INTRODUCTION
1. INTRODUCTION AND REVIEW OF LITERATURE

Due to ever increasing human population coupled with the limited availability of space for land-based food production systems, a large number of people across the globe are affected by short and inconsistent supply or unavailability of quality food. A plausible solution to the problem could be efficient and sustainable utilization and effective management of enormous water resources as more than 70% of the earth surface is covered with water. Amongst a variety of food items present in the aquatic system, fishes are considered as the most important group of the organisms suitable for human consumption. In general, plant products are limiting in one or the other essential amino acids and/or essential fatty acids. However, fishes have well balanced amino acid and fatty acid profile especially polyunsaturated fatty acids which are highly desirable in the diet of human beings (Khan et al. 2011d).

Capture fisheries and aquaculture supplied the world with about 148 million tons of fish in 2010. World fish food supply has grown dramatically in the last five decades, with an average growth rate of 3.2 percent per year in the period 1961-2009. World per capita food fish supply increased from an average of 9.9 kg in the 1960 to 18.4 kg in 2009 (FAO, 2012). Inland water capture production continued to grow continuously, with an overall increase of 2.6 million tons in the period 2004-2010. Total global capture production in inland waters has increased dramatically since the mid-2000 with reported and estimated total production at 11.2 million tons in 2010. Nevertheless, inland waters are seriously underestimated in some regions or overfished in many parts of the world and human pressure and changes in the environmental conditions have seriously degraded important bodies of freshwater [e.g. the Aral Sea (Kazakhstan) and lake Chad (Africa)]. Dams in India have led to fisheries collapse in almost all of its major rivers, severely affecting biodiversity and livelihoods. The drastic modification of freshwater habitats by damming streams and siltation of rivers leading to reduction in their depth has also profoundly affected many fish species like the Indian shad, carps, catfishes etc. Fisheries in the Ganga river declined due to large-scale water diversions through barrages.
and canals. Fisheries in Krishna, Godavari, Mahanadi, Pennar, Narmada, Tapi, Sabarmati, Mahi and Cauvery estuary have collapsed or are rapidly collapsing or declining because of absence of freshwater in the estuaries all round the year and destruction of the mangrove forests (Dandekar, 2012).

India is one of the 17 mega biodiversity hot spots contributing 60-70% of the world's biological resources and contributing 11.72% of globefish biodiversity. Fisheries sector in India has shown outstanding growth and ranks third in the world in total fish production and contributes around 1.07% of the countries Gross Domestic Products (GDP) and 5.34% of the agricultural GDP (Lakra, 2010). With third position in fisheries and second in aquaculture, the country has high potentials in the sector for rural development, domestic nutritional security, employment generation, gender mainstreaming as well as export earnings, that only few other activities can provide (Lakra, 2010). Growth in the global inland water catch is wholly attributed to Asian countries, with the remarkable increases reported for 2010 production by China, India and Myanmar (FAO, 2012). Inland fisheries resources of India in terms of area are vast. The Ganga and Brahmaputra river systems along with their tributaries measure 16,523 km in length. Mahanadi, Godavari, Krishna and Cauvery in the peninsular region have a combined length of 6,437 km. The west flowing rivers Narmada and Tapti and the smaller drainages of the Western Ghats measure about 3,380 km. All these rivers together support a large network of over 1,20,000 km of man-made irrigation canals.

The Ganga and the Brahmaputra river systems in particular are renowned for their bounty of fish fauna, both in terms of variety and richness. The river Ganga is the largest river in India and the fifth longest in the world. The basin of river Ganga, which has very high cultural, heritage and religious values, drains about 1,060,000 km² area (Welcomme, 1985). The river originates from ice-cave ‘Gaumukh’ (30º55' N/70º7' E) in the Garhwal Himalaya at an altitude of 4,100 m and discharges into the Bay of Bengal. The length of the main channel from the traditional source of the Gangotri glacier in India is about 2,550 km (Sarkar et al., 2011). The Ganga is the original home of the prized Indian major carps (Catla catla, Labeo rohita and Cirrhinus mrigala), mahseers,
snow trouts (*Schizothorax* sps.), the hilsa (*Tenualosa ilisha*), several economically important catfishes (*Sperata seenghala, Sperata aor, Clarias batrachus, Wallago attu, Silonia silondia, Pangasius pangasius, Ompok bimaculatus*, etc.), to mention only a few. Many such fish species are acclaimed for their intrinsic qualities such as fast growth rate, hardiness, and flavor and are highly rated as delicacies (Ayyar, 2008). Rivers serve as primary habitat for the original germplasm of Indian fishes. Riverine fisheries are considered to generate yields below subsistence level. The present-day riverine fishery yield is low, with an average yield of 0.3 tons per km, which is only 15 percent of the estimated potential. Catch statistics over many years indicate a declining trend for riverine catches, both in quantitative and qualitative terms (Upare, 2007). The average yield of major carps in river Ganga declined from 26.62 to 2.55 kg/ha/year during the last four decades. Biologically and economically desirable fish species have started to be replaced by low-value species as their populations are rapidly declining (Upare, 2007).

Conservation of fish genetic diversity is not only important for sustainable fishery but it also helps in national development. It is true that freshwater aquaculture for rohu, catla, mrigal, silver carp, grass carp and common carp has showed considerable growth but these fishes are produced in the commercial mode and channelized to urban markets, poorer people cannot access them through subsistence fishing. Sustainable exploitation of fish stock and fish habitat is a matter of deep concern for fishery scientists and administrators all over the world. Man has been exploiting aquatic resources ever since his presence on this planet to meet his basic necessities. However, the past century has witnessed increasing pressure on freshwater fish stock and fish habitat mainly due to anthropogenic activities (Ghosh and Ponniah, 2001). Irrational harvesting coupled with practically no effective fisheries management in practice, has led to the reduction in catches of a considerable number of fish species. The important riverine fishery of Indian major carps has either almost collapsed or is at the threshold of collapse (Chaudhari, 2004).

Freshwater fish are one of the most threatened taxonomic groups (Darwall and Vie, 2005) because of their high sensitivity to the quantitative and qualitative alteration of aquatic habitats (Laffaille et al., 2005; Kang et al., 2009; Sarkar et al., 2008). As a
consequence, they are often used as bioindicator for the assessment of water quality, river network connectivity or flow regime (Chovance et al., 2003). Today, the fish diversity and associated habitats management is a great challenge (Dudgeon et al., 2006). Conservation measures to mitigate the impact of the pressures have largely been slow and inadequate and as a result many of the species are declining rapidly (Lakra et al., 2010). With respect to the environmental status of the rivers, the enhancement of fish yield appears to be a distant possibility. The multiple uses of these resources make the implementation of ameliorative measures difficult. Evidently, conserving the germplasm in an open water regime is more purposeful than efforts to increase yield, because biodiversity could at least be preserved, particularly the fish fauna. Irrational forms of exploitation can endanger the delicate balance of a fragile inland fishery ecosystem (Tietze et al., 2007). The aquatic resources and their biological diversity are the country’s national wealth and the conservation of the precious aquatic germplasm with prescience and vision is our bounden duty to posterity (Ayyar, 2008).

Present scenario of the natural fisheries resources warrants the formulation and implementation of scientifically sound and efficient management policies that may ensure the protection of the precious biodiversity (particularly the highly vulnerable food fishes) and its sustainable exploitation by human beings. Moreover, formulation of scientifically sound and efficient fisheries management policies requires precise information on several basic biological parameters particularly age and growth and other population characteristics. Unfortunately, however, information on these parameters for most of the commercially important food fishes from river Ganga is either incomplete or not evaluated for accuracy and precision. Consequently, flawed management policies may be devised if it is based on data that lacks scientific validation. Basic biological data are the foundation on which all assessments of fisheries resources are built. These include parameters such as the size and age composition of the population and catch (both landed and discarded), growth rates, and maturation. The most thorough assessments include age specific estimates of stock biomass, mortality rates, and predictions of future stock conditions. These require knowledge of the size and age composition of the catch and indices of relative abundance by age. Rates of growth, mortality (due to natural causes
and fishing), and reproduction can only be calculated if changes in maturity or size (and numbers) at age can be monitored over time. Fish age is also a critical correlate to many biological and pathological processes. Age and length data are utilized in models that allow assessment scientists to estimate the biomass of fish and shellfish populations at age and to examine the potential effects of continuing removals from those populations. If scientifically sound fisheries management policies are adopted based on precise biological information, then it may lead to conserve and even increase the population of a particular fish species in an environment.

Determination of age and growth rate is very important in ichthyological investigations, as fish growth is one of the main factors that determine stock conditions (Mikhailov and Prodanov, 1983). The ability to obtain precise estimates of age is fundamental to the estimation of dynamic rate functions such as mortality and recruitment. Given the importance of age and growth information, determining the best structure for ageing should be a high priority. Growth is perhaps the most studied of all parameters used to describe the life history of exploited fish. It is usually expressed as a mathematical equation describing the mean growth of a population and relating size to age (Katsanevakis and Maravelias, 2008). The length-weight relationship studies are considered a prerequisite in fish biology investigations. It is mainly required to know the variations in expected weight from the known length groups, which are, in turn, the indications of fatness, breeding and feeding state and their suitability to the environment (Saha et al., 2009). Length-length relationships are important for comparative growth studies (Moutopoulo and Stergiou, 2002). Length-length relationships help in inter-conversion of total length data with other morphometric characters (Manimeghalai, 2010). The study of condition factor is important to understand the life cycle of fish species and contribute to an adequate management of the species and to the maintenance of the ecosystem equilibrium (Haruna and Bichi, 2005).
1.1. INTERNATIONAL STATUS

The ability to age fish accurately is an essential first step for age-based assessment of fish population and successful resource management (Brennan and Cailliet, 1989). Different methods have been employed for the determination of fish age. Amongst all the methods, the mark-release-recapture method is considered as the most accurate but its application is limited in fisheries due to a number of constraints such as time and money. Another method of fish age determination is based on analysis of length frequency data. This method is useful for fish which breed only once in a year but it cannot be used to determine the age of an individual fish. For this method sample consists of a large number of individuals, collected preferably on a single day, and should include representatives of all sizes and age groups in the population. Many species of fish can be aged from the discontinuities which occur in their skeletal structures. The hard parts that can be studied for age determination are the scales, otoliths, vertebrae, dorsal and pectoral spines/rays, opercular bones, urohyal bones, hyomandibular etc.

Age determination is invariably accompanied by various sources of error. A variety of methods exist through which age interpretations can be validated (Campana, 2001). The term validation has two meanings; in a narrower sense the term is used to determine the temporal meaning of the growth increment used in ageing and in a wider sense, the term is used to prove that the whole age determination procedure is accurate. The validation methods can be roughly divided into indirect and direct method. Indirect validations are verification methods that support the growth rates determined by the age reading. The length-based methods, age based methods, marginal otolith structure development, back-calculation methods, elemental composition and isotopes method are the indirect methods for age validation (Morales-Nin, 2000). Comparison of age estimates between structures is an alternative technique to validation that may provide useful information on the accuracy and bias of age estimating structures (Sylvester and Berry, 2006). Ages of fish are estimated by the comparison of readings from various structures and different readers (Barnes and Power, 1984; Barber and McFarlane, 1987;
Casselman, 1987). The most reliable ageing method may vary among species. Thus, studies on the precision of ageing structures for a selected fish species becomes highly significant (Baker and Timmons, 1991; Kimura and Lyons, 1991; Polat and Gumus, 1995). Calcified body structures may not always form a complete growth sequence through the life of the subject; false checks can be laid down; or annuli can overlay each other especially in older fish at the margin thereby making interpretation difficult (Beamish, 1979; Campana, 2001). The effect of errors in the determination of the age structure of a fish population can have serious repercussions for management decision-making. This is because the biological productivity of the fishery will be either under- or overestimated (Campana, 2001). Errors in determining the ages of fish need to be minimized wherever possible by incorporating a validation method.

Several studies have focused on comparing ages enumerated from different bony structures in an attempt to quantify the precision and to identify possible bias associated with each structure. Studies on comparisons of age estimates from various structures have been undertaken for many species, viz., *Catostomus commersonii* (Scidmore and Glass, 1953; Ovchinnynk, 1969; Quinn and Ross 1982); *Stizostedion vitreum vitreum* (Campbell and Babaluk, 1979); *Clarias gariepinus* (Clay, 1982); *Platyichthys stellatus* (Campana, 1984); *Salmo clarki* (Hubert et al., 1987); *Acipenser transmontanus* (Brennan and Cailliet, 1989); *Lota lota* (Guinn and Hallberg, 1990); *Salvelinus alpines* (Krzykawski and Radziun, 1993); *Pomoxis nigromaculatus* (Kruse et al., 1993); *Dissostichus eleginoides* (Cassia, 1998); *Arripis trutta* (Gauldie, 1998); *Perca flavescens* (Niewinski and Ferreri, 1999); *Acipenser oxyrinchus* (Stevenson and Secor, 1999); *Lutjanus johnii*, (Marriott and Cappo, 2000); *Paralichthys dentatus* (Sipe and Chittenden, 2001); *Lepomis macrochirus* (Hoxmeier et al., 2001); *Micropterus salmoides, M. dolomieu* and *M. punctulatus* (Long and Fisher, 2001); *Dissostichus eleginoides* (Ashford et al., 2001); *Etheostoma caeruleum* (Beckman, 2002); *Cynoscion nebulosus* (Ihde et al., 2002); *Ictalurus punctatus* (Buckmeier et al., 2002); *Pomatomus saltrix* (Sipe and Chittenden, 2002); *Scaphirhynchus albus* (Hurley et al., 2004); *Hypophthalmichthys nobilis* (Nuevo, 2004); *Brycinus nurse* (Saljiu and Fagade, 2004); *Ptychocheilus lucius* (Hawkins et al., 2004); *Stenodus leucichthys* (Howland et al., 2004); *Parapercis colias* (Carbines, 2004);
Hemisorubim platyrhynchos (Howland et al., 2004); Liza ramada (Gocer and Ekingen, 2005); Lutjanus johnii (Marriott and Cappo, 2005); Lepomis macrochirus (Edwards et al., 2005); Micropterus salmoides, Micropterus dolomieu, Perca flavescens and Ameiurus nebulosus (Maceina and Sammons, 2006); Catostomus commersonii (Sylvester and Berry, 2006); Mystus vittatus (Hossain et al., 2006a); Cycleptus elongates (Bednarski and Scarnecchia, 2006); Moxostoma anisurum, M. carinatum, M. macrolepidotum and M. valenciennesi (Reid, 2007), Cyprinus carpio (Phelps et al., 2007, Yilmaz and Polat, 2008); Glyptosternum maculatum (Li and Xie, 2008); Toxotes jaculatrix, Toxotes chatareus, Boops boops, Diplodus vulgaris, Diplodus sargus, Lithognathus mormyrus, Pagellus acarne, Pagellus erythrinus and Spondyliosoma canthus (Abecasis et al., 2008); Sander lucioperca (Bostanci, 2008); Salvelinus fontinalis (Stolarski and Hartman, 2008); Salvelinus confluentus (Zymonas and McMahon, 2009); Amia calva (Koch et al., 2009); Barbus pectoralis (Ozcan and Balik, 2009); Alosa pontica (Visnjic-Jeftic et al., 2009); Mastacembelus mastacembelus (Gumus et al., 2010); Tinca tinca (Erguden and Goksu, 2010); Carpiodes velifer, C. cyprinus, C. carpio (Spiegel et al., 2011); Schizothorax o’connori (Ma et al., 2011); C. carpio (Weber and Brown, 2011); Oxygynocypris stewartii (Jia and Chen, 2011); Lota lota (Edwards et al., 2011); Lepomis macrochirus (Kowalewski and Maple, 2012); Lepidotrigla argus (van der Meulen et al., 2013); H. molitrix (Seibert and Phelps, 2013) etc.

Growth has been one of the most intensively studied aspect of fish biology as it indicates the health of the individual and the population. Growth of an organism can be defined as a change in its size (length and weight) over a period of time or it may be defined as the change in calories stored as somatic and reproductive tissues. Abundant food supply and existence of other favorable conditions result in fast growth rate, whereas slow growth rate indicates the opposite. The rate of growth varies in fishes from species to species, and for the same fish from different localities, as it is influenced by various factors. Fish do not grow all the time and at the same rate as there are many factors that affect the growth rate of fish. The important and apparent ones are temperature, photoperiod, dissolved oxygen, salinity, predation, parasitism and state of maturity. The maturation of gonads greatly influences the growth rate. The fish typically
grow much faster in size in first few months or year of life until maturation. After maturation, an increased amount of energy is diverted to the growth of gonads. As a result, growth rates of mature fish are much slower than those of immature fish. Besides these exogenous factors i.e., those imposed by environment, there are some endogenous factors that determine the growth rate such as, genetic composition and physiological condition of fish (Ali, 1999).

A number of growth curve models (e.g. Von Bertalanffy, Gompertz and Logistic growth curve) to study the fish growth parameters are available. However, the most widely used model for growth in fisheries is credited to von Bertalanffy (1957). Several researchers successfully used von Bertalanffy growth model for the estimation of growth in different fish species such as *Oreochromis niloticus* (Getabu, 1992); *Albula vulpes* (Crabtree et al., 1996); *Labeo cylindricus* (Weyl and Booth, 1999); *C. carpio* (Vilizzi and Walker, 1999); *Ictalurus punctatus* (Starkey and Scarnecchia, 1999); *Gobius paganellus* (Azevedo and Simas, 2000); *Beryx splendens* (Adachi et al., 2000); *Gaidropsarus guttatus* (Morato et al., 2003); *Carassius gibelio* (Balik et al., 2004); *Hemisorubim platyrhynchos* (Penha et al., 2004); *Capoeta capoeta angorae* (Alp et al., 2005); *Gerres sp.* (Kanak and Tachihara, 2006); *Anguilla anguilla* (Melia et al., 2006); *C. catla* (Nargis, 2006); *Schilbe mystus* (Adedolapo, 2007); *Chiloscyllium plagiosum* (Chen et al., 2007); *Oreochromis niloticus* (Gomez-Marquez et al., 2008); *Clarotes laticeps* (Abowei and Davies, 2009a); *Barbus pectoralis* (Ozcan and Balik, 2009); *Monopterus albus* (Yang and Xiong, 2010); *Mastacembelus mastacembelus* (Gumus et al., 2010); *Schizothoraz o`connori* (Ma et al., 2010); *Nelusetta ayraudi* (Miller et al., 2010); *Oxygymnocepris stewartii* (Huo et al., 2012); *Xiphias gladius* (Akyol and Ceyhan, 2013); *C. carpio* (Sedaghat et al., 2013); *Thunnus alalunga* (David Wells et al., 2013) etc.

Studies on length-weight relationship of fishes are important in fishery biology because they allow the estimation of the average weight of fish of a given length group by establishing a mathematical relation between the two (Berg, 1981). Length-weight relationship has been studied by several researchers in different fish species viz., *Perca fluviatilis* (Le Cren, 1951); *Hilsa ilisha* (Shafi and Quddus, 1974); *C. carpio* (Erdem,
1984); Corphyaenoides rupestris (Atkinson, 1989); Amblypseudonosodon mola (Afroz et al., 1991); Alia coila (Alam et al., 1994); L. bata (Azadi and Naseer, 1996); Botia lohachata (Mortuza and Mokarrama, 2000); Heterobranchus longifilis (Anibeze, 2000); Channa punctata (Ali et al., 2000); Tor putitora (Zafar et al., 2001); Monopterus cuchia (Narejo et al., 2002); Clarias lazera (Korkmaz, 2003); Lepidocephalichthys guntea (Dhakal and Subba, 2003); C. catla (Zafar et al., 2003); Scardinius erythrophthalmus (Okgerman, 2005); Tenualosa ilisha (Nurul Amin et al., 2005); Mystus vittatus (Hossain et al., 2006a); C. carpio (Balik et al., 2006); Rhinomugil corsula (Mortuza and Rahman, 2006); Aspitrigla cuculus, Chelidonichthys obsures, Chelidonichthys gurnardus, Chelidonichthys lucernus, Chelidonichthys lastoviza, Lepidotrigla cavihonne, Lepidotrigla dieuzeidei and Trigla lyra (Olim and Borges, 2006); Trisopterus minutes (Metin et al., 2006); Cirrhinus reba (Narejo, 2006); Carasius gibelio (Tsoumani et al., 2006); Amblypseudonosodon mola, C. punctata, Hypor amphus quoi, Macrognathus aculeatus, Macrognathus pancerus, Nandus nandus, Puntius sophe and Setipinna phasa (Hossain et al., 2006b); Pseudorasbora parva (Britton and Davies, 2007); Eutropiichthyes vacha (Soomoro et al., 2007); Aries maculates, Aries tenuispinins, Hilsa kelee, Anodontostoma chacunda and Triacanthus biaculeatus (Arshad et al., 2008a); Acetes vulgaris (Arshad et al., 2008b); Hemiramphus far (Yousuf and Khurshid, 2008); Parastromateus niger (Dadzie et al., 2008); Labeo boga (Pervin and Mortuza, 2008); Pterygoplichthys pardalis (Samat et al., 2008); Capoeta sieboldii (Yildirim et al., 2008; Yilmaz et al., 2010); Boops boops (Kara and Bayhan, 2008); W. attu, Sperata sarwari (Yousaf et al., 2009); Heterobranchus bidorsalis (Agbebi et al., 2009); Glossogobius giuris (Joadder, 2009); Chaetodon fremblili, Chaetodon miliaris and Chaetodon multicinctus (Franklin, 2009); Rita rita (Laghari et al., 2009); Phoxinus phoxinus, Cobitis vardarensis, Neogobius gymnnotracelus, Proterorhinus marmoratus, Petroeleicus borysthenicus and Gambusia holbrooki (Tarkan et al., 2009); Alburnoides bipunctatus, Alburnus adanensis, Capoeta barroisi, Carassius carassius, C. carpio, Gambusia affinis, Oncorhynchus mykiss, Rutilus rutilus, Sander lucioperca, Silurus glanis, Squalis cephalu and Tinca tinca (Erguden and Goksu, 2009); Salmo dentex, Chondrostoma knerii, Rutilus basak, Scardinius plotizza, Squalius svalorize and Cobitis narentana (Dulcic et al., 2009); Hypophthalmichthys nobilis, Hypophthalmichthys molitrix and Ctenopharyngodon idella (Wanner and Klumb,
Length-length relationships (LLRs) are important for comparative growth studies (Moutopoulos and Stergiou, 2002). Length-length relationships have been studied in several fish species such as, Salmo trutta (Arslan et al., 2004); Barbus albanicus; Leuciscus cf. svallize and Lepomis gibbosus (Bobori et al., 2006); Eutropiichthyes vacha (Soomro et al., 2007); Boops boops (Kara and Bayhan, 2008); Capoeta sieboldii (Yildirim et al., 2008); Arius maculates, Arius tenuispinis, Hilsa kelee, Anodontostoma chacunda and Triacanthus biaculeatus (Arshad et al., 2008a); Parastromateus niger (Dadzie et al., 2008); Rita rita (Laghari et al., 2009); Hypsoblennius gilberti, Gibbonsia elegans, Clinocottus analis, Oligocottus snyderi, Gobiesox rhessodon, Girella nigricans, Hermosilla azurea, Labrisomus multiporosus and Paraclinus integrifinnis (Ruiz-Campos et al., 2010); Aspidoparia morar, Amblypharyngodon mola, Lepidocephalus guntea and Puntius ticto (Hossain, 2010); Chela cachius (Ahmed et al., 2012); Stolephorus tri (Hazmadi et al., 2012); Tor macrolepis (Pervaiz et al., 2012); Atherinomorus duodecimalis (Mazlan et al., 2012); Ambassis urotaenia, Nematalosa come, Chelonodon patoca (Chu et al., 2013) etc.
Condition factor (K) is used to compare the condition, fatness or wellbeing of a fish and it is based on the hypothesis that heavier fish of a given length are in better physiological condition (Bagenal and Tesch, 1978). Condition factor is also used as an index for monitoring of feeding intensity, age and growth and feeding intensity (Fagade, 1979). It is strongly affected by biotic and abiotic factors and can be used to judge the status of the aquatic ecosystem in which fish live (Anene, 2005). Condition factor has been studied for different fish species such as *Tilapia leucosticta* (Siddiqui, 1977); *Tilapia guineensis* (Fagade, 1978); *T. zilli* (Dadzie and Wangila, 1980); *Sarotherodon niloticus* (Arawomo, 1982); *Alestes nurse, Synodontis schall, S. schneider* and *Tilapia zilli* (Oni et al., 1983); *Chromidotilapia guntheri* (Fagade, 1983); *Carassius auratus* (Salam and Davies, 1992); *Heterobranchus longifilis* (Anibeze, 2000); *Tor putitora* (Zafar et al., 2001); *Brycinus nurse* (Salii, 2004); *C. catla* (Zafar et al., 2003); *Gerres oblongus* (Sivashanthini and Abeyrami, 2003); *Chromidotilapia guntheri, Tilapia cabrae, Tilapia mariae* and *T. zilli* (Anene, 2005); *Scardinius erythrophthalmus* (Okgerman, 2005); *Rhinomugil corsula* (Mortuza and Rahman, 2006); *Labeo boga* (Pervin and Mortuza, 2008); *Parastromateus niger* (Dadzie et al., 2008); *Capoeta sieboldii* (Yildirim et al., 2008); *Tympanotus fuscatus* (Jamabo et al., 2009); *Callinectes amicola* (Abowei and George, 2009b); *Glossogobius giuris* (Joadder, 2009); *Rasbora tawarensis* and *Poropuntius tawarensis* (Muchlisin et al., 2010); *Ailiichthys punctata, Botia lohachata, Chanda nama, Laubuca laubuca, and Mystus cavasius* (Hossain et al., 2012), *Netuma thalassinus, Parastromateus niger, Sillago sihama, Pelates quadrilineatus* and *Nematolosa nasus* (Daliri, 2012); *Scardinius erythrophthalmus, Carassius auratus gibelio, C. carpio, T. tinca; Hemiculter leucisculus* (Moradinasab et al., 2012) etc.
1.2. NATIONAL STATUS

In India, several researchers have successfully used scales for age determination in a number of fish species such as in *L. rohita* and *C. mrigala* (Khan and Hussain, 1941); *Blennius pholis* (Qasim, 1957); *C. mrigala* (Jhingran, 1957, Kamal, 1969, Johal and Tandon, 1987); *Ophicephalus punctatus* (Qasim and Bhatt, 1964); *Channa striatus* (Bhatt, 1969; Kilambi, 1986); *Ophicephalus striatus* (Bhatt, 1970 a); *Trichiurus lepturus* (Narasimham, 1970); *L. rohita* (Khan and Siddiqui, 1973; Johal and Tandon, 1985); *L. bata* (Chatterjee et al., 1979); *Tor putitora* (Johal and Tandon, 1981); *Cirrhinus reba* and *L. gonius* (Khan, 1981); *Gadusia chapra* (Ansari, 1982); *C. catla* (Johal and Tandon, 1983; 1992), *Colisa fasciata* (Johal et al., 1989); *Labeo calbasu* (Tandon et al., 1989); *Rita rita* (Tamubi Devi, 1991); *C. marulius* (Dua and Kumar, 2006) etc. Opercular bones and scales were used for age and growth studies in *O. punctatus* (Qasim and Bhatt, 1964). Pathani (1981) studied the age and growth of *T. putitora* from lakes of Kumaon hills in the Himalayas using scales and opercular bones. Reddy (1981) studied the growth checks on scales and opercle and their validity in age determination of *Channa punctata* from Gunther, Andhra Pradesh. Abbas and Siddiqui (1987) studied the age and growth of *C. punctatus* using opercular bones. Singh and Rege (1968) reported that in *Tachysurus sona* vertebrae can be employed for age determination in the absence of scales but not as a substitute for scales. Jayaprakash (1973) observed the formation of annuli on vertebrae of *Otolithoides brunneus*. Sunder and Subla (1984) observed the occurrence of growth rings on the vertebrae, opercular bones and otoliths of *Schizothorax curvifrons* and found that periodic markings on these parts are laid annually. Pectoral spines were used for age and growth studies of *Mystus gulio* (Pantulu, 1961) and *Pangasius pangasius* (Pantulu, 1962). Ramakrishniah (1988) employed pectoral spines of *Mystus aor* from Nagarjunasagar for age determination and back-calculations. Kohli (1989) used pectoral spines as an age indicator in *Heteropeustes fossilis*. Dobriyal and Singh (1990) successfully employed otoliths and scales for ageing *Barilius bendelisis*. Nair (1949) studied growth rings on otoliths of *Sardinella longiceps*. Radhakrishnan (1954) and Camp (1954) studied the occurrence of growth rings on the otoliths of the Indian

As discussed elsewhere (Section 1.1) the evaluation of precision of age estimates is a prerequisite for the development of successful fisheries management of the target fish species. In India, so far the published literature on these aspects is available only from our laboratory for a small number of fish species such as *L. rohita*, *C. catla* and *C. marulius* (Khan and Khan, 2009); *C. mrigala* (Khan et al. 2011a); *C. gariepinus* (Khan et al. 2011b); *C. punctata* (Khan et al. 2013a); *W. attu*, *H. fossilis* and *C. batrachus* (Khan et al. 2013b). However, there are no published reports available on the assessment of precision of age estimates in *L. bata*, *H. molitrix*, *O. pabda* and *M. armatus*.

As the age of a fish and its growth are closely related, the assessments of age and growth rate are conducted together. The rate of growth varies in fishes from species to species, and for the same fish from different localities, as it is influenced by various factors (Khanna, 1996). In India, several researchers have used von Bertalanffy Growth Function for the estimation of growth in fishes such as, *C. catla* (Natarajan and Jhingran, 1963); *L. rohita* (Khan and Siddiqui, 1973); *L. bata* (Chatterji et al., 1979); *Sillago indica* (David and Pancharatna, 2003); *Valamugil seheli* (Venkatesha et al., 2003); *Euthynnus affinis* (Khan, 2004); *Sardinella longiceps* (Ganga and Pillai, 2006); *Gafrarium tumidum* (Jagadis and Rajagopal, 2007); *Lactarius lactarius* (Zacharia and Jayalbalan, 2010); *Puntius carnaticus* (Kumar and Kurup, 2010); *Thunnus albacores* (Rohit et al., 2012) etc.

Indian researchers have studied length-weight relationship in a number of fish species viz., *L. rohita* and *C. mrigala* (Khan and Hussain, 1941); *C. catla* (Natarajan and Jhingran, 1963); *Gudusia chapra* (Jhingran, 1968); *Trichiurus lepturus* (Narasimham,
1970); Puntius sarana (Sinha, 1972); L. gonius (Chondar, 1972); Clarias batrachus (Sinha, 1973); Nemipterus japonicus (Vinci and Kesavan, 1974); L. calbasu (Pathak, 1975); C. batrachus (Thakur, 1975); Mugil cephalus (Rangaswamy, 1976); L. bata (Chatterji et al., 1977); C. mrigala and C. carpio (Soni and Kathal, 1979); L. gonius (Chatterji, 1980); T. putitora (Johal and Tandon, 1981); Puntius amphibious (Kumar et al., 1984); Gerrus lacidus (Murthy et al., 1986); Valamugil sehci (Gowda et al., 1987); Colisa fasciata (Johal et al., 1989); Otolithes ruber (Jayasankar, 1990); Puntius sophore (Reddy and Rao, 1992); C. batrachus (Goswami and Sharma, 1996); C. mrigala (Sarkar et al., 1998); Horabagrus brachysoma (Kumar et al., 1999); Botia lohachata (Subba and Pandey, 2000); Epinephelus taevina and E. malabarichus (Shanmugam et al., 2000); Rasbora daniconius (Sunil, 2000); Stolephorus bataviensis (Doddamani et al., 2001); Puntius denisonii (Mercy et al., 2002); Monopterus cuchia (Narejo et al., 2002); Liza macrolepis (Sandhya and Shammem, 2003); Lepidocephalichthys guntea (Dhakal and Subha, 2003); Oreochromis mossambicus (Hatikakota and Biswas, 2004); Mastacembelus armatus (Serajuddin, 2005); Chanos chanos (Raizada et al., 2005); Liza parsia (Rao et al., 2005); Rasbora daniconius (Harish Kumar et al., 2006); Otolithes cuvieri (Telvekar et al., 2006); Channa punctata (Haniffa et al., 2006); Mystus cavasius (Venkateshwarlu et al., 2007); Puntius filamentosus (Prasad and Ali, 2007); Jhonius gengeticus (Mandal et al., 2008); Horabagrus brachysoma (Anvar et al., 2008); Chitala chitala (Sarkar et al., 2009); Scarus ghobban (Varghese et al., 2009); Notopterus notopterus, G. chapra, L. calbasu, Puntius sarana, C. mrigala, Ompok bimaculatus, Mystus tengara, M. cavasius, Sperata aor, S. seenghala, Eutropiichthys vacha, W. attu, Rhinomugil corsula and M. armatus (Sani et al., 2010); Mystus vittatus (Tripathi et al., 2010); Arius sunrostratus (Ambily and Nandan, 2010); Amblypharyngodon mola (Baishya et al., 2010); T. putitora (Patiyal et al., 2011); Liza parsia (Renjini and Bijoy Nandan, 2011); Ompok pabda (Gupta et al., 2011); Barbodes carnaticus, Puntius filamentosus, Puntius sarana, Labeo calbasu, L. rohita, Cirrhinus cirrhosus, Cirrhinus reba, C. catla, Tor khudree, Mystus armatus, M. cavasius, S. aor, Ompok bimaculatus and Pangasius pangasius (Muralidharan et al., 2011); Oncorhynchus mykiss (Shah et al., 2011); Schizopyge curvifrons (Mir, 2012); Schizopyge curvifrons, Schizopyge niger, Schizothorax esocinus, Schizothorax labiatus and Schizothorax plagiostomus (Khan and
Of the ten species examined in the present study, to the best of our knowledge no reports were available on length-weight and length-length relationships from the selected river except our research articles (Khan et al., 2011c; Khan et al., 2012a; Khan et al. 2012b). However, the LWR and LLR information on some species were available from some other waterbodies (Froese and Pauly, 2012). No report of length-length relationship was available on FishBase for *O. pabda*, *W. attu* and *L. bata*.

Condition factor (K) has been studied for a number of fish species such as, *Trichiurus haumela* (Prabhu, 1955); *Gudusia chapra* (Jhingran, 1968); *Trichiurus lepturus* (Narasingham, 1970); *Clarias batrachus* (Thakur, 1975); *Plotosus canius* (Sinha, 1981); *Gerrus lacidus* (Murthy et al., 1986); *Otolithes ruber* (Jayasankar, 1990); *Trichiurus lepturus* (Swain, 1993); *Mystus cavasius* (Venkateshwarlu et al., 2007); *Horabagrus brachysoma* (Anvar et al., 2008); *Thenus orientalis* (Saha et al., 2009); *Labeo gonius* (Dars et al., 2010); *Oncorhynchus mykiss* (Shah et al., 2011); *O. pabda* (Gupta et al., 2011); *Onchorhynchus mykiss* (Shah et al., 2011); *Schizopyge curvifrons* (Mir et al., 2012); *Schizothorax niger* (Shafi and Yousaf, 2012a); *C. catla*, *L. rohita* and *C. mrigala* (Ujjania et al., 2012); *Puntius conchonius* (Shafi and Yousuf, 2012b); etc.
1.3. CRITICAL APPRAISAL

A perusal of the available literature reveals the academic and applied significance of the basic biological information in the management of a selected fish population. It also suggests that there are a number of commercially/ecologically important fish species which are being included in the list of threatened fishes but still there is no precise information on various basic biological parameters of such fishes and thereby hampering the development of scientifically sound management/conservation strategies. Fish species selected in the present study are economically important species having good market value across the country. Due to increased pressure of fishing (overexploitation) and human interventions leading to habitat deterioration, the fish population structure experiences great variation over time. However, the basic information needed to develop scientifically sound management policies is still warranted particularly that related to precise age estimation and growth pattern in changing environments across all the major habitats of the fish. In earlier reports on age and growth studies from India, age has been estimated usually with only one ageing structure. These studies did not focus thoroughly on the clarity of annual rings in different ageing structures with respect to different size class and ageing errors. In India, studies on precise age estimation in fishes are limited only to our research laboratory at Department of Zoology, Aligarh Muslim University, Aligarh. However, globally studies on precise age estimation using maximum possible ageing structures/methods are being given high priority in researches on fish biology. Moreover, calculation of age based parameters in fish growth studies are also affected by imprecise data.

In view of the observations, as noted above, the present research investigation was undertaken in order to develop the necessary basic biological information required for the formulation and implementation of scientifically sound fishery management policies for the selected fishes (Channa marulius, Channa punctata, Labeo bata, Hypophthalmichthys molitrix, Mastacembelus armatus, Heteropneustes fossilis, Clarias batrachus, Clarias gariepinus, Wallago attu and Ompok pabda) belonging to six families (Channidae, Cyprinidae, Mastacembelidae, Heteropneustidae, Claridae and Siluridae).
1.4. OBJECTIVES

The objectives of the study were as follows:

1) to evaluate and compare different ageing structures (i.e., scales, otoliths, vertebrae, opercular bones and fin rays/spines) for their age estimates so as to identify and quantify the differences in precision and bias between readers and among pairs of ageing structures,

2) to fit the age-length data to the von Bertalanffy growth model, and

3) to investigate the length-weight relationship, length-length relationship and condition factor.