CHAPTER 2: REVIEW OF LITERATURES

Fish production has grown in a steady way in the last fifty years, with the supply of food fishes increases at an average annual rate of 3.2 percent. Per capita fish consumption also increased from an average of 9.9 kg to 19.2 kg worldwide. According to FAO report China has been owing to the dramatic expansion in its fish production, particularly in aquaculture sector (FAO, Rome 2014, World Review of Fisheries and Aquaculture).Inland water capture fishery production found to be 11.6 million tonnes in 2012. Global aquatic production reachesitsall-time high altitude of 90.4 million tonnes (live weight equivalent) in 2012 (US$144.4 billion), including 66.6 million tonnes of food fish and 23.8 million tonnes of aquatic algae.(FAO. 2012. The State of World Fisheries and Aquaculture 2010. Rome. 197pp.)

During the period 2000–2012 food fish aquaculture production expanded at an average annual rate of 6.2 percent (9.5 percent in 1990–2000) from 32.4 million to 66.6 million tones worlwide. In the same period, annual growth was relatively faster in Africa (11.7 percent) and Latin America and the Caribbean (10 percent). Excluding China, production in the rest of Asia grew by 8.2 percent per year (4.8 percent in 1990–2000). The annual growth rate in China found during 2000-2012 averaged 5.5 percent (12.7 percent in 1990–2000). Similar trend found in North America, higher production found during 2000 than the year 2012. Chile and Egypt became million-tonne producers in 2012. Brazil has also improved its ranking significantly in recent years. However, Thailand’s production fell to 1.2 million tonnes in 2011 and 2012 due to flood damage and shrimp disease. Japanese aquaculture recovered slightly in 2012 followed by the 2011 tsunami. (Ye, Y., Cochrane, K., *et. al*, 2013.)

Indian Aquaculture:

According to FAO (2009) Aquaculture in India has a long history; there are references to fish culture in Kautilya's Arthashastra (321–300 B.C.) and King Someswara's Manasollas (1127 A.D.).India's share in the world's fish production has increased to 6.3% at present (NFDB, 2018). Ayyappan and Diwan (2006) described that fishery sector occupies an important place in the socio-economic development of the country. Fish production in the country, sixth largest producer, has been showing an increasing trend and has reached a record level of 12.60 million tonnes (NFDB, 2018). The fisheries sector contributes Indian Rupiah (Rs.) 45106.89 Crore to the national income which is 0.91 percent of the total Gross Domestic Product (GDP) and 5.23 percent of the agricultural GDP of India (NFDB, 2018). India, with a total aquaculture production of about 3.2 million metric tonnes (6.3% percent) is ranked second in world aquaculture production. According to FAO (2001) India has rivers and canals of 0.2 million kms, reservoirs of 3.1 million hac and tanks and ponds of 2.2 million hac offering tremendous scope for fish production. India also ranks second to China in inland capture fisheries. According to Sarkar S. K. 2002, freshwater aquaculture depends mainly on carp culture that account for around 80% of the total inland fish production and have proved sustainable at different levels of production over the years.

Fisheries Scenario in West Bengal:

Among Indian states, West Bengal occupies the first position in production and consumption of fish. According to Annual Report 2011 -12(Govt. of India, 2012), West Bengal produced 1.61 MT of fish during the year 2011-12 constituting 19.49 percent of the total production of India. West Bengal state is blessed with a vast impounded water area. Every district has got waterlogged area. According to S. Ramachandran *et. al.*, 1998, these waterlogged areas are the real potential of the state for pisciculture. It contains 3 districts namely Uttar Dinajpur (4,000 hac), Bankura (2,000 hac) and lastly Purulia (100 hac).

In fresh water aquaculture West Bengal is among the front runner states of India where the average productivity (around 5tonnes / hac / yr) is significantly higher in comparison to the national average of 2.2 tonnes /hac /yr (Tripathi, 2003). According to Mondal, A. and Das, S. K. 2005, West Bengal accounts for 30% of the all India fish production in inland sector, whereas it produces 62% of total fish seed production of India. Total fish production in the state has increased from 14.71 lakh tonnes in 2007-08 to 14.84 lakh tonnes in the year 2008-2009 .Fish seed production has increased from 14,000 million in 2008-09 to 15,000 million in the year 2009-10. *L. rohita* and *C. catla* were the most preferred culturable species. Besides these, *C. mrigala*, *Hypophthalmychthys molitrix*, *L. bata*, *C. carpio*, *C. idella*, *L. calbasu* and *M. rosenbergii* were also cultured. *H. molitrix* and *C. idella* were cultured due to their faster growth rate. *Oreochromis niloticus, O. mossambicus*, and *Puntius javanicus* were also widely cultured because of their high proliferation rate. Despite the ban imposed by the West Bengal Government, 3.8% and 34.6% of the farmers cultured *Clarias gariepinus* and *Aristichthys nobilis*, respectively (T. Jawahar Abraham, S. K. Sil, *et. al*, 2010). Purulia and its surroundings districts where good potential for inland water resources are existing, can be exploited for more fish production, while the fact remains that inland production from Purulia district has decreased up to 47% due to lack of trained manpower, infrastructures and marketing facilities. R. Singh, P. K. Pandey and A. Sinha (2011) reveal that skilled man powers are urgently required to increase fish production from untapped aquatic resources. According to Veerina, Nandeesha and Gopal Rao (1993) West Bengal is an example of how farmers have been able to utilize their inventive potentials to evolve a technology that has stood the test of time for centuries. Nandeesha and

Ramakrishna (2005) told that traditional technology evolved by farmers gave a yield of 3-4 tonnes/ha and the scientific community attempted to enhance this yield to 10 tonnes, by incorporating additional species into the system.

Fish culture practices:

Major categories of aquaculture systems

There are different kinds of aquaculture systems. It ranges from very extensive, through Semi-intensive and highly intensive (Smith and Phillips, 2001). About 70-80% of the total global production of farmed takes place within extensive and semi- intensive farming Systems. In this culture system, fishes are raised in earthen ponds, pens and cages, rice fields or small water bodies.

Extensive Aquaculture:

Total dependence on natural productivity, very little management over the stocks and adoption of traditional techniques of aquaculture is that the extensive aquaculture system (Smith and Phillips, 2001). The limiting issue for growth here is that the obtainable food supply by natural sources, normally zooplankton feeding on pelagic. Tilapia species filter feed directly on phytoplankton that makes production high (FAO, 1987).

In extensive fish farming, economic and labor inputs are usually low. Natural food production plays a awfully necessary role, and also the system's productivity is comparatively low. Fertilizer could also be used to increase fertility and therefore fish production. (EiraCarballo, Assiah van Eer, Ton van Schie, AldinHilbrands, 1996)

Intensive aquaculture:

In intensive aquaculture system, fish are fed with external food provide (Smith and Phillips, 2001). According to FAO (1987), oxygen, fresh water and food are provided to fish. It involves the adoption of full complement of culture techniques as well as scientific pond design, fertilization, supplemental feeding or solely feeding without fertilization; full measure of stock manipulation, disease control, scientific harvesting, high level inputs and high rate of production. Fish production per unit of surface is usually high. It is labor and time intensive. Intensive fish farming involves a high level of inputs and stocking the ponds with as several fish as possible. The fish are fed supplementary feed, while natural food production plays a minor role. In this system, difficult management problems can arise caused by high fish stocking densities (increased susceptibility to diseases and dissolved oxygen shortage). The high production costs force one to fetch a high market price in order to make the fish farm economically feasible (Eira Carballo, Assiah van Eer, Ton van Schie, Aldin Hilbrands, 1996)

Semi-intensive:

This system involves the implementation of mid-level ability, where the fish depend partially on natural productivity by phytoplankton and aquatic organisms. Fertilization is done to enrich the water which also facilitates the growth of natural feed. There is continuously a, supplementary feeding, with stock management. The level of input is often medium compare with the other system (FAO, 1987).

Semi-intensive fish farming needs a moderate level of inputs and fish production is increased by the use of fertilizer and/or supplementary feeding. This means higher labor and feed costs, but higher fishyields usually more than compensate for this (Eira Carballo, Assiah van Eer, Ton van Schie, Aldin Hilbrands, 1996)

Multiple stocking Multiple Harvesting:

In West Bengal intensive fish culture is going on following the 'multiple stocking and multiple harvesting' method of culture practice. Multiple stocking and multiple harvesting (MSMH) could be a system of composite fish farming, through which fish production can be augmented by many folds (6 to 10 ton/hectare/year). In this system, stocking density is high, 12000 - 14000 no's carp fingerlings per hectare. Harvesting is done after the fishes attain a size of 500 gms. The farmers needn't to possess a giant capital to fulfill the assorted recurring expenditure of fish cultivation. He has to manage the pond for a maximum period of 4 months, thereafter he starts earning which is reinvested for purchasing of various items required for further fish rearing. Therefore, a marginal farmer can even take up scientific fish farming with his meager resources by adopting this technique. There are several other advantages; however, the prime advantage is that the production is much higher than yearly composite fish culture system (Fisheries Dept. Govt. of West Bengal).

Productivity of Different Culture System:

Composite fish culture is being successfully undertaken in ponds, small reservoirs, rain fed seasonal tanks and lakes (Mohanty and Pattnaik, 1984; Dwivedi et al., 1985; Khan, 1990; Samantha Roy, 1990; Piska, 1999; 2000).

National Aquaculture Sector Overview: India discussed that the culture systems in the country depends on the availability of input and the investment capabilities of the farmer. Extensive aquaculture is administered in relatively large water bodies with stocking of the fish seed because the only input and utilizing natural productivity, elements of fertilization and feeding have been introduced into semi-intensive culture. (Food and Agriculture Organization of the United Nations, 2009)

According to Roy (2008) the fish production of West Bengal is increasing over the year but the productivity of the fishery sector shows a very less increment over the year due to over fishing, lack of quality fish seed in proper ratio, lack of marketing infrastructure, socioeconomic and environmental constraints and again the most farmers used to follow traditional technology due to the absence of fishery extension services (Singh, 2001).

Table 1: Summary of comparative features among the three main culture systems (AQUACULTURE METHODS AND PRACTICES: A SELECTED REVIEW) FAO:

Parameter	Extensive	Semi-Intensive	Intensive
Species Used	Monoculture or Polyculture	Monoculture	Monoculture
Stocking Rate	Moderate	Higher than extensive culture	Maximum
Engineering Design and Layout	May or may not be well laid-out	With provisions for effective water management	Very well engineered system with pumps and aerators to control water quality and quantity
Pond Size	Very big ponds	Manageable-sized units (up to 2 ha each)	Small ponds, usually 0.5-1 ha each

Pond Condition	Ponds may or may not be fully cleaned	Fully cleaned ponds	Fully cleaned ponds
Fertilizer	Used to enhance natural productivity	Used regularly with lime	Not used
Pesticides	Not used	Used regularly for prophylaxis	Used regularly for prophylaxis
Food and Feeding Regimen	None	Regular feeding of high quality feeds	Full feeding of high-quality feeds
		Depending on stocking density used, formulated feeds may be used partially or totally	
Cropping Frequency (crops/y)	2	2.5	2.5
Quality of Product	Good quality	Good quality	Good quality
	Culture species dominant but extraneous species may occur	Confined to culture species	Confined to culture species
	Variable sizes	Uniform sizes	Uniform sizes

Status of seed rearing and fish culture practices of the District:

According to Das *et.al.*, (2019) although fishery could be a crucial sector of keeps for the local people, however still the technology of cultivation has not been well established among them. Fishes are feed with domestically offered feed materials like banana leaf, banana pseudo stem, rice bran, trash etc. In their observe, correct stocking density and selection of compatible species is additionally not maintained There are several fish culture technologies available and among them, the Composite Fish Culture (CFC) system is that the most sustainable for this region (Rout, M., and Tripathi, S.D., 1998). in this system, distinctive compatible species of Indian and Exotic carps of various feeding habits are stocked with and cultured within the same pond in order that all its ecological niches are utilized by the fishes(Mahapatra B. K, Vinod K, Mandal B. K, Bujarbaruah K. M, 2006)

Effect of water quality parameter on pond productivity:

Water is one amongst the foremost voluminous compounds in earth roughly covering three-fourth of the earth's surface. Majority of water offered on earth is saline in nature; solely a little amount exists as fresh water. Fresh water has become a scarce commodity due to over exploitation and pollution (Ghose and Basu, 1968; Gupta and Shukla, 2006; Patil and Tijare, 2001; Singh and Mathur, 2005).The first study of water quality of a fish pond in India was in all probability done by Sewell (1927) once he studied the mortality of fish within the museum tank in Calcutta. Pruthi (1932) also studied thoroughly the water condition of the same tank in reference to mortality of fishes.

Since then a number of workers have studied the physico-chemical condition of inland waters either in connection with fish mortality or as part of general hydrological survey. To mention a few of them, there are the studies by Alikunhi *et al*., (1948), Ganapati *et al*., (1945, 1950, 1953), Chacko and Srinivasan(1954), Thivy *et al.*, (1948), Chacko et al. (1954),Ganapati (1949, 1950), Ganapati and Chacko (1951), Chacko and Ganapati (1949), and Mookherjea and Bhattacharya (1949). In some cases the water quality of fish ponds has also been studied to explain the factors responsible for the phenomenal growth of fish in a pond (Chacko and Ganapati, 1950). Besides these stray observations, a more systematic and extensive study of the physico-chemical quality of fishery waters was taken up by Madras Fisheries Department in connection with Madras rural piscicultural scheme (Menon *et al.*, 1959). This contains data on physicochemical conditions of a number of ponds and tanks in various districts of Madras and Andhra Pradesh.

In the growing aquaculture trade, it is accepted that good water quality is needed to maintain viable aquaculture production (King, 1998).Poor water quality may result in low profit, low product quality and potential human health risks. Production is reduced when the water contain contaminants that can impair development, growth, reproduction, or even cause mortality to the cultured species (Stone and Thormforde, 2003).Some contaminants can accumulate to the purpose where it threatens human health even in low quantities and cause no obvious adverse effects (King, 1998).Water quality for aqua culturists refers to the standard of water that allows fortunate propagation of the required organisms (Boyd, 1995). The desired water quality is decided by the particular organisms to be cultivated and has several elements that are interlacing. Sometimes a component can be controlled separately, but because of the complex interaction between components, the composition of the total array must be addressed (ICLARM, 2006).

Growth and survival, which together determine the ultimate yield, are influenced by a number of ecological parameters and managerial practices (Boyd and Tucker, 1998).High stocking density of fish or crustaceans in ponds typically exacerbates issues with water quality and sediment deterioration. Wastes generated by aquaculture activity (feces and unconsumed feed) initial settle among the bottom, as a consequence of organic waste and substance of degraded organic matter is accumulated in sediment and water. Part of the waste is flushed out of the ponds immediately or later, after the organic matter has been degraded (Boyd, 1990).Low dissolved oxygen level is that the major limiting water quality parameter in aquaculture systems (Boyd, 1995).A critically low dissolved oxygen level happens in ponds significantly when algal blooms die-off and consequent decomposition of algal blooms and might cause stress or mortality of prawns in ponds. Chronically low dissolved oxygen levels will reduce growth, feeding and moulting frequency (Boyd, 1990).

Another major consequence of aquaculture production may be a high degree of variability in the concentration of dissolved nitrates, nitrites and ammonia (Schwartz and Boyd, 1994).The environmental conditions that make high ammonia concentrations may also cause increase in nitrite concentration. Both ammonia and nitrite can be directly toxic to culture organisms or can induce to sub lethal stress in culture populations that results in lowered resistance to diseases (Boyd, 1998).

Development of aquaculture activities at a selected site cannot be meted out solely by considering planned facilities and therefore the the quality of water on the location at its origin however also on the aspects of water quality management (Boyd, 1990).

There is a strong relationship between the water quality in the pond and that in the water-surrounding environment as cited by (Boyd, 1995).

The fish perform all its physiological activities within the water – respiration, excretion of waste, feeding, maintaining salt balance and copy. Thus, water quality is that the determinative issue on the success or failure of an aquaculture operation. The continuing degradation of water resources because of anthropogenic sources necessitates a suggestion in choosing sites for aquaculture using water quality as a basis (Boyd, 1998).

Growth of fish:

Wootton (1992) explained that,a lot of different factors act together to determine the growth rate of fish and how large they will become. The growth pattern observed is the result of interaction between a potential for growth defined by the genotype of the fish and the environmental conditions experienced by the fish (Wootton, 1992). Some of these factors are constants, e.g. the species type; whiles others are variable e.g. pH, salinity and alkalinity. Rapid growth indicates abundant food and other favorable conditions, whereas slow growth is likely to indicate just the opposite. Growth can be defined as the change in size (length, weight) over time or, energetically, as the change in calories stored as somatic and reproductive tissues (Moyle and Joseph, 1988). Moyle and Joseph (1988) noted that, metabolism is the sum of anabolism (the tissue synthesis or "building up" aspect of metabolism) plus catabolism (the energy-producing breaking of chemical bonds or "tearing down" aspect). Thus, the rate of anabolism exceeds that of catabolism in a growing fish. From Wootton (1992), the presence of other fishes in a fish's environment can reduce growth rates through interference or exploitation competition. Growth could also be either somatic or reproductive. Somatic growth results in growth in the body cells which usually brings about a physical change or development in the body. It involves division and growth of the body cells and tissues. Reproductive growth is development of the gonads and gametes in the body, that is, maturation of the female and male sex cells and organs.

Wootton (1992), once more explicit that, growth can even be at negative rate which is termed degrowth. The growth pattern in fishes might even vary among organisms of the same species certain organisms might even wish to reach sexual maturity even with scarce quantity of food and so tend to continually be smaller in size (Brogowskiet. al., 2004).According to Brogowskiet. al., (2004), the principal factors dominant anabolic processes are growth hormones secreted by the pituitary and steroid hormones from the gonads. However, the speed of growth of fish is very variable as a result of it's greatly enthusiastic about a range of interacting environmental factors like water temperature, levels of dissolved oxygen and ammonia, salinity, and photoperiod. These factors act with each {other|one another} and with other factors like the degree of competition, the quantity and quality of food eaten, and therefore the age and state of maturity of fish. These factors is summed into physical and chemical each remarked as abiotic and biological (biotic) (Brogowskiet. al.,) 2004)

Factors affecting Fish Growth

Physical factors

Temperature

Temperature influences the onset of fish spawn, aquatic vegetation growth and therefore the biological demand for oxygen in ponds. As water temperature will increase, it holds less oxygen. in addition, plants and animals use additional oxygen due to inflated respiration rates. These factors un remarkably lead to less available oxygen for fish throughout the summer and fall months (Russell, 2011).Temperature is one in all the foremost vital environmental variables. in keeping with Woiwode et. al., (1991), temperature is understood to influence both ingestion and metabolism that, however, additionally have an effect on growth rates. under conditions of unlimited food provide, a rise in temperature can cause a rise in food intake, however at high temperatures there'll be an abrupt decline in rates of ingestion which can successively have an effect on growth (Woiwode et. al., 1991).

Turbidity

According to Moyle (1990), turbidity refers to however clear the water is. The bigger the quantity of total suspended solids within the water, the higher the measured turbidity. The key supply of turbidity within the open water lakes is usually plant life, however nearer to shore, particulate might also be clay and silts from shoreline erosion (Moyle 1990). As particulate of silt and clay and different organic materials settle to all-time low, they will suffocate new hatched larvae and fill the areas between rocks that might have employed by aquatic organism as environment. Fine particulate materials can even harm sensitive gills structures, decrease their resistance to diseases, prevent correct eggs and larval development and potential interfere with particle feeding activities. Increased turbidity enhanced affects the speed of chemical change that causes the reduction of oxygen levels in daytime. This may cause the state of anoxia which may lead to the death of the fish (Moyle, 1990).

Chemical Factors

Dissolved oxygen

DO levels, although hooked in to temperature, usually typically by them a crucial issue affecting the growth rate of fishes. Moyle and Joseph (1988) measured a significant reduction in rate of growth and food conversion potency in juvenile largemouthed bass bass (Micropterusalmonides) when dissolved oxygen fell below around 5mg/l at 26ºC. Presumably, the reduced oxygen below this threshold precludes “extra” aerobic, energy requiring activities like growth and replica reproduction maintenance cost. Some fishes arrange to swim to additional favourable environments. However, a report by Mallya, (2010) shows that, the period of time during which the oxygen level drops below the specified minimum level, will cause the fish to become stressed. it is this stress that causes fish death. quite that, fish cut back food intake, resulting in a reduction in growth. Mallya, (2010), once more explicit that, reproduction is inhibited, and both fertilization success and larval survival are compromised. Once the oxygen level is maintained close to saturation or even at slightly super saturation at all times it'll increase growth rates, cut back the food conversion ratio and increase overall fish production. Because the dissolved oxygen concentration decreases, respiration and feeding activities additionally decrease. As a result, the growth rate is reduced and therefore the chance of a illness attack is multiplied. However, fish isn't able to assimilate the food consumed once DO is low (Mallya, 2010)

pH

In an experiment by Brogowski et. al., (2004), mortality of bluegills was highest (32%) for fish at the pH 5.5 treatment. This was twice as high as the loss of fish in the aquaria of pH 6.5. Significant decreases in length and weight between 5.5 and 6.5 were observed over 30 days.The length of fish in ph 5.5 was 49.6% less than that of fish in pH 12.5 and 7.5.A similar trend was observed for weight changes. Bluegill weight gain was 61.6% lower at pH 5.5 as compared to those in pH 6.5 and 7.5.Lowering ph from 7.5 to 6.5 had very little impact on mortality and growth of fish. A significant distinction seems once the ph level is reduced to pH 5.5.

Ammonia(NH3)

Moyle and Joseph, (1988) indicated that ammonia is the primary excretory product of fishes, but if it is present in high concentrations, it will slow growth rate. For example, juvenile channel catfish display a linear drop in weight gain with increasing ammonia in their water. The mechanism of growth inhibition by ammonia is still unknown. It is generally acknowledged that un-ionized ammonia (NH3) in the water produces more toxic

effects on fishes than an equal concentration of the ionized form ($NH4+$). Although ammonia is a "natural" compound, its effects on fishes are typical of many pollutants, which also reduce growth rates when present at sub lethal levels.
Biological Factors

Competition either inside or among species, for restricted food provides could slow growth.

Moyle and Joseph (1988) according that freshwater bream, a species during which the adults and young each eat nearly a similar aquatic invertebrates and aren't barbarian, become stunted when the population size reaches a particular level. Fertilization, of the pond will increase the invertebrate food base and consequently bluegill total biomass. However, the common size of the bluegill remains little as growth slows and a few reproductions continue.

Biological constraints to the development of economic tilapia farming area unit their inability to resist sustained water temperatures below 50 to 52 ºC and early sexual maturity that leads to spawning before fish reach market size (Popma and Masser, 1999).

Food Availability

Food availableness conjointly moves with different factors also, particularly temperature, to affect the growth of fishes on a seasonal basis. For example, Moyle and Joseph (1988) found marked seasonal differences in growth (length increases) in northern Indiana bluegill populations. Bluegill growth was accelerated during the warmer months of plentiful food. Striped mullet (*Mugil cephalus*) from south Texas coastal waters show cycles of seasonal growth similar to those of bluegills, except that growth virtually ceases during the warmest months of midsummer through mid autumn. Photoperiod (day length) may additionally affect seasonal growth phenomena. For example, Moyle (1988), found a close association between growth of Lake Whitefish (*Coregonus clupeaformis*) and seasonal photoperiod but no relationship between the spring water temperatures and growth. Small tench, captured by electro-fishing from a single wild population and then released in four farm ponds, were able, because of plentiful food, to grow as much in a single year as they might have in four years in their original lake setting (Gray and Setna, 1931).

Age and Maturation

Age and Maturity area unit typically the most effective predictors of relative growth rates in fishes, although the absolute growth rates are strongly influenced by environmental factors. Thus, fish grow usually very quickly in length within the 1st few months or years of life, until maturation.Then increasing amounts of energy are diverted from growth of somatic to growth of gonadal tissues.As a consequence, growth rates of mature fish are much slower than those of immature fish.Partly in because of the amount of gonadal tissues, however, mature fish are typically heavier per unit length than immature fish. This is reflected in their high condition factor (K) (Moyle and Joseph (1988).

Planktons and aquatic food web:

Plankton occupies the pelagic zone of the water column which is named after its pelagic inhabitants (Ricklefs, 2007).Plankton is the basis of freshwater and saltwater ecosystems, meaning that all aquatic life is dependent upon the energy and oxygen it provides. Plankton is important to the food web as the initial food source for every food chain. Phytoplankton is the primary producer of all aquatic food chains, gaining energy from the sun to perform photosynthesis, providing food, energy and oxygen needed to sustain plant and animal life. Energy not used by the phytoplankton for maintenance is available as food for the animals that consume it (Ricklefs and Miller, 2000).

Plankton's wide range of sizes makes them a useful food supply for animals and alternative plankton. Even whale-sharks, one among the most important animals within the ocean, feed totally on plankton. Filter feeders are the first consumers of plankton, as they feed by filtering water through their mouths and consume the food that is still. Filter feeders embrace any range of species, like fish, mammals, and squid. Because the base of the organic phenomenon, the balance of energy in aquatic ecosystems relies upon the provision of plankton within the water zone of the water column (Burnham, 2001).

Since the microbial food web was postulated (Azam *et al*., 1983), food web interactions within the plankton of lakes and oceans have received a lot of attention (Ducklow, 1991; Stone *et al*., 1993; Gaedke *et al*., 2002). As main consumers of bacterial production, the productive protozoans play an important role among the plankton. They are an essential component of the pelagic food web and thus of pivotal importance in the degradation of organic matter in aquatic ecosystems. In addition, several species of ciliates and flagellates are able to consume algae and other protozoans and could perform similar functions in the food web as the metazoans (Sanders, 1991; Sherr and Sherr, 1994; Arndt *et al*., 2000).

Only 3 percent of the light shining on the ocean absorbed by Phytoplankton. By comparison, plants onto land absorb about 15 percent of the offered sunlight. This discrepancy is caused by the ocean itself, which absorbs sunlight in varied degrees. This competition for vital light resources is a limiting factor for the rate of primary production in aquatic ecosystems (Denny, 2008).Phytoplankton is consumed by herbivorous animal microorganisms called zooplankton. Populations of zooplankton provide nourishment for secondary consumers such as fish, whales and crustaceans. Without plankton, smaller fish and crustaceans would be without a food source and would die, causing a linear effect of death and extinction among bigger fish and mammals. Plankton takes in carbon dioxide and gives off oxygen during the process of respiration, supplying half of the Earth's oxygen, affecting the survival of aquatic and land food web.

Biological characteristics of water particularly planktonic community indicate the status of the productivity of a water body. Abundance and composition of plankton vary seasonally and depend on the variation in physico-chemical characteristics of a water body.

The correlation and inter correlation among the physico-chemical parameters and planktonic group have also been made due to the lesser quality of nutrients in water bodies (Sedamkar and Angadi, 2003).

Baruah *et al*. (1998) conducted a detailed water quality and planktonic population assessment of both urban and rural water bodies and concluded that excessive human activities in urban areas profoundly affected the water quality as well as plankton population.

Raut and Pejaver (2003) studied the rotifer diversity of three macrophytes infested lakes from Thane city, Maharashtra that include Lake Ambegosale, Lake Rewale, Lake Makhmali. Rotifera with 19 species belonging to 9 genera were obtained. This was compared with uninfested lakes in which only 10 species belonging to 6 genera were obtained. The study showed that the macrophytes helped to increase the diversity of rotifers and rotifer population varied between mesotrophic and oligotrophic lakes.

Kumar (2013) conducted an investigation on Samrat Ashok Sagar (popularly known as Halali reservoir) of Madhya Pradesh with special reference to its zooplankton diversity in relation physico-chemical characteristics. They were identified 105 (One hundred and five) zooplankton species from Samrat Ashok Sagar which consisted of Rotifera 43 species (41 %), Cladocera 25 species (24%), Protozoa 20 species (19%), Copepoda 12 species (11 %) and Ostracoda 5 species (5%).

The investigation on physicochemical characteristics at completely different sites unconcealed its alkaline nature, appropriate for aquaculture practices. Most diversityof zooplankton population was recorded at macrophytic sites throughout summer season. They also studied the occurrence of Zooplankton consisted of 3 species of Protozoa, 23 species of Rotifera, 16 species of Crustecea (including the species of Cladocera, Copepoda and Ostracoda), 7 species of Mollusca and 10 species of Insecta.

Jyotsna *et. al.,*(2014) studied the seasonal changes of phytoplankton in relation to the physico-chemical parameters of Satyavaram pond in Andhra Pradesh. The dominant members belonged to Chlorophyceae (44 genera) followed by Cyanophyceae (20 genera), Bacillariophyceae (15 genera) and Euglenophyceae (3 genera). The abundance of various algal groups in the pond was in the percentage of Chlorophyceae (60.95%), Cyanphyceae (20%), Bacillariophyceae (15.55%) and Euglenophyceae with 3.5% in two year study.

Rahman and Hussain (2008) investigated the abundance of zooplankton of a culture and a non culture pond of the Rajshahi University Campus in Bangladesh. They identified four groups of zooplankton of which copepods (1260 No.1-I and 973.33 No.rl in pond - 1 and pond - 2 respectively) were most dominant. A total of 9 genera of zooplankton were identified of which Cyclopes (68.25% and 60.28 % total copepods) was most abundant in both ponds. After completion of investigation they concluded that the culture pond showed better result than that of the non culture pond regarding zooplankton production.

Dalal and Gupta (2013) studied the plankton diversity of two temple ponds - Radhamadanakhra pond (RM) and Mandirdighi (MD) in Silchar town in Assam. They recorded total of twenty six phytoplankton and twenty six zooplankton from both RM and MD ponds. Fifteen species were common at both the ponds.

Amphipleura sp. *Stauroneis sp*. and *Cosmarium s*p. were the species that were recorded only from RM and *Mesocyclops sp*. *Diacyclopssp.Acanthocyclops sp*. and *Bosmina sp*. were recorded only from RM pond.

Study on the occurrence and distribution of plankton in different months of a year in a railway pond (Bihar) was conducted by Singh *et al*. (1999) and recorded that the maximum density of phytoplankton (mainly Chlorophyta, Cyanophytaand Crysophyta) were during the month of March to April (5871 to 4027 No.m·3) and zooplankton (mainly Rotifera, Copepoda and Cladocera) were during the month of September to October (2097 to 2663 No.m·3).

Macrophytes:

Macrophytes are considered as an important component of any aquatic ecosystem as far as the primary productivity is concerned. Macrophytes function as integrators of environmental condition to which they are subjected and reflect the nutrient status of their habitat by their presence or absence and abundance and therefore are often effectively used as biological indicators (Suominen, 1968; Uotila, 1971).

According to Sugunan *et al*., (2000) a rich variety of aquatic macrophytes grow in the beels of West Bengal affecting their ecology and fisheries and even some times threatening the existence of these water bodies. Several scientists have tried to analyses the diversity of macrophytes and its influence on the ecology and productivity of the aquatic environment.

Varghese (1993) recorded eleven species of macrophytes from domestically polluted tropical ponds and reported their biomass production with maximum in summer and minimum in monsoon. The abundance, diversity and impact of macrophytes on the ecology of flood plain lakes of Bihar have also been extensively reported by Jha (1989, 1995 and 1997) and Sinha and Jha (1997).

Mitra (1989 and 1997) has reported about the macrophytic communities and its associated fauna in the bee is of West Bengal. An extensive survey of macrophytes in the beels of Assam was carried out by Sugunan and Bhattachariya (2000).

Several workers have tried to find out the influence of aquatic macrophytes on the pollutants present in the waters. Scheffer (1999) opined that macrophytes can enhance water clarity, reduce phytoplankton biomass through shedding and reduce nutrient availability.

Singh *et al*. (1998) observed the infestation of Eiehorniaerassipes, Nelumboueifera and Ipomoea aquatica @ 1.12 kg/m2, 0.5 kg/m2 and 0.206 kg/m2 (dry weight) respectively in some eutrophic ponds of Bihar which resulted in low abundance of phytoplankton and D.O. by preventing the sunlight penetration.

Mondal *et al*. (1998) recorded seventy species of macrophytes compising 60 (sixty) genera from the stagnant water bodies of Purulia District, West Bengal. They opined that the macrophytes acts as biofilters in reducing toxicity and pollutant load from water bodies. Also reported that Pistia stalioted, Eiehornia erassipes and Hydrilla vortieillata were able to accumulate heavy metals such as mercury and chromium.

Plankton Diversity with relation to physico – chemical Parameters:

The present fresh water regime is approximately 2.7 % of the total global water, of which rivers and lakes constitute only 0.01% (Dhoundial, 1993). The various physico chemical characteristics, the dynamics of plankton population, the fishery potential and the methods of improvement of the water bodies formed a subject of detailed discussion by various scientists. In the early half of the last century various workers have thoroughly studied the different aspects of water bodies. (Weibe, 1930; Rice,1938; Redfield, 1934; Yoshimura, 1935; Campbell, 1941 and Chandler, 1944).Weibe (1930) investigated the plankton production in fish ponds. Rice (1938) studied the phytoplankton of river Thames. Campbell (1941) studied the vertical distribution of rotifera in Douglas lake, Michigan and reported that the abundance of rotifer can be attributed to factors like dissolved oxygen, carbon dioxide and pH. Chandler (1944) studied the limnology of western Lake Erie and emphasized the effect of temperature on physicochemical factors of water and plankton. During the second half of the 20th century lot of workers have contributed valuable information about various aspects of lentic and lotic water bodies of different countries.(Welch,1952; Pennak,1955; Jitts,1961; Hutchinson,1967; Odum,1971; Villar*et al*., 1996; Lind *et al*., 1997). More precise and diversified research is going on in the hydrology, plankton study and fisheries sector in this century also. (Magdeleno *et al*., 2001; Yahia *et al*., 2004; Castro *et al*., 2005; Kideys *et al*., 2005; Zaho Wen *et al*., 2005) Magdeleno *et al.* (2001) has studied water pollution is an Argentine river and opined that the pollution of rivers is manifested by low oxygen content, high levels of nutrients, suspended matter, and heavy metals. According to Bhatnagar (1984) cladocerans and copepods play marked role in vertical migration on daily basis. Ushakumari *et al*., (1991) while reporting the ecological parameters of Basman Lake recorded the absence of any direct relation between temperature and plankton production. Sharma and Sharma (1999) studied the freshwater rotifers of Meghalaya. Sharma (2000) studied the rotifers of tropical flood plain Lake of Upper Assam and commented that the rotifers depict a qualitative predominance in floodplain lakes. Khanna *et al*., (2000) while investigating the seasonal periodicity of plankton in Ganga River found that total planktonic concentration was the highest in the month of January from where it decreases continuously. Choudhary and Devendrakumar (2001) studied the phytoplankton population of Boorsa lake and reported that chlorophyceae constituted the major group of the lake, and the summer months produced relatively more plankton than the rainy and winter months.Nandi and Das (2003) while studying the diversity and population of zooplankton in a manmade bhery system in West Bengal noticed a tendency of diminishing overall population density of zooplankton with increase in salinity. Sharma (2005) studied the rotifer communities of flood plain lakes of Assam and observed that water temperature, conductivity, dissolved oxygen, and alkalinity record significant relationships with rotifer abundance. Silas and Pillai (1975) studied the dynamics of zooplankton in Cochin backwater. Madhupratap (1978) studied the ecology of zooplankton of Cochin backwaters and reported that copepod occupied dominant status in Cochin backwaters. The effect of temperature and various other physical and chemical factors on ecology of water bodies have been studied by various scientists. (Rice, 1938; Chandler, 1944; Rao,1955; Klein,1957; Munawar,1970; Patil et *al*.,1985) Chandler (1944) studied the limnology of Lake Erie and emphasized the effects of temperature on aspects like species density, diversity of plankton and physico chemical factors of water. Reports are plenty on the relationship between the atmospheric temperature and water temperature, suggesting that they move more or less hand in hand in smaller water bodies.The studies of Sreenivasan (1964) and Banergee (1967) emphasized the importanceof temperature on primary production. Pillai *et al*., (1975) and Usha Kumari *et al*., (1991) reported that water temperature has no direct impact on plankton production. But Vashist and Sharma (1975) found that low temperature is responsible for increased plankton production. Khatri (1984)while working on the seasonal variation of primary production of Lakhotia lake in Rajasthan confirmed that low temperature favours increased productivity. But Habib *et al*., (1997) reported that light was directly related to phytoplankton growth and temperature, constitutes the limiting factor for algal development. Studies on the effect of pH on aquatic system have been made by various workers. (Weibe, 1930; Welch, 1952; Jana, 1973; Mitra, 1982).Weibe (1930) reported that pH is controlled by photosynthesis of aquatic plants and phytoplankton. Various other workers also reported increase in plankton production with rise in pH (Davis 1955; Moitra and Bhattacharya, 1965; Jana 1973; Bhatnagar, 1984; Ushakumari*et al*., 1991). Vashist and Sharma (1975) found pH as a controlling factor only in the case of some rotifers. Lopes *et al*., (2005) observed a significant relationship between distribution of phytoplankton species and pH elaborating the importance of pH in aquatic systems. Silas and Pillai (1975) while studying the dynamics of zooplankton in Cochin backwaters observed high numerical abundance of zooplanktons during high saline pre monsoon period. Various workers related the dissolved oxygen content with plankton and productivity. (Campbell,1941; Ganapati *et al*., 1952; Biswas,1972; Balkhi *et al*., 1984; Usha Kumari *et al*., 1991; Wasidlewska,1992). Campbell (1941) observed the vertical distribution of rotifera in Douglas Lake and attributed the abundance of rotifer to dissolved oxygen. Ganapati *et. al*., (1952) found that low concentration of dissolved oxygen may favour the abundance of blue green algae.Biswas1972) and Balkhi *et al*., (1984) pointed out that temperature and dissolved oxygen have their influence on the abundance of plankton. Singhal *et al*., (1986) studied physico chemical environment and plankton of managed ponds. They found that the depletion of oxygen content which occurred in August could be attributed to low photosynthetic activity or respiratory activity of heterotrophic organisms counter balancing the photosynthetic production of oxygen. UshaKumari *et al*.,

(1991) studied the ecological parameters of Basman Lake of Motihari and reported that oxygen concentration and plankton abundance were closely and directly related. Pushpendra Kumar Khare (1998) studied the ecology of Jagat Sagar pond and reported that total plankton density showed marked and significant correlation with dissolved oxygen. According to Hutchinson (1967), nutrients are the limiting factors for phytoplankton production. Niroj and Sinha (1998) studied the pollution in the ponds of Orrissa and opined that phosphate as such is not harmful to organisms but it stimulates algal growth causing eutrophication in stagnant water bodies. Sharma and Hussain (1999) while studying the temporal variations in the abiotic factors of a tropical floodplain attributed the lower phosphate content in water to its uptake by the luxuriant growth of aquatic macrophytes. Reynold (1984) studied the ecology of fresh water plankton, and found that the soluble reactive silicon is the only form of silicon available for diatoms and other phytoplankton. Habib *et al.*, (1997) studied the seasonal changes in the phytoplankton community structure in relation to physico chemical factors in a fresh water lake. Aravind kumar (1995) studied the periodicity and abundance of plankton in Tropical wetland of Bihar and found that the total plankton density showed a marked and significant correlation with phosphate and nitrate content. According to Moesenburg and Vanni (1991) zooplankton affects phytoplankton communities by recycling nutrients. Patil (2002) observed that temperature plays an important role in the seasonal periodicity of planktons. Sath *et al.*, (2000) studied the temporal trends of phytoplankton diversity in the river Ganga at Haridwar and reported that the plankton concentration was the highest in the month of Dec–Jan and the lowest in June–July. Godhantaraman (2001) reported the abundance of plankton exhibited a clear seasonal variation ie. highest in summer and lowest in monsoon. Hillbert *et al.*, (1960) opined that turbidity and percentage light transmission were found to influence plankton production significantly. Similar results were obtained later by Menzel and Ryther (1961), Prasad and Nair (1963)and Venu and Seshavatharam (1984). Aquatic systems all over the world are subjected to plankton studies. Some of the important works are those of Khan and Ejike (1984); Chidobemand Ejike (1985) and Wani (1998). Khan and Ejike (1984) studied the limnology and plankton periodicity of a reservoir in Nigeria and reported the dominance of Bacillariophyceae.

Plankton Diversity and Fish Production:

The larvae of carps feed mostly on zooplankton (Bardach *et al*., 1972), because zooplankton provide the necessary amount of protein requires for the rapid growth and development of different organs specially the ground of fishes. Brood fishes productivity depend on zooplankton as an ideal food source of them. Zooplankton constitutes important food item of many omnivorous and carnivorous fishes. The larvae of white fish (Mullet) feed mostly on zooplankton (Dewan *et al*., 1977) because zooplankton provides the necessary amount of protein for the rapid growth and especially that of the gonad. Zooplankton contributes about 82% of the food item of *Anabas testudineus* (Shafi and Mustafa, 1976), 32% of *Notoptrus notoptrus*(Mustafa and Ahmed, 1979).The main food item of *Xenentodon cancila* and the zooplankton contributes about 23% of the food item of *Macrobrachium rosenbergii*, 47% of the *Catla catla*(Ali and Islam, 1981), 6.37% of the *Labeo rohita* (Ali and Islam, 1981), 24.19% of the *Oreochromis nilotica* (Islam *et. al*., 1984), 38.5% of the *Rohteecotio* (Ali *et al*,. 1985) and 30% of the *Mystus vittatus* (Bhuiyan and Haque, 1984). Bhuyan (1988) observed that the food of *Cirrhina reba* constitute mainly of zooplankton.

Study of planktonic diversity contributes to an understanding of the environmental status of a water body. Much work has been carried out in India on the phytoplankton of freshwater habitats (Lund and Talling, 1957; Sreenivasan, 1976; Reynolds, 1984, Gujaria and Harish Kumar, 1992, Ravikumar *et al*., 2006, Tsai and Gonulal, 2007, Sivakumar and Senthilkumar, 2008 and Bhartikhare and PramodPatil, 2011). In freshwater ecosystem zooplanktonic organisms are important food sources for many aquatic animals specially fishes. The main for major carps like rui,catla and their hybrids were found to be plankton in origin.

P.K.and Naser, M.N., 2009). Zooplankton plays an important role in indicating the water quality, eutrophication status and productivity of a freshwater body. (Mikschi E, 1989). The planktons not only increase fish production but also help in bioremediation of heavy metals and other toxic material. Plankton can also act as biomarker for water quality assessment for fish production (ArunavaPradhan, *et al*., 2008).

Reservoir fishery Development:

To optimize fish yield from Inland Fisheries sector, recent research has been directed towards reservoirs the manmade impoundments with assemblage of both lacustrine and fluviatile characters with huge untapped potentials are called 'fish mines'. The only option left before us is the reservoirs for augmenting fish production through capture as well as culture based capture fisheries applying different fisheries enhancement procedures (A.K. Das, N.P. Shrivastava, K. K. Vass and B.L. Pandey, 2008).

Reservoirs are of high ecological, economic and recreational importance. A large number of reservoirs have been constructed in India during the last five decades, with the primary objective of storing river water for irrigation and power generation. All man-made impoundments created by obstructing the surface flow, by erecting a dam of any descript ion, on a river, stream or any water course, have been reckoned as reservoirs (Sugunan, 1995). Fish Seed Committee of the Government of India (1996) termed all water bodies of more than 200 ha in area as reservoirs

(Desai and Shrivastava, 2004). It has also been agreed to classify uniformly reservoirs of the country into small (<1000 ha), medium (1000 to 5000 ha) and large (>5000 ha) based on their hectarage. In India, medium and large reservoirs are fewer in number but small reservoirs are numerous. A detailed study made by FAO in 1995 has estimated a total of 19.370 reservoirs in the country with a total area of 3.15 million ha which included 19,134 small reservoirs with an area of 1,485,557 ha, 180 medium reservoirs covering 507,298 ha and 56 large reservoirs with a water surface area of 160,511 ha (Sugunan, 2011).

India has 19,370 nos. of reservoirs spread over 15 states with an estimated 3.15 million ha surface area at full capacity, and this is expected to increase due to execution of various water projects in the country (Desai, 2006).

The area under reservoirs is expected to reach 6.0 million ha in another two decades. Therefore reservoirs are one of the most potential fisheries resource for future fisheries development of India. Scientific management of these waters through selection of right species and stocking, stock manipulation, fishery regulations, harvesting schedules, adoption of pen and cage culture technologies, and development of package of practices for different categories of reservoirs would help in increasing the fish production from these water bodies(S. Ayyappan and A.D. Diwan, 2006,Fisheries Research and Development in India).

Bundh / Reservoir Fisheries Development Project in Bankura and Purulia Districts:

Benfish implemented this project with a view to enhancing production of fish from 100 Kg to 500 Kg per year per hectare by adoption of modern technology without disturbing ecological condition, irrigation, and flood control in the two districts. This project created employment generation for 3600 rural fishermen who formed Primary Fishermen's Co-operative Societies.

The project includes 47 Bundhs and Reservoirs covering 8785 hectare of water area (Benfish, govt of West Bengal).

Integrated Farming System:

Association of two or more farming components that become part of entire system is termed as integrated farming. Out of many farming systems involving fish with agri-horticulture, modern trend now-a-days is integration of livestock with fishery. Integrated farming has immense potentiality to emerge out as an effective tool for improvement of rural economy due to low investment and high profitability (Nanda and Bandopadhyay, 2011).

Many authors have stressed the importance of fish livestock integration in utilisation of waste product, income generation and diversification of product (Woyanarovich, 1979; Yadav, N.K., 1987; Little and Muir, 1987; Sharma and Das, 1988; RadheyShyam, 1995; Kaunhog, 1996; Sharma *et al.,* 1998). Fang *et al.,*(1994) observed the effect of animal manure protein (Chicken, duck, pig, cow) on fish yield and reported that the conversion efficiency of manure protein into fish protein was about 40% on a dry weight basis in the fish pond. Nutrients requirement of fish pond which depends mainly on the nutrients status of pond soil and fish density there in, can be fulfilled by supplying needed quantity of excreta by regulating the number of chicks stocked with pond. Integrated fish farming by recycling of poultry manure in fish pond have been reported by Sharma *et al.,* 1998; Cruz and Shehadeh 1980; Woynarovich, 1980; Sharma *et al.,* 1985; Sharma and Olaha, 1986; Sharma and Das, 1988; Gavina, 1994 and Borah *et al.,* 1998 in India and abroad. Ashwathanarayana (1979) has compared the effectiveness of poultry manure, sheep and goat manure and pig dung on carp production and found poultry and sheep manure as equally effective. Woyanarovich (1979) obtained a yield of 15-18 t/ha/year from the water treated with poultry and pig manure. Kapur (1984) reported the 20% increase in fish yield with poultry-piggery waste combination in a ratio of 1:1 as compared to poultry waste alone.