Int. J. Aquat. Biol. (2022) 10(2): 78-91
ISSN: 2322-5270; P-ISSN: 2383-0956
Journal homepage: www.ij-aquaticbiology.com

Review Article

Review on biology and culture potential of *Notopterus notopterus* (Pallas, 1769)

Sandipan Gupta*[1], Archisman Ray[2]

[1]Department of Industrial Fish and Fisheries, Brahmananda Keshab Chandra College, West Bengal State University, Kolkata, India.
[2]Department of Fisheries, Utkal University, Bhubaneswar, Odisha, India.

Abstract: *Notopterus notopterus* (Pallas, 1769), popularly known as bronze featherback, is a commercially important table fish due to its high nutritional resources. It has also been considered as a potent candidate for the ornamental fish industry. It is a predominant species of tropical South-East Asia. Due to overexploitation, habitat destruction, pollution and other anthropogenic stresses, the population of this fish species are under threat and it has been categorized under lower risk near threatened and vulnerable categories in India and Bangladesh, respectively. Conservation of any fish species can be successfully done by a large-scale culture which ensures the supply as well as reduces the pressure on natural stock. The successful culture of a new candidate species needs proper knowledge on its feeding and reproductive biology. This review has been focused to consolidate the information on morphological characteristics, feeding and reproductive biology, and culture of bronze featherback and identifying the scope of future research to support its fishery and conservation.

Article history:
Received 2 February 2022
Accepted 24 April 2022
Available online 25 April 2022

Keywords:
Bronze featherback
Feeding habit
Reproductive biology
Culture
Conservation

Introduction

Notopterus notopterus (Pallas, 1769), commonly known as bronze featherback or Asian knife fish belongs to the family Notopteridae under the order Osteoglossiformes of superorder Osteoglossomorpha. It is a species of tropical South-East Asia (Yanwirsal et al., 2017). Its native range is India, Bangladesh, Pakistan, Nepal, Thailand, Malaysia, Vietnam, Laos, Philippines, Cambodia, Myanmar, and Indonesia (Day, 1878; Mirza, 1982; Rahman, 1989; Talwar and Jhingran, 1991; Roberts, 1992; Srivastava et al., 2012a; Ng, 2020). In India, it has been documented in Ganga, Brahmaputra, Mahanadi, Krishna, Godavari, and Cauvery (Talwar and Jhingran, 1991; Sugunan and Sinha, 2001; Jayaram, 2010). The species is reported to inhabit floodplains, stagnant backwaters, ponds, pools, and lakes but also can enter the brackish water of the river mouth (Day, 1878; Talwar and Jhingran, 1991; Rainboth, 1996; Kiran et al., 2004; Srivastava et al., 2010, 2012a; Yanwirsal et al., 2017; Heng et al., 2018). This species is also reported to be a member of "grayfish" guild, which generally takes short migration from the floodplain where it resides during the wet season for reproduction and feeding to the main river channel where it refuges in marginal vegetation or deeper parts of pools of the channel over the dry part of the season (Heng et al., 2018). It has been recognized as a significant freshwater fish resource due to its nutritional value and has been reported to contribute to the nutritional security of rural people in its native ranges (Haniffa et al., 2004; Kiran et al., 2004; Shillewar and Nanware, 2009; Srivastava et al., 2010, 2012a; Mustafa et al., 2014; Achakzai et al., 2015; Borah et al., 2015; Yanwirsal et al., 2017; Yulindra et al., 2017; Minh et al., 2019; Sukendi et al., 2020a, b). This fish species has been reported to be consumed both in fresh as well as in dried form (Parameswaran and Sinha, 1966; Borah et al., 2015; Chandio et al., 2016) and has high economic importance in South and Southeast Asian countries (Achakzai et al., 2015; Sukendi et al., 2020a, b). Its blending with broken white leg shrimp (*Litopenaeus vannamei*) to prepare dry fish sausage has also been reported (Minh et al., 2019). Recently it has been

*Correspondence: Sandipan Gupta
E-mail: sandipangupta2007@gmail.com

Figure 1. *Notopterus notopterus* (Pallas, 1769).

considered to have ornamental value and has been reported to have a good preference amongst the aquarium fish hobbyists (Gupta and Banerjee, 2008, 2012a, b, 2013, 2018) (Fig. 1).

The natural population of *N. notopterus* is declining due to monsoon delay, overexploitation, habitat destruction, pollution, and other anthropogenic pressures (Haniffa et al., 2004; Palaniswami and Manoharan, 2010; Yulindra et al., 2017). As per IUCN Red List of threatened species, it belongs to 'Least Concern' category (Ng, 2020), though in India and Bangladesh, it has been considered as 'Lower Risk Near Threatened' (CAMP, 1998) and vulnerable (IUCN Bangladesh, 2015), respectively. Thus, captive culture can be the best solution to continue its fishery and conserve the species in the wild (Sukendi et al., 2020a).

Successful culture of a new candidate species requires feeding and reproductive biology knowledge. Considering the nutritional and ornamental value of bronze featherback, substantial research has been conducted on its morphology, feeding, and reproductive biology, though works on its culture are meager. This review has been prepared to consolidate the existing information on its morphology, biology, and culture and to point out the scope of future research to support its conservation and fishery.

Morphological, morphometric and meristic characters: The body is oblong shaped and strongly compressed. The dorsal profile is a bit more convex than the abdominal part. The head is concave. The mouth is moderate and the maxilla extends up to the mid orbit of the eye. An external row of strongly curved teeth is present in either jaw, with an internal finer one. Several rows of fine teeth are also present on the vomer and palate; the tongue also bears 12-14 backwardly directed fine teeth. Scales are minute; those on the operculum are a bit larger. The lateral line is present, almost straight and complete. The dorsal fin is short and is inserted midway between the snout tip and the end of the caudal fin. The pectoral fin is moderate and extends just beyond the anal fin origin. The pelvic fin is rudimentary. The anal fin is very long and confluent posteriorly with a short caudal fin. Body-color silvery-white with numerous fine gray spots between the lateral line and the dorsal margin of the body. The dorsal side is blackish, and a yellow gloss can be observed on the head. The dorsal fin has a white tip and the anal fin has a black margin. Eyes are golden in color (Day, 1878; Mohsin, 1962; Hamza, 1980; Talwar and Jhingran, 1991; Shillewar, 2009). The morphometric and meristic characteristics of *N. notopterus* have been summarized in Table 1.

Growth pattern: Studying the age and growth using scales, Srivastava et al. (2013) have reported that in *N. notopterus,* the fastest growth occurs during the first year of life, which starts to decline from the second year the and beyond the fifth year of age, with very little difference in growth rate has been reported. There are different views regarding the growth pattern of wild populations of *N. notopterus,* summarized in Table 2.

Feeding habit: *Notopterus notopterus* is predominantly a carnivorous fish (Menon et al., 1959;

Table 1. Morphometric and meristic characters of *Notopterus notopterus.*

	Characters	Value
Morphometric characters	Ratio of Head Length (HL) and Caudal Fin Length (CFL)	5-5.5 (Day, 1878)
	Ratio of Body Depth (BD) to Total Length (TL)	3.5-4 (Day, 1878) 3.5-3.8 (Shillewar, 2009)
	Ratio of Body Depth (BD) to Standard Length (SL)	3.25 (Shillewar, 2009)
	Ratio of Eye Diameter (ED) and HL	4.5-5 (Day, 1878)
	Ratio of HL and TL	4.9 (Shillewar, 2009)
	Ratio of HL and SL	4.4-4.6 (Shillewar, 2009)
	Ratio of Snout Length (SnL) to HL	4.5-5 (Shillewar, 2009)
	Ratio of ED to HL	4.5-5 (Shillewar, 2009)
	Ratio of ED to SnL	1.0 (Shillewar, 2009)
	Ratio of Pre-dorsal length to SL	1.8 (Shillewar, 2009)
	Ratio of pectoral fin length to HL	1.3 (Shillewar, 2009)
	Ratio of pelvic fin length to HL	7.3-8.6 (Shillewar, 2009)
	Ratio of anal fin base length to TL	1.5 (Shillewar, 2009)
	Ratio of anal fin base length to SL	1.3 (Shillewar, 2009)
	Ratio of caudal fin length to TL	10.2 (Shillewar, 2009)
	Ratio of caudal fin length to SL	9.07 (Shillewar, 2009)
Meristic characters	Scales on lateral line	225 (Day, 1878)
	Fin formula D (Dorsal fin); P (Pectoral fin); V (Ventral/Pelvic fin); A (Anal fin); C (Caudal fin)	D 7-8; P 17; V 5-6; A 100-110; C 19 (Day, 1878) D 7-8; P 15-17; V 5-6; A 99-104 (Rahman, 1989) D 7-9; A + C 100-110; V 5-6 (Talwar and Jhingran, 1991)

Table 2. Growth patterns of *Notopterus notopterus* (wild population).

Authors	Growth Pattern of *N. Notopterus*			Locality
	Male	Female	Combined	
Parameswaran and Sinha (1966)	Isometric	Isometric	Isometric	Killa Fish Farm, Cuttack, Odisha, India
Hamza (1980)	Positive Allometric	Negative Allometric	-	West Bengal, India
Kalita and Rath (1996)	Isometric	-	-	Odisha, India
Khan (2003)	Negative Allometric	Negative Allometric	Negative Allometric	Tilaiya reservoir, Jharkhand, India
Kiran et al. (2004)	Positive Allometric	Negative Allometric	-	Jannapura pond, Karnataka, India
Shillewar (2009)	Negative Allometric	Positive Allometric	-	Godavari River, Maharashtra, India
Roy Choudhury (2009)	Isometric	Isometric	Isometric	East Kolkata Wetland, West Bengal, India
Isa et al. (2010)	-	-	Positive Allometric	Pedu Lake, Kedah, Malaysia
Naeem et al. (2010)	Negative Allometric	Positive Allometric	Negative Allometric	Indus River, southern Punjab, Pakistan
Sani et al. (2010)	-	-	Negative Allometric	Betwa and Gomti River, Uttar Pradesh, India
Kumar et al. (2014)	-	-	Negative Allometric	Gomti River, Uttar Pradesh, India
Achakzai et al. (2015)	Isometric	Isometric	Isometric	Manchar Lake, Sindh, Pakistan
Borah et al. (2015)	Isometric	Isometric	Isometric	Assam, India
Kaur and Rawal (2017)	-	-	Positive Allometric	Sukna Lake, Chandigarh, Punjab, India
Kaushik et al. (2019)	-	-	Isometric	Pokoriya River, Assam India

Mohsin, 1962; Das and Srivastava, 1979; Mustafa and Ahmed, 1979, Hamza, 1980; Yang, 1988; Hossain et al., 1990; Talwar and Jhingran, 1991; Shillewar and Nanware, 2009; Srivastava et al., 2012b; Borah et al., 2015; Chakrabarti and Ghosh, 2015; Khadse and Gadhikar, 2017; Khaing et al., 2020). Its obliquely placed and slightly upturned mouth, prominent lower jaw, a deep cleft reaching the outer rim of the orbit, presence of teeth on the vomer, palatine and pterygoid, widely set gill rackers, short alimentary canal, and

muscular sac like stomach support its carnivorous feeding habit (Srivastava et al., 2012b). Kiran and Waghray (1998) have reported a slightly different view regarding its feeding habit; they have documented this fish species as omnivorous with a tendency towards carnivory. Its benthic feeding habit has been concluded by Rainboth (1996) and Srivastava et al. (2012b), observing the presence of detritus and molluscan remains in the gut. Mohsin (1962) and Srivastava et al. (2012b) have detailed the morphological description of the alimentary canal of *N. notopterus*. The alimentary canal is short, muscular, bag-shaped, and less coiled. The oesophagus is a short, muscular tube; its posterior part forms a flask-shaped muscular stomach. The cardiac and pyloric parts of the stomach are narrow, while the middle part of the stomach is wide. The two finger-like pyloric caecae are present (Rahimullah, 1935, 1945; Khanna, 1961; Mohsin, 1962; Das and Nath, 1965). Pylorus leads to the intestine, which ends in the rectum. A distinct sphincter is present in between the intestine and rectum. Rectal caecum, some finger-like processes are present in the rectum. The liver is bi-lobed; the right lobe is larger than the left lobe. The gall bladder is elliptical, and a short bile duct that comes out from it opens into the intestine. Spleen is present beneath the stomach. The pancreas is a compact structure extended over the stomach's surface and the anterior part of the intestine. The exocrine pancreas contains basophilic zymogen cells that produce and store pancreatic enzymes supplied to the alimentary canal to properly digest protein-rich food (Chakrabarti and Ghosh, 2015). The stomach, esophagus, and rectal caecum have longitudinal folds internally, but these are transversely arranged in the pyloric caeca and intestine.

Mandal and Chakrabarti (1996) studied the architectural pattern of the mucosal epithelium of the alimentary canal of *N. notopterus*. The mucosal surface of the buccopharynx bears a low number of irregular and narrow mucosal folds, an adaptive feature for carnivorous fish like *N. notopterus* which feeds on comparatively large prey and requires good space for easy transmission of the food to the next part of the alimentary canal. The mucosa of the buccopharynx comprises oval, pentagonal, and hexagonal stratified epithelial cells provided with unbranched and concentrically arranged micro ridges; in between these micro ridges, narrow concavities are present, which store the little mucin to lubricate the food. The buccopharyngeal epithelium bears very prominent taste buds (Mohsin, 1962). The oesophageal mucosal surface bears spaced oval or rounded stratified epithelial cells with thick and linearly arranged micro ridges. In between micro ridges, broad and deep channels are present, which retain mucus for food lubrication and provide mechanical support to the mucosal villi during swallowing large prey items. The mucosal layer of the stomach is with numerous primary folds that combine to form deeper and rounded concavities. This complicated arrangement of mucosal folds allows high distension to hold the ingested food for further digestion. The gastric mucosal folds consist of oval or rounded columnar epithelial cells, which contain short and stubby microvilli; these microvilli contain a considerable amount of mucus that protects the subsurface cells from stomach acidity and mechanical injury. A good number of gastric pits are present in between epithelial cells. The mucosa folds in the distal part of pyloric caecae are interdigitated and fused to form a thick meshwork to increase the surface area of the caecal lining (Mohsin, 1962). The intestinal mucosa bears irregular wavy folds enclosing a zig-zag pattern of concavities in between them, allowing partial retention of partly digested food for further digestion and absorption. The columnar epithelial cells bear densely packed microvilli, which helps in enhanced absorption rate by increasing the surface area. The rectal mucosa is the reticulated arrangement of mucosal folds that increase the surface area for accommodating the undigested food.

Mookerjee and Mazumdar (1946) in their study from West Bengal, India, documented that the fry feed on protozoa and small crustaceans while the adults feed on fish, insect larvae, shrimps, worms, algae, and vegetable debris. Menon et al. (1959), in their study in Tamil Nadu, India have reported that in the young

stage, it is mainly entomophagous; feeds mainly on larvae and adults of Plecoptera, Ephemeroptera, *Ranatra*, and flea with a small amount of filamentous algae (*Osciallatoria* and *Spirogyra*) and mollusks (*Lymnaea* sp.); the adolescent and adult stages are primarily carnivore in nature; feed on small fishes (*Puntius* spp., *Esomus danricus* etc.) and crustaceans as its most preferred food items. Mohsin (1962) has reported that it mainly feeds on small fishes, frogs, and other aquatic animals. Parameswaran and Sinha (1966) have documented that the fry of *N. notopterus* feeds exclusively on plankton with a distinct preference for zooplankton; the most commonly encountered zooplankton reported are *Arcella*, *Brachionus*, *Moina*, *Bosmina*, *Diaptomus*, *Cyclops*, and *Cypris*; juveniles feed on plankton in addition to notonectids, insect larvae, and small shrimps; the adults mainly consume shrimps, insects, insect larvae and small fishes (*Amblypharyngodon mola*, *Puntius* sp. etc). David et al. (1969) have reported insects, fish and fish remains, digested organic matter, prawns, and plant tissues in its diet. Hamza (1980) has reported the presence of insects (nymphs, larvae, and adults of Coleoptera, Diptera, Ephemeroptera, Odonata and Hemiptera) and insect parts (mandibles, antennae, chelae, jaws, and compound eyes in semi-digested condition), semi-digested animal material, macrophytes (*Lemna*, *Azolla*, *Pistia*, *Wolffia*), algae (*Cymbella* sp., *Diatomella* sp., *Cyclotella* sp., *Campylodiscus* sp., *Nitzschia* sp., *Navicula* sp., *Gomphonema* sp., *Euglena* sp., *Phacus* sp.), crustacean, fish and fish scales, annelids, molluscs, sand and mud in the gut content of *N. notopterus*; insects and insect parts have been reported as the most preferred food item by him. Hossain et al. (1990) have reported maximum prevalence of crustacea and fishes in the gut content; they also have documented the presence of insects, debris and mud, plant parts, algae, protozoa, annelids, molluscs and semi-digested matter. Azadi et al. (1994), in their study at Kaptai reservoir, Bangladesh, have documented molluscs as their main food, followed by animal remains, fish, plant parts, insect larvae, insects, crustaceans, blue-green algae, fish scales, green algae, and diatoms. Rainboth (1996) has documented the presence of small fishes, crustaceans, insects and vegetable matters in its gut content. Kiran and Waghray (1998) in their study at Saroornagar Lake, Hyderabad, India reported the presence of insects, chironomids, fish, prawns, dragonfly nymph, nematodes, and aquatic weeds in the gut content of *N. notopterus* along with items like fish scales, rice husks, semi-digested gastropods, roots of aquatic weeds, appendages of crustaceans etc; aquatic insects have been reported as the most preferred food item and among the enlisted aquatic insects, hydrophillid beetles predominated over other food items. Shillewar (2009) reported the presence of leech, prawns, ants, water bugs, bivalves and fishes in the gut content of *N. notopterus*. Roy Choudhury (2009) has documented maximum preference for prawns in *N. notopterus*; she also has documented algae, gastropods, zooplankton, aquatic insects, fishes, debris in its gut content. Srivastava et al. (2012b) have documented that the diet of *N. notopterus* consists of shrimps, fishes, insects and their larvae, plant matter, organic detritus, fish scales and diatoms. Prawns (*Macrobrachium* sp.) have been reported as the main food item, followed by carp minnows and weed fishes (*Puntius* sp., *Amblypharyngodon mola*, *Esomus danricus*, *Ambassis* spp. and *Glossogobius giuris*), insect and insect larvae, plant matter and decayed organic matter; fish scales and diatoms have been reported as accidental food. Borah et al. (2015) reported maximum preference of molluscs in *N. notopterus* followed by crustaceans and insects; the accidental occurrence of debris and algae has also been reported. Burnawi and Pamungkas (2016) have reported the presence of fish, aquatic insects, detritus, worms etc., in its gut content while Heng et al. (2018) have documented insects, plants and fish as preferred food items for this fish species. Minh et al. (2019) have reported shrimps and aquatic insects as a favorite food for this fish species. Khaing et al. (2020) have reported fish, insects, crustaceans, and plant matter in the gut content of *N. notopterus*.

Seasonal fluctuation in feeding activity and euriphagism has been reported by Hamza (1980),

Hossain et al. (1990), Kiran and Waghray (1998), Shillewar (2009), Roy Choudhury (2009) and Srivastava et al. (2012b). Low feeding intensity in the winter months and during the breeding season has been documented. Euriphagism i.e. seasonal variation in diet composition has been reported due to the variation in the availability of prey items in the aquatic habitat.

Age-wise succession in the diet has been reported by Mookerjee and Mazumdar (1946), Menon et al. (1959), Parameswaran and Sinha (1966) and Srivastava et al. (2012b). The fry are exclusively plankton feeders; young fishes prefer prawns and insects and the older fishes have been reported to prefer large food items like fish. Srivastava et al. (2012b) have concluded that fry are surface feeders while young and adults can explore all the strata of the aquatic habitat to get the food of their choice.

Reproductive biology

Identification of sex: Sexes of *N. notopterus* can be distinguished by the shape of the genital papillae. In males, the genital papilla is conical, more pointed and tipped with a reddish color and longer than the rudimentary pelvic fin while in females, the genital papilla is broader, less pointed, whitish in color, and shorter than the pelvic fin (Mookerjee and Mazumdar, 1946; Weitkamp, 2005).

Gonad maturity stages and ova diameter: In *N. notopterus*, the gonad is easily visible in females in respect to males (Mookerjee and Mazumdar, 1946). Hamza (1980) has studied the gonad morphology and maturity stages in detail. In the male, the testis is present unilaterally on the left side of the body and ventrally to the swim bladder; and attached to the wall of the abdominal cavity by the mesorchium. It is triangular in shape and the posterior portion of the testis is slightly thicker as compared to the anterior portion. During the stage of maturation, the testis becomes translucent while during the spawning season it becomes creamy-white with a pinkish tinge. The ovary is single lobed, laterally compressed, and situated ventrally beneath the swim-bladder, on the left side of the alimentary canal, attached to the body wall and enclosed in a mesovarium. The oviduct is short and runs dorsally on the left side of the ovary. With maturation, the color of the ovary changes from light yellow to pink or golden as the fish prepares itself for spawning. The mature ovary is compact, pale golden yellow in color and occupies the maximum part of the body cavity. Hamza (1980) has documented seven gonad maturity stages in this fish species, which has been summarized with their characteristic features in Table 3. Hamza (1980) and Azadi et al. (1995) have classified ova in six different stages as per their diameter. Hamza (1980) have documented mean ova diameter of 0.80, 1.15, 1.85, 2.15, 2.50 and 2.60 mm for stage I, II, III, IV, V and VI, respectively while Azadi et al. (1995) have documented 0.69, 1.069, 1.724, 1.965, 2.069 and 2.414 mm for the same.

Size and age at first maturity: Early maturation of females than males have been reported by most of the earlier workers (Hamza, 1980; Azadi et al., 1995). Hamza (1980) has documented 238 mm and 242 mm as length at first maturity for female and male respectively while 189 mm and 195 mm has been reported by Azadi et al. (1995) for the same. A different view has been put forward by Gustomi et al. (2016) who have reported the early maturation of males (135 mm) than females (162 mm). Parameswaran and Sinha (1966), Satish and Kulkarni (2014a) and Borah et al. (2015) have reported that *N. notopterus* matures in the first year of its life while Hamza (1980) has reported that it matures in the second year.

Gonado Somatic Index and breeding periodicity: Based on the earlier researches (Parameswaran and Sinha, 1966; Roy Choudhury, 2009; Borah et al., 2015; Chandio et al., 2016; Gustomi et al., 2016; Rizki et al., 2017), it has been observed that Gonado Somatic Indices of male range 0.06-4.1% and female 0.05-8.25%. *Notopterus notopterus* is a monsoon breeder (Parameswaran and Sinha, 1966; Mustafa and Ahmed, 1979; Azadi et al., 1995; Haniffa et al., 2004; Srivastava et al., 2012a). Mookerjee and Mazumdar (1946) have reported May-July as its breeding season while Menon et al. (1959) have documented that it breeds between June-October in Tamil Nadu, India.

Table 3. Detailed stages of Gonadal maturity in *Notopterus notopterus* (Hamza, 1980).

Maturity Stage	Male	Female
Stage I (Immature)	Testes thin, transparent, grey in color, small compact mass, and hardly distinguishable from the ovary.	Ovary transparent, thin, compact mass, somewhat grayish in color. Ova are minute, microscopic, spherical and remain in clusters.
Stage II (Developing)	Testes slightly thicker than the previous stage, compact and grayish-white in color.	Ovary translucent, thick and granular in appearance to the naked eyes. Ova increased in size, semi-opaque and pale yellow in color.
Stage III (Maturing I)	Testes thicker than the previous stage, triangular in shape, and pale cream in color.	Ovary increases in weight and length, becomes triangular, opaque. Ova are distinguishable by the naked eyes, creamy pale whitish in color due to the appearance of minute yolk granules.
Stage IV (Maturing II)	Testes thicker, creamy in color, and with further increase in weight.	Ovary thickens further, prominently granulated mass and pale yellow in color. Ova moderately large, different in size, spherical to globular, densely packed, yellowish in color and easily visible to naked eyes.
Stage V (Mature)	Testes white creamy in color and soft firm in texture, weighing more than the previous stage, milt comes out on slight pressure on the testis over abdomen.	Ovary lobulated and prominently granulated. Ova of different sizes, more transparent round eggs mixed with opaque ones, golden yellow in color.
Stage VI (Spawning)	Testes fully extended, firm in texture and rosy in color. Milt comes out on putting pressure on abdomen.	General appearance same as earlier stage, but ovary is slightly softer in touch and yellowish to pale brown in color. Ova transparent, yellowish in color, ready to be shed.
Stage VII (Spent)	Testes not yet entirely empty, shrunken in size, creamy white in color.	Ovaries are reduced in size, few left over ova which are yellowish in color can be observed.

Parameswaran and Sinha (1966) have reported late May to July as its breeding season in Odisha, India. It has been reported to breed during June-August at Kaptai reservoir, Bangladesh (Azadi et al., 1995) while Shafi and Quddus (1982) have reported its spawning period of May to July in some parts of Bangladesh. Hamza (1980) in his work at West Bengal, India has documented that in *N. notopterus* breeding season starts in April and continues till August and the peak breeding activity can be observed during June-July. Shillewar (2009) has documented its breeding season from June-October at Godavari River, Nanded, Maharashtra, India. Borah et al. (2015) have reported April to July as its breeding season with spawning peak during May-June at Assam, India. Spawning period of June-August with peak spawning in July has been reported by Chandio et al. (2016) in Pakistan. Gustomi et al. (2016) have reported February-July as the breeding season for this fish species in Simpur dam, Indonesia.

Due to the presence of various developmental stages of oocytes in the ovary, *N. notopterus* has been reported as a fractional spawner (Azadi et al., 1995; Weitkamp, 2005; Srivastava et al., 2012a; Yanwirsal et al., 2017) though Parameswaran and Sinha (1966) and Borah et al. (2015) have reported that it spawns only once during the breeding season. *Notopterus notopterus* has further been reported as a substrate spawner (Mookerjee and Mazumdar, 1946; Pinxteren, 1974; Friese, 1980; Axelrod and Burgess, 1981; Sathish and Kulkarni, 2014a; Yanwirsal et al., 2017).

Fecundity: *Notopterus notopterus* has been described as a low fecund fish (Parameswaran and Sinha, 1966; Hamza, 1980; Azadi et al., 1995; Kalita and Rath, 2000; Shillewar, 2009; Srivastava et al., 2012c; Chandio et al., 2016). Low fecund fishes used to show parental care towards their progeny to enhance the survivability and to compensate for the ova paucity that has also been reported in this fish species (Southwell and Prashad, 1919; Mookerjee and Mazumdar, 1946; Friese, 1980, Axelrod and Burgess, 1981; Shafi and Quddus, 1982; Kottelat et al., 1993; Yanwirsal et al., 2017). In India, earlier researchers have documented a fecundity range of 175-4,493 for this fish species. The reported fecundity ranges are as follow: 200-1,000 (Menon et al., 1959), 175-1,188 (Parameswaran and Sinha, 1966), 175-1,875 (Hamza, 1980), 200-600 (Patil and Kulkarni, 1996), 102-1,646 (Kalita and Rath, 2000), 127-360 (Shillewar, 2009), 192-612 (Roy Choudhury, 2009), 151-1,392

(Srivastava et al., 2012c) and 340-4,493 (Borah et al., 2015). In Bangladesh, a fecundity range of 53-748 has been reported by Azadi et al. (1995). Jantrachit and Nuangsit (2008) have documented a fecundity range of 246-989 from Bung Lahan Chaiyaphum Province, Thailand. Gustomi et al. (2016) have documented a fecundity range of 1,051-6,057 while Rizki et al. (2017) have reported a fecundity range of 1,630-5,526 in their study in Indonesia. Chandio et al. (2016) in their study at Keenjhar Lake, Pakistan documented a fecundity range of 105-1,500.

A significant linear relationship of fecundity with total length, total weight, ovary weight, ovary length, ova diameter, and age has been reported (Parameswaran and Sinha, 1966; Hamza, 1980; Bhuiyan and Islam, 1991; Azadi et al., 1995; Patil and Kulkarni, 1996; Kalita and Rath, 2000; Shillewar, 2009; Srivastava et al., 2012c; Borah et al., 2015; Chandio et al., 2016; Rizki et al., 2017).

Sex ratio: Conflicting information is available on the sex ratio in the natural environment; male dominance has been reported by Azadi et al. (1995) and Shillewar (2009), female dominance has been documented by Kiran and Puttaiah (2006) while the presence of both the sexes in equal proportion has been documented by Parameswaran and Sinha (1966), Hamza (1980), Sathish and Kulkarni (2014b), Gustomi et al. (2016) and Rizki et al. (2017).

Courtship and spawning: This species has been reported to initiate its courtship and spawning activities during the daytime in the presence of an ambient temperature range of 26-28°C (Friese, 1980; Yanwirsal et al., 2017). These acts have been reported to last for about seven days (Friese, 1980). The eggs are large, round, opaque, and devoid of oil globules (Mookerjee and Mazumdar, 1946; Pinxteren, 1974; Axelrod and Burgess, 1981; Azadi et al., 1995; Yanwirsal et al., 2017); they are also of sticky in nature and remain attached to the substrate (Friese, 1980; Axelrod and Burgess, 1981; Borah et al., 2015). The number of eggs per spawning is less in comparison to other Notopteridae. Axelrod and Burgess (1981) have reported a range of 30-100 per spawning, while Yanwirsal et al. (2017) have documented a range of 15-225 for the same.

Captive breeding and culture: The first report of the natural propagation of *N. notopterus* in captivity has been reported by Haniffa et al. (2004); they have suggested a stocking density of two brooders/m^3 area for natural spawning to occur. Later Sukendi et al. (2020b) tried to standardize the culture of *N. notopterus* in cages. They have recommended a stocking density of 5 fishes/m^3 and a supply of trash fish thrice a day as feed to achieve maximum production in a 60 days culture duration.

Hamza (1980) was the first to test the potential of *N. notopterus* for captive breeding using both homoplastic and heteroplastic pituitary injection @ 6 mg/kg of body weight for both the sexes (sex ratio male: female = 2:1) for breeding in captivity. The injection has been applied to both sexes in equal split doses and as a single large dose for females and males. Maximum fertilization rate (90%) has been reported in three cases; homoplastic injection in two equal split doses, heteroplastic injection in two equal doses, and heteroplastic injection in a single large dose. After a long gap of about 30 years, Srivastava et al. (2010) tried to breed *N. notopterus* in captivity using the synthetic hormone ovaprim. In their experiment; they applied the intramuscular injection of ovaprim to both the sexes (sex ratio male: female = 2:1) @ 0.5 ml and 1.0 ml/kg of body weight and achieved 85-94% hatching rate and 80-85% hatchling survival, though they did not specify the most suitable dose among the two applied doses. Yulindra et al. (2017) have further studied captive breeding using ovaprim and have suggested the efficiency of a dose of 1.5 ml/kg of body weight in respect to ovulation, egg production, egg diameter and maturity and rate of fertilization.

Yanwirsal et al. (2017) bred *N. notopterus* in aquarium tanks by supplying proper nutritional diets to the brooders. In their experiment, the brooders were acclimatized in confined condition for 2-6 months and were fed once a day with sliced beef heart and/or frozen chironomids. After the acclimatization period, the formed pair spawned. After the larvae started to take exogenous feed, they were supplied with fresh, newly hatched *Artemia* nauplii for the first seven days

and from the 8th day, older *Artemia* nauplii and small pieces of *Tubifex* were supplied. After attaining three months of age, the juvenile fishes were fed additionally with small pieces of beef heart twice a week or alternatively with a mixture of fish, shrimp, sliced meat, and paprika bound by gelatin.

Conclusions

Although there is a dearth of knowledge on its culture, the present review report depicts the availability of sufficient information on morphological characters, food and feeding habit, and reproductive biology of *N. notopterus*. Earlier studies have concluded that *N. notopterus* primarily is a carnivorous fish. Studies on mouth morphology, morphology of the alimentary canal and architectural pattern of the mucosal epithelium of the alimentary canal have further confirmed the earlier conclusion. The efficiency of the young and adult stages to explore all the strata of the aquatic habitat for capturing the prey items as well as their wide range of prey preferences have strengthened the choice of *N. notopterus* as a potential new candidate species for culture. Meanwhile, the early life stages of any fish require a nutritionally balanced diet to enhance the growth rate and reduce mortality. Though earlier researchers have reported the planktivorous nature of *N. notopterus* fry, no reports are available on formulation of nutritionally enriched micro-diets for the early life stages of this fish species. Study on digestive enzyme profile and extracellular enzyme-producing bacteria of alimentary canal are some modern methodologies that can be used to confirm the feeding habit of early life stages and as per that further study can be conducted to formulate an age-specific balanced nutritional diet. On the other hand, lack of knowledge is there on sex specific feeding and digestion of the brooders. Proper knowledge of the nutritional requirements of the brooders can improve their health status which in turn can improve the quality of seed produced. Thus in coming day research can be conducted to collect this information to strengthen the culture of this fish species.

There are contradictory views present regarding the sex-wise and overall growth pattern of this fish species. This difference in the views may be due to the combination of several factors like seasonal effect, variation in habitat, the difference in the number of specimens studied, maturity stages, sex, degree of stomach fullness, health status of the studied specimens, the difference in catch techniques etc. (Tesch, 1971; Weatherly and Gill, 1987; Wooten, 1998; Li et al., 2014).

Variation in size and age at first maturity has also been reported for this fish species. As maturation is directly related to the length and age of the fish (Hunter et al., 2015); differences in growth rate may have some impact on variation in size and age at first maturity. Long-term changes in environmental variables such as temperature and food availability may impact the growth rate (Jorgensen, 1992) and in turn may result in variation in maturity size and age (Heino et al., 2002). The role of environmental conditions in inducing phenotypic flexibility may also impact size and age at first maturity (Ishida et al., 1993; Cox et al., 1997; Wertheimer et al., 2004). Thus, further research is needed to identify the specific reasons behind the variation in size and age at first maturity in this fish species.

Though ample information is available on different aspects of the reproductive biology of *N. notopterus*; the captive culture of this fish species has not been standardized so far. The reasons behind this are lack of availability of seeds in the natural habitat as well as lack of knowledge on a suitable dose of inducing agents and captive rearing of early life stages. Earlier researchers who worked on induced breeding of *N. notopterus* only tried to standardize the dose of pituitary and synthetic hormone injection, but still induced breeding of this fish species is at the experimental trials. Yanwirsal et al. (2017) who tried to move further with the rearing of early life stages and juveniles in captivity, reported only the different types of feed supplied to these stages, but they have not documented the suitability of these feed in the improvement of growth rate, disease resistance and survivability. Thus future research to standardize the dose of inducing agents, the stocking density to rear

the different life stages in captivity and information on a suitable nutritionally balanced diet to improve the growth and survivability of the early life stages are needed. In addition to that knowledge on disease infestation, prophylactic and treatment measures are very essential for culturing any fish species in captivity; but so far no information is available on these aspects for this fish species.

The breeding coincidence of this fish species with monsoon season has been reported by many earlier researchers, though Weitkamp (2005) and Yanwirsal et al. (2017) have not found any correlation of gonad maturation and courtship behavior with any environmental parameters. Thus gathering information on natural inducing factors can be really an issue of interest for future studies. Meanwhile, Yanwirsal et al. (2017) have emphasized supplying nutritional diets to promote the breeding of *N. notopterus* in captivity.

Notopterus notopterus is a hardy fish in nature (Kalita and Rath, 2000) and has already been reported as a suitable species for captive culture in open water bodies (Kiran et al., 2004; Chandio et al., 2016). Though to date, the culture methodologies of this fish species are at a preliminary level and have not been standardized so far. Recently, Sukendi et al. (2020b) have tried to culture this fish species in cages, but further refinement is needed to standardize the technique. On the other hand, the suitability of this fish species to be cultured with other commercially important fish species needs to be evaluated. In this regard, the recommendation of Chaudhuri et al. (1975) can be considered, who stated the suitability of *Chitala chitala* (closely allied species of *N. notopterus*) as a controlling agent of insects and weed fishes in composite culture with Indian Major Carps due to its insectivorous and piscivorous characters. *Notopterus notopterus* bears the same feeding habit, thus can be experimented in polyculture with Indian Major Carps.

Thus, overall it can be concluded that further studies are needed to gather knowledge on induced breeding and captive culture of *N. notopterus* to support its fishery and conservation. The information summed up in this review report on feeding and reproductive biology will also help the fish biologists and policymakers to implement proper recommendations and laws to support the sustainable development of its fishery and conservation.

References

Achakzai W.M., Saddozai S., Baloch W.A., Soomro A.N., Menon N. (2015). Length-weight relationship and condition factor of *Notopterus notopterus* (Pallas, 1769) from Manchar Lake Sindh, Pakistan. Sindh University Research Journal (Science Series), 47: 515-518.

Axelrod H.R., Burgess W.E. (1981). Spawning *Notopterus notopterus.* Tropical Fish Hobbyist, 29: 36-42, 44-49.

Azadi M.A., Islam M.A., Nasiruddin M., Quader, M.F. (1994). Food and feeding habits of a featherback, *Notopterus notopterus* (Pallas) (Notopteridae: Clupeiformes) from the Kaptai reservoir. Chittagong University Studies, Part II: Science, 18(2): 183-190.

Azadi M.A., Islam M.A., Nasiruddin M., Quader M.F. (1995). Reproductive biology of *Notopterus notopterus* (Pallas) in Kaptai reservoir, Bangladesh. Bangladesh Journal of Zoology, 23: 215-220.

Bhuiyan A.S., Islam M.N. (1991). Fecundity of *Notopterus notopterus* (Pallas) (Notopteridae: Clupeiformes). 16th Annual Bangladesh Science Conference. BAAS. Abstract 34. pp: 27.

Borah B.C., Gogoi R., Rahman A., Hussain M. (2015). Biology of *Notopterus notopterus* (Pallas) raised in small ponds of Assam. Journal of Inland Fisheries Society of India, 47(1): 27-35.

Burnawi B., Pamungkas Y.P. (2016). Contents of the intestine Putak (*Notopterus Notopterus*) catches of fishermen in Lubuk Lampam Waters of Ogan Kemuning Ilir Regency, South Sumatra. Litkayasa Engineering Bulletin, 14: 19-21.

C.A.M.P. (1998). Conservation assessment and management plan for freshwater fishes of India. In: S. Molur, S. Walker (Ed.). Workshop Report. Zoo Outreach Organization, Coimbatore/CBGS and NBFGR, Lucknow, India. 158 p.

Chakrabarti P., Ghosh S.K. (2015). Comparative histological and histochemical studies on the pancreas of *Labeo rohita* (Hamilton, 1822), *Mystus vittatus* (Bloch, 1790) and *Notopterus notopterus* (Pallas, 1769). International Journal of Aquatic Biology, 3(1): 28-34.

Chandio M.H., Narejo N.T., Jalbani S., Khan, P. (2016).

Breeding biology of featherback *Notopterus notopterus* from Keenjhar Lake, district Thatta, Sindh, Pakistan. Pakistan Journal of Nutrition, 15: 547-550.

Chaudhuri H., Chakrabarty R.D., Sen P.R., Rao N.G.S., Jena S. (1975). A new high in fish production in India with record yields by composite fish culture in freshwater ponds. Aquaculture, 6(4): 343-355.

Cox S.P., Hinch S.G. (1997). Changes in size at maturity of Fraser River sockeye salmon (*Oncorhynchus nerka*) (1952-1993) and associations with temperature. Canadian Journal of Fisheries and Aquatic Sciences, 54: 1159-1165.

Das S.M., Nath S. (1965). The comparative anatomy of the alimentary tract and its modification in relation to the food and feeding habits in some fishes of Jammu Province (India). Ichthyology, 4: 63-68.

Das S.M., Srivastava A.K. (1979). On the relative length of gut (RLG) in some food fishes of Uttar Pradesh with changes from fingerling to adult stage. Journal of the Inland Fisheries Society of India, 11(1): 6-11.

David A., Ray P., Govind B.V., Rajagopal K.V., Banerjee R.K. (1969). Limnology and fisheries of the Tungabhadra Reservoir. Bulletin of Central Inland Fisheries Research Institute, Barrackpore, West Bengal, India, 13. 188 p.

Day F. (1878). The Fishes of India being a Natural History of the Fishes Known to Inhabit the Seas and Fresh Waters of India, Burma and Ceylon, 1st Ed. William Dowson and Sons, London. 778 p.

Friese U.E. (1980). Aquarium fish. Tropical Fish Hobbyist Publication. 93 p.

Gupta S., Banerjee S. (2008). Ornamental fish trade in West Bengal. Fishing Chimes, 28(8): 25-27.

Gupta S., Banerjee S. (2012a). Indigenous ornamental fish: a new boon in ornamental fish trade of West Bengal. Fishing Chimes, 32(1): 130-134.

Gupta S., Banerjee S. (2012b). Present status of Galiff street market, the wholesale ornamental fish market of Kolkata. Fishing Chimes, 32(5): 34-35, 39-42.

Gupta S., Banerjee S. (2013). Indigenous ornamental fish trade of West Bengal, 1st Ed., Narendra Publishing House, New Delhi, India. 63 p.

Gupta S., Banerjee S. (2018). Indigenous ornamental fish: Exploring new orientation in trade dynamics. In: B.K. Mahapatra, A.K. Roy, N.C. Pramanik (Eds.) Aquatic Resources and Sustainable Management. Narendra Publishing House, New Delhi, India. pp: 269-288.

Gustomi A., Sulistiono S., Yonvitner, Y. (2016). Reproductive Biology Featherback (*Notopterus notopterus* Pallas, 1769) in Simpur Reservoir, Bangka Island. Journal Ilmu Pertanian Indonesia JIPI, 21: 56-62.

Hamza A. (1980). Studies on certain aspects of biology and reproduction of genus *Notopterus.* PhD Thesis, University of Calcutta, Calcutta, India. 252 p.

Haniffa M.A., Arockia Raj A.J., Nagarajan M., Perumalsamy P., Seetharaman S., Singh S.P. (2004). Natural breeding in captivity - a possibility for conservation of threatened freshwater feather back *Notopterus notopterus*. Aquaculture Asia, 9: 36-38.

Heino M., Dieckmann U., Godo O.R. (2002). Measuring probabilistic reaction norms for age and size at maturation. Evolution, 56 (4): 669-678.

Heng K., Chevalier M., Lek S., Laffaille P. (2018). Seasonal variations in diet composition, diet breadth and dietary overlap between three commercially important fish species within a flood-pulse system: The Tonle Sap Lake (Cambodia). PLoS ONE, 13: e0198848.

Hossain M.A., Parween S., Taleb A., Rahman M.H. (1990). Food and feeding habit of *Notopterus notopterus* (Pallas). University Journal of Zoology, Rajshahi University, 9: 1-6.

Hunter A., Speirs D.C., Heath M.R. (2015). Fishery-induced changes to age and length dependent maturation schedules of three demersal fish species in the Firth of Clyde. Fisheries Research, 170: 14-23.

Isa M.M., Rawi C.S.M., Rosla R., Shah S.A.M., Shah A.S.R.M. (2010). Length-weight relationships of freshwater fish species in Kerian River Basin and Pedu Lake. Research Journal of Fisheries and Hydrobiology, 5: 1-8.

Ishida Y., Ito S., Kaeriyama M., McKinnell S., Nagasawa K. (1993). Recent changes in age and size of chum salmon (*Onchorhynchus keta*) in the North Pacific Ocean and possible causes. Canadian Journal of Fisheries and Aquatic Sciences, 50: 290-295.

I.U.C.N. Bangladesh (2015). Red List of Bangladesh. Volume 5: Freshwater Fishes. IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh. 360 p.

Jantrachit P., Nuangsit S. (2008). Some biological aspects of grey feather back, *Notopterus notopterus* (Pallas, 1780) in Bung Lahan, Chaiyaphum Province. Nakhon Ratchasima Inland Fisheries Research and Development Center. Technical Paper No. 45.

Jayaram K.C. (2010). The freshwater fishes of Indian

region. 2nd Ed., Narendra Publishing House, New Delhi, India. 616 p.

Jorgensen C., Enberg K., Dunlop E.S., Arlinghaus R., Boukal D.S., Brander K., Ernande B., Goerdmark A., Johnston F., Matsumura S., Pardoe H., Raab K., Silva A., Vainnika A., Dieckmann U., Heinno M., Rijnsdrop D.A. (2007). Managing evolving fish stocks. Science, 318: 1247-1248.

Kalita K., Rath R.K. (1996). Length-weight relationship of male *Notopterus notopterus* (Pallas). Journal of Ecology and Environment, 14: 983-984.

Kalita K., Rath R.K. (2000). Fecundity of freshwater featherback *Notopterus notopterus* (Pallas). Journal of Ecology and Environment, 18: 1023-1025.

Kaur V., Rawal Y.K. (2017). Length-Weight Relationship (LWR) in *Notopterus notopterus* (Pallas) from Sukhna Lake, Chandigarh. International Journal of Pharmacy and Biological Sciences, 12(4): 63-65.

Kaushik K.K., Sahu P., Nath R. (2019). Length-weight relationship of *Notopterus notopterus* (Pallas, 1769), *Anabas testudineus* (Bloch, 1792) and *Clarias batrachus* (Linnaeus, 1758) from Pokoriya River, Morigaon, Assam, India. International Journal of Environmental Science and Technology Research, 8(10): 3087-3088.

Khadse T.A., Gadhikar Y.A. (2017). Histological and ultrastructural study of intestine of Asiatic knife fish, *Notopterus notopterus.* International Journal of Fisheries and Aquatic Studies, 5(1): 18-22.

Khaing M.M., Khaing M., Yee K (2020). Food and feeding habits of some freshwater fishes from Ayeyarwady River, Mandalay District, Myanmar. IOP Conference Series: Earth and Environmental Science, 8th International Fisheries Symposium, Songkhla, Thailand. 416(1): 012005.

Khan M. (2003). Length-weight relationship and relative condition index of *Notopterus notopterus* (Pallas) of Tilaiya reservoir, Bihar. Records of the Zoological Survey of India, 101(3-4): 233-239.

Khanna S.S. (1961). Alimentary canal in some teleostean fishes. Journal of the Zoological Society of India, 13: 206-219.

Kiran B.R., Puttaiah E.T. (2006). Food and feeding habits and sex ratio of feather back, *Notopterus notopterus* from Jannapura pond, Karnataka. Journal of Ecobiology, 18: 127-131.

Kiran B.R., Puttaiah E.T., Kumar K.H. (2004). Length-weight relationship of Feather back, *Notopterus notopterus* (Pallas) from Jannapura pond, Karnataka, India. Zoos Print Journal, 19(4): 1449-1450.

Kiran G., Uma V., Waghray S. (1998). Food and feeding habits of *Notopterus notopterus* (Pallas) of Saroornagar Lake, Hyderabad (A.P.). Indian Journal of Fisheries, 45(3): 355-359.

Kottelat M., Whitten A.J., Kartikasari S.N., Wirjoatmodjo S. (1993). Freshwater fishes of Western Indonesia and Sulawesi. Periplus Editions, Hong Kong. 221 p.

Kumar R., Yadav S.S., Tripathi M. (2014). Studies on length–weight relationship of seven commercially important freshwater fish species of Gomti River Lucknow (U.P.) India. International Journal of Fisheries and Aquatic Studies, 1(3): 1-3.

Li Q., Xu X.L., Huang J.R. (2014). Length-weight relationships of 16 fish species from the Liuxihe national aquatic germplasm resources conservation area, Guangdong, China. Journal of Applied Ichthyology, 30(2): 434-435.

Mandal D.K., Chakrabarti P. (1996). Architectural pattern of the mucosal epithelium of the alimentary canal of *Notopterus notopterus* (Pallas) and *Oreochromis mossambicus* (Peters): A comparative study. Acta Ichthyologica et Piscatoria, 26(1): 15-23.

Menon M.D., Sreenivasan R., Krishnamurthi B. (1959). Report to the Indian Council of Agricultural Research on the Madras Rural Piscicultural Scheme worked from 1st July, 1942 to 31 March, 1952. Govt. Press, Madras. 171 p.

Minh N.P., Pham V.T., Thuy T.T., Phien L.T.N., Thai T.D. (2019). Different parameters in development and evaluation of dry fermented sausages processed from blends of broken shrimp and bronze featherback (*Notopterus Notopterus*) meat. Journal of Pharmaceutical Sciences and Research, 11: 1422-1426.

Mirza M.R. (1982). A contribution to the fishes of Lahore. Polymer Publications, Urdu Bazaar, Lahore, Pakistan. 48 p.

Mohsin S.M. (1962). Comparative morphology and histology of the alimentary canals in certain groups of Indian teleosts. Acta Zoologica, 43(1): 79-133.

Mookerjee H.K., Mazumdar S.R. (1946). On the life history of *Notopterus notopterus* (Pallas). Journal of the Dept. of Sciences, Calcutta University, 2: 88-100.

Mustafa G., Ahmed A.T.A. (1979). Food of *Notopterus notopterus* (Pallas) (Notopteridae: Clupeiformes). Bangladesh Journal of Zoology, 7: 7-14.

Mustafa M.G., Singha S., Islam M.R., Mallick N. (2014).

Population dynamics of *Notopterus notopterus* (Pallas, 1769) from the Kaptai reservoir of Bangladesh. SAARC Journal of Agriculture, 12: 112-122.

Naeem M., Salam A., Gillani Q., Ishtiaq A. (2010). Length-weight relationships of *Notopterus notopterus* and introduced *Oreochromis niloticus* from the Indus River, southern Punjab. Pakistan Journal of Applied Ichthyology, 26(4): 620.

Ng H.H. (2020). *Notopterus notopterus*. The IUCN Red List of Threatened Species 2020: e.T166433A60 584003.https://dx.doi.org/10.2305/IUCN.UK.2020.1.R LTS.T166433A60584003.en. Retrieved 1/12/2021.

Palaniswami R., Manoharan S. (2010). Mettur reservoir fisheries: past and present status. Fishing Chimes, 30: 132-135.

Parameswaran S., Sinha M. (1966). Observation on the biology of the featherback *Notopterus notopterus* (Pallas). Indian Journal of Fisheries, 13(1 & 2): 232-250.

Patil M., Kulkarni R.S. (1996). Observations on the fecundity in the freshwater fish *Notopterus notopterus* (Pallas) from Bhosga Tank, Gulbarga. Journal for Nature Conservation, 8(1): 57-60.

Pinxteren M.C.A. van. (1974). Gelungene Zucht mit einem Messerfisch, *Notopterus* spec. Aquarien und Terrarien Zeitschrift, 37: 364–369.

Rahimullah M. (1935). On the pyloric caecae of the family Notopteridae. Proceedings of Indian Science Congress. 25 p.

Rahimullah M. (1945). A comparative study on biology, histology and probable function of the pyloric caeca in Indian fishes together with a discussion on their homology. Proceedings of the National Academy of Sciences India, Section B, 21: 1-37.

Rahman A.K.A. (1989). Freshwater fishes of Bangladesh. PhD Thesis, Zoological Society of Bangladesh. Department of Zoology, University of Dhaka, Dhaka, Bangladesh. 364 p.

Rainboth W.J. (1996). Fishes of the Cambodian Mekong. FAO Species Identification Field Guide for Fishery Purposes. FAO, Rome. 265 p.

Rizki A.A., Efizon D., Putra R.M. (2017). Reproductive biology of feather back Fish (*Notopterus notopterus* Pallas, 1769) from the Sail River, Pekanbaru Regency, Riau Province. Online Journal of Study, Faculty of Fisheries and Marine Sciences, University of Riau, Riau, 4: 1-11.

Roberts T.R. (1992). Systematic revision of the old world freshwater fish family Notopteridae. Ichthyological Exploration of Freshwaters, 2(4): 361-383.

Roy Choudhury S. (2009). Biometry, bioindices and foraging in threatened fish *Notopterus notopterus* (Pallas). M.FSc. Thesis, West Bengal University of Animal and Fishery Science, Kolkata, India.

Sani R., Gupta B.K., Sarkar U.K., Pandey A., Dubey V.K., Lakra W.S. (2010). Length–weight relationships of 14 Indian freshwater fish species from the Betwa (Yamuna River tributary) and Gomti (Ganga River tributary) rivers. Journal of Applied Ichthyology, 26(3): 456-459.

Sathish S.V., Kulkarni R.S. (2014a). Age related seasonal changes in the gonadal activity of the fish *Notopterus notopterus* (Pallas). International Journal of Science and Research, 3(11): 3020-3026.

Sathish S.V., Kulkarni R.S. (2014b). Studies on distribution and sex ratio of *Notopterus notopterus* in the aquatic bodies in and around Gulbarga. International Journal of Science and Research, 3(12): 409-410.

Shafi M., Quddus M.M.A. (1982). Fisheries in Bangladesh (in Bengali). Bangla Academy, Dhaka, Bangladesh. 444 p.

Shillewar K.S. (2009). Biology of *Notopterus notopterus* (Pallas) from Marathwada region. PhD Thesis, Swami Ramanand Teerth Marathwada University, Nanded, India. 183 p.

Shillewar K.S., Nanware S.S. (2009). Food and feeding habit of fresh water fish *Notopterus notopterus* (Pallas) from Godavari river, Nanded, Maharashtra. Biomedical and Pharmacology Journal, 2(2): 489-490.

Southwell T., Prashad B. (1919). Notes from the Bengal fisheries laboratory, No. 6. Records of Indian Museum, 26: 215-240.

Srivastava S.M., Gopalakrishnan A., Singh S.P., Pandey A.K. (2012a). Embryonic and larval development of threatened Bronze Featherback, *Notopterus notopterus* (Pallas). Journal of Experimental Zoology, 15(2): 425-430.

Srivastava S.M., Singh S.P., Pandey A.K. (2012b). Food and feeding habits of threatened *Notopterus notopterus* in Gomti River, Lucknow (India). Journal of Experimental Zoology, 15(2): 395-402.

Srivastava S.M., Singh S.P., Aprajita K., Pandey A.K. (2012c). Fecundity of threatened bronze featherback, *Notopterus notopterus* (Pallas) from River Gomti, Lucknow (India). National Journal of Life Sciences, 9: 193-200.

Srivastava S.M., Singh S.P., Pandey A.K. (2013). Age and

growth of threatened bronze featherback *Notopterus notopterus* in Gomti River, Lucknow (India). National Journal of Life Sciences, 10: 121-127.

Srivastava S.M., Srivastava P.P., Dayal R., Pandey A.K., Singh S.P. (2010). Induced spawning of captive stock of threatened bronze feather back, *Notopterus notopterus* for stock improvement and conservation. Journal of Applied Biosciences, 36(2): 144-147.

Sugunan V.V., Sinha M. (2001). Sustainable capture and culture based fisheries in freshwater of India. In: T.J. Pandian (Ed.). Sustainable Indian Fisheries. National Academy of Agricultural Sciences (ICAR), New Delhi. pp: 43-70.

Sukendi S., Thamrin T., Putra R.M., Yulindra A. (2020a). Behavior and reproduction of belida fish (*Notopterus notopterus*, Pallas 1769) in different stocking density and nurtured with different types of feed. Journal of Animal Behaviour and Biometeorology, 8: 181-189.

Sukendi S., Thamrin T., Putra R.M., Yulindra A. (2020b). Cultivation technology of bronze feather back (*Notopterus notopterus*, Pallas 1769) at different stocking densities and types of feed. IOP Conf. Series: Earth and Environmental Science, 430: 012027.

Talwar P.K., Jhingran A.G. (1991). Inland fishes of India and adjacent countries. Vol. 1.1st Ed., Oxford and IBH Publishing Co., New Delhi, India. 1063 p.

Tesch F.W. (1971). Age and growth. In: W.E. Ricker (Ed.). Methods for assessment of fish production in fresh waters. Blackwell Scientific Publications, Oxford. pp: 99-130.

Weatherly A.H., Gill H.S., Casselman J.M. (1987). The Biology of Fish Growth. London: Academic Press, London. 443 p.

Weitkamp H. (2005). Untersuchungen zur Reproduktions biologie von *Notopterus notopterus* (Pallas, 1769). Bachelor-Arbeit im Studiengang Agrarwissenschaften. Humboldt-Universität zu Berlin.

Wertheimer A.C., Heard W.R., Maselko J.M., Smoker W.W. (2004). Relationship of size at return with environmental variation, hatchery production, and productivity of wild pink salmon in Prince William Sound, Alaska: does size matter? Reviews in Fish Biology and Fisheries, 14: 321-334.

Wootton R.J. (1998). Ecology of Teleost Fishes. Kluwer Academic Publishers, Dordrecht, The Netherlands. 386 p.

Yang Y.S. (1988). Food resource utilization partitioning of fifteen fish species at Bukit Merah Reservoir, Malaysia. Hydrobiologia, 157: 143-160.

Yanwirsal H., Bartsch P., Kirschbaum F. (2017). Reproduction and development of the Asian bronze featherback *Notopterus notopterus* (Pallas, 1769) (Osteoglossiformes, Notopteridae) in captivity. Zoosystematics and Evolution, 93(2): 299-324.

Yulindra A., Lumbantoruan R.P., Zulkifli Sukendi S. (2017). Effect of granting ovaprim with different dosage to ovulation and egg quality of Knife Fish (*Notopterus notopterus*). International Journal of Oceans and Oceanography, 11(2): 189-199.