REVIEW OF LITERATURE

Reproduction is the natural phenomenon of all the organisms to exist for next generations and fish is also one of them. Every fish species has immense power of prodigality and if the conditions are favourable then the population may increase to the explosive level. But it seldom happens because, from the beginning of gametogenesis to the attainment of maturity, there are a number of factors responsible for untimely death of embryos, juveniles and adults even before they start reproducing. Many commercial and productive fish species are adversely affected in modem times, due to severe fast and undesirable changes detrimental to their surroundings, survival and viability. Hence it needs conservation for the future generation. Therefore, the species are to be managed, conserved and exploited accordingly. For the proper management of the species, the fundamental knowledge on various aspects of biology, reproduction and breeding behaviour are very much necessary. In studies of fisheries biology, it is important to determine the cycle of maturation and depletion of gonads. Determination of maturity stages finds primary application in providing basic knowledge on the reproductive biology of a stock (Venkataramanujan and Ramanathan, 1996). According to Arocha (1997) knowledge on gonad development in individual fish is required to establish the duration of spawning season, the size and age at maturity and spawning pattern.

Maintaining aquariums is one of the widespread leisure pursuits in the world today. This growing interest has resulted in increase in global aquarium fish trade. As per Das, (2003), aquarium fish trade has a turnover of US$ 5 billion and it has annual growth

rate of 8 percent. This offers a lot of scope for its development. There is moderate demand of *Badis badis* among the aquarium fish hobbyist but it is popular as beautiful small indigenous ornamental fish. This fish has been considered eatable fish due to its good taste. In Indian market, trade of *Badis badis* still relies upon wild collection, which is having depleting effect on natural stock. This situation points out the need to give attention on captive maturation and captive breeding of this species, which also demands the study of the biology of it. This work not only will help ornamental fish industry but also will help to conserve this indigenous variety.

2.1. Freshwater fish diversity in the World

Fishes comprise nearly half of all vertebrate species; the group includes approximately 15,700 marine and 13,700 freshwater species (Fish Base: www.fishbase.org). Although fresh water ecosystems such as rivers, lakes and wetlands occupy less than 2% of the earth‘s total land surface, they provide a wide range of habitats for a significant proportion of the world‘s plant and animal species. Many are yet to be discovered, but the number of freshwater species worldwide is estimated at between 9,000 and 25,000 (Cosgrove and Rijsberman, 2000). However, this number is rapidly decreasing due to human interference. Physical alteration, habitat degradation, excessive water withdrawal and pollution have contributed directly or indirectly to decline the freshwater species. Other factors that reduce freshwater biodiversity include the incursion of non-native species and the mismanagement of inland fisheries. Today, approximately

20% of the world's freshwater fish is vulnerable, endangered or extinct (Revenga *et al*., 1998).

2.2. Freshwater species diversity in India

India is endowed with vast and varied resources possessing river ecological heritage and rich biodiversity. In the world India is considered one of the mega biodiversity nations and in terms of freshwater mega-biodiversity, it holds ninth position (Mittermeier and Mittermeier, 1997). According to Ayyappan and Birdar (2004) the country has various freshwater fishery resources like rivers (45,000 km), canals (1,26,334 km), ponds and tanks (2.36 million hectares),and reservoirs (2.05 million hectares). In India, the assessment of freshwater fishes is done mainly on six drainage systems- Indus river system, Upland cold-water bodies, Gangetic river system, Bramhaputra river system and East and West flowing river systems. India has a vast expanse of open inland waters with richest fish resources in the world with an assemblage of about 2,508 species depicting diverse characteristics, of which 930 belonging to 326 genera inhabit the inland waters. The natural aquatic ecosystems of India are being subjected to considerable stresses, the adverse effects of which are being manifested in fish populations they harbour. A need has, therefore, arisen to conserve the vast and diverse fish genetic resources for their efficient utilization.

Much of the early studies on the freshwater systems of the Indian subcontinent started with the works of British officers working for the East India Company, who took great interest in the natural history of the region. Some early contributions were enlisted

and described in _The Fishes of the Ganges‘ by Hamilton-Buchanan (1822) and by others like McClelland (1839), Sykes (1839) and Jerdon (1849). Some of the most important contributions to such studies were made by Francis Day in his Fishes of India (1875–1878). Substantial literature is now available on the identification and systematics of freshwater fishes of India, starting with Hora‘s contributions between the 1920–1950s and the most recent texts by Talwar and Jhingran (1991), and Jayaram (1999, 2010). Though most of these contributions have been taxonomic in nature, there exist some works on the biogeographic distributions of fishes in the region as well (Jayaram, 1974).

There have been extensive studies on the Freshwater fishes of India, notably by, Hamilton (1822); Shaw and Shebbeare (1937); Hora (1921 a, b; 1930; 1937; 1942; 1951; 1953); Hora and Law (1941); Mishra (1959); Menon (1974, 1999); Dey (1973); Jayaram (1981, 1999, 2006, 2010); Sen (1982, 1985); Talwar and Jhingran (1991); Nath and Dey (1997, 2000); Dey and Kar (1989, 1990); Kar and Dey (1986); Kar *et al*. (2002, 2004); Kar (1984; 1990; 2003 a, b; 2005 a, b, c). Most of them are concerned with taxonomy, biology and aquaculture. The knowledge gaps in our taxonomic system, the shortage of taxonomists and the resulting handicap to biodiversity management and conservation have been called the _taxonomic impediment‘ by the Convention on Biological Diversity (cf. Workshop on _Removing the Taxonomic Impediment‘ 1998, Darwin, Australia; http://www.biodiv.org/programmes/cross-cutting/taxonomy/ darwin-declaration.asp).

2.3. Diversity of freshwater Perches

Perciforms dominate in vertebrate ocean life and are the dominant fish group in many tropical and subtropical freshwaters. Perciformes, is the largest order of vertebrates, containing about 41% of all bony fishes. Perciformes is the most varied of all orders of fish and the largest vertebrate group, containing 20 suborders, 160 families, some 1,539 genera and approximately 10,033 species (Nelson, 2006). About 26% of the species normally occur only in fresh water (the majority of these being cichlids and percids). A comprehensive and authoritative account of the fishes of the Indian region was published by Francis Day in 1889. The publications by Jayaram (1981, 1999, 2010), Datta Munshi and Srivastava (1988) leave much to be desired. Talwar and Jhingran (1991) in their attempt to classify the freshwater teleosts of India, have thrown light on the behaviour, feeding, reproduction, growth habitat and population structure of Inland fishes which would become handy for augmenting their production, conservation and management. Johnson and Patterson (1993) presented evidence that the perciforms may be part of a monophyletic group only if the members of the orders Scorpaeniformes (including the Dactylopteridae), Pleuronectiformes, and Tetraodontiformes would be included (Nelson, 2006). There is evidence that the last three ordinal taxa are probably derivatives of perciform lineages, although there is also evidence that the Tetraodontiformes (and Caproidae) are pre-perciforms (Springer and Johnson, 2004). Unlike in Nelson (1994), Johnson and Patterson (1993) excluded the family Elassomatidae from the Perciformes but included the family Caproidae. During the interveningmore than 100 years, nothing substantial has been published to bridge the gap and it is unfortunate that a monophyletic

order Perciformes cannot be recognized. In addition, most families in many suborders are not currently definable in terms of common shared derived characters and thus may not be monophyletic (Nelson, 2006). Some 52 families have a single genus, 23 have a single species (i.e., are monotypic), and 21 have 100 or more species. Three suborders, the Percoidei, Labroidei, and Gobioidei, account for over three quarters of the species. This may be the basal evolutionary group from which the other perciform groups and the remaining two orders have been derived. Even if this were not so, it is probably not a monophyletic group, being recognized solely on primitive characters. There are 25 families of perciforms represented in Indian inland waters. Suborder Percoidei is the largest of the Perciformes containing 79 families, 549 genera and about 3,176 species. The eight largest families are Gobiidae, Cichlidae, Serranidae, Labridae, Blenniidae, Pomacentridae, Apogonidae, and Sciaenidae. Together with 5,479 species, they constitute about 55% of the species. Most perciforms are marine shore fishes, while about 2,040 species normally occur only in freshwater, and at least some individuals of about 2,335 species occur in freshwater for at least part of their life history (Nelson, 2006).

2.4. Status of Badid species

The behaviour of *Badis badis* is similar, in general, both to that of ―nandid fishes and that of anabantoid fishes; trenchant differences also exist. It is impossible at this time, on behavioural evidence alone, to assess the relative importance of the behavioural &dings. However, the remarkable and consistent agreement in the performance of the spawning embrace suggests a close relationship of Badis to anabantoid fishes rather than

to the ―nandids. The osteological studies confirm this hypothesis. Badis apparently split off from the ancestral anabantoids before they acquired the air-breathing adaptation. The osteological differences between Badis and the anabantoids stem chiefly from the modifications accompanying aerial respiration. Bleeker (1853) erected the genus Badis for *Labrus badis* Hamilton, 1822 under the family Nandidae. After a comparative study on the osteology, behavior and ontogeny of the two genera, Badis and Nandus. The genus Badis is separated from the nandid based on the characters of serrated pre-opercular margin and toothed tongue. A new family, Badidae, was established based on osteological characters by Barlow et al. (1968) in which Badis has been incorporated. However, Kullander & Britz (2002) did a thorough revision of the family and genus Badis and its led to the introducing and explaining of a new genus Dario, and till date, the family Badidae consist of two valid genera Badis and Dario (Eschemeyer and Fricke, 2015; Valdesalici & Van der Voort, 2015a & 2015b).The genus Badis Bleeker has added many recognized species newly, growing from 4 in 1957 to 24 in 2016. The three distinguish forms of regional variety within *B. badis* led Day (1875),now a days they are recognized as three different species—*B. badis, B. assamensis Ahl, and B. ruber* Schreitmüller (Kullander and Britz, 2002).The description of *B. siamensis* by Klausewitz in 1957 took the species count to 4. Kullander and Britz (2002) during revision of the genus added 8 more species—*B. blosyrus, B. chittagongis, B. corycaeus, B.ferrarisi, B. kanabos, B. khwae, B. kyar*, and *B. pyema*. Since the revision of the genus Badis another 12 species have been enlisted and described— *B. tuivaiei* by Vishwanath & Shantain 2004, *B. dibruensis* by Geetakumari & Vishwanath in 2010, *B. juergenschmidti* by

Schindler & Linke in 2010, *B. singenensis* by Geetakumari & Kadu in 2011, *B. triocellus* by Khynriam & Sen in 2013, *B. britzi* by Dahanukar, Kumkar, Katwate & Raghavan in 2015, *B. andrewraoi* by Valdesalici, van, der & Voort in 2015, *B. autumnum* by Valdesalici, van, der & Voort in 2015, *B. kyanos* by Valdesalici, van, der & Voort in 2015, *B. soraya* Valdesalici, van, der & Voort in 2015, *B. laspiophilus* by Valdesalici, van, der & Voort in 2015, and *B. pancharatnaensis* by Basumatary, Choudhury, Baishya, Sarma & Vishwanath in 2016.

Badids are distributed in India, Myanmar, Bangladesh, Nepal, Thailand, Bhutan, Pakistan, and China (Ruber *et al.*, 2004), with the maximum number of species in India and Myanmar. *Badis badis*, as currently well-defined, is widely distributed in Pakistan, Nepal, India, Bhutan, and Bangladesh. However, since many populations which are formerly classified as *B. badis* have been now recognized as species (Kullander and Britz 2002, Geetakumari and Vishwanath, 2010, Khynriam and Sen, 2011, Basumatary *et al.*, 2016), it is possible that many more species remain to be discovered.

The species *Badis badis* was named by Hamilton (1822). It was described by Kullander and Britz (2002) from its native place, Ganges River System. It was also reported from the Yamuna River (Himachal Pradesh), Ganges tributaries in Nepal, the Mahanadi River System in Chhattisgarh and Orissa states and parts of Assam state including Guwahati, Kaziranga National Park, Brahmaputra River Drainage and Dibru River Basin by Kullnader and Britz (2002). Rajbanshi and Csavas (1982) described *Badis badis* from Bhutan and Mirza (2002) from Pakistan. Kullander and Britz (2002)

described the neotype locality as 'shore of Tumapao River' close to Duma village (Ganges River drainage), about 65 kilometers north-north east of Calcutta, West Bengal, India, 22°58'03″N, 88°49'49″E. Valdesalici and Van Der Voort (2015) reported and recorded 5 new species of genus *Badis* from West Bengal. The species, *Badis* and rewraoi was recorded from Balason River, Mahananda River drainage in West Bengal. He described that *B.* and rewraoi possesses a color pattern that distinguishes from all of its congeners. It can bedistinguished from *B. badis, B. chittagongis, B. dibruensis, B. ferrarisi, B. kanabos, B.soraya* and *B. tuivaiei* by the absence of a blotch on the superficial part of the cleithrum abovepectoral-fin base; from *B. assamensis* and *B. blosyrus* by the absence of opercular blotch and absence of two parallel rows of dark spots and alternating light and dark stripes along its physique; from *B. khwae, B. ruber* and *B. siamensis* by the absence of a cleithral blotch and absence of a blotch on the dorsolateral aspect of the caudal peduncle; from *B. corycaeus* and *B. pyema* by the absence of an ocellus on caudal-fin base; from *B. kyar* by the presence of aconspicuous median black blotch on caudal peduncle; from *B. singenensis* by the absence of a postero-dorsal opercle blotch and absence of three dorsal-fin blotches and a single round blotch on the anal-fin base; from *B. juergenschmidti* by the absence of white margins on dorsal and ventral aspects of the caudal fin in males and presence of a strongly curved caudal-fin base bar; and from *B. britzi* by the presence of a conspicuous median black blotch on the caudal peduncle. Other diagnostic characters useful to differentiate *B. andrewraoi* from other congeners include the presence of side bar on its nape (vs. absence in all other species except *B. ferrarisi, B. juergenschmidti*, in some *B. soraya, B. autumnum* and *B.*

kyanos), and a medially broader posterior-most bar, displaying as a partially absorbed second median caudal peduncle blotch (vs. absence in all species except *B. autumnum* and *B. kyanos*). It is most closely resembles *B. autumnum* and *B. kyanos* in terms of color pattern but it can be distinguished from *B. autumnum* by the absence of a conspicuous dark blotch on pectoral-fin base, absence of a blotch above opercular spine base, vertical bars restricted to lower half of body (vs. bars 1 to 3 often conspicuous and complete, remaining bars fainter and strongly reduced, present only dorso-laterally), absence of a black caudal-fin margin, outlining entire fin, and by having 18 circumpeduncular scales (vs. 16-18). It differs from *B. kyanos* by the presence of vertical bars restricted to lower half of body (vs. forming large, fragmented black blocks dorso-laterally and entro-laterally or bars reduced and present only dorso-laterally), and a pale color pattern when stressed (vs. a dark grey body, a metallic dark blue operculum, with flanks almost entirely devoid of bars, and large, fragmented black blocks dorso-laterally). *Badis autumnum* was reported from Rathbari stream, Singimari River drainage in West Bengal. *Badis autumnum* is distinguished from all other congeners by its color pattern consisting of two autapomorphies. The percoid fish species, *Badis kyanos* was described from the Chel River, Tista River Drainage in West Bengal. The small sized species, *Badis laspiophilus*, reported from the Shipra swamp area, Torsa River drainage in West Bengal, showed the presence of two blotches in dorsal fin and a single round blotch on the anal fin with 14-16 circum-peduncular row scales. Cleithral, opercle, dorso-lateral and caudal peduncular blotches are absent. And *Badis soraya* from the Lish River, Tista River drainage in West Bengal, has a maximum size of 3.2cm Standard length (SL) in nature.

Kullander and Britz (2002) described ten new species of the family, Badidae and genus *Badis*. *Badis assamensis* was reported from different parts of Assam including Rivulet falling in the Dibru River, Brahmaputra River drainage, River let falling in the Dibru River and Kalmoni sub-drainage: Rani garden. He described that the species possesses a prominent dark blotch postero-dorsally on opercle and two rows of irregular blackish blotches alongside. The species differs from *B. blosyrus* by shorter jaw. *Badis blosyrus* from Janali River, Raimana, Brahmaputra River drainage, Assam, possesses a prominent dark blotch posterodorsally on opercle and two rows of irregular blackish blotches alongside. The species differs from *B. assamensis* in having a longer jaw. Another new species of genus *Badis*, *Badis chittagongis* was recorded from the hill streams near Chittagong in Bangladesh. The species possesses a conspicuous dark blotch covering superficial part of cleithrum above the pectoral fin base; absence of a dark blotch on its dorso-lateral part of caudal peduncle. It also shows a series of prominent dark blotches present along middle of dorsal fin. Distal extra-scapular is present. A new Badis species, *Badis corycaeus* described from Myanmar, shows caudal fin base with a prominent dark spot at the center, surrounded by a light ring and differs from *B. pyema* in having a deeper body. *Badis ferrarisi* from Myanmar, possesses a distinct blotch on superficial portion of the cleithrum, but distinguished by color pattern of flanks which includes about 11 dark brown to blackish vertical bars, commonly connected by similarly pigmented horizontal band, and by having single short extra scapular with one distal pore instead of two. A rounded caudal fin is present with no dark blotch on the caudal peduncle. The species, *Badis khwae* observed from Thailand, possesses a dark blotch on the dorso-

lateral aspect of the caudal peduncle present. Rounded caudal fin; blotch on caudal peduncle small and confined to the side of the caudal peduncle. A Dark bar is present entirely across the caudal fin base with the dorsal most portions darker and separated from the rest by a light band instead of the 3 dark blotches in most *Badis* species. *Badis kyar* was recorded from Thailand with extremely slender body. Neither dorsal fin lappets nor pelvic fin margin are thickened. Caudal fin base is present with a wide, curved bar. Color pattern features 10 dark entire, strongly curved dark bars across caudal fin base, prominent in males. Neither dark blotch on superficial part of cleithrum, postero-dorsally on opercular margin, nor on dorso-lateral side of caudal peduncle. *Badis pyema* reported from Myanmar can be distinguished in having an extremely slender body and caudal fin base with a prominent dark spot at the center, surrounded by a light ring. The species differs from *B. corycaeus* in colour pattern where males are overall light with scattered black spots on each scale on sides. *Badis ruber* described from Mekong basin in Laos and Thailand, Salween and Irrawaddy basins possesses a large caudal peduncle blotch, extending dorsally across dorsal margin of caudal peduncle. The species also shows the presence of black spots in vertical bars on sides; faint pattern of alternating light and dark stripes along the side. The species *Badis siamensis* is endemic to Thailand and shows the presence of a small caudal peduncle blotch which is confined to side of caudal peduncle. Dahanukar, Kumkar, Katawate and Raghavan (2015) recorded another percomorph fish, *Badis britzi* from Nagodi tributary of the west-flowing Sharavati River in Karnataka. It can be distinguished by having a slender body, which distinguishes it from all other congeners except *B. pyema* and *B. kyar*. Its color pattern is composed of 11 dark, clearly-

defined bars, most closely resembles that of *B. kyar* and *B. juergenschmidti*. Geetakumari and Vishwanath (2010) reported a new species, *Badis dibruensis* from the Dibru River, Brahmaputra drainage in Assam. *B. dibruensis* was diagnosed from its closest congener, *Badis badis* in possessing the following combination of characters: 2 (vs. 3) pre-dorsal bones; small oval shaped (vs. large rectangular shape) black blotch in the mid of caudal fin base. It can be distinguished from the three species, i.e., *B. badis*, *B. kanabos* and *B. tuivaiei* by the absence (vs. presence) of vertical bars on sides, dark black to brown. Schindler and Linke (2010) recorded a new species, *B. juergenschmidti* only from the type locality, Ka Dat Chaung River in south eastern central Myanmar. The species is indicated by the absence of a blotch on the postero-dorsal corner of its opercle and that of the cleithral blotch. It is also indicated by the presence of one bar on caudal fin base, broad solid in adult males and caudal fin of adult males shows a white margin postero-dorsally and postero-ventrally. G. A. von Maydell (1957) collected a new percomorph species, *B. kanabos* rom the Janali River, Brahmaputra River Drainage, Assam by the presence of a conspicuous dark blotch anteriorly in the dorsal fin, between 3^{rd}-5^{th} spine. It also indicated the presence of vertical bars on sides as multiple emphasized narrow lines. Caudal fin is present with a dark bar across base or mid basal rounded dark blotch. Basumatary, Choudhury, Baishya, Sarma and Vishwanath (2016) reported a new percoid fish species, *B. pancharatnaensis* from Hasila Beel, a riverine wetland of Brahmaputra drainage in Assam and can be distinguished from all its congeners in having a combination of the following characters: dark brownish black bars on sides present; a series of dark blotches along middle of dorsal-fin present; a prominent black blotch on

the superficial part of cleithrum present; elongate median caudal blotch with a posterior bar surrounding the caudal-fin base; pointed pelvic-fin reaching beyond vent in both sexes and pointed soft dorsal and anal-fin. Geetakumari and Kadu (2011) recorded a new fish species from the Singen River, Arunachal Pradesh. *B. singenensis* is with the following combination of characters: a conspicuous black blotch postero-dorsally on opercle, at the base of opercle spine, round and usually covering portion of several scales; three distinct dark blotches at dorsal fin base, first blotch behind third spine, second behind sixth dorsal spine and third behind the fifth and sixth soft dorsal ray; another distinct black blotch at the base of anal fin behind the fifth soft anal fin ray. A new *Badis* species, *B. triocellus* reported by Khynriam and Sen (2011) from Arunachal Pradesh, Assam and Meghalaya can be distinguished by the having the following characters: three distinct black blotches on fins, two on anterior and posterior end of dorsal fin respectively and one on anal fin; anterior blotch on dorsal fin is present in between 3^{rd}-5^{th} dorsal spine, posterior one present slightly above base of last 3-4 soft rays; on anal fin, blotch is present a little above the base of last 3 soft rays; light to dark brown blotch on middle of the opercle, a brownish blotch at middle of the base of caudal fin and a faint pattern of alternating light to brown irregular stripes along the sides of the body are additional combination of characters. Vishwanath and Shanta (2004) described a new percoid fish species of the *Badis* genus, *B. tuivaiei* from Manipur which shows the presence of a conspicuous black blotch on superficial part of the cleithrum above pectoral fin base. A black blotch between third and fourth dorsal spine and a mid-basal rounded black spot on caudal fin are present. The species has slightly projecting lower jaw.

2.5. General biology

Studies on external morphology are needed for identification of sex externally. Body shape, colour, belly structure, structure and colour of vent, fins and end of the caudal peduncle etc. are the external morphological features of fish. The external morphology and taxonomy of Blue perch *Badis badis* have been studied by Hamilton (1822); Bhuiyan (1964); Rahman (1989); Jhingran and Talwar (1991); Jayaram (1999); Shafi and Quddus (2001); Kullander and Britz (2002).

General biology of any species mainly includes the study of morphometric and meristic characters. The body shape can be well described by the morphometric aspects. Meristic counts are the countable structures like rays and fins. Morphomeristics is commonly used for taxonomical identification and differentiation of individual species and species from different stocks (Lourie *et al*., 1999; Doherty and McCarthy, 2004; Jayasankar *et al*., 2004). The fin formula of *Badis badis* given by different workers are as follows; D. XVI-XVIII/ 7-10; P. 12; A. III/6-8; C. 16 (Bhuiyan, 1964); D. XIII/ 12; P1. 15; A. III/7-8 (Rahman, 1989); D. XVI-XVIII/7-10; P. 12; V. I/5; A. III/6-8 (Talwar and Jhingran, 1991); D. VI-XVII/ 7-10; P. 12; A. III/6-8; C. 16 (Shafi and Quddus, 2001); D. XV-XVII/ 7-10; P. 12; V. I/5; A. 6-8; P: 12 (Kullander and Britz, 2002). According to Rahman, 1989 lateral line is interrupted at 20 or 21 scales; often absent (Talwar and Jhingran, 1991); 25-26 scales (Rahman, 2005); 26-30 scales (Talwar and Jhingran, 1991) and 26-33 scales (Shafi and Quddus, 2001) in longitudinal series. Similarly, the lateral line is interrupted or absent with 26-33 scales present in the

longitudinal series (Jayaram, 1999) and, 25-27scales in lateral row and 19-20 circumpeduncular scales (Kullander and Britz, 2002).

The body of *Badis badis* is elongated and relatively compressed; body of the species is covered with moderate-sized ctenoid scales. Mouth of the fish is relatively small and slightly upturned; terminal. Eyes are large. Presence of villiform teeth on jaws, vomer and palatines; none on tongue. Opercle is present with one sharp spine. Air bladder is large and simple. A single dorsal fin is inserted above the base of pectoral fins with longer spiny portion than the soft portion (Jayaram, 1999). Sexes are separated. Fish of this genus have sharp spine on the opercle, soft and spinous parts of the dorsal fin contiguous, three spines in the anal fin, tubed, and a rounded tail fin. The species has conspicuous dark blotch on superficial part of cleithrum above baseof pectoral fin. Lacks a dark caudal peduncle blotch. Has a series of prominent dark blotches along dorsal fin base and/or a series of dark blotches along middle of dorsal fin; and has indistinct bars on side. Has a distal extrascapular (Kullander and Britz, 2002). Kullander and Britz, 2002 said that the body depth of *Badis badis* is 30.7-38.9%SL; interorbital width 6.5-8.3% SL.

This species is reported from tropical waters of India, Bhutan, Bangladesh, Pakistan, and Nepal. In India and Bangladesh the species is reported from both Ganges, Mahanadi and Brahmaputra river drainage. The fish is native to the Ganges- River system, from the Yamuna River in Himachal Pradesh state, India, to its delta in Bangladesh. It is also known from Ganges tributaries in Nepal, while in India there are additional records from the Mahanadi River system in Chhattisgarh and Orissa states, and

parts of Assam state including the city of Guwahati, Kaziranga National Park, and the Dibru River basin. When Hamilton described this species he did so only from field notes and drawings, therefore Kullander and Britz (2002) designated a neotype in order to avoid confusion with similar-looking congeners. Neotype locality is _shore of Tumapao River close to Duma village (Ganges River drainage), about 65 kilometers north-north east of Calcutta, West Bengal, India, 22°58‘03″N, 88°49‘49″E‘.It is also found that the fish are occurs solitarily in rivers, ponds and ditches. Also found in swamps. It lives in tropical freshwaters in temperatures of 23 °C - 26 °C, pH range: 6.0 - 8.0.The neotype locality is a wide (>100m), shallow (<1m depth), slow-moving stream that flows through rice fields and does not have a great deal of marginal vegetation. The water was described as ―moderately turbid‖ and ―brownish‖ with a substrate of mud in which some (unspecified) aquatic plants grow. Descriptions of other collection localities suggest the species to favour turbid waters with low water flow and growths of submersed vegetation. It is often associated with water lily beds, and in the Dibru River occurs sympatrically with *B. assamensis*.

Mahapatra (2016) studied some aspects of biology of *Badis badis* (Ham. 1822) from North Eastern Hill Region. According to Mahapatra (2016) the maximum and minimum total length observed was ranging from 389 experimental fishes are 38.00 mm and16.50mm, respectively. The maximum and minimum weight observed from 389 experimental fishes are 0.81g and 0.05g respectively. In that study r2 0.958 is indicating the very good fit of model in all cases. The functional form of relationship between L-W of the species were fitted as Log W= - 5.35 + 3.35Log L. The 'b' value of fish showed

3.35 indicating the allometric growth of *B. badis* and was found to be significantly different at 1% level. The mean K value was calculated from the length and weight of B. badis. The condition factor of the fish is 0.0015. The condition factor indicates the poor physiological condition of the fish.

2.6. Feeding biology

Feeding biology is obligatory for efficacious management practices in fisheries and aquaculture. Food is the main source of energy and that is why knowledge on food and feeding habits of fishes have a great significance in aquaculture. Food is essential for growth, development; reproduction and survival of all organisms. Food and feeding habits of any species are intimately associated with the ecological niche that they inhabit in the natural environment. Hence, studies on the feeding habit help in understanding the feeding ecology of the species as well as imperative to expand larval rearing. Studies on the food and feeding habit of different fishes have been carried out by many workers like Moffet and Hunt (1943), Khan (1947), Hynes (1950), Karim and Hossain (1972), Doha (1974), Dewan and Saha (1979), Jhingran (1983), Bhuiyan and Haque (1984), Bhuiyan and Islam (1990, 1991), Hossain *et al*. (1991), Bhuiyanetal. (1997, 1998, 1999) and others. Jhingran (1983) stated that the natural foods of fishes are classified under three groups, viz., main food, occasional food and emergency food. The inducements to food are of two kinds, (a) factors affecting the appetite including season, light intensity, time of day, nature of last feeding, temperature and any internal rhythm that may exists; (b) food stimuli observed by the sense like smell, taste, sight and the lateral line system that

release and regulate the momentary feeding act. Feeding with appropriate high energy diets rich in protein, vitamins and minerals is required for adequate breeding of ornamental fishes in confined waters (Encina *et al*., 1997). The modern studies exhibited that the various effects on growth and reproductive performance of fish is triggered by live feeds (Salas *et al*., 2009). Incomplete information is available on the effects of food on brood stock, fecundity and larval survival of ornamental fishes. Geetakumari and Vishwanath (2010); Kullander and Britz (2002); Rüber, Britz, Kullander and Zardoya (2004); Schindler and Linke (2010); Vishwanath and Shanta (2004) reported that all the Badis species, except for *Badis badis, Badis ruber* and *Badis blosyrus*, have the same diet. All these *Badis* species are micro-predators feeding on small aquatic crustaceans, worms, insect larvae and other zooplankton. They can be a little picky in the aquarium and may not accept dried foods although in some cases they will learn to take them over time. At any rate they should always be offered regular meals of small live or frozen fare such as Artemia, Daphnia or glass worm in order to develop ideal colour and conditioning. They‘re somewhat shy, deliberate feeders and it‘s also important all species develop issues with obesity and become more susceptible to disease when fed chironomid larvae (blood worm) and/or Tubifex so these should be omitted from the diet. On the other hand, the species, *Badis badis* accepts all foods, staple diet provided by quality flakes; blood worms and white worms should be given as treats (aquafish.net, 2014). The species, *Badis ruber* (Burmese Badis) usually ignores any flake food offered to it. This species prefers to be given live or frozen foods, which they consume eagerly. Blood worms, white worms and brine shrimp are ideal food (aquafish.net, 2014). And *Badis*

blosyrus only accepts live or frozen foods. Their favorite food seems to be brine shrimp, blood worms and glass worms.

The ratio between the gut length and total length (RLG) has been estimated by dividing the gut-length by total length of the body (Al-Hussaini, 1949). Das and Nath (1965) calculated the relative length of the gut in L. dero as 8.9. They found RLG value in *Puntius conchonius* and *Barbus hexastichus* as 3.3 and 2.3, respectively, which indicated that the fish is omnivorous. The length of the digestive tract is closely related to the type of food. Hugueny and Pouilly (1999) gave an opinion on relative gut length and assumed to be higher in magnitude in detritivores and herbivores. Piet (1998) found that relative gut length is linked to herbivory. Bowen (1988) gave a view that a functional explanation for the long intestine in herbivorous species is that one or more essential components of their diet are slow to be digested and both a long residence and extensive exposure to absorptive surfaces are required. Das and Nath (1965) recorded an average RLG value for Tor tor as 2.14. Bhattacharjee and Dasgupta (1998) reported that the RLG value for A. morar (Ham.) as 1.02 and Dasgupta (2001) reported the RLG values for *L. gonius, L .rohita, L. bata* and *L. calbasu* as 9.420, 8.08, 7.75 and 4.51 respectively.

Feeding intensity symbolizes to the degree of feeding as specified by the relative fullness of the stomach. Singh *et al*. (2013) conveyed that there is difference in the feeding intensity with respect to maturity stages, seasonal variation, spawning season, and accessibility of desired food items. Gastro-somatic index determines the feeding intensity of the fish. The gastro-somatic index of mature fish is little during the spawning

period, as compared to the non-spawning duration. Study of food and feeding habits of fishes have diverse significance in fishery biology (Singh *et al*., 2013).

2.7. Reproductive biology

For an enhanced understanding of the biology of any fish population, information on reproductive cycles is needed (Lazarus, 1990). The knowledge of reproductive cycle and its functional mechanism helps in proper breeding of the species. Information about spawning behaviour is more essential for captive timely management of fish stock. In case of major carps, natural spawning commonly overlaps with the South-west monsoon in North-Eastern India and Bangladesh and continues from May to August. It continues from June to September in North India and Pakistan. The spawning season seems to be variable in the southern portions of India (Jhingran, 1968; Khan and Jhingran, 1975; and Jhingran and Khan, 1979). According to Natarajan and Jhingran (1963), under natural conditions Indian major carps breeds only once in a year. Recently, however in a season/year under controlled conditions Indian major carps have been bred more than four times (Gupta *et al*., 1995).

According to Gratzek (1992) reproduction of any species involves successful accomplishment of a number of key steps, viz., brood stock selection, brood stock conditioning, spawning, hatching and survival - growth of larvae and fry. By mismanagement of one or more of these steps, most problems can be traced. Brood stock must be in good health, colour, strong and vigorous with no deformities. Decreased productivity may be seen in older breeders because of age or acquisition of age related

diseases. Often less fertility is seen in younger breeders and certain species might show more cannibalism and less parental care (Gratzek, 1992). The major factors that affect quality and productivity of fish eggs are age and nutritional status of brood stock (Izquierdo *et al.*, 2001). Through maintenance of optimal water quality, nutrition, habitat and reduction of pathogenic load, brood stock conditioning is achieved. Omnivores and carnivores brood stock have need of high quality protein foods that contain essential fatty acids, carbohydrates, vitamins and minerals. In culture of ornamental fishes, reproductive capacity is also reduced due to external and internal parasites. To avoid unwanted spawning activities, there should be segregation of sexes as soon as possible (Gratzek, 1992).

Differentiating sex is the primary step in developing a captive breeding program for a fish species. Sexual dimorphism depicts the morphological features with which we can successfully segregate them sex-wise. Differences in the selective pressures experienced by the sexes can ultimately result in the evolution of sexual dimorphism of morphological traits (Andersson, 1994). Fish exhibits wide variations in the possession of sexual dimorphic characters. In some species, there exists a highly remarkable difference between male and female as they should have been mistaken to be a different species, while some others are found to be extremely identical in morphological features.

The females can be distinguished from their male counterparts by colouration and during the breeding season from their swollen belly. Female *Badis badis* rate somewhere between drab and plain most of the time. Males are more colourful than females (which

are without the red or blue colour on their flanks), making them the more preferred for export (Mahapatra, 2016).

Gonadosomatic index (GSI) is an index of gonad size relative to fish size. It is a good indicator or tools to understand the gonadal development in fishes (Dadzie and Wangila, 1980). The body weight percentage of a fish is used to define the production of eggs by the gonadosomatic index. Gonad progress can encourage physiological or behavioural responses in the fish (Moyle and Cech, 1988). The Gonadosomatic index is one of the most important measures in the estimation of the reproductive period and maturity condition of a fish. The gradually increasing values of Gonadosomatic index gives the picture about the dynamics of gradual gonadal maturation and the maximum Gonadosomatic index means the point of maximum reproductive maturity and beyond that a steep fall because of spawning, the shedding of eggs. Sexually mature fish had high GSI values and in females these were as much as six times greater than in males (Chellappa *et al*., 2003).

According to Moyle and Cech (2004) some species are nest spawners and lay eggs in the nest and others called substrate spawners, which lay eggs in the spawning substratum. According to Mohanta *et al.* (2008) spawning often take place all through the early sunrise hours. During the commencement of breeding season, males chase females, stimulating them to discharge their eggs by bumping and pushing them. Occasionally the courtship lingers for numerous hours or even days and then the female discharge the eggs, which are inseminated by the milt released simultaneously by male. Within 12 to 48

hours, the eggs may perhaps be hatched out and the yolk sac fry developed. The freshly hatched early larvae carry on to nurse off their yolk sacs for around 4 to 7 days till they become free swimming. Proper feeding should be done at this time and water quality must be maintained (Gratzek, 1992). According to some fish breeder and farmers, Badis sp. are cave spawners that form temporary pair bonds. The sexually mature male species stays in his burrow and the ripe female goes to him thereby initiating spawning. In breeding condition, rival males become increasingly combative and begin to display courtship behaviour towards the females entering their respective territories. During this process, they display changes in colour pattern, with the body darkening to almost black and the blue fins intensifying in colour. The locking of mouths is common with the male attempting to drag his partner into the cave. The ripe females do not show aggressive behaviour. After entering the burrow the female is at first attacked by the male, but the pair soon starts Carouselling. An intricate stimulus-response chain, with appreciable overlap, characterizes the interaction that results in the male enfolding the female, spawning, release and the subsequent period of quiescence. A receptive female enters and spawning takes place with 30-100 typical eggs. The eggs fall to the floor of the burrow where they adhere. The male manifests typical fanning movements when engaged in sexual behaviour.

Fecundity may be defined as the number of mature eggs in the ovary of female fish prior to spawning (Bagenal and Braum, 1978). Many fishery researchers have worked on the fecundity of diverse fishes (Naeem *et al.*, 2005; Jakobsen *et al.*, 2009; Mekkawy and Hassan, 2012; Shinkafi *et al.*, 2011). The awareness of fecundity is one of

the significant parts of the reproductive biology (Nikolsky, 1963). According to Khallaf and Authman (1991) fecundity is not a persistent feature but it is altered with differences in ecological conditions and species specific reasons. Fecundity is useful to apprehend if fish has attained maturity and is able to spawn the number of eggs in the spawning period. The difference in fecundity may occur due to the dissimilarities in environmental conditions and food consumption by the fish. The disparity of fecundity is very common witnessed in fishes (Doha and Hye, 1970). The number of eggs spawned by female is at the mercy of several factors like age, size, and ecological conditions.