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Morphometric Traits as Efficient Indicators of Larval Stage-Specific Plasticity in Silver Pompano, *Trachinotus blochii* (Lacépède, 1801)

SILPA R.[1], ABUTHAGIR IBURAHIM S.[1], SURYA S.[2], KARANKUMAR RAMTEKE[1], DAYAL DEVADAS[1],
VINEETH P.[1] and ASHA T. LANDGE[1]*

[1]ICAR - Central Institute of Fisheries Education, Panch Marg, Off Yari Road, Mumbai - 400 061, Maharashtra, India
[2]Vizhinjam Regional Centre of ICAR - Central Marine Fisheries Research Institute, Vizhinjam - 695 001, Kerala, India

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Morphological development, allometric growth, and behaviour of hatchery-reared silver pompano,*Trachinotus blochii* were studied from hatching to metamorphosis (0-23 days post-hatch (dph). In view of larval identification, to surpass critical periods in culture practices a total of 230 larval specimens of hatchery reared silver pompano were collected. A total of five post-embryonic stages were identified based on differences in morphology namely; Yolk sac (0-3 dph), Pre flexion (4-10 dph), Flexion (11 dph), Post flexion (12 dph), Juvenile (13-23 dph). The length has progressively increased in each larval stage, ultimately reaching 24 mm by the end of metamorphosis. This study showed that the development of the eye, head, and body depth had slower growth than the fish growth in length. All the morphometric traits efficiently differentiated each larval stage due to differences in stage-specific plasticity. This morphometric, morphological, and allometric study in the larval stage of silver pompano will be a baseline data to strengthen the easy identification of larval stages, improve culture practices and supplement future studies on the species.

(***Key words:*** *Allometry, Metamorphosis, Plasticity, Silver pompano, Trachinotus blochii)*

The larval stages are having a critical period in the life of marine fish. The organism will develop the phenotype of an adult fish during this period, which includes the development of tissues and organs as well as the maturation of some of the most significant physiological processes (Mazurais *et al.*, 2011). Fish respond to environmental changes that are both predictable and unpredictable throughout their lifetimes (Mendoza-Barrera *et al.*, 2018). All these differences appear in the initial developmental stages and are considered as the consequences of modified environmental conditions and feeding habits (Khemis *et al.*, 2013). They may influence behavioural responses, morphological and skeletal traits, and physiological characteristics. During this stage, significant quantitative morphometric changes occur. The hatchery-reared larvae exhibit considerable difference in morphological changes and behaviour from the wild (Khemis *et al.*, 2013). Inadequate hatchery raising procedures will result in significant death rates, body deformities, and a slowdown in growth throughout the larval phases (Nowosad *et al.*, 2021).

Successful hatchery production of the species depends on the knowledge of its morphological development and allometric growth during the larval stage (Eagderi *et al.*, 2017). Furthermore, understanding the stage-specific plasticity of the larvae is crucial in developing culture practices and improving the survival and growth rate of the fish in captivity (Green and Fisher, 2004). Fisheries management and aquaculture both benefit from knowing the morphological development and growth trends of juvenile fish. Allometry, or the pattern of covariation between many phenotypic traits or either between morphological measurements, can depict the progression developmental record of an animal's growth trajectories, leading to morphological integration (Pélabon *et al.*, 2014). By changing environmental factors and feeding procedures, larval rearing techniques can be improved by identifying typical patterns and spotting developmental abnormalities.

The silver pompano, *Trachinotus blochii* also known as the Snub nose pompano, American pomfret, Buck-nosed trevally, or Snub-nosed dart, belongs to the order and family Carangidae. It is one of the most

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**Corresponding author:* E-mail: ashalandge@cife.edu.in often used high-value species for mariculture due to its faster growth rate, superior meat quality, and powerful market need (Nazar *et al.*, 2012). It is a euryhaline, pelagic, active-swimming, omnivorous fish with vital schooling behaviours and a broad range of salinity and temperature tolerance. Silver Pompano is only caught occasionally in the capture fisheries, and its supply is limited. So, the culture of the species is the only way to meet the commercial demand. *Trachinotus blochii*'s global aquaculture production increased from 52 tonnes in 2005 to 110194 tonnes in 2014 (FAO, 2016), emphasizing its importance as a prospective species for mariculture. After realising the cultural significance of pompano in Indian waters, the Mandapam regional centre of ICAR- Central Marine Fisheries Research Institute (CMFRI) began developing broodstock in 2008; the first successful breeding and seed production of the species were accomplished in 2011 (Nazar *et al.*, 2012). As an outcome, the silver pompano fishery is a successful enterprise in India's coastal regions.

As per the IUCN Red List, pompano is included in the Least Concern (LC) category (IUCN, 2021). The changing transformation patterns in the post-embryonic stages of marine fishes are very minimally reviewed, notably in India. Silver pompano shows a large scale of morphometric variations in the entire larval phase compared to the other species in Carangids. Though culture techniques and scientific studies concerning silver pompano have been popularised in India for over a decade, little is known about its larval phenology and morphometry. Vizhinjam Regional Centre of ICAR-CMFRI has determined that the survival rate of this species is less than 20%. This research would contribute to a better understanding of size-related adaptations as indications of early growth goals and knowledge of fish biology, taxonomy, behaviour, and ecology. Thus, data on the morphometric, morphological and allometric studies on the larvae will be a baseline data to strengthen the identification of larval stages, improve culture techniques and future studies on the species.

MATERIALS AND METHODS

Larvae used in the present study were obtained from induced breeding of domesticated brood stock of silver pompano held in the hatchery facility at Vizhinjam Regional centre of ICAR- CMFRI (Long: E. 76° 59'15", *Lat*: N. 8° 22' 30"). Human chorionic gonadotropin (HCG) was given to both male and female fish at a dose of 350 IU per kg body weight. Spawning started 36 to 48 hours following hormone therapy. The spawning occurred between the hours of late at night and early in the morning. The fertilized eggs float to the surface water and were scooped up with a 500 µm net.

The fertilized eggs produced by captive broodstock were quantified, and they were incubated in circular tanks with a capacity of 2 tonnes and a stocking density of 20 nos L^{-1}. Each tank was filled with dechlorinated sea water (salinity psu) and aerated to a volume of 1.5 tonnes. The stocked eggs were hatched between 13-18 hours after incubation, with 98% hatching rate. Aeration was supplied to the tanks with an increasing rate during the larval rearing. Green water was supplied to the tanks, and feeding began with enriched rotifers, shifted to enriched *Artemia nauplii*, and finally shifted to inert larval diets (Table 1).

Before feeding, the *Artemia nauplii* were enriched with algae for 22 hours compared to 12 hours for the rotifers. Each tank's salinity (measured using a portable refractometer), dissolved oxygen (DO) content (determined using Winkler's technique), and temperature (measured using a mercury thermometer) were recorded every five days. Water temperature, DO and salinity were maintained at 28°C, 4.5 mg L^{-1} and 35 ppt, respectively. Fish were under the natural photoperiod, and translucent FRP sheets were used to reduce the hatchery roof's luminescence by 70%.

Total of 10 specimens were randomly sampled from each culture on daily basis upto the end of metamorphosis period. Pro-phenoxy ethanol was used to anaesthetize the larvae before the study's procedures. Due to the fragile nature of the larvae during the early stages (0-5 dph), no anaesthetic was used to take images. Preliminary testing revealed that they responded aggressively to it, resulting in abrupt mortality and morphometry alterations, therefore quick overdoses were avoided. Photographs of various larval and juvenile stages were taken as needed. A Zeiss Axio Lab. A1 compound microscope with a ZEISS AxiocamERc 5s and ZEN 2 lite software was used to take pictures of the yolk-sac stage. Using a Leica S8APO stereo

***Table 1.** Analysis of impact of plant growth regulator on the growth, yield and quality of vegetables*

Sl. No.	DPH (Days Post Hatch)	Algae/plankton/ artificial feed	Frequency of feeding	% of Water exchange
1	0-2	Algae (*Nannochloropsis* sp, *Isochrysis* sp)	Once in a day	0%
2	3-13	Algae, Rotifer	2 times a day	20%
3	13-20	Algae, Enriched rotifer	2 times a day	70%
4	15-18	Formulated feed (0.2 mm)	3 hours interval	100%
5	19-25	Formulated diet (0.3 mm)	3 hours interval	100%

zoom microscope coupled to a camera (Leica DFC 290) and Leica application suite version 4.1.0 software, subsequent larval stages were captured. Using digital cameras, late larval stages and juveniles were captured (Nikon D7100 & Nikon D90). A linear combination of three programmes, tpsUtil V1.38 (Rohlf, 2006), tpsDig2 V2.1 (Rohlf, 2006) and PAST (Hammer *et al.*, 2001), were used to extract morphometric data from the photographs of each larval stage.

For this study, a total of 5 different developmental stages were identified according to Ahlstrom and Ball (1954) *i.e.*, Yolksac, preflexion, flexion, postflexion and juvenile. To extract the morphometric features, a total of 12 landmarks were employed up to the preflexion stage (Fig. 1A), followed by 16 landmarks for the flexion and juvenile phases (Fig. 1B). The characters are 1-12 Total length (TL), 1-7 Standard length (SL), 3-4 Eye diameter (ED), 10-11 Caudal peduncle depth (CPD), 1-19 Head length (HL), 6-8 Body depth (BD), 13-15 base of dorsal fin length (DF. BASE), 1-18 Pre pectoral length (PPL),

***Table 2.** Characters and its changes*

Characters	Yolk sac		Preflexion		Flexion		Postflexion		Juvenile	
	b value	p	b value	p	b value	p	b value	p	b value	p
SL	0.5152	0.0000*	0.738	0.000*	-0.3632	0.1139	0.6121	0.0540	0.8627	0.0000*
ED	0.0999	0.0000*	0.125	0.000*	0.1881	0.1490	0.7861	0.4279	0.4190	0.0000*
HW	0.1355	0.0005*	0.330	0.000*	0.4080	0.0046*	-0.0206	0.8515	0.4048	0.0000*
BD	0.3666	0.0332	0.242	0.000*	2.4566	0.0067*	0.0161	0.8804	0.1020	0.0000*
CPD	0.1484	0.6273	0.092	0.000*	1.2098	0.0109*	0.0218	0.8709	0.3942	0.0000*
PDL							0.1379	0.7000	0.5222	0.0000*
PAL							0.5576	0.2126	0.5222	0.0000*
PPL							1.0047	0.3060	0.5801	0.0000*
DF. BASE							0.4009	0.5557	0.0859	0.0000*
AF. BASE							0.0366	0.8309	0.2994	0.0000*

Note: b, the growth coefficient of different body segments during the larval stages of silver pompano, *Trachinotus blochii* (*P<0.01).

1-13 Pre dorsal length (PDL), 1-16 Pre anal length (PAL), 16-17 Base of anal fin length (AF. BASE) (Table 2).

Allometric growth was calculated as a power function of Ls using non-transformed data: $y = aL^b$; where y was the measured character, 'a' the intercept, and 'b' the growth coefficient (Fuiman, 1983). When isometric growth occurred, b =1; allometric growth was positive when b was >1, and negative when <1 (Vansnik *et al.*, 1997). Linear regressions were performed on the log transformed data according to logy = log a + blog x, using LS (full form) as independent variable (Choo and Liew, 2006). All the analysis were done in R (R Core Team, 2021). Linear regression was performed on log-transformed data following Fuiman (1983) and VanSnik *et al.* (1997). In the daytime, general observations were taken in the raising tanks to evaluate the behaviour and swimming ability of the larvae.

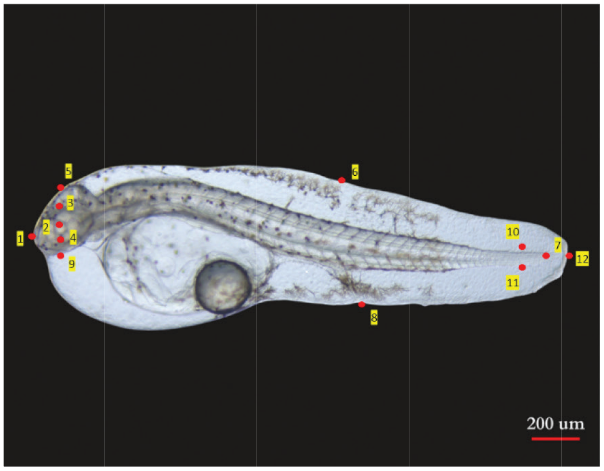


Fig. 1. A. *Image of Yolksac stage of T. blochii showing the 12 anatomical landmarks*

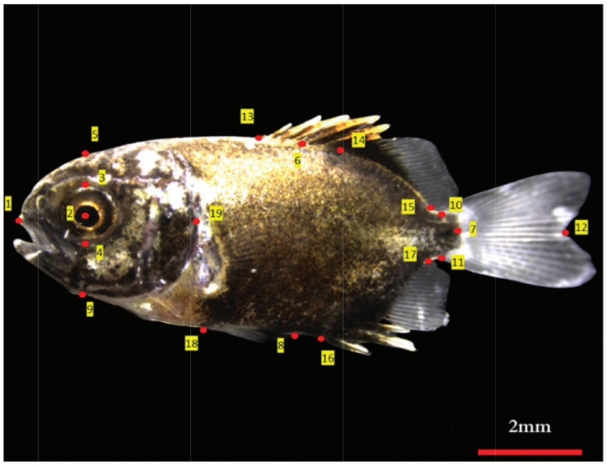


Fig. 1. B. *Image of juvenile stage of T. blochii showing the 19 anatomical landmarks.*

RESULTS AND DISCUSSION

Growth, behavior and morphology

Larval stages were categorized into five post-embryonic stages. They are Yolk sac (0-3 dph), Pre flexion (4-10 dph), Flexion (11 dph), Post flexion (12 dph), Juvenile (13-23 dph). The relation between total length and days post hatch in silver pompano from 0 dph to metamorphosis (23 dph) was observed. The growth pattern of silver pompano followed an exponential curve with moderate growth in the initial larval phase (Fig. 2).

When the eggs hatched, the larvae were dispersed throughout the whole tank's surface at the top of the water column. The freshly hatched larvae were distinguished by a twisted ventral head and a large yolk sac. As the characteristic for carangids, the larvae hatched with massive, elongate yolk sacs that stretched beyond the head and along the ventral area of the head and stomach. *Trachinotus blochii* had one oil globule at the yolk sac stage (Fig. 3a). The oil globule is transferred posteriorly to a location just anterior but ventral to the pectoral bases. When the yolksac expands as a result of its contents being absorbed; nevertheless, the globule still maintains its posterior position inside the yolksac. The location of the oil globule helps in the identification of the larvae. Examples of species having the oil globule in the yolksac's posterior region include hake and Pacific mackerel (Ahlstrom *et al.*,1954). The yolksac stage of *Trachurus trachurus*, in the family Carangidae shows oil globule in the anterior part of the yolk sac (Brownell, 1979). The overall length in yolksac stage (0-3 dph) ranges from 2.077 to 3.394 mm with a mean value of 2.757 ± 0.08 mm. The posterior region of the yolk

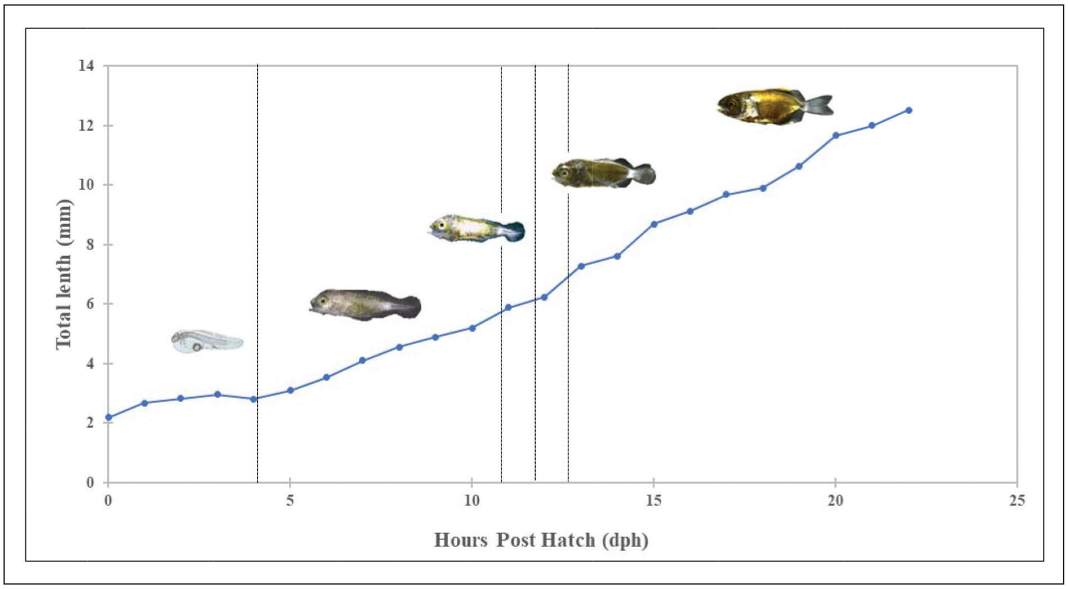


Fig. 2. *Growth in terms of total length of silver pompano, Trachinotus blochii from hatching until the juvenile stage*

sac develops an oil globule with a spherical form. The yolk sac covers 40% of the total length with a single oil globule at the posterior part and its volume get reduced on second day. Primary resorption began at 48 hours and continued until the globule was fully eliminated at three days post-hatch (dph), which coincided with the removal of the final endogenous food source (about 2 days). The findings of Nazar *et al.* (2012) shows that the resorption took place three to four days after hatching, were consistent with this outcome. This stage is characterized as planktonic, free-floating with feeble swimming movements. The mouth is not functional, and external feeding was not observed in this stage. The yolksac stage only lasts three days, which is a very short time. On the second day, the mouth begins to open, and it is distinguished by a single embryonic fin that extends from the cephalic to the caudal area. Eyes are reduced (0.1905 ± 0.01 mm) with less pigmentation. From 3 dph onwards, melanin pigmentation progressively begins on the head and upper portion of the body and spreads throughout the body as the larva grows. The head width of larvae increases throughout the course of development, reaching values of 0.2977 ± 0.02 mm at the end of yolk sac stage with a body depth of 0.7257 ± 0.07 mm. Yolk-sac larvae were translucent and lacked all significant organs and systems.

Prelarval stage development and differentiation were more intensive than yolk sac stage. These modifications required significant adaptations in how the growing fish interacted with its environment, which were seen in structural and morphometric changes. The larval buoyancy diminished as a result of the total absorption of yolksac, which caused them to migrate with the water column. The preflexion stage began with first feeding (3 dph) (2.80 mm TL) and ended in 10 dph (5.19 mm TL). The total length and standard length of the pre flexion stage has been increased with a mean value of 3.178 ± 0.12 mm and 3.178 ± 0.09 mm respectively. The yolk sac and oil globule were completely digested at the start of this stage. Even though the eyes developed pigmentation at 3 dph (0.357 ± 0.015 mm) and mouth opened by 2 dph exogenous feeding were not visible. At 4 dph, the eye's lens became visible, the mouth (0.2854 mm) and anus opened, and the lower jaw bones could be made out. In general, the mouth size of the larvae in *T. blochii*, which begin exogenous feeding four days after hatching, is 0.2854 mm, which is nearly the same as the mouth size (0.228 ± 0.0131 mm) seen in the exogenous feeding stage of the Indian pompano

Trachinotus mookalee (Ranjan *et al.*, 2018) and Florida pompano *Trachinotus carolinus* (0.266 ± 0.075 mm) (Hoff, 1978). Small folds around the mouth opening served as a distinction between the lower and upper lips. At 8 dph (4.56 mm TL), six pairs of opercular spines were visible and the head width have been noticed as 0.812 ± 0.039. Predation and malnutrition are the primary causes of larval mortality in the initial stages (Bailey and Houde,1989). Young fish have a higher chance of survival when they develop the morpho-functional systems required to avoid predators and find extra-terrestrial food sources. According to the current research, which supports the prior notion, the existence of six pairs of opercular spines was a defence mechanism that was evident in the preflexion phase starting at 8 dph (4.563 mm TL) and grew more pronounced at 12 dph. The longest of the six opercular spine measures about 0.7218 mm in length. Nazar *et al.* (2012) reported the formation of the 6 opercular spine begins at 12 dph in the larval development of *T. blochii.* In contrast to Nazar *et al.* (2012), we observed the presence of opercular spines beginning at 8 dph of the larval development. Jack Mackerel's (*Trachurus symmetricus*) top margin of the operculum developed two to three tiny spines at about 5 mm (Ahlstrom *et al.*,1954). Due to cannibalistic behaviour of the larvae, mortality rate was high during this period. The upward flexion of the notochord signalled the end of the preflexion stage, and the dorsal, pectoral, anal, and caudal fin folds started to differentiate but rays were not yet clear.

Flexion stage was observed in 11 dph with 5.88 ± 0.02 TL. Most of the larvae displayed the development of hypural bone together with the emergence of caudal fin rays from the start of this stage. The depth of caudal peduncle was noticed as 0.402 ± 0.032 mm in the flexion stage. The fin fold contracted in the caudal peduncle, and the first caudal fin rays appeared in the middle of the notochord tip. The caudal fin is where rays first develop, followed by the dorsal and ventral fins. According to Ahlstrom *et al.* (1954), the caudal fin is the first to lay down lepidotrichia (real rays or spines), which is found similarly in the case of *T. blochii.* The pectoral, anal, soft dorsal, spinous dorsal, and ventral fins follow in that sequence.

The post flexion stage observed in 12 dph (6.244 ± 0.020 mm TL). With coloration, the dorsal (2.053 ± 0.033 mm TL), anal (1.363 ± 0.008 mm TL), and pectoral fins began to form. Although larvae at this stage resemble juvenile morphologically, their caudal and dorsal fins are not fully grown.

Lastly, juvenile stage was observed from 13 dph (7.28 mm TL with a mean value of 9.719± 0.21 mm TL) till metamorphosis. From this point on, all the paired and single fins had fully developed. Fishes showed a circular movement around the walls of the tanks few days prior to metamorphosis. Larvae's swimming process was noticeably enhanced at the post-flexion and juvenile stages compared to hatchlings and prelarvae, and fish activity rose. This finding demonstrates that the development of unpaired fins, rapid length growth, and positive growth in tail depth all occur simultaneously with the improvement in fish swimming ability, enabling larvae to disperse actively over a large area and take advantage of the feed, hunt for food, and avoid predators. For avoiding predators, burst swimming may be advantageous; its speed relies on length (Blaxter, 1986).

The various alterations in *T. blochii*'s size and body composition were connected to the body's anterior and posterior regions as well as its swimming habits. For T. blochii, there are three distinct growth patterns that can be seen (Fig. 2), one from hatching to 3 dph (yolk sac stage), where a moderate growth is seen; a second stage is relatively long period, which extends from 4 -10 dph; where larval length increased up to 5.19 mm with a limit in the longitudinal growth of the larvae; and finally, from flexion to juvenile stage, with a smaller growth increment, which gave rise to metamorphosized individual in the 23 dph. The Maximum length of silver pompano measured at 23 dph is 12.915 mm which is almost similar to the observation of Nazar *et al.* (2012) *i.e.*,12.5mm. Ranjan *et al.* (2018) described that the newly hatched Indian pompano, *Trachinotus mookaleelarvae* measured 2.12 ± 0.02 mm in total length, and showed a fast growth allowing them to attain the metamorphosis by 17th day

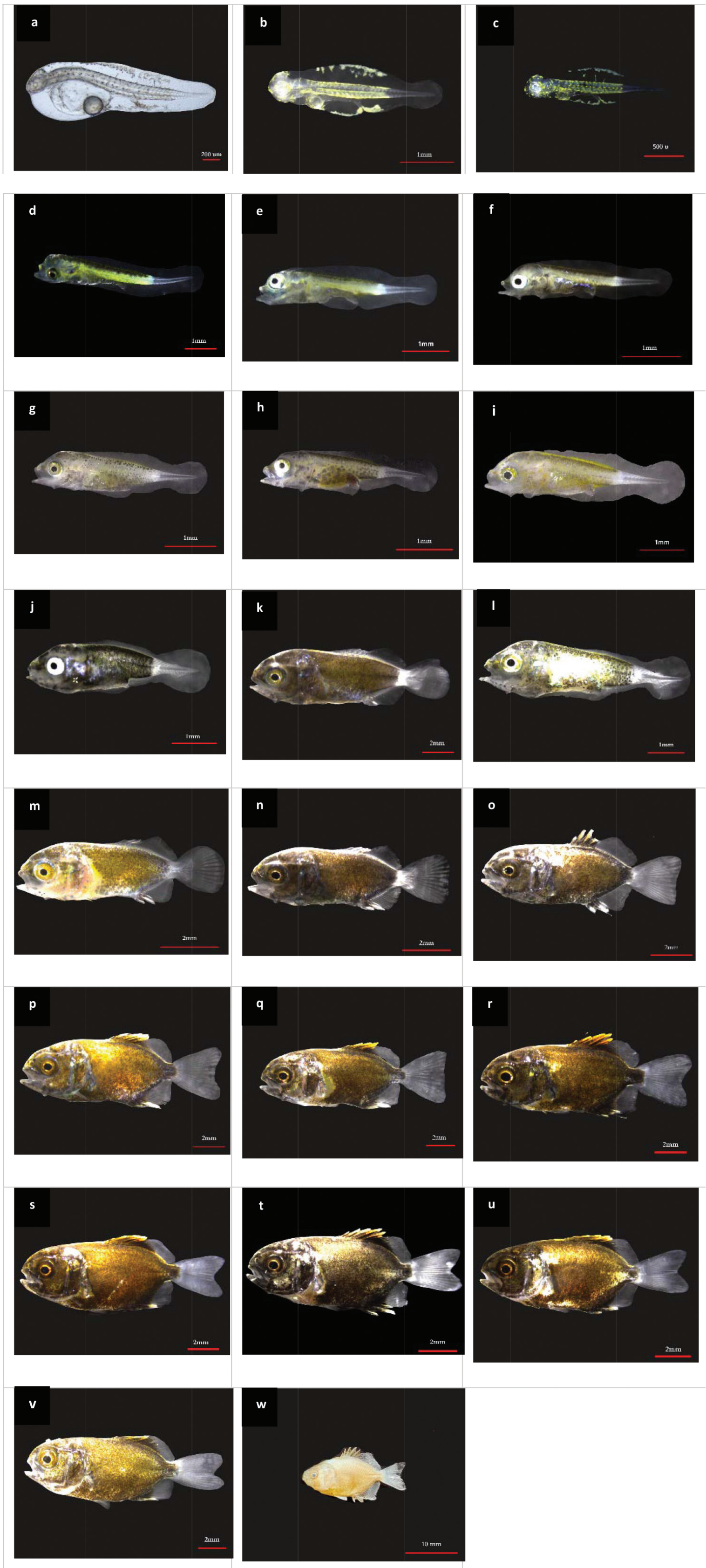


Fig. 3. *The early larval development of T. blochii. Shown are multiple individuals taken from the same batch of larvae. Scale bar as indicated in respective figures. (a) A newly hatched larva, (b)1 dph larva, (c) 2 dph larva, (d) 3 dph larva, (e) 4 dph larva; preflexion stage begins (f) 5 dph larva, (g) 6 dph larva, (h) 7 dph larva, (i) 8 dph larvae, (j) 9 dph larva, (k) 10 dph larva, (l)11 dph, larva showing flexion stage (m)12 dph; larva showing postflexion stage, (n)13 dph larva; juvenile stage begins, (o)14 dph larva, (p)15 dph larva; postflexion completed, (q)16 dph larva (r) 17 dph larva; in transition stage, (s)18 dph larva, (t)19 dph larva (u) 20 dph larva, (v) 21 dph larva, (w) 23 dph larva.*

with a total length of 27.33 ± 0.10 mm, whereas the larvae of freshly hatched silver pompano, *Trachinotus blochii* measured on average of 2.1823 mm and were slightly longer. In silver pompano, the acceleration in length was moderate till preflexion stage. Although the morphological and behavioural development of the larvae of *Sarda chiliensis lineolata* happened quickly throughout stages L1-L4, and found that their length only modestly increased. The primary cause of the fish's length decline was morphological changes, which are unavoidable during the larval stages of all fish species. In the early stages of larval development, moderate growth is related to the internal growth of mandibular and ocular features (Pepe-Victoriano *et al.*, 2021). It may possibly because the energy was used to improve eyesight, eat more efficiently, and swim more effectively (Aisa *et al.*, 2014).

3.2 Allometric growth

For the purpose of assessing the relationship between size and shape, linear regression analysis was carried out. Growth in total length (TL) from hatching to metamorphosis was correlated with age (dph) by a potential function. Measured body sizes and growth rates fluctuated during this time. Like other marine fish species, *T. blochii* exhibits fast growth during the larval stage. In order to develop the traits of an adult organism, it undergoes significant changes in its morphology, physiology, and functional systems (sensory, digestive, locomotor, and respiratory systems). In this study, we quantify that the development of the body's structural components namely, the depth of the body, the colour of the eyes, and the overall development of the head grow more slowly than the fishes' lengths. The various alterations in *T. blochii*'s size and body proportions were linked to variations in the formation of the anterior and posterior body regions as well as changes in swimming and eating behaviour.

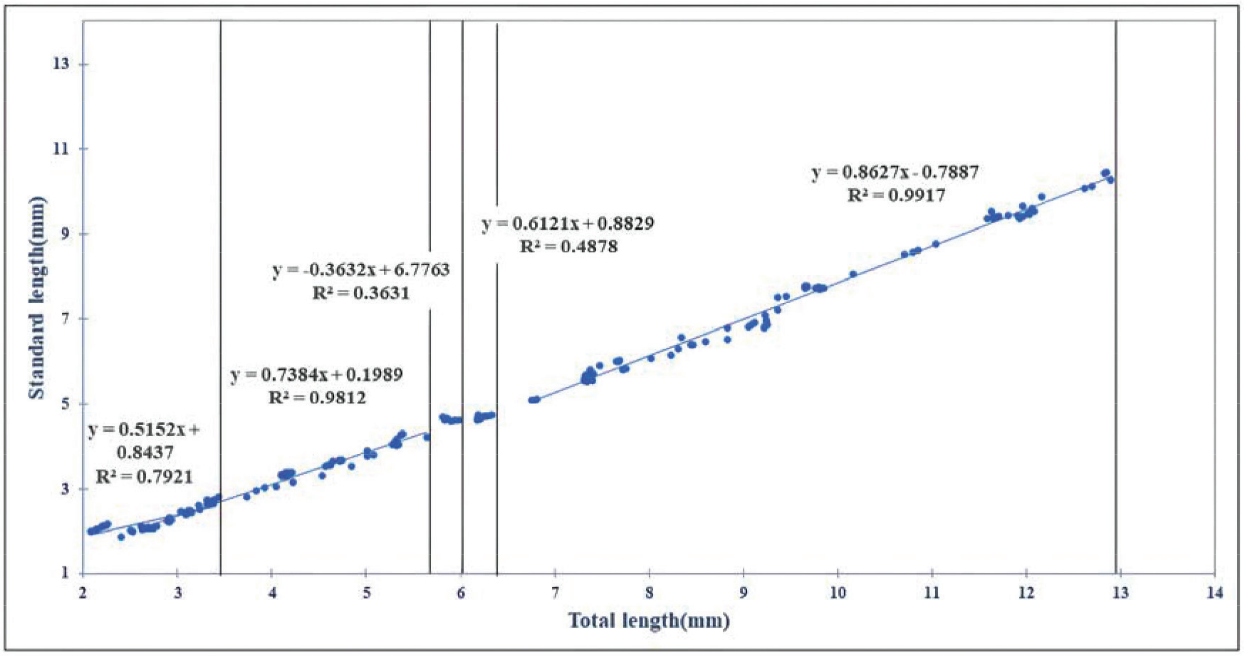
All the stages of larval development were examined for growth of standard length and total length. It displays (Fig. 4A) an allometric development pattern that is negative in the yolksac stage (b = 0.5152, P = 0.0001), preflexion (b = 0.7384, P = 0.0000), postflexion (b = 0.6121, P = 0.0540), and the juvenile stage (b = 0.8627, P = 0.0000). On the other hand, the flexion stage exhibits negative growth (b = -0.3632, P = 0.1139) for the same developmental stage (Fig. 4A). Negative allometric growth throughout the yolk sac stage concurrent with physiological modifications to optimise food uptake and meet expected feeding priorities. According to Khemis *et al.* (2013) negative allometric growth in the preflexion stage of larval development describes the enormous number of physiological changes that would be taking place, allowing an energy flow to these activities, and so limiting the larva's longitudinal expansion. Negative growth in the Standard length of the flexion stage (b = -0.363) coincides with the development of hypural bone, where upward flexion of the notochord was visible.

During the larval development process, the growth of head height and eye diameter was examined at stages 1, 2, 3, 4, and 5. The growth in head width follows a negative allometric growth from the yolk sac stage of larval development up to 23 dph; yolk sac (b = 0.13546), preflexion (b = 0.3304), flexion (b = 0.40801), postflexion (b = 0.7861) and juvenile stage (b = 0.404846). The eye diameter follows a negative allometric growth in the yolk sac (b = 0.0999), preflexion (b = 0.1247), flexion (b = 0.1881), and juvenile stage (b = 0.102) whereas postflexion shows a negative growth with a b value of -0.0206 (Fig.4B). The growth pattern of the mouth width coincided with the full transition to exogenous feeding. In the larval stages of *T. ovatus*, the mouth width showed positive allometric development, but the juvenile stage showed negative allometric growth (Yang *et al.*, 2017). The transition to exogenous feeding, which participates in the feeding activities, causes the olfactory, tactile, and gustatory sense systems to reach full development (Kasumyan & Kazhlayev, 1993). Because the larval transition to external nutrition once the yolk sac becomes exhausted, positive head development throughout the larval phase explains why they require a working food intake system (Vansnik *et al.*,1997). The prelarva hatches with a relatively undeveloped head, but it quickly grows in length to accommodate ingesting food particles of progressively larger sizes (Osse *et al.*, 1997). In the larval stages of *T. ovatus*, the head length exhibited positive allometric growth, and in the juvenile stage, head length showed isometric growth (Yang *et al.*,2017)

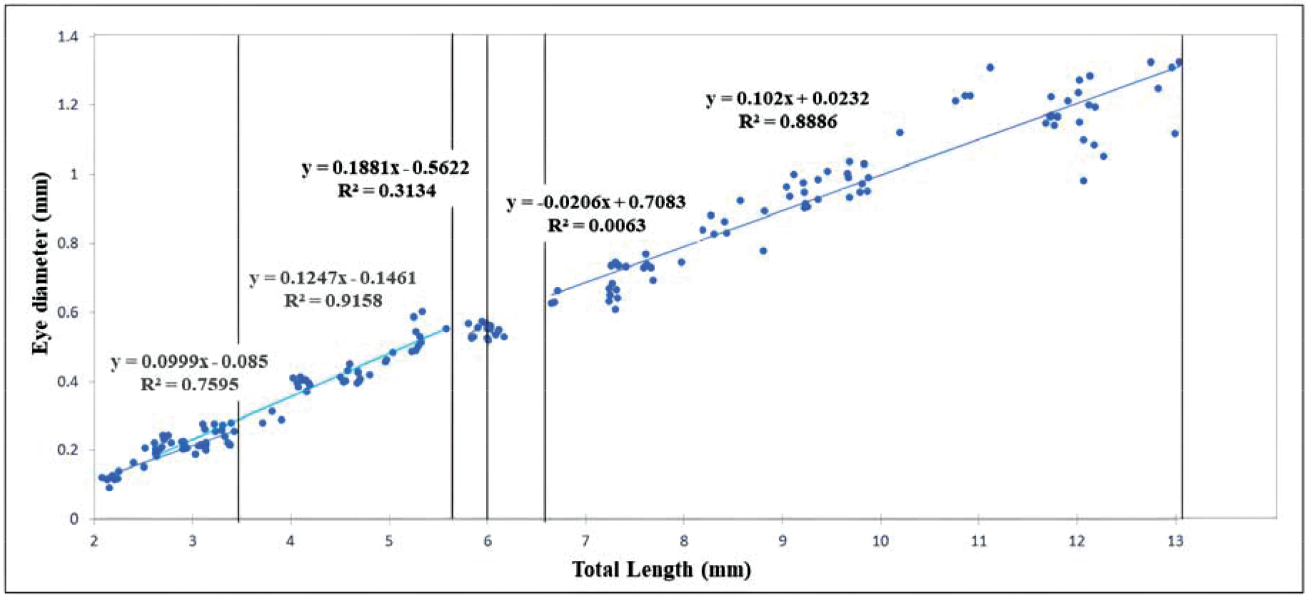
Growth analysis of body depth was performed for larval development stages 1, 2, 3, 4, and 5. For all the larval stages, the body depth presented a negative allometric growth rate of (b = 0.3666), (b = 0.24177), (b = 2.4566), (b = 0.0161), (b = 0.3942), respectively. Positive body depth in the preflexion stage is seems to be correlated with the development of the digestive tract (Yasunaga,1972). Body depth in the flexion stage showed positive allometric may reflect its priority for the development of the fins that is related to vital functions such as hydrodynamics and swimming ability.

The increase of caudal peduncle depth and total length was examined using the same phases of larval development as shown in the previous figures. The caudal peduncle depth displayed a negative allometric growth during larval stages 1, 2, 3, and 4, with a b value of 0.0601, 0.0918, 1.2098, 0.0218, and 0.0859 respectively (Fig.4E). The formation and differentiation of the hypural plate may be related to the positive allometric development of CPD in the flexion stage (Ortíz-Galindo *et al.*, 2000). The tail region length exhibited positive allometric growth in the larval stage of *T. ovatus* and in juvenile stage, it exhibited an isometric growth. Walker (2004) claims that these behaviours are frequently linked to the use of both caudal fin motions to provide impetus and enhance swimming.

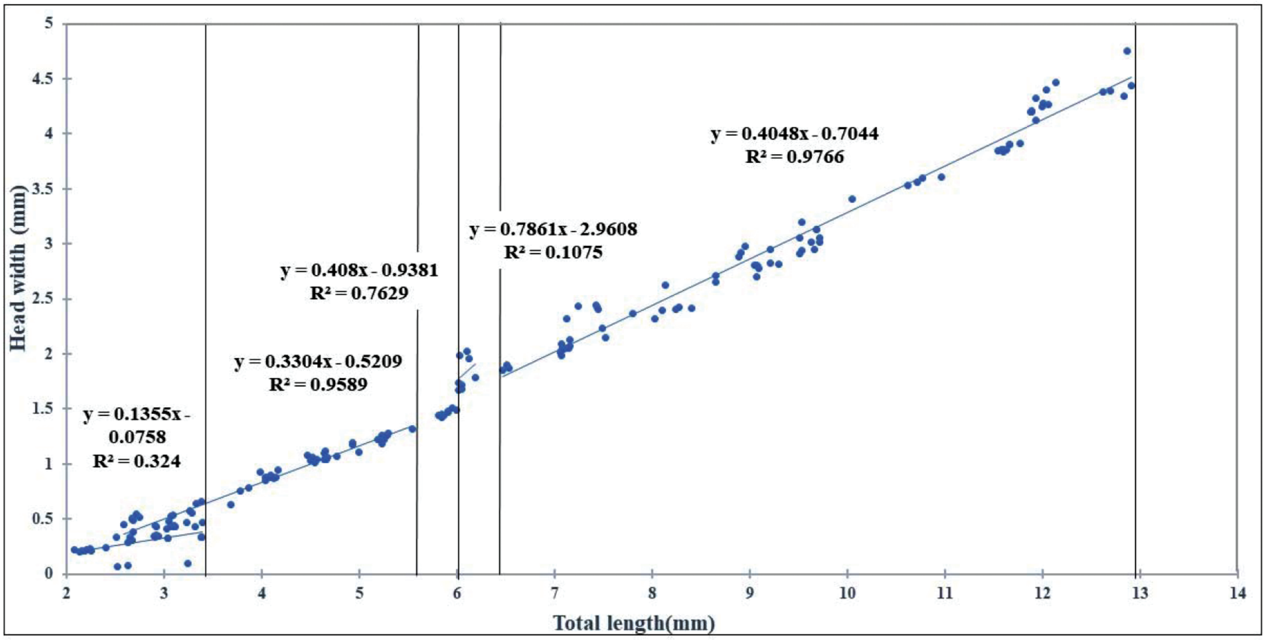
Pre-dorsal length of *T. blochii* larvae presented negative allometric growth (b = 0.1379) and (b = 0.52217) in relation to total length at postflexion and juvenile stages, respectively. Pre-anal fin length likewise showed negative allometric growth (b = 0.55 and b = 0.58). With a, b value of 1.005, pre pectoral length in post flexion exhibits positive allometric growth.



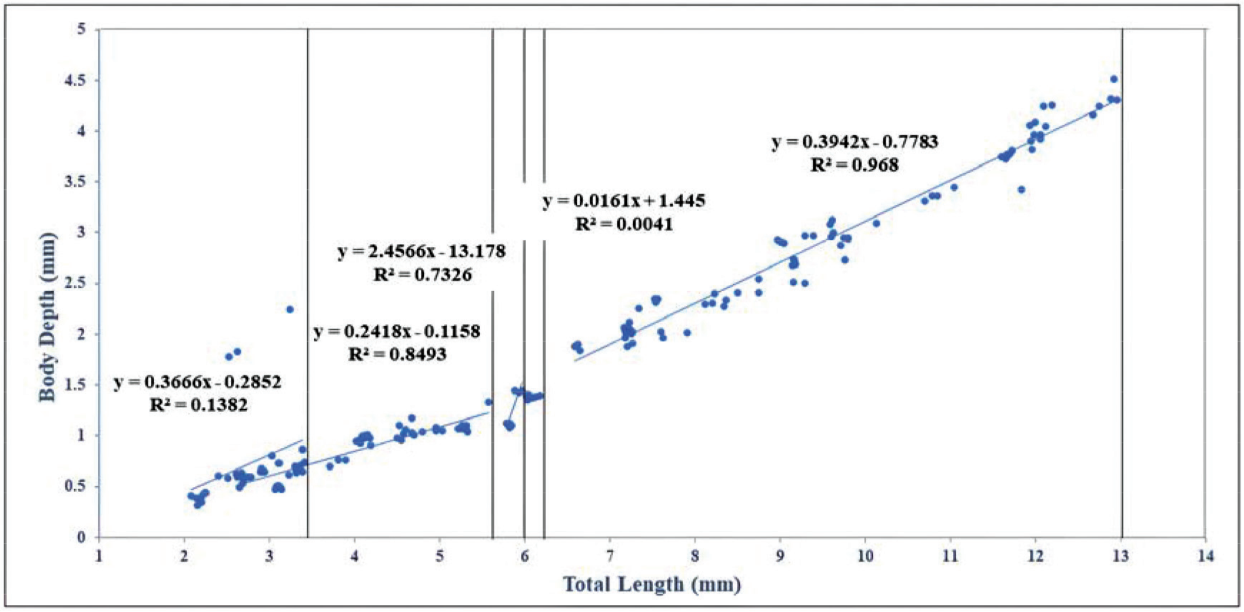
4. A


Eye diameter (mm)
Total Length (mm)
y = 0.0999x - 0.085
R² = 0.7595
y = 0.1247x - 0.1461
R² = 0.9158
y = 0.1881x - 0.5622
R² = 0.3134
y = -0.0206x + 0.7083
R² = 0.0063
y = 0.102x + 0.0232
R² = 0.8886
0
0.2
0.4
0.6
0.8
1
1.2
1.4
2
3
4
5
6
7
8
9
10
11
12
13

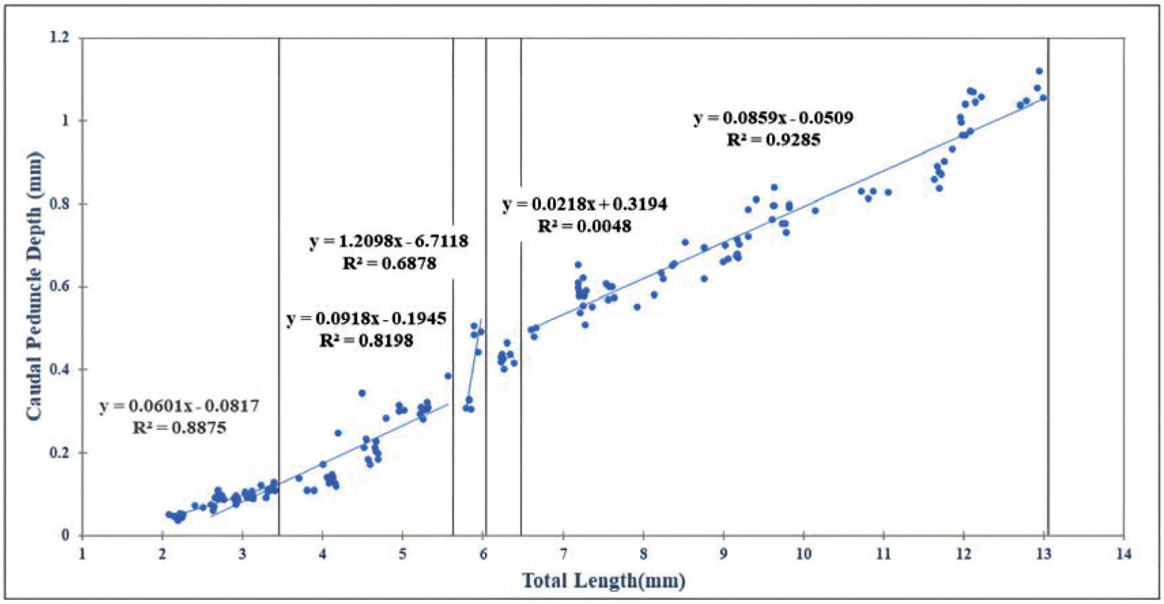
4. B


Head width (mm)
Total length(mm)
y = 0.1355x - 0.0758
R² = 0.324
y = 0.3304x - 0.5209
R² = 0.9589
y = 0.408x - 0.9381
R² = 0.7629
y = 0.7861x - 2.9608
R² = 0.1075
y = 0.4048x - 0.7044
R² = 0.9766
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
2
3
4
5
6
7
8
9
10
11
12
13
14

4. C



4. D



4. E

Fig. 4. *Allometric growth equations and relationships for different body regions selected for total length in silver pompano, T. blochii during development stages A (Yolksac), B (Preflexion), C (Flexion), D (Postflexion) and E (Juvenile)*

CONCLUSION

In conclusion, early growth and stage specific plasticity were associated with vital functions such as feeding, sensorial and breathing which appeared to be more critical during the first 23 dph (LS < 12.8 mm) in the larval stages of silver pompano and thus warrants more control in all possible culture parameters during this period. Study on descriptive morphology and stage specific morphological changes helps to unveil the critical period theory of larval survival. The allometry analysed between different morphological features can be used to describe the evolutionary developmental history of the animal's growth trajectories. From the study it is inferred that, silver pompano can be selected as a better model fish from the Carangid group to describe the evolution of phenotypic plasticity, when categorizing the stage specific allometric and non-allometric growth pattern. Hence, morphometric, morphological and allometric studies on the larvae will be a baseline data to strengthen identification of larval stages from natural waters, to improve culture techniques and future studies on the species.

Ethical statement

The animals used in the present study were treated in accordance with guidelines of the committee for the purpose of control and supervision of experiments on Animals (CPCSEA), Department of Animal Husbandry and Dairying, Ministry of Fisheries, Government of India for the care and use of animals.

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CONFLICTS OF INTEREST

The authors report no conflicts of interest.

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