

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1. An overall view of the importance of water

Water is the soul of nature and is one of the basic requirements of mankind. It is also the most essential environmental component for the well being of the living world. Life originated in water and most of the biological phenomenon takes place in liquid medium (**Dhamak , 2013**). About 70% of Earth's surface is water, of which 97.5% is saline and 2.5% is fresh. Less than 1% of this 2.5% amount of freshwater is accessible.

According to **Postel et al., (1996)** human population used 54 percent of all the fresh water contained in rivers, lakes, and aquifers and this percent is expected to climb by at least 70 percent in 2025. By 2025, 50 countries and more than 3.3 billion people will face water stress or scarcity and majority of these countries, 40 of them, are in the near East, North Africa, and sub-Saharan Africa (**Gardner-Outlaw and Engelman, 1997; UNFPA, 1997**).

In 1996, 734 species of endangered fish of the world, 84 percent are found in freshwater environments. Globally, over 20 percent of all freshwater fishes are endangered, vulnerable, or recently extinct (**Brautigam, 1999**).

Therefore, water is essential at all level, that is, from cellular to ecosystem and within the body of each living being. Water is the key substance for existence and continuity of life. Human beings depend on this resource for all their needs. For existence and survival of aquatic fauna like phytoplankton, zooplankton and fish which are the major elements of food chain in aquatic ecosystem this resource plays a key role (**Dhamak , 2013**).

2.1.2. Freshwater aquatic environment

Communities of plants and animals living in water are known as aquatic ecosystem. Aquatic or watery environment are divided in to fresh water and marine water (**Lerner et al., 2001**). **Welch (1952)** defined Limnology as the branch of science which deals with biological productivity of inland waters and with all the causal influences which determine it and again **Wetzel (2001)** explained it as the study of the structural and functional interrelationships of organisms of inland waters as they are affected by their dynamic physical, chemical and biotic environments.

Flowing fresh water environment is called lotic ecosystem for obvious reason of unidirectional water movements along a slope in response to gravity (**Wetzel, 2001**). Lotic environments are fundamental components of regional and global biogeochemical cycles, acting as both transport pathways and sites of elemental transformations and storage and they act as sources of drinking water, fisheries resources, irrigation supplies, and waste removal systems (**Roy, 2014**). They are characterized by interactions among physical, chemical and biological processes, which reach a higher degree of complexity downstream (**Wehr and Descy, 1998**).

Due to high population densities and multiplicity of industrial and agricultural activities expose most hydrographic basins to heavy and rising environmental impacts especially to pollution by domestic and industrial waste residues (**Salomoni et al., 2006**). River water finds multiple uses in every sector of development like agriculture, industry, transportation, aquaculture, public water supply and so on (**Kumar, 2010**). River pollution in India has now reached a point of crisis. Surface waters are most vulnerable to pollution due to their easy accessibility for disposal of wastewaters (**Patel and Minakshi, 2015**).

2.1.3. Water quality parameters

Fish are in equilibrium between potential disease organisms and their environment. Changes in this equilibrium such as deterioration in water quality (environment) can result in fish becoming “stressed” and vulnerable to disease and it is very important to know something of the water quality parameters that have influence on growth and survival of aquatic organism (Lokare, 1989). Water is known as blue gold, one of the most priceless gifts of Nature is also regarded as the life line of Earth, because evolution of life and development of human civilization could not have been possible without water and rivers (Patel and Vaghanib, 2015). Yahya *et al.*, (2012) stated that management and protection strategies had to develop for each water basin individually because, polluted water used for drinking, domestic purpose as well as for irrigation without assessing its suitability in different parts of the world.

Table.1. Different analytical water quality parameters Standards guideline values as per WHO, Indian standard and USEPA (Patil *et al.*,2012)

Sl. No.	Parameters	WHO	Indian Standards	US EPA
1	pH	6.5 to 9.5	6.5 to 9.5	6.5 to 9.5
2	Specific Conductivity (μScm^{-1})	-	-	2500
3	Total Dissolved Solids (mg l^{-1})	-	500	-
4	Dissolved Oxygen (mg l^{-1})	6	6	-
5	Free Carbon dioxide (mg l^{-1})	200	-	-
6	Total Alkalinity (mg l^{-1})	-	200	-
7	Total Hardness (mg l^{-1})	200	300	<200
8	Ammonium-N (mg l^{-1})	0.3	0.5	0.5
9	Nitrite -N (mg l^{-1})	3	45	0.5
10	Nitrate-N (mg l^{-1})	45	45	50
11	Phosphate-P (mg l^{-1})	-	5	-

2.1.3.1. Temperature

Temperature is one of the essential physical parameter of water quality to be measured because it influences the aquatic life by altering the dissolved oxygen concentration in the water making oxygen less available for respiration and metabolic activity of aquatic organisms (**Tank and Chippa, 2013; Jalal and Sanalkumar, 2012**). The air temperature is the resultant effect of several meteorological factors such as solar radiation, humidity, wind etc. and also the latitudinal and altitudinal position of the place under study (**Wetzel, 2001**). Water temperature plays a very important role in some physiological processes like release of stimuli for breeding mechanisms in fish, both under natural and artificial conditions (**Hora, 1945; Chaudhuri, 1964**). Water temperature is an affective factor to control the chemical reactions and its rate within the water body that determines the usefulness of the water (**Metcalf and Eddy, 2003**). The standard temperature for sustaining aquatic life varies between 28°C to 30°C (**Weldermeriam, 2013**). Temperature is a measure of how much heat is present in the water, and cold water holds more oxygen than warm water. Warm water enters the river, raises the temperature of the downstream area and changes the oxygen levels. These are forms of thermal pollution. Thermal pollution is one of the most serious ways humans affect rivers. Cutting down trees along the bank of a river or pond also raises the water temperature (**Lodh et al., 2014; Mandal et al., 2012**).

2.1.3.2. pH (Hydrogen Ion Concentration)

The pH an important parameter of water maintains the acidic or basic property of an aquatic ecosystem and determines the suitability of water for various purposes such as drinking, bathing, cooking, washing, agriculture and so on. The higher range of pH indicates higher productivity of water (**Gopalkrushna, 2011**) because availability of

carbonates and bicarbonates in water enhance free carbon dioxide level by dissociation and acts as a raw material for photosynthesis. According to **Boyd (1982)**, at extremely high or low levels namely pH of 9 or 4, was unsuitable for most organisms and young fish and insects. The pH of natural water ranges between the extremes of <2 -12 (**Wetzel, 2001**). pH can vary from its normal levels (6.5 to 8.2) due to pollution from automobiles and coal-burning power plants (**Mandal et al., 2012**). pH was positively correlated with electrical conductance and total alkalinity. Most of the similar studying suggested that water samples were slightly alkaline due to presence of carbonates and bicarbonates (**Tank and Chippa, 2013 and Gopalkrushna, 2011**). The pH level of water having desirable limit is 6.5 to 8.5 as specified by the BIS. Pure water is said to be neutral, with a pH of 7.0. Water with a pH below 7.0 is considered acidic while, with pH greater than 7.0 is considered as basic or alkaline. The pH acts as a pollution indicator of water and pH of natural water can provide important information about many chemical and biological processes and provides indirect correlations to a number of different impairments. The acidic pH may be due to the high organic load and decomposition. The rain water is responsible for neutralization and finally makes it alkaline (**Saha, 2014**). **Mishra and Yadav (1978)** reported high pH value rivers and lakes in Central India.

2.1.3. 3. Specific Conductivity

The electrical conductivity represents the total concentration of soluble salts or mineral salts in water (**Trivedy and Goyal, 1986**), so making it sour and unsuitable for drinking (**Saha, 2014**). Conductivity is a measure of the ability of water to pass an electrical current which is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulphate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge) (**Mondal et al., 2014**). Organic compounds like oil, phenol, alcohol, and sugar

do not conduct electrical current very well and therefore have a low conductivity when in water. **Mondal et al., (2014)** also reported that conductivity is also affected by temperature. Warmer water have higher conductivity than cooled water. The conductivity of rivers in the United States generally ranges from 50 to 1500 $\mu\text{mhos/cm}$ and inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 $\mu\text{hos/cm}$ (**Mondal et al.,2014**). Specific conductance of north western Himalayan river water ranged from 20 to 468.2 $\mu\text{mho cm}^{-1}$ and it increased upstream to downstream (**Singh, 1988**). In glacier-fed Trishuli river system of Nepal it varied from .2 to 534.0 $\mu\text{mho cm}^{-1}$ (**Thapa et al., 2010**) and in the rivers of Bhutan Specific conductance ranged from 20-140 $\mu\text{mho cm}^{-1}$ (**Dubey, 1978**). Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macro-invertebrates. Industrial waters can range as high as 1000 $\mu\text{mhos/cm}$ (**United States Environmental Protection Agency, 1986**). Electrical conductivity is directly related to concentration of ionized substances in water and may also be related to problems of excessive hardness.

2.1.3. 4. Total Dissolved Solids (TDS)

According to **Mandal et al., (2012)** Total dissolved solids are measure of dissolved matter (salts, organic matter, minerals and so on) in water, and TDS can be toxic to aquatic life through increases in salinity or changes in the composition of the water, or it may include substances that are toxic to people or aquatic life. Most aquatic ecosystems involving mixed fish fauna can tolerate TDS levels of 1000 mgL^{-1} (**Boyd, 1999**). Total Dissolved Solids define the color and electrical conductivity of the water body and the amount of TDS in water indicates salinity of water and may also be used as an indicator for rapid plankton growth and sewage (**Tank and Chippa, 2013**). In natural

waters, salts are chemical compounds comprised of anions such as carbonates, chlorides, sulphates, and nitrates (primarily in ground water), and cations such as potassium (K), magnesium (Mg), calcium (Ca), and sodium (Na) and in ambient conditions, these compounds create a balanced solution if there are additional inputs (natural and anthropogenic source) of dissolved solids in the system, the balance is altered and detrimental effects may be seen (Tiwari, 2015).

2.1.3. 5. Dissolved Oxygen

Oxygen is the single most environmental parameter that exerts a tremendous effect on growth and production through indirect effect on feed consumption and metabolism and its direct effect on environment (Lokare, 1989). Dissolved oxygen in water is an indicator for water quality and diversity of living things. The reason behind the fact is the turbulence and oxygenation resulting from rainfalls and mixing up of gleaming aerated water (Saha, 2014). The DO value indicates the degree of pollution in the water bodies (Gupalkrushna, 2011). Deficiency of dissolved oxygen gives bad odour to water due to anaerobic decomposition of organic wasters (Manivasakam, 1980). Almost all plants and animals need dissolved oxygen for respiration. A good quality of water should have a solubility of oxygen from 7.0 to 7.6 mg/l at 30°C respectively (Kudesia, 1985). Hancock (1973) and (Welch, 1952) reported that it was maximum in winter and minimum in summer. Krishnamurthy (1990) reported that greater qualities of Oxygen recorded during summer. In the progress of summer, dissolved oxygen decreased due to increase in temperature and also due to increased microbial activity (Moss, 1972; Morrissette, 1978; Sangu, 1987; Kataria, 1996). In the rivers of north eastern Himalaya values of dissolved oxygen ranged from 3.6 to 15.4 mg L⁻¹ (Acharjee, 2013). Jhingran (1991) reported average value of 9.4 mgL⁻¹ in the river Brahmaputra.

Oxygen enters into the water by aerial diffusion and as a photosynthetic by-product of aquatic plants and algae (**Lodh et al., 2014**). The DO depends upon the temperature, salinity and pressure of the water. The aquatic life gets distressed when DO levels drops to 4 to 2 mgL⁻¹ (**Francis-Floyd, 2003**) and as DO level falls, undesirable changes in odor, taste and color reduces the usefulness of water (**Tank and Chippa, 2013**). DO in correlation with water body gives direct and indirect information for example bacterial activity, photosynthesis, availability of nutrients, stratification and so on (**Premlata, 2009**). Addition of domestic sewage, municipality wastes, waste from market and hospital encourage the growth of micro organisms which use the dissolved oxygen for decomposition. The concentration thus gradually decreases (**Patra et al., 2011**).

2.1.3.6. Free Carbon dioxide

Carbon dioxide (CO₂) is readily soluble in water but very little amount of CO₂ is present in simple solution because, small amount of CO₂ is present in the atmospheric air. Apart from this, decomposition of organic matter and the respiration of aquatic plants and animals contribute to the free CO₂ present. Water percolating through the vegetation and soil take up CO₂ released from the soil. Carbon dioxide combines chemically with water to form carbonic acid (H₂CO₃), dissociates partly to produce hydrogen (H⁺) and bicarbonate (HCO₃⁻) ions (**Faurie et al., 2001**). CO₂ can build up to significantly high levels in systems with large numbers of fish and relatively slow water turnover (**APHA, 2005**). **Thapa-Chhetry and Pal (2011)** reported free CO₂ to range from 4.15 to 5.92 mg L⁻¹ in Nepal. **Biswas and Boruah (2002)** reported the range of free CO₂ to be from 1.9 to 12.3 mg L⁻¹ in the river Brahmaputra with an average value of 5.2 mg L⁻¹. The free CO₂ found in the Relli river water was low and varied from 0.6 mg L⁻¹ to 5.8 mg L⁻¹ with a mean value of 3.1 mg L⁻¹ (±1.4) (**Acharjee and Barat, 2012**). The presence of carbonic

acid (H_2CO_3) in water may be good or bad depending on the water's pH and alkalinity (Saha, 2014).

2.1.3. 7. Total alkalinity

Alkalinity is an indicator for a solution's capacity to react with acid and "buffer" its pH. Water is said to be **alkaline** when concentration of the hydroxyl ions exceeds that of hydrogen ions (Trivedy and Goel, 1984). Total alkalinity is the sum of hydroxides, carbonates and bicarbonates. Increased dilution of river water may be responsible for lower values of alkalinity in rainy seasons (Bhargava, 1982).. Alkalinity is not a pollutant and it is measured in water that have "acid-neutralizing" ability, and pH measures the strength of an acid or base (Saha, 2014). In rivers and streams of the north eastern Himalaya total alkalinity ranged from 12 to 207.7 mg L^{-1} (Bhattacharjya *et al.*, 2002). Biswas and Boruah (2002) reported range of total alkalinity from 44.3 to 110.8 mg L^{-1} with an average value of 63.4 mg L^{-1} in the river Brahmaputra. NWWFCC (2001) recorded range of total alkalinity from 13 to 120 mg L^{-1} in the rivers of Bhutan.

2.1.3. 8. Total hardness

Total hardness is defined as the sum of calcium and magnesium hardness express in mg l^{-1} as CaCO_3 . The anions responsible for hardness are mainly bicarbonate, carbonate, sulphate, chloride, nitrate and silicates etc (Trivedy and Goel, 1984). According to Swingle (1967a), a total hardness of 50 mg L^{-1} is the dividing line between soft and hard water. Kannan (1991) had classified water on the basis of hardness values in the following manner, 0- 60 mg l^{-1} soft, 61-120 mg l^{-1} moderately hard, 121-180 mg l^{-1} hard and above 180 mg l^{-1} very hard. Calcium hardness in freshwater is in the range of 10 to 250 mg l^{-1} , often double that of magnesium hardness (5 to 125 mg l^{-1}) and total hardness of 630 mg l^{-1} as CaCO_3 (Pawari and Gavande, 2013).. A high concentration of

hardness may be due to leaching from of the soils or due to the high background concentration of the waters. The limit of total hardness value for drinking water is to be within 300 mgL⁻¹ of CaCO₃. Higher concentration of hardness was found to be due to natural accumulation of salt, surface runoff and water entering from direct pollution by human activities (**Pawari and Gavande, 2013**).

2.1.3. 9. Ammonium-N

Ammonia is naturally present in surface water and groundwater and can be produced by the deamination of organic nitrogen containing compounds and by the hydrolysis of urea. The problem of taste and odour may arise when the ammonium-N (NH₄-N) level is greater than 2 mgL⁻¹. Greater than 10 mgL⁻¹, appreciable amounts of NO₃-N may be produced from NH₄-N under suitable anaerobic conditions (**WHO, 1993** and **Kempster et al., 1997**). **Ammonium ion** (NH₄⁺) is also brought to natural waters by animal and human wastes. Even more than nitrates, it is preferentially absorbed by plants. It is also produced by fishes and zooplankton, which leads to very rapid development of phytoplankton in waters in which this chemical form of nitrogen cannot be detected by chemical analyses (**Faurie et al., 2001**). Distribution of ammonia in unpolluted rivers ranges from 0.005 to 0.040 mg L⁻¹ with an average value of 0.018 mgL⁻¹ (**Wetzel, 2001**). **Lodh et al., (2014)** found that ammonia level was higher than the prescribed value of BIS and average value is ranges between 0.06 to 3.20 mgL⁻¹.

2.1.3. 10. Nitrite-N

Nitrite (NO₂⁻) is not abundant in water. They are rare because they constitute only a passing form between the ammonia and nitrate, during the processes of nitrification and denitrification. In natural waters, any concentration higher than 10 µgL⁻¹ indicates a dysfunction of microbial mechanisms involved in the nitrogen cycle (**Faurie**

et al., 2001) and water is not suitable for drinking purpose if the concentration is greater than 0.05mg l^{-1} (WHO, 1992). Nitrites are readily oxidized to nitrates and are seldom present in significant concentration in the surface waters (Roy, 2014). Nitrite nitrogen concentrations in the Himalayan Rivers ranged from traces to 0.035 mg L^{-1} (Semwal and Akolkar, 2006). Thapa *et al.*, (2010) recorded range of $\text{NO}_2\text{-N}$ and $\text{NO}_3\text{-N}$ together in the river Trishuli of Nepal Himalaya ranged from nil to 0.138 mg L^{-1} . According to Barat and Jha (2002) $\text{NO}_2\text{-N}$ ranged $0.002\text{-}0.030\text{ mg L}^{-1}$ in the sub Himalayan Rivers Mahananda of North Bengal.

2.1.3. 11. Nitrate–N

Inorganic nitrogen present in water as Nitrate ($\text{NO}_3\text{-N}$) is the main nutrient that accelerates the growth of hydrophytes and algae. Nitrate occurs in water from various natural sources and human activities like food production, agriculture and manure disposal of domestic and industrial sewage. Welch (1952) opined that nitrate in natural waters will be in a continuously changing state due to the relation of nitrate with nitrifying bacteria and demand by nitrate consuming organisms such as phytoplankton and higher aquatic plants. Nitrate ($\text{NO}_3\text{-N}$) is one of the important nutrients in water body which is the common form of nitrogen in natural water (Saha, 2014). High level of nitrates is found in rural areas because of extensive application of nitrogenous fertilizers in agriculture (Lodh *et al.*, 2014). In urban areas sewage water rich in nitrates contaminate surface water thus increases the nitrate amount. (Tank, 2013; Gopalkrushna, 2011). An average $\text{NO}_3\text{-N}$ concentration of nearly $100\mu\text{g N L}^{-1}$ is found in natural river waters (Wetzel, 2001). Range of $\text{NO}_3\text{-N}$ in Himalayan River varied from traces to 0.315 mg L^{-1} (Semwal and Akolkar, 2006). The concentration of nitrate-nitrogen was more during monsoon than during winter months in the river Brahmaputra

and ranged from 0.030 to 0.300 mg L⁻¹ (**Jhingran, 1991**). A small amount of nitrate is common in all kinds of surface water. Most natural water are deficient in nitrate having a concentration usually below 5 mg/L, but certain polluted surface water and ground water may have substantially higher quantities.

2.1.3.12. Phosphate-P

Phosphate has a limited source in nature and also acts as a limiting factor for productivity of water body. Phosphate may occur in lake as a result of domestic waste, detergent and agricultural runoff containing fertilizer (**Gopalkrusna, 2011**). Phosphorous is an essential nutrient to living organisms and inorganic phosphate is the main ingredient of eutrophication in a water body (**Saha, 2014**). PO₄-P averages about 10 µg L⁻¹ worldwide among unpolluted rivers (**Meybeck, 1982**). Algae require only small amounts of phosphorus. Excess amounts of phosphorus can cause eutrophication leading to excessive algal growth called algal blooms (**WHO, 1992**). According to **Strokal et al., (2016)** eutrophication increased day by day in Chinese rivers from direct discharge of manure. **Flura et al., (2016)** worked on Meghna river and reported that water quality of Meghna river were safe for aquatic lives, but the continuous sewage disposal may create problems in the future. **Barat and Jha (2002)** reported that values of PO₄-P in the river Mahananda ranged from 0.060 to 0.0340 mg L⁻¹.

Some authors have been made enormous contribution on Indian rivers like **Mishra and Tripathi (2003)** on river Ganga; **Swar and Singh (2004, 2006)** on Meghalaya, **Singh and Gupta (2010)** on the Thoubal rivers; **Kumar et al., (2014)** on Kali river; **Baitule et al., (2015)** on Nag River at Nagpur city; **Patela and Vaghanib (2015)** on Par River Valsad, Gujarat and **Lamare and Singh (2016)** on Lukha River of Meghalaya.

Some pioneer work have been made on water quality of West Bengal rivers like, **Mondal *et al.*, (2010)** on North 24-Parganas; **Mandal and Das (2011)** on Torsha River; **Mandal *et al.*, (2012a)** on Karala river; **Mandal *et al.*, (2012b)** on the drinking water quality of Chamurchi tea garden of Darjeeling; **Saha (2014)** on Shutunga river; **Mozumder *et al.*, (2015)** on Mahananda river; **Chakrabarty and Nath (2015)** on tributary of Ganga.

2.2. Importance of Fish

Fish is an important group of the vertebrates which influences the life of human and is a good source of protein and occupying a significant position in the socio-economically fabric of South Asian countries (**Dhamak, 2013**). Fishes also provide several by- products such as fish meal, fish glue, fish oil and so on.

Fish diet provides different minerals like Ca, Mg, P, Na, Fe, I and rich source of protein in the form of simple proteins with different essential amino acids, fats, and traces of vitamin B Complex and so on along with non-protein nitrogenous forms. They have good taste and are easily digestible with growth promoting value (**Dhamak, 2013**). Fish provides nutrition and foreign money through ornamental fish.

Fish fat contains Omega-3 long-chain PUFA, including EPA and DHA, are dietary fats with an array of health benefits (**Su *et al.*, 2008**). EPA and DHA are incorporated in many parts of the body including cell membranes (**Lazzarin *et al.*, 2009**) and play a role in anti inflammatory processes and in the viscosity of cell membranes (**Smith *et al.*, 2011; Conquer *et al.*, 2000**). EPA and DHA are essential for proper fetal development and healthy aging (**Dunstan *et al.*, 2007**). DHA is a key component of all cell membranes and is found in abundance in the brain and retina (**Krauss-Etschmann *et al.*, 2007**).

According to **Rajender (2013)** the concept of entrepreneurship development through Ornamental fish farming is gaining popularity day by day. Ornamental fish farming is an important primary industry (**Lim and Wong, 1997**). The Ornamental fish trade plays an important role in the socio-economic upliftment of backward class and females in our country with little investment of money (**Rajender, 2013**).

In last the 25 years, unprecedented population growth and rapid industrialization coupled with intensive agricultural activities have exerted intolerable stress over the aquatic ecosystems. These developments have given rise to new management and conservation concepts based on basic research (**Dhamak, 2013**). The lack of information on the ichthyo-fauna is a big handicap for popularizing little known fish variety in a particular ecosystem. Thus, there is need to survey fish fauna associated with different fresh water habitats, which will help in planning methods for their production and effective exploitation (**Sharma and Nayak, 2001**).

2.2.1. Ornamental fish

Ornamental fishes are also called ‘living jewels’ for their beautiful colour and playful behaviour. Ornamental fishes are typically small sized; attractive and bizarre shaped in appearance (**Dey, 1996**). Since ornamental fishes are usually kept in glass aquarium, these are popularly also known as aquarium fishes. Ornamental fishes are the most popular pets in the world (**Singh, 2005**). Aquarium keeping has emerged as the second most popular hobby in recent years next to photography (**Chapman, 1997**). The ornamental fish market in the world for public aquaria is less than 1%, and 99% of the ornamental market is still for the hobbyist. Aquarium keeping of fish began in 1805 with the first public display aquarium at Regent’s Park in England in 1853. Development of aquaria picked up and by 1928, there were 45 display aquaria open to public, and at

present, there are over 500 aquaria functioning worldwide (**Handbook of Fisheries and Aquaculture, 2015**).

According to **Kottelat and Whitten (1996)** India occupied eighth position in the world and third in Asia. **Mittermeier and Mittermeier (1997)** also stated, that India was the megabiodiversity country which occupied the ninth position in the world. About 21,730 species of fishes have been recorded in the world; of which about 11.7% are found in Indian waters. Out of the 2546 species so far listed, 73 belonged to cold freshwater, 544 to the warm fresh water, 143 to the brackish water and 1440 to the marine ecosystem (**International Consultation on Biological Diversity, 1994**).

2.2.1.1. Ornamental fish diversity in India

In India, aquarium hobby is nearly 70 years old and dates back to pre-independence era (**Ayyappan et al., 2006**). India's overall ornamental fish trade was about 1.06 million US\$ during the year 2009 (**UNCOMTRADE, 2014**). India possesses rich resources namely, the lagoons and coral reefs of Lakshadweep and Minicoy Islands, Andaman and Nicobar islands, Gulf of Kutch complex, Coast of Kerala, Cape Comorin, Gulf of Mannar and Palk bay are abound with highly attractive and varied species of ornamental fishes. India has recorded at least 150 commercially important ornamental fish species and trade mainly indigenous freshwater species collected from rivers (**Madhu et al., 2009**). About 600 freshwater fish species of ornamental value have been reported worldwide from various aquatic environments. Indian waters possess a rich diversity of ornamental fishes with over 200 varieties of indigenous species (**Swain et al., 2001**). Prominent among the fresh water Indian ornamentals are Loaches, Eels, Barbs, Catfish, and Goby (**Ayyappan et al., 2006**). About 90 % of ornamental fish is traded from Kolkata port followed by 8 % from Mumbai and 2 % from Chennai (**Ghosh**

et al., 2003). 400 species of ornamental fishes belonging to 175 genera and 50 families were reported in the Indian waters by **Satheesh (2002)**. Indian ornamental fish were primarily dependent on wild catch (85%) and a few artificially bred varieties (15%) of exotic fish (**Mahapatra et al., 2006**).

According to **Anna Mercy (2009)** out of the 300 species of fishes inhabiting the different river systems of the Western Ghats, 155 were considered as potential ornamental fishes. Among them 120 species were endemic to the Western Ghats and most of them belonged to the categories of barb, loaches, danios, killifishes, hill trout and catopras; again **Raju Thomas and John (2009)** observed 102 species of ornamental fishes from the inland waters of Kerala.

Several workers reported on ornamental fish diversity in India like **Usha et al., (2013)** 12 ornamental species, **Rahana et al., (2014)** found 30, **Sirajudheen and Biju (2014)** recorded 138 species; **Sureshkumar et al., (2014)** reported 20 species of indigenous ornamental fishes from Western Ghats. **Rao et al., (2013)** reported 58 species from Andhra Pradesh; **Kumar et al., (2013)** reported 100 from Mahanadi, Bhubaneswar; **Rao (2014)** reported 53 species from Andhra Pradesh and **Patel et al., (2014)** reported 61 species;

In North- East India, **Chakravartty et al., (2012)** reported 67 species; **Baro et al. (2014)** recorded 49 species; **Khomdram et al., (2014)** recorded 139 species from Manipur; **Goswami and Zade (2015)** reported 81 species of fishes and **Biswas et al., (2015)** reported 109 species.

2.2.1. 2.Ornamental fish diversity in West Bengal

Several investigators worked on different rivers of West Bengal on fish diversity like **Mandal et al., (2012)** who identified 67 species from Sundarban; **Basu et al. (2012)** reported 41 ornamental fish species from Cooch Behar district; **Baro et al. (2014)**

recorded 49 ornamental fishes from the Sankosh river; **Mahapatra and Lakra (2014)** reported 41 ornamental fish from East Kolkata Wetlands and **Acharjee and Barat (2014a)** reported 20 species of loaches from Terai and Dooars region of North Bengal; **Pal (2015)** listed 58 species from North Bengal.

Recent studies done in North Bengal by **Das (2015)** recorded 53 ornamental from Torsa river; **Dey et al. (2015a)** reported 58 ornamental out of total recorded 138 fishes from Kaljani river; **Debnath (2015)** recorded 46 ornamental out of 73 recorded fishes from Gadadhar river; **Dey and Sarkar (2015)** recorded 55 ornamental fishes out of 107 recorded species from Torsa river; **Dey et al. (2015e)** reported 46 ornamental fishes from Ghargharia river; **Sarkar et al., (2015)** recorded 24 and 26 ornamental fish species from the river Torsa and Ghargharia respectively whereas, **Paul and Das (2016)** reported 52 species of indigenous ornamental fish from Cooch Behar district of West Bengal.

2.3. Fish Biology Study

Information of biology of all types of fishes is a must, not only, for conservation of biodiversity and ecosystem but also, for commercialization of food production on sustainable basis through farming or enhancement of fish production in the natural habitat by stocking. For efficient planning of fisheries development, it is imperative to have complete information on the biology of fishes and ecology of water bodies (**Sarma, 2008**).

2.3.1. Fish growth parameters

2.3.1.1. Gonado-Somatic Index (GSI)

Gonado-somatic Index (GSI) is the measure of the relative weight of the gonad with respect to total or somatic weight (**King, 1996**). Usually, the percentage of body weight of fish that is used for egg production is determined by the Gonado-somatic Index

(Agbugui, 2013). It increases in fish with its maturation, being maximum during the peak period of maturity and declining abruptly after spawning (Khanna and Pant, 1967). Total spawners are said to produce a large number of smaller sized eggs which are deposited over a short period of time while, the multiple spawners produce fewer and larger eggs with a longer breeding period which may last throughout the year, wherein only a proportion of the eggs ripe in the gonad at one spawning (Lowe-McConnell, 1987), though total spawners are said to have a higher GSI than multiple spawners (Wootton, 1990).

Many researchers have worked on the Gonado- Somatic Index of different fishes and reported that high GSI indicates peak breeding season of fishes and this statement was supported by the following authors Sathyanesam (1962) on *Mystus seenghala*; Khanna and Sanwal (1971) on *Channa gachua*; (Raizada, 1971) on *Rasbora daniconius*; Bisht (1972) on *Schizothorax richardsonii*; Arockiaraj *et al.*, (2004) found five developmental stages of gonad in *Mystus montanus*; Joshi and Pathani (2009) worked on *Botia almorhae* from Kumaun Himalaya; Bandpei *et al.*, (2011) studied *Rutilus frisii kutum* from Southern Part of Caspian Sea, Iran; Islam *et al.*, (2012) investigated *Sillaginopsis panijus* from the Meghna River Estuary, Bangladesh; Shinkafi and Ipinjolu (2012) on *Auchenoglanis occidentalis* from River Rima, North-Western Nigeria; Ghanbahadur and Ghanbahadur (2012) on *Cyprinus carpio*; Amtyaz *et al.*, (2013) on *Pomadasys stridens* from Karachi Coast, Pakistan; Ghanbahadur *et al.*, (2013) on *C. gachua*; Nandikeswari and Anandan (2013) on *Terapon puta* from the Bay of Bengal, Pondicherry; Ashwini *et al.*, (2013) on *Channa bleheri* ; Agbugui (2013) on *Pomadasys jubelini*; Tiwari *et al.*, (2014) on *Channa marulius* ; Wagle (2014) on *Schizothorax richardsonii* collected from Nallu River of Lalitpur district; Roy and Manda (2015) reported on *Labeo bata* ; Oliveira *et al.*,

(2015) on *Hemiramphus brasiliensis* from Brazil; **Chakrabarti and Banerjee (2015)** on *X. cancila*; **Jan and Ahmed (2016)** on snow trout, *Schizothorax plagiostomus*; **Pal and Mahapatra (2016)** on *Amblypharyngodon mola*; **Sales et al., (2016)** on *Hypostomus francisci*; **Dey et al., (2016)** on *Barilius barila* and **Mahmud et al., (2016)** on *Channa striata*.

2.3.1.2. Condition Factor

Condition factor or K- factor or Ponderal Index is used to compare the 'condition', 'fatness' or well being of fish, and it is based on the hypothesis that heavier fish of a given length are in better condition (**Bagenal & Tesch, 1978**). Condition factor has been used as an index of growth and feeding intensity (**Fagade, 1979**). According to **Le Cren (1951)**, 'Kn' greater than 1 indicates good general condition of fish. Fish with high value of 'Kn' are heavy for its length, while with low 'Kn' are lighter (**Bagenal and Tesch, 1978; Froese, 2006**). According to **Brody (1945)** and **Lagler (1952)** the growth of fishes obeys the Cube law when fish stay an ideal environmental condition. It is also a useful index for the monitoring of feeding intensity, age and growth rates in fish (**Oni et al., 1983**). It provide external measures of overall health of the fish (**Naeem et al., 2011**). The K value indicates the size at which the fish matures and the variation in the value in relation to size may attribute spawning and feeding intensity due to availability of select food or absence of food (**Mohanraj, 2008**). The Length-Weight relationship parameters and Condition factor have been found very useful to evaluate the well-being of populations, their biology for scientific management of fisheries in stock assessment (**Ujjania et al., 2012**). It is also important to note that the Physio-chemical parameters of water influence vertical and horizontal migrations of fishes in aquatic ecosystem, their distribution and feeding pattern (**Imam et al., 2010** and **Dar et al., 2012**). Higher value of Condition factor was reported in matured fish (**Olurin and Aderibigbe, 2006**;

Telvekar et al., 2006). The value of 'K' usually shows fluctuations which may due to sample size, different stages of maturity, spawning on the parts of females or difference in weight of food content in the stomach (**Dars et al., 2010**). Variations in the condition factor of many fishes were observed in relation to their reproductive cycle (**Narejo et al., 2002**).

According to **Arockiaraj et al., (2004)**, Condition factor of *Mystus montanus* was ranged from 4 to 6 and 6 to 9, respectively. **Deka and Gohain (2015)** reported relative condition factor of *Rita rita*, *Pangasius pangasius* and *Chitala chitala* were ranged 0.78 to 1.55, 0.85 to 1.30 and 0.79 to 1.24 respectively from Brahmaputra river system of Assam, India. (**Jyrwa et al., 2015**) reported condition factor ranged 1.43 to 2.19 of *Neolissochilus hexagonolepis* from Meghalaya. Recently, **Rahman et al., (2016)** studied on *M. vittatus* and reported that minimum and maximum Condition factor was 0.95 and 1.32, respectively, with a mean value of 1.14 ± 0.09 indicating, that mature female *M. vittatus* stock was in good condition in the Padma River. **Lal et al., (2016)** reported condition factor of *M. armatus* to be 0.22 (SD=0.07) and 2.84 (SD=0.28) for *Etroplus suratensis*.

2.3.1.3. Length-Weight Relationship

Length-weight relationship of fish is an important fishery management tool because they allow the estimation of the average weight of the fish of a given length group by establishing a mathematical relationship between the two (**Beyer, 1987**). The length and weight relationship indicates the gonad development of fish (**Le Cren, 1951**). The study of length-weight relationship also helps in setting up yield equations (**Beverton and Holt, 1957; Ricker, 1958**) for estimating the numbers of fish landed, and in comparing populations in time and space (**Pandey et al, 1974**). The deviation from the general Cube Law governing the length weight relationship have been utilized by fishery

biologists to determine the condition and general well being of fish and serves as a useful index of the nutritional and biological cycle of the species (**Jhingran, 1972**). As length and weight of fish are among the important morphometric characters, they can be used for taxonomy and ultimately in fish stock assessment. While attempting a study of the biology of a fish, it is usual to analyze the mathematical relationship between its length and weight. This analysis reveals the extent to which the two variables, length and weight are related to each other and thereby help one to calculate with ease one variable when the other is known (**Chandrika & Balasubramonian, 1986**). The study of length-weight relationship of fishes have two objectives, (i) to determine the type of mathematical relationship between two variables so that if one variable is known the other could be computed and (ii) to know the well being of fish and also type of growth, that is, whether isometric or allometric (**Kumar et al., 2005**).

The literature available on length-weight relationship have been given by **Jhingran (1952); Chatterji (1980); Chatterji et al., (1980); Choudhary et al., (1982); Malhotra (1982, 1985); Mohan and Sankaran (1988); Kurup (1990); Pandey and Sharma (1998); Sarkar et al., (1999); Sunil(2000); Mercy et al., (2002); Kumar et al. (2005) and Prasad et al., (2007)**.

Recently, some important work has been carried out on length –weight relationship of fishes by **Joshi and Pathani (2009)** on *Botia almorhae*; **Vaitheeswaran et al.,(2012)** on *Panulirus versicolor*; **Islam et al., (2012)** on *Sillaginopsis panijus* from the Meghna River Estuary, Bangladesh; **Jan et al., (2014)** studied on *Schizothorax plagiostomus* collected from the river Jhelum, Kashmir; **Rejitha and Pillai (2015)** on six coral reef fishes, *Chaetodon octofasciatus*, *Lutjanus decussatus*, *Lutjanus rivulatus* ,

Lutjanus lutjanus, *Lutjanus johnii* and *Apolemichthys xanthurus* and **Lal et al., (2016)** on 57 freshwater fish species from three diverse ecological regimes in India.

2.3.2. Fecundity

Fecundity has been considered as the number of ripening eggs in the female prior to spawning (**Begenal and Braum, 1968**). It is described as the number of matured eggs, filled with yolk or all vitellogenic oocytes found in the ovary immediately before the reproduction process (**Bagenal, 1963**). Fecundity is important in the estimation of abundance and reproductive potential (**Gupta, 1967**). **Begenal (1967)** also stated, that in most fishes, the number of eggs does not change significantly as the season progresses. Fecundity appears to bear some broad relationships to the care or nurture accorded to the eggs (**Lagler et al., 1967**). **Franz (1910)** and **Clark (1934)** have observed that fecundity in the fishes, they studied, increased in proportion to square of length. Similarly, the existence of straight line relationship between fecundity and weight of fish has been reported by several workers (**Benegal, 1957; Pillay, 1958; Kandhar, 1959; Bridger, 1961; Varghese, 1973**). They found that the relationship between fecundity and weight to be curvilinear which indicates that length is also an important factor for determining the fecundity of fish as has been reported by **Smith (1947), Begenal (1967) and Manooch (1976)**. Fecundity studies have been considered useful in tracing the different stocks or populations of the same species of fish in different areas (**Gupta, 1967**). Knowledge about fecundity of a fish is essential for evaluating the commercial potentialities of its stock, life history, practical culture and actual management of the fishery (**Lagler, 1956; Doha and Hye, 1970**). Knowledge of fecundity is also important for understanding the life history and for modelling population dynamics of a species (**Bruch et al., 2006**) as fecundity varies from one species to another, depending on the

environmental conditions, length, age and so on (**Jacob 2013**). Fecundity has no relation with fish age (**Simpson, 1951; Bagenal, 1957 and Sarma, 2008**).

The literature available on fecundity have been given by **Guar and Pathani (1996)** on *Barilius vagra*; **Islam et al., (2012)** on *Sillaginopsis panijus* from the Meghna River Estuary, Bangladesh; **Shinkafi and Ipinjolu (2012)** on *Auchenoglanis occidentalis* from River Rima, North-Western Nigeria; **Agbugui (2013)** on *Pomadasy jubelini*; **Nandikeswari and Anandan (2013)** on *Terapon puta*; **Jan et al., (2014)** on *Schizothorax plagiostomus*; **Wagle (2014)** on *Schizothorax richardsonii* ; **Oliveira et al., (2015)** on *H. Brasiliensis*; **Dey and Barat (2015)** on *Botia almorhae*; **Dey et al., (2015d, 2015c and 2015b)** on *Botia dario*, *Botia lohachata* and *Botia rostrata*; **Dey et al., (2016)** on *Barilius barila*. **Silva et al., (2016)** on *Cynoscion leiarchus* from Southern Brazil; **Gomez-Marquez et al., (2016)** on *Poecilia sphenops* is a batch breeder, from Mexico; **Pal and Mahapatra (2016)** on *Amblypharyngodon mola*; **Rahman et al., (2016)** on *Mystus vittatus*; **Sales et al., (2016)** on *Hypostomus francisci* from Brazil and **Jan and Ahmed (2016)** on *Schizothorax plagiostomus* in river Lidder, Kashmir Himalaya.

2.3.3. Captive breeding of ornamental fish

According to **Minckley and Deacon (1991)** captive breeding is one of the proven techniques of saving endangered species from extinction and increase its population size with the help of sound breeding techniques under controlled conditions. Captive breeding is one of the major steps in the conservation programme of a species. It also can provide critical life history information, as well as helping supplement of existing or restoring populations and allows discovery of important behavioural or life history characteristics that may constrain reproduction of rare species in altered natural habitats (**Rakes et al.,**

1999). Such ecosystems are declared as national parks, biosphere reserves and sanctuaries but, the constraints in in-situ conservation are the need for large investment of finance, trained manpower, reorientation and modification of development project like river-valley project which have to be earned out (**Padhi, 1987**).

Although the merits of supplemental breeding are debated (**Hutchins et al., 1997**), this approach has become a common management technique for many fish species (**Brown et al., 2000**). Captive raised specimens can be re-introduced in the natural habitat thereby protecting the species from extinction. Supplemental breeding is an intensive population management strategy wherein, adults are captured from nature and spawned in controlled settings, and the resulting offsprings are later released into the wild (**Fiumera et al., 2004**). It is also a good conservation method for endangered freshwater fish species (**Philippart, 1995; Poncin and Philippart, 2002**). In ex-situ conservation, the fish species are conserved outside its natural habitat. This includes (1) Live Gene Bank where the threatened species are reared in captivity and bred therein and (2) Gamete/Embryo Bank where cryopreservation of milt, eggs and embryos is carried out (**Pandey and Das, 2002**).

Bindu (2006) reported three caveats for employing seed production and stocking method for commercially farmed aquatic species. Firstly, many species are reticent to mature and spawn in captivity. It is often difficult to simulate in captivity, the environmental conditions, cues and triggers that are necessary for successful reproduction, particularly the unique river habitat situations essential and conducive for spawning. Successful development of captive breeding requires a sound understanding of general biology and reproductive characteristics of the species. Secondly, small size of the fish species and low fecundity of some of the species render development of artificial

breeding techniques difficult (**Poncin & Philippart, 2002**). In high fecund species where large numbers of eggs are produced by the spawning female, high mortality of early life history stages such as the fertilized egg, larvae, post larvae, fry and fingerlings in captivity is another problem. This might also sometimes lead to a more serious situation of artificial selection. Thirdly, the high costs of keeping aquatic organisms in hatchery systems might encourage the use of small broodstock populations and this might lead to inbreeding related problems and negative consequences in the released stocks. Conservation of these threatened stocks can be done either through in-situ or ex-situ methods and threatened fish species are conserved by protecting the ecosystem in which they occur naturally or the habitat restoration is done (**Thumpy, 2009**).

Kiyzhanovsky (1949) reported five types of spawning of fish like i) Lithophils : Fishes which spawn on hard, stony surface, ii) Phytophils : Fishes which lay eggs among aquatic plants, iii) Psammophils : Fishes which deposit eggs in sandy surface, iv) Ostracophils : Fishes which deposit eggs inside a bivalve and v) Pelagophils : Fishes which spawn freely in column of water and the eggs float.

Hypophysation is the technique of breeding of fishes in confined waters with the injection of pituitary extracts for the production of seeds. A recent development in induced breeding is the stimulation of endogenous gonadotropin release from the pituitary of the treated fish using synthetic analogue of gonadotropin releasing hormone (GnRH). Hypophysation technique was first reported by Brazilians (**Von Ihering, 1937**) and this technique was used for Indian carps by **Chaudhuri & Alikunhi (1957)** and then Blue Revolution occurred in seed production of exotic and Indian Major Carp. **Varghese et al. (1976)** and **Varghese and Rao (1976)**, used pituitary of marine catfish (*Tachysurus* spp.) for carp induced breeding. **Chondar (1985)** used HCG for spawning

of carp except silver carp. **Peter et al., (1988)** reported that LH-RH analogue combine with pituitary or HCG to get the desired spawning success. In 1990, used LH-RH and its analogues for induced breeding of carp (**Tripathi and Khan, 1990**). Ovaprim is a mixture of the analogue of salmon gonadotropin releasing hormone (SGnRH_a) and a dopamine antagonist domperidone. Ovaprim hormone was more effective than mammalian releasing hormone (**Sherwood et al., 1983**). Then **Nandeesh et al. (1990)** reported the Ovaprim, a synthetic hormone, which saves time and reducing post-spawning mortality. In 1997, Ovatide launched which contain salmon gonadotropin releasing hormone (SGnRH_a) and a dopamine antagonist and was successfully tested by the Central Institute of Fisheries Education (CIFE). WOVA-FH was manufactured by Syndel laboratory, Canada in 1988, used for induced breeding of carp and other fishes along with shrimp. It contained salmon gonadotropin releasing hormone (SGnRH_a), propylene glycol and a domperidone. WOVA-FH was easy to use than Ovaprim (**Dey et al., 2015b, 2015c and 2015d**). **Das et al., (2016)** used three different types of inducing agents like Ovaprim, Ovatide and WOVA-FH for breeding threatened fish, *Osteobrama belangeri* and reported that fertilization rate was significantly higher ($P < 0.05$).

Some important work on captive breeding of ornamental fish that have been done are *Danio rerio* (**Kimmel et al., 1995**); *Ompok bimaculatus* (**Sridhar et al., 1998**); *C. batrachus* (**Mahapatra et al., 2000; Dhawan and Kaur, 2004**), *Heteropneustes fossilis* (**Alok et al., 1998; Vijayakumar et al., 1998; Sreedhar and Haniffa, 1999; Pandian et al., 2001**), *Ompok malabaricus* (**Haniffa et al., 2001**), *Ompok pabo* (**Mukherjee and Das, 2001**); *Etroplus suratensis* (**Bindu, 2006**); Cherry barb (*Puntius tittैया*) (**Sundarabharthy et al., 2004**); *Macrogathus aculeatus* (**Das and Kalita, 2003**); *Devario aequipinnatus* (**Kharbuli et al., 2004**); *Puntius gelius* (**Sarma, 2008**); *Macrogathus aral* and *M. pancalus* (**Singh, 2011**); *Anabas testudineus* (**Kumar et al.,**

2010 and Pius, 2010); *Ompok pabda* (Purkayastha *et al.*, 2012); *Puntius sarana* (Udit *et al.*, 2014); *Devario aequipinnatus* (Dey *et al.*, 2014); *Anabas testudineus* (Sarkar *et al.*, 2015); *Ompok bimaculatus* (Malla and Banik, 2015); *Botia almorhae* (Dey and Barat, 2015); *Botia rostrata* (Dey *et al.*, 2015b); *Botia lohachata* (Dey *et al.*, 2015c); *Botia dario* (Dey *et al.*, 2015d); *Barilius barila* (Dey *et al.*, 2016) and *Sahyadria denisonii* (Sajeevan and Anna Mercy, 2016).

2.3.4. Behaviour study

The patterns of reproductive behaviour among teleost fishes range from the simple release of gametes in the proximity of conspecifics to complex sequences which may include defense and preparation of a nest site or territory, pair formation, and spawning (Liley & Stacey, 1984). Reproductive strategies have already been categorized in cyprinid fish (Balon, 1984; Turner, 1986). In some groups, fertilization is internal and results in the release of fertilized eggs, larvae, or sexually mature offspring. The term reproductive behaviour can be used in general to encompass all activities involved in reproduction. Sexual behaviour is restricted to any behavioural interaction between the sexes leading to the union of gametes (Liley & Stacey, 1984). Knowledge of behavioural patterns and characteristics of spawning aggregation is important to fully understand the function of group spawning in a species (Shapiro *et al.*, 1993).

According to Erisman and Allen (2006), fish breeding behavioural pattern was thirteen type (Table.2). In the case of externally fertilizing species, it is important to distinguish between pre-spawning and spawning behaviours. Pre-spawning behaviour includes sexual activities, often referred to as courtship, involved in the search for, and attraction and excitation of, a potential sexual partner (Jacob, 2013). The male fish dressed up in overall reddish tinge and the depth of the colour varied. Based on maturity status of the gonad and spawning, is the complete removal of ovulated eggs from the

ovary, is accomplished by the accompanying of the male holding behaviour. In this behaviour, male hold the female by curving its body in a semi- circle fashion along the dorsal side. During this behaviour, it brings the genital regions to a close proximity. Each male holding lasted approximately one second. (Jacob, 2013)

Table 2. Different behavioural patterns shown during courting and spawning based on (Erisman and Allen, 2006)

Behaviour	Occurrence	Description
1) Female display	Courtship	A gravid female hovers motionless in the water column or adjacent to the substrata, using a fanning motion of the pectoral and caudal fins to maintain position; body is relatively straight with the head angled upwards at 20–60°.
2) Lateral display	Courtship	Sexually active male shows its colourful flanks in a special way towards the female along with tail quivering.
3) Hover	Courtship	A courting male hovers in close proximity to a female
4) Rubbing	Courtship	A male approaches a gravid female from the side or from underneath; the snout, operculum and dorsal portion of the male’s body make physical contact with the lower abdomen of the female as he swims past.
5) Nipping	Courtship aggression	One individual will nip or bite the posterior flank or caudal region of another individual; often occurs during courtship chase and aggressive chase events; during courtship, male nipping behaviour is often followed by female darting behaviour.
6) Bumping	Courtship aggression	The snout or operculum of a male makes physical contact with the lower abdomen of the female for several seconds; sometimes resulting in displacing the location and orientation of the female.
7) Following	Courtship	The ripe male swims behind a gravid female, without

		making physical contact with the female; common during early courtship periods.
8) Courtship chase	Courtship	Ripe male swims rapidly after a gravid female
9) Darting	Courtship	A female swims in an erratic manner, constantly changing directions while swimming away rapidly from chasing males; usually it ends in hiding in safer places available in the tank.
10) Female colour change	Courtship	The overall body became more silvery, the spots becoming less distinct
11) Male colour change	Courtship	The overall body became more reddish, the spots becoming less distinct. As the courting progresses the red colour deepens.
12) Male holding	Spawning	The male hold the female across her body through dorsal side in such a way that both the genital openings come close; it lasts for one second.
13) Pausing	Spawning	This is the part of the holding behaviour, lasts for a fraction of second, during which the release of gametes occur.

According to **Paray *et al.*, (2013)** breeding behaviour or courtship behaviour is a very important act in fish breeding and it varies from simple swimming of the breeders along the side of each other to elaborate act of nest building and intense male competition inherent in group spawning. The absence of breeding behaviour from any of the breeders often results in spawning failure (**Marimuthu *et al.*, 2001**). Several factors like body size, pigmentation, age, and social dominance, environmental conditions, mating history, female reproductive state, male dominance and aggression are known to affect the mating behaviour of fishes in many species (**Deaton, 2008; Marimuthu *et al.*, 2001; Arockiaraj *et al.*, 2004**).

Few workers have studied on breeding behaviour of fishes. As for information, **Thakur (1976)** on behaviour of *Heteropeneustes fossilis*; **Hutchings et al., (1999)** on *Gadus morhua* in Nova Scotia, Canada; **Arockiaraj et al., (2003)** on *Mystus montanus*; **Anna Mercy et al., (2003)** on *Pristolepis marginata*; **Haniffa et al., (2004)** on *Channa punctatus*; **Prado et al., (2006)** on *Hoplias malabaricus*; **Graya and Kinnon (2006)** on Telmatherinidae; **Veerappan et al., (2009)** on sound producing behaviour of *Kathala axillaris*; **Jones (1940)**; **Padmanabhan (1955)**; **Norman and Greenwood (1963)**; **Pal and Southwick (1965)**; **Indira (1986)** and **Chandran et al., (2013)** studied on breeding behaviour of *Pseudosphromenus cupanus*; **Paray et al., (2013)** on breeding behavior of the *Channa striatus* and **Behera et al., (2016)** observed pairing and chasing courtship behaviour of climbing perch, *Anabas testudineus* from West Bengal.

2.3.5. Embryonic development

Embryonic development of suitable protocols for the mass rearing of larval fish represents one of the important barriers for the successful propagation of most of the freshwater species (**Thakur, 1980**). **Blaxter (1974)** suggested, that fish eggs and larvae are useful for estimating the fish stock. Different modes of larval development are evident in fishes. It depends on the fact to which taxa it belonged to. The development seen in egg scatterers is different from fishes showing parental care. The mouth brooders release very few eggs with big size. The live bearers produce juveniles directly by passing the larval stage (**Wourms, 1981**).

Embryonic and larval developmental studies provide sufficient information regarding the successful rearing of larvae (**Mathew et al., 1996**). Most authors accept the division of fish development into five periods; embryo, larva, juvenile, adult and senescence (**Kovac and Copp, 1996**). Refining the techniques of larval rearing is very

important for practical and commercial applications (**Liao, 1993**). Great variation in size exists among species in young fishes before they become free living forms [free from yolk sac after 3-5 days] (**Diwan and Dhakad, 1995**). Apart from the academic interest, experimental based information on these early stages is required for progress in the advanced fields of fish culture (**Thampy, 2009**). Despite the success in artificial propagation of *Garra surendranathanii*, by induced spawning it is necessary to understand the developmental biology of the species which is a prerequisite for successful rearing of the species and commercialization of the induced breeding techniques (**Thampy, 2009**).

Jacob (2013) Studying on the evolution of development showed large scale comparisons of diverging taxa in a known phylogenetic context to uncover the developmental pathways of animals. **Galis and Sinervo (2002)** explained the similarity of early embryos resulting from a variety of developmental constraints names Teratogens, and studied on the early life stages of fishes which are important because, the requirement of young fish changes rapidly as a function of age. The embryonic and larval development studies provide useful information for the successful rearing of larvae.

Noakes (1991) gave a detailed review of developmental stages, hatching, feeding, social behaviour and parental-young interactions in cichlid larvae. Several authors worked on embryonic development of different fishes like **Kimmel et al., (1995)** on Zebra fish; **Arockiaraj et al., (2003)** on *Mystus montanus* ; **Schmidt and Starck (2004)** on Zebra fish; **Dirisu and Innocent (2004)** on *Clarias gariepinus* from Nigeria; **Bindu, (2006)** on two ornamental fishes *Eetroplus suratensis* and *Horabagrus brachysoma* from Western Ghats; **Mohammadi et al., (2012)** on Yellow fin sea bream (*Acanthopagrus latus*) from south of Persian Gulf , Iran; **Bindu and Padmakumar (2012)** on *Eetroplus*

maculata; **Purkayastha et al., (2012)** on *Ompok pabda*; **Udit et al., (2014)** on *Puntius sarana*; **Sarkar et al.,(2015)** on *Anabas testudineus*; **Dey and Barat (2015)** on *Botia almorhae*; **Dey et al.,(2015c, 2015d and 2015b)** on *Botia lohachata*, *Botia dario* and *Botia rostrata* ; **Anna Mercy et al., (2015)** studied on embryonic development of *S. denisonii*; **Samuel Moses et al., (2016)** on *Pangasianodon hypophthalmus* from Tamil Nadu; **Guralp et al., (2016)** on Pike perch (*Sander lucioperca*) from Vodnany; **Yang et al., (2016)** on Yellowtail Kingfish, *Seriola lalandi* from Korea and **Dey et al., (2016)** on hill stream fish *Barilius barila*.

2.3.6. Supplementary feed for larval rearing in captive breeding

Nikolsky (1963) categorized fishes according to their extent of variation and types of food consumed by them such as a) Euryphagic: feeding on varieties of food. b) Stenophagic: feeding on few selected types of food and, c): Monophagic: feeding on single type of food. The main problems arising in larval fish rearing is the relatively smaller size of the mouth and limited yolk reserves of the larvae (**Shirota, 1970**). The rearing of early life stages by fish culturists is important because the requirement of young fish change rapidly with every hour or days. Working definitions of developmental stages for aquaculture are, therefore, practically very useful (**Haylor, 1992 and Thampy, 2009**).

The success in the hatchery production of fish fingerlings for stocking in the grow-out production system is largely dependent on the availability of suitable live food organisms for feeding fish larvae, fry and fingerlings. The availability of large quantities of live food organisms such as, marine rotifer (*Brachionus plicatilis* and *Brachionus rotundiformis*) and *Artemia* nauplii to meet the different stages of fry production has contributed to the successful fry production of at least 60 marine finfish species and 18

species of crustaceans (**Dhert, 1996**). Many of the modern larviculture technologies used in marine food fish hatcheries could be adapted for application in the freshwater ornamental fish production. Some of the possible applications have been reported in by **Dhert et al., (1997)**.

According to **Lima et al., (2003)**, the industrial development of freshwater ornamental fish culture has been hampered by the lack of suitable live feeds for feeding the fish at the various production stages. Currently, inert food items such as egg yolk suspension, milk powder or powdered feeds and natural plankton bloom induced by artificial fertilisation of water are used in larval feeding, and *Moina* and Tubifex that are cultured in water enriched with organic manure are fed to bigger fish or brooders. There is also no suitable live feed for feeding early fish larvae with small mouth. These traditional practices not only limit the fish stocking density, but also adversely affect fish quality. Many freshwater ornamental fish farmers have shifted from *Moina* to the cleaner *Artemia nauplii* for feeding their young fish.

Recently, some work have been done on larval rearing in captivity by **Vishwas Rao and Ajith Kumar (2014)** on captive breed of *Pterapogon kauderni* and comparative high growth rate, when larvae were fed with algal enriched *Artemia* than the Poly Unsaturated Fatty Acid (PUFA). The larvae were reached the marketable size within 45 days. Brood fish were fed with boiled clam meat, octopus, oyster, squid and trash fish thrice a day. **Afroz et al., (2014)** studied on larval rearing of spiny eel, *Mastacembelus pancalus* in captivity and reported that larvae started to feed with *Artemia nauplii* when 5-10 days old, *Moina* sp at 11-20 days old, blood worm at 21-35 days old, tubifex species and blood worm (*Chironomid* sp.) at 35-50 days old and small shrimp after 50 days. **Dey et al., (2015d, 2015c and 2015b)** and **Dey and Barat (2015)**

studied on *Botia* loaches namely *Botia dario*, *Botia lohachata*, *Botia rostrata* and *Botia almorhae* and reported that at first larvae were fed with *Paramecium* sp. and then *Artemia* after 3days. The larvae also consumed small sized zooplanktons.

Larval rearing in captivity of many fishes have been studied by several workers. **Karim and Hossain (1972)** on *Mastacembelus pancalus*; **Serajuddin and Mustafa (1994)** on *Mastacembelus armatus*; **Umezawa et al. (1991)** on *Anguilla rostrata*; **Ignatius et al., (2001)** on *Amphiprion sebae*; **Das and Kalita (2003)** on *Macrognathus aculeatus*; **Suresh et al.(2006)** on *Macrognathus pancalus*; **Williot et al., (2009)** on *Acipenser sturi*; **Oliveira and Hable (2010)** on *Macrognathus pancalus*; **Rahman et al. (2011)** on *Mastacembelus pancalus*; **Rahman and Awal (2016)** on *Channa striatus* and **Ghosh et al., (2016)** on Clownfish, *Amphiprion Clarkii*.

2.4. Histological study of the gonads

Studies on the gonad developmental cycle and histological examination of gonads are appropriate to determine the precise spawning period and frequency in a breeding season (**Conover 1992**). The knowledge about different stages of fish gonadal maturation provides important information necessary to prohibit fishing during the reproduction period; allowing the fishery stock to recover (**Noble and Jones 1993**).

The fishes reproduce in their natural environment to produce offspring and continue their progeny. Both environmental and hormonal factors are extremely important in regulating reproductive behaviour and spawning in fishes (**Chakrabarti and Choudhury, 2015**). Various central mechanisms translate environmental cues into chemical messengers which function to activate and maintain the reproductive organs. In this regard, the functional relationship between the hypothalamus and pituitary gland is important (**Chakrabarti and Choudhury, 2015**). The pituitary has a central role in

controlling gonadal activity and the identification and distribution of the cell types in the pituitary gland of the different teleosts. These have attracted some investigators from the histochemical, ultrastructural and immunocytochemical techniques (**Ali, 2003; Al-Absawy, 2004; Chatterjee and Chakrabarti 2014**). The spermatogenesis is a very active process and the testicular cycle in a majority of freshwater teleosts, which are seasonal breeders, undergo remarkable changes during various periods of the season (**El-Boray, 2001; Suwanjarat *et al.*, 2005 and Ahmed *et al.*, 2013**).

Reproduction in most of the tropical and subtropical fish species is periodic, and the peak reproductive event. Spawning, occurs in the most suitable time of the year to ensure maximum survival and growth of the young. Annual fluctuation in photoperiod and its dependant variable temperature are considered as the primary environmental factors regulating reproductive cycle of fish. (**Garg and Sundararaj , 1985; Davis *et al.*, 1999; Bhattacharyya and Maitra 2006**). Fish reproduction, especially teleost has achieved more attention among fisheries scientists during recent few years due to economic interest and nutritional requirements among increasing population (**Roy and Mandal, 2015**).

Reproductive development in fishes is well understood by histological techniques which are the most reliable method to determine the reproductive state of fishes (**West 1990**). The ovarian histological pattern of teleosts is described according to the division of ovarian tissues into seven or eight (**Crim and Glebe 1990**) or five (**Brown-Peterson *et al.*, 2011**) stages of maturity based upon the presence of dominant gametogenic cell types. In the case of synchronic oogenesis, all the oocytes develop at the same time, ovulation also being simultaneous. According to **Dopeikar *et al.*, (2015)** group synchronous ovary consists of at least two populations of the oocytes at different

developmental stages; teleosts with this type of ovary generally spawn once a year and have a relatively short breeding season. In the case of asynchronous ovulation, different development stages of the oocyte maturation and ovulation in groups may be found within the ovaries (**Nagahama 1983, Nejedli et al., 2004**).

The testicular maturity can be judged by visual observation on the morphology and histological survey (**Rath et al., 2000**). However, many have classified development stages of testes as Stage I as resting phases, Stage II as late immature phase, Stage III as maturing phase, Stage IV as mature phase and Stage V as spent phase. Testes are composed of a large number of seminiferous tubules or lobules, which are closely bound together by a thin layer of connective tissue (**Rath et al., 1984**). During breeding season, seminiferous tubules are filled with sperm and a few numbers of spermatogonia are seen. After breeding season, empty and collapsing seminiferous tubules are seen, some of which contain residual or unexpelled sperm (**Sanwal and Khanna, 1972**). **Das (2002)** studied testicular maturity of *Anabas* and identified three phases of testes that is spawning, post spawning and preparatory .

Some of the earlier works on gonad histology on different fishes by authors like **Arockiaraj et al., (2004)**, who found five developmental stages of gonad in *Mystus montanus*; **Agbugui, (2013)** reported six developmental stages of gonad in *Pomadasys jubelini* namely, immature, quiescent, maturing, mature, running and spent from Nigeria; **Amtiyaz et al., (2013)** observed seven developmental stages of gonad in *Pomadasys stridens* from Karachi Coast, Pakistan; **Oliveira et al., (2015)** investigate six phases of oocyte development and four developmental phases of the spermatogonia in *H. brasiliensis*: spermatogonia, spermatocytes, spermatids and spermatozoa of *H. Brasiliensis*; **Chakrabarti and Banerjee (2015)** found five stages of spermatogonia of

X. cancila; **Behera et al., (2015)** observed two testicular cyclicity of *Anabas testudineus*. According to **Dopeikar et al., (2015)** five gonad developmental stages namely Stage I (never spawned), Stage II (Early developing; developing; ovaries and testes beginning to develop, but not ready to spawn), Stage III (Spawning capable; fish were developmentally and physiologically able to spawn), Stage IV (Regressing; cessation of spawning) and Stage V (Regenerating; sexually mature, reproductively inactive) of *Barbus lacerta* from Bibi-Sayyedana River, Tigris basin.

Recently, gonad histology of many fishes have been studied by several workers viz **Roy and Manda (2015)** on *Labeo bata*; **Chakraborty and Choudhury (2015)** on *Notopterus notopterus*; **El-Nasr (2016)** on *Gerres filamentosus* from Hurghada Red Sea, Egypt; **Mahmud et al., (2016)** on *Channa striata* from Bangladesh; **Silva et al., (2016)** on *Cynoscion leiarchus*; and **Sales et al., (2016)** on *Hypostomus francisci* from Brazil.

2.5. Molecular characterization of DNA barcoding

DNA barcode is a new tool for taxon recognition and classification of biological organisms based on sequence of a fragment of mitochondrial gene, Cytochrome Oxidase I (COI). In view of the growing importance of the fish, DNA barcoding for species identification, molecular taxonomy and fish diversity conservation is essential (**Nagpure et al., 2012**). Molecular taxonomy is now used in harmony but in addition to other classical morphological data to delimit species (**Tautz et al., 2002**). Although it has been well accepted that DNA taxonomy can solve many taxonomic problems but still it has not got a central role in it. Presently, scientists are working on phylogeny and phylogeography of different species using the DNA as the central theme of their analysis. Although the morphological attributes are going to play the major role in the taxonomic

description, DNA can be given a better position than what it has today. We believe the best way to give DNA its fair chance in taxonomy will be to implement “DNA barcoding” as an international unit for identification of species (**Kalyankar , 2012**).

Different molecular markers, such as allozymes, mitochondrial DNA, RAPD have been used to observe genetic variation and evolutionary relationship amongst the different taxa. DNA barcoding is a species level identification system based on mitochondrial DNA. Mitochondrial DNA was used to examine the evolutionary and taxonomic relationships amongst taxa. The DNA barcoding is based on a small sequence of about 655bp of mitochondrial gene Cytochrome oxidase subunit I (COI) with universal primers (**Hebert, 2003a**). An international interest in fisheries sparked to launch the “Barcode of Life Project (iBOL)”. **Hebert (2003b)** determined that mtDNA cytochrome oxidase subunit 1 (CO1) was a suitable gene marker for fish species identification due to the fast evolution of the mtDNA, its maternal inheritance and haploid condition (**Moore,1995**). The use of COI gene for barcoding is a suitable marker for discriminating between closely related species of fishes.

Some important molecular work for species identification at gene level were done by few worker, **Ward et al., (2008)** barcoded 15 fish species from Northern (Atlantic and Mediterranean) and Southern (Australasian) Hemisphere waters and found that 13 species had low genetic variation and two species namely, *Lepidopus caudatus* showed 2.75% and *Zeus faber* showed 7.44% genetic distance between northern and southern clades. **Lakra et al., (2011)** working on 115 marine fish species covering Carangids, Clupeids, Scombrids, Groupers, Sciaenids, Silverbellies, Mullids, Polynemids and Silurids representing 79 Genera and 37 families from the Indian Ocean have been barcoded for the first time using Cytochrome c oxidase I gene (COI) of the mtDNA. The

average Kimura two parameter (K2P) distances within species, genera, families, orders were 0.30%, 6.60%, 9.91%, 16.00%, respectively; **Nagpure et al., (2012)** developed a Fish Barcode Information System (FBIS) for Indian fishes and the database contained 2334 sequence records of COI gene for 472 aquatic species belonging to 39 orders and 136 families, collected from available published data sources and this system also contained information on phenotype, distribution and IUCN Red List status of fishes. **Krishna et al., (2012)** were barcoded 10 species from River Krishna region, Andhra Pradesh, India and recovered a new species; **Chandra et al., (2012)** worked on Cytochrome Oxidase I (COI) DNA barcodes for the identification of two commercially important coldwater species of Genus *Schizothorax* (Snow trout) and mean intra-specific nucleotide sequence divergence was 1.75% (range 0.00-3.50%) and inter-specific divergence of *S. richardsonii* was 0.00% (range 0.00040-0.00080%) and *S. progastus* was 0.00% (range 0.00036-0.000206), respectively; **Sarkar et al., (2013)** worked on 58S and 28S ribosomal RNA genes of *Pangio pangia* from Ganga river basin ; **Rahman et al., (2013)** barcoded three genera and ten species of mullets (Family : Mugilidae) (*Liza macrolepis*, *Liza parsia*, *Liza planiceps*, *Liza subviridis*, *Liza tade*, *Liza vaigiensis*, *Mugil cephalus*, *Valamugil cunnesius*, *Valamugil seheli*, *Valamugil speigleri*) and among 10 species the sequence for *Valamugil speigleri* was not available in the GenBank and all species were clearly differentiated with COI gene sequences.

Recently some work on barcoding of fish by **Vij et al., (2014)** were collected. Asian seabass from Western and Eastern Coastline of India, Andaman and Nicobar Islands, Bangladesh and Australia, Malaysia, Indonesia, Thailand and Singapore and barcoded all the sequences analyzed concordantly point to the existence of at least two distinct species one representing the Indian subcontinent plus Myanmar, and a second, representing Southeast Asia (Singapore, Malaysia, Thailand and Indonesia) plus

Northern Australia; **Ambili et al., (2014)** identified three *Tor* species from Southern Western Ghats, Kerala with the help of COI and *Tor khudree*, *Tor malabaricus* and *T. mussullah* was confirmed through DNA barcoding, morphometric and meristic characters. **Jegatheesh et al., (2014)** studied six endemic fishes of the Western Ghats belonging to *Dawkinsia* genus and reported that all these six species are genetically distinct; five haplotypes within *filamentosa* group indicated that high level of genetic diversity found within COI sequences of studied species and *Dawkinsia* exhibited very close genetic similarity with *D. filamentosa*. **Bineesh et al., (2014)** confirmed four species of elasmobranch, *Rhynchobatus australiae*, *Dasyatis microps*, *Himantura granulate* and *Aetomylaeus vesperilio* from Arabian Sea coast of India with the help of barcoding. **Kannan et al., (2014)** using Cyt b and COI of mitochondrial DNA of *Dawkinsia tambraparniei* from Southern Western Ghats, India and recovered that Cyt b gene sequences showed that all populations belonged to a single haplotype and no nucleotide variation was observed between populations and in the case of COI gene sequences, two haplotypes were found and the pair wise genetic distance between *D. tambraparniei* and *D. arulius* was low; **Kannan et al., (2014)** using Cyt b and COI of mitochondrial DNA of *Dawkinsia tambraparniei* from Southern Western Ghats, India and recovered that Cyt b gene sequences showed that all populations belonged to a single haplotype and no nucleotide variation was observed between populations and in the case of COI gene sequences, two haplotypes were found and the pair wise genetic distance between *D. tambraparniei* and *D. arulius* was low.

2.6. Ichthyofauna diversity in different rivers of India

According to **Cohen (1970)** approximately, there are 19650-21535 living species of fish. These one third are freshwater and two-third are marine. **Nelson (2006)** reported about 27,977 species of fish of which 11,952 were freshwater and 16,025 were marine and diadromous.

According to **Kottelat and Whitten (1996)**, India occupied eighth position in the world and third in Asia. **Mittermeier and Mittermeier (1997)** stated, that India was a megabiodiversity country which occupied the ninth position in the world. About 21,730 species of fishes have been recorded in the world; of which about 11.7% are found in Indian waters. Out of the 2546 species so far listed, 73 belong to cold freshwater regime, 544 to the warm fresh water domain, 143 to the brackish water and 1440 to the marine ecosystem (**International Consultation on Biological Diversity, 1994**).

Other important work done in India on Ichthyodiversity were by **Menon (1962)** who listed 218 species from Himalayan; **Mahanta (2006)** 258 freshwater fish species; **Ghosh and Lipton (1982)** reported 172 species; **Talwar and Jhingran (1991)** stated 930 fish species; **Tamang (1993)** reported 48 species from Sikkim and **Sinha (1994)** listed 230 species; **Choudhury (2005)** 297 and **Goswami et al., (2012)** 422 species from North-Eastern India.

Many authors who worked on fish diversity of different rivers of West Bengal, **Sanyal et al., (2012)** reported 207 species from Sundarban;. **Mahapatra et al., (2015)** reported 190 native freshwater fish species; **Paul and Chanda (2015)** listed 44 indigenous fish species and **Mistry (2016)** recorded 47 species. Earliest study of fish diversity in West Bengal was done by British surveyors **Shaw and Shebbeare (1937)** who first reported that there were 131 fish species from North Bengal; **Hora and Gupta**

(1940) reported 58 species of fishes from Kalimpons ; **Mukherjee *et al.*, (2002)** recorded 39 local Endangered species present in West Bengal; **Patra and Dutta (2010)** recorded 31 species of Cypriniformes fish from River Karala; **Acharjee and Barat (2013a)** reported 65 from Teesta river; **Acharjee *et al.*, (2014a)** reported 20 species of loaches from Darjeeling Himalaya; **Dey *et al.* (2015a)** reported 138 species from Kaljani river and **Dey *et al.*, (2015f)** reported 141 species three district of East Himalayan region; **Dey and Sarkar (2015)** recorded 107 from Torsa river; **Das (2015)** recorded 105 Torsa and **Debnath (2015)** recorded 73 Gadadhar river.