reported by Lake (1967b), except for the OgD (Table 1). The reason may be due to differences in parent nutrition resulting in different biochemical composition of eggs. Eggs obtained from naturally foraging broodfish should contain a biochemical composition that is suitable for producing larger eggs and larvae with higher viability of

Table 1 Egg and larval development of silver perch, *Bidyanus bidyanus* from wild and domesticated broodfish

Factor	After Lake (1967b)	This experiment (mean ± S.E.)
Broodfish source	Wild	Domesticated
Broodfish size (kg)	0.7–3.2	1.5–3.5
Temperature at spawning (°C)	23.3	21
Nature of egg	Pelagic	Pelagic
The diameter of ova (mm): averages in parentheses	0.7–1.3 (1.2)^{b}	1.08 ± 0.01^{a} (n = 600)
The diameter of water-hardened egg (mm): averages in parentheses	2.75–2.80 (2.78)^{b}	2.17 ± 0.01^{a} (n = 600)
The diameter of yolk (mm): averages in parentheses	1.00–1.25 (1.14)^{b}	0.81 ± 0.01^{a} (n = 70)
Yolk length at hatch (mm)	–	1.35 ± 0.03 (n = 70)
Yolk volume at hatch (mm^3)	–	0.58 ± 0.06 (n = 70)
The diameter of oil globule (mm): averages in parentheses	0.45–0.59 (0.54)^{a}	0.62 ± 0.01^{b} (n = 70)
Oil globule volume at hatch (mm^3)	–	0.14 ± 0.01 (n = 70)
Number of oil globules and position in yolk sac (minor ones neglected)	1 Posterior	1 Posterior
Egg colour	Colourless	Colourless
Hatching time (h) and temperature range (°C) in parentheses	30–31 (26–27)	30–32 (21–22) (n = 3)
TL of larvae at hatching (mm): averages in parentheses	3.5–3.7 (3.6)^{b}	2.85 ± 0.06^{a} (n = 70)
Maximal larval TL attained on the yolk sac reserves (mm)	–	11.97
Maximal larval TL attained on the oil globule reserves (mm)	–	14.31
Time from hatching to attainment of maximal TL on yolk sac (h)	–	96
Time from hatching to attainment of maximal TL on oil globule (d)	–	10
Age at first feeding (days)	6	5
Age at free swimming (days)	5	4

Data in the same row having the same superscript letters ($^{a,\ b}$) indicate not significantly different at α level of 0.05

offspring (Kjørsvik et al. 1989). On the other hand, the biochemical composition of eggs resulting from domesticated broodfish can be altered through changes in diet (Bromage 1998; Kjørsvik et al. 1990; Sargent 1995). However, until now, the quality of eggs produced from domesticated silver perch has not been compared to those of wild broodfish. Regardless of the comparison with larvae resulting from wild broodfish, the observed TL in the current study (2.85 ± 0.06) is still comparable to the Japanese flounder, *Paralichthys olivaceus* (2.62 ± 0.03 mm) (Dou et al. 2002). However, it is smaller than the Thai pangas, *Pangasius sutchi,* which has a TL of 2.98–3.10 mm (Islam 2005), the rohu, *Labeo rohita,* which has a TL of 4.58 ± 0.04 mm, and singhi, *Heteropneustes fossilis,* which has a TL of 3.32 ± 0.054 mm (Mookerji and Rao 1999). Even though the initial size of a silver perch larva is smaller, its initial yolk sac volume is relatively larger in terms of the YsL-TL ratio (0.54) than for Thai pangas (0.42) (Islam 2005), illustrating that the larvae is better equipped, in terms of its endogenous reserve as an energy source, to challenge the possibility of delayed exogenous feeding. It also demonstrates that the increase in total length is a biologically important aspect of the yolk-sac larval stages (Peterson et al. 1996) as the TL is directly related to the mouth opening and the size of prey that the larvae are able to ingest (Klimogianni et al. 2011).

During the first 96 hph the TL increased significantly ($P < 0.05$) compared to the next 144 h, whereas at the same time, the yolk sac volume was reduced significantly ($P < 0.05$) due to their absorption. Conversely, the volume of the oil globule was not intensely absorbed. The oil globule consumption during the yolk-sac stage of the silver perch seems lower than the marine species common pandora, *Pagellus erythrinus*, reared at comparable temperature at 18–21 °C (Klimogianni 2004). A probable cause is a delay in oil globule adherence to the larval body (Klimogianni et al. 2011), which occurred mostly at 120–240 hph (Fig. 2). This is much later compared to another marine species, the sharp snout sea bream, *Diplodus puntazzo*, which occurred at 4–6 hph. This could be advantageous to silver perch larvae as they get the opportunity to utilize both endogenous yolk and exogenous food (termed as the 'mixed feeding period') (Chai et al. 2011) for a longer time (6 days). This is much longer than the Chinese sturgeon, *Acipenser sinensis,* whose mixed feeding period only lasts for 2 days (Chai et al. 2011). Larvae have to start their capability to feed on an exogenous diet during the time when both endogenous and exogenous sources of diet are available; if not, they will hurt from continuous food shortage (Blaxter and Hempel 1963). An extended period of the mixed-feeding time is advantageous for larvae to gather enough feeding skills to develop their exogenous feeding capability, to escape from food shortages, and hence increase their probability of survival rates.

Since the onset of feeding occurred at 5 dph and the yolk-sac stage of the silver perch larvae lasted after 10 dph, it indicates that the mixed feeding period occurs for 6 days (from 5 to 10 dph). Consequently, the existence of appropriate prey organisms at this stage is of particularly significance for their endurance and the recruitment achievement of the silver perch. The same pattern is demonstrated by the Chinese sturgeon, where exogenous food deprivation can be maintained for 7 days (Chai et al. 2011).

The yolk-utilization rate of the silver perch during the first 24 h was about 61%, which is faster compared to 40% for singhi, *Heteropneustes fossilis*, another freshwater fish with a nearly equal activity pattern, illustrated by the intermittent bursts of rapid movement followed by relatively longer periods of rest during the yolk-sac stage (Mookerji and Rao 1999). However, silver perch has a longer period of mixed feeding (6 days) compared to only 2 days for singhi.

Only about 5% larvae initiated feeding at 5 dph, when <5% of the initial yolk reserves (yolk-sac + oil globule) were remained, lower than for singhi where nearly 40% of the larvae initiate feeding when about 20% of the yolk sac reserves remained at about 26 °C. Furthermore, the rate of oil-globule utilization was slightly lower and about 33% still remained when the yolk sac totally disappeared at 5 dph. These trends were also observed by Mookerji and Rao (1999) in rohu and singhi. Exogenous feeding generally commences before the yolk is fully absorbed (Ghelichi et al. 2010; Gisbert et al. 2000, 2004; Haga et al. 2014; Islam 2005; Kailasam et al. 2007; Klimogianni et al. 2011; Mookerji and Rao 1999; Peña and Dumas 2005; Shan et al. 2008; Wang 2010; Yang 2007), as was also observed in the present study.

The size at first feeding of silver perch must be taken into account for successful rearing of larvae, with the use of suitable live feed or formulated diet. The temperature and level of activity are two important factors influencing the rate of depletion of yolk reserves in newly hatched larvae (Quantz 1985; Rana 1990; Wang et al. 1987). Since, in the current study, the temperature was set at a constant temperature, internal factors related to the natural activity of the silver perch larvae is the only main cause of yolk sac absorption. In an aquaculture context, however, the effect of temperature may be sufficiently relevant to regulate it under

controlled nursery conditions to allow larval yolk reserves to last longer by setting a lower rearing temperature (Bagarinao 1986).

In general, nearly all freshwater fish species are demersal spawners, providing their eggs and larvae with a relatively more hospitable and predictable environment. Consequently, relative to marine fishes, freshwater fishes are generally less fecund and produce larvae which, at hatching, are larger and suffer less pre-metamorphosis mortality (Houde 1974; Mookerji and Rao 1999). The mortality of unfed silver perch during the early life history of larvae was significantly affected by the availability of the yolk sac. After the exhaustion of the yolk sac, the larvae may suffer from a nutrient deficiency due to delayed first feeding, and result in significantly increased mortality at 5 dph onward, reaching 50% at 7 dph. This suggests that the availability of the oil globule alone cannot maintain a high survival rate until the end of the yolk-sac stage, but supports fish during the 'mixed feeding period'. At this phase, exogenous feedstuff would help to satisfy the nutritive necessities for larval growth.

In conclusion, at hatching, silver perch larvae from the captive broodfish measured around 2.5 mm in TL and had a large yolk sac which is completely resorbed at 90 hph, whereas the oil globule remained until 240 hph. Even if the onset of feeding occurred at 5 dph, 100% feeding occurred later, at 6 dph. This indicates that silver perch larvae have about 5 days (from 6 to 10 dph) to perform exogenous feeding before the endogenous deposits are totally absorbed. The unfed larvae experienced low mortality (<10%) during the first 96 hph, before it increased significantly (more than double) in the next 24 h. No larvae survived when initial feeding was delayed beyond 240 hph. In addition, although most of the egg and larva parameters of domesticated broodfish were inferior compared to the eggs and larvae produced from wild broodfish, their oil glubule was larger and therefore they may have better viabilty.

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