Growth and reproduction, like all the vital processes of life, require energy which is provided by the food. Study of food and feeding, breeding biology and growth are important aspects of life. Understanding food, feeding and nutrition of fish is one of the essential prerequisite for successful aquaculture production. Many workers have studied feeding, breeding and growth in a number of fishes in nature and in captivity. In the following pages an attempt has been made to review the important contribution made by different workers on the food and feeding, breeding biology and age and growth of fishes from different parts of the world.

2.1. Food and Feeding

Homans and Wladykov (1954) have observed that the Haddock (Melanogrammus segilifinus) ceased to take its food during the spawning season, after the termination of which they feed voraciously trying to regain the weight lost due to spawning.

Alikunhi (1958) made observations on the feeding habits of young carp. He also studied the variability of food depending on its abundance in the environment.

Qayyum and Qasim (1964) studied the feeding habits of Channa punctata and revealed it to be a carnivore. They reported that fishes like Esomus danricus, Barbus, Puntius siphore, insects like water bugs and dragon fly nymphs form the major items of its diet.
Kamal (1966) studied the gut contents of juveniles of *Labeo rohita* and observed insect larvae as the principle item of food, showing its food preference as a typical larvicidal fish in origin. He (Kamal 1967) also studied the food and alimentary canal in *Labeo rohita* (Ham.), whose juveniles feed on zooplankton and in *Cirrhina mrigala* whose fry feed on phytoplankton and zooplankton, cladocerans forming the main part of food.

Das (1967) while discussing the ecology of fishes showed that plankton and bottom fauna are important constituents of fish food, and distributed it into pendonic, limnetic and paralimnic fauna, and also gave biological niches for fishes. He further added that percentage of herbivorous fishes increase when we proceed from south to the north in India.

Karamchandani (1967) observed feeding habits of *Tor for* and reported that the early fry and juveniles subsisted entirely on macro-vegetation and filamentous algae and the fish started feeding on animal food (insects and molluscs) in insignificant quantities after growing in size of 301mm. They observed flesh and long slender spines of fishes in its gut contents.

Subla and Das (1970) conducted a detailed study on the feeding habits, the food and the seasonal fluctuations in feeding of nine Kashmir fishes. The authors concluded that *Schizothorax richardsonii* is a bottom feeder and a predominantly herbivorous fish.

Kurian (1977) developed a new approach for assessing the food habits of fishes. The new method was described as Index of Relative Importance. The proposed Index of Relative Importance was built by considering the unit volume of food items weighed by its frequency of occurrence and was expressed as;

\[
\frac{[(Vi \times Fi)/Ni]}{\sum(Vi \times Fi)/Ni} \times 100
\]

Where, \(Vi\) = Volume of the food item

\(Fi\) = Frequency of occurrence of the food item. \(Ni\) = Food
Chatterji (1978) studied the food and feeding habits of *Labeo gonius* from the river Kali and concluded that the fish mainly feeds on phytoplanktonic organisms; diatoms, green algae and decayed organic matter. The intensity of feeding was found to be maximum during the post monsoon and winter months.

Nautiyal and Lal (1984) studied the food and feeding habits of fingerlings and juveniles of mahaseer (*Tor putitora*) in Nayar River. Observations on the nature of food and feeding habits indicated that the fish is monophagic, column feeder and carnivorous.

Sunder *et al.* (1984) studied the gut contents of *Cyprinus carpio specularis* (Linn.) of Dal Lake and found it to be mainly a bottom feeder, chiefly feeding on diatoms, algae, desmids and crustaceans. Decayed organic matter was also reported in insignificant quantities in the gut of the fish.

Baloni and Tilak (1985) studied the ecological parameters of *Schizothorax richardsonii*. The authors conclude that the *Schizothorax richardsonii* is a bottom feeder and predominantly herbivorous fish without true stomach. They further concluded that water temperature plays an important role in the various vital activities of the fish. The temperature tolerance of *Schizothorax richardsonii* ranges from 6.0 to 24.5°C.

Khan (1988) worked on the food and feeding habits of fresh water carp, *Cyprinion rnacrostromus* in Iraq. Diatoms and decayed organic matter along with sand and mud were found to be the main food items of fish which is an indication of its bottom feeding habit. Not much difference was noted in the food composition of male and female fishes. Seasonal variations in the intensity of feeding were great which was found higher in maturing and lower in the case of ripe individuals.

Zamal and 011evier (1995) tried to find out the effect of feeding and
starvation on growth, gross body composition and fatty acid composition of body muscle and liver. The authors concluded that relative composition of fatty acids was influenced by starvation.

Paul et al. (1996) conducted 59 days feeding trial on Cherax destructor, reared communally and maintained on 16 isoenergetic diets containing crude protein levels of 15, 20, 25 and 30%. For each protein level the fish meal component was replaced by soybean meal, Mean percentage weight gain per day ranged from 2.98% (15% protein, 60% soybean meal diet) to 11.75% (30% protein, 40% soybean meal diet). When soybean meal was included at a level of 40-60%, growth rate was reduced relative to that achieved with control diets at 15% and 20% protein levels.

Fagbenro (1998) conducted a study to determine the apparent digestibility of various oilseed cakes/meals in African fish diets. Soybean cake, sunflower cake, banneseed/sesame press cake, cotton seed cake, groundnut cake, macadamia press cake and menhaden fish meal obtained from Pfizer (livestock). The oilseed cakes were milled to fine powder (25011.m) and analysed for dry matter, crude protein, crude lipid, crude fiber and total ash contents in triplicate. Amino acid composition was determined with the help of LKB 415, Alpha-plus amino acid analyzer after treating the hydrolysate with 6 moll per liter HCl under reflux for 24 hr at 110°C. Oilseed cakes were generally well digested by African catfish but protein content of cotton seed cake was also poorly digested by the dwarf catfish.

Fernandes et al. (1999) formulated diets for Nile tilapia on the basis of apparent digestibility coefficient (ADC) values for a number of ingredients of plant or animal origin. The digestibility of various diet components was measured by using an inert marker in the feed and using the Guelph faeces collecting system. ADC values of ingredients tested generally high, especially for fish meal. It was found that extruded seed meal (92.6%),
defatted soybean meal (94.4%), full fat toasted soybean (90.0%) and micronized wheat (88.6%) were the best vegetable proteins tested. Lupin seed meal and faba bean had similar ADC values for protein and energy. The authors concluded the fish meal can be replaced partially with plant proteins without negative effects.

Wing-Keong et al. (2000) studied the effect of feeding rate on growth, feed utilization and body composition of a tropical bagrid catfish. Catfish fingerlings with an average initial body weight of 12 g were fed a practical diet (36.2% protein, 16.5KJ/g diet) at rates of 1, 2, 2.5, 3, 3.5, 4 or 5% of their weight per day in two equal meals. Based on the growth, feed efficiency and body composition a feeding rate 2.5% body weight per day was recommended for Mystus nemurus fingerlings raised at 29°C.

Bhanja et al. (2001) conducted three experiments on gold mahaseer (Tor putitora Ham.); snow trout (Schizothorax richardsonii) and Chinese carps to study the effect of supplemental vitamins on growth, survival and feed conversion efficiency (FCE). The gold mahaseer and snow trout recorded significantly higher weight gain of 21.4 - 46.2 and 142.5 - 317.3% and 4.57-10.80 and 2.58-5.25% better feed conversion efficiency (FCE) in the vitamin supplemented diets than that of control diet. Survival rate of golden mahaseer was not affected by supplementation of vitamins, whereas in snow trout it was significantly higher. Among Chinese carp, only common carp recorded significantly better weight gain (27.6% - 78.6%) in the vitamin supplemented diets than that of control diet. They finally conclude that combination of vitamin A+ E + C has significant effect on growth and FCE in golden mahaseer, snow trout and common carp.

Xie et al. (2001) incorporated several plant proteins in the experimental feed of gibel carp (Carassius auratus gibelio). The proteins incorporated were soybean cake (SBC), potato protein concentrate (PPC),
peanut cake (PNC), cotton seed cake (CSC). The fish meal was used as control. The feeding rates observed were ranked in the order; CSC> PNC> SBC> PPC.

Adeparusi et al. (2002) conducted a study to determine in vivo apparent digestibility of nutrients in raw and processed lima bean diets fed to *Nile tilapia*, *Oreochromis niloticus*. All the diets were formulated at 30% crude protein level. Autoclaved soybean meal was used as control diet. The soybean content of the control diet was replaced with either raw or processed (raw, heated or autoclaved) lima bean meal. The diets were fed to *Nile tilapia* fingerlinks at a stocking rate of 35 fish per tank. Faecal collection was carried out by hand stripping the rectal region of fish at four hours after each feeding. Acid insoluble ash was used as an internal marker. Proximate analysis of diets and faeces were carried out for crude protein, lipid, crude fiber, energy and the acid insoluble ash. These were used to calculate the digestibility coefficients of nutrients. High nutrient digestibility was observed in processed feed compared to raw feed.

Oseni (2002) conducted a feeding trial to evaluate the potential of replacing fish meal with processed animal by-product meals, meat meal and blood meal (4:1 ratio), in practical diets for juvenile grouper (*Epinephelus coioides*). Eight isonitrogenous diets were formulated to contain 45% protein and 12% lipid. Fish meal was replaced by 0%, 10%, 20%, 30%, 40, 60%, 80% and 100% of meat meal and blood meal (4:1) mixtures (diets 1-8). The diet with 100% fish meal (diet 1) of trash fish as feed (diet 9) was used as control. Grouper juveniles were reared in 250 per circular fiberglass tanks maintained in a flow through sea water system. Each dietary treatment was tested in quadruplicate groups of 25 fish per tank arranged in a completely randomized design. Fish were fed the diet twice per day at a daily feeding rate of 5-6% of biomass and trash fish at 10-12% of biomass for 60 days. Percentage weight gain, specific growth rate (SGR), survival rate, feed conversion ratio (FCR)
and body composition of grouper juveniles were measured. It was concluded that up to 80% of fishmeal protein can replaced by processed meat and blood meal coming from terrestrial animals with no adverse effects on growth, survival and feed conversion ratio of *E. coioides* juveniles.

Kalla *et al.* (2003) studied the effect of soybean on growth, digestibility and nutrient retention in *Mugil cephalus*. Fish meal was replaced with equal proportion of hydrothermically processed full fat soybean at four inclusion levels (25, 50, 75 and 100 gKg⁻¹ of diet). Growth performance was evaluating by feeding the fish once only at the rate of 5% body weight per day maintained under laboratory conditions for 70 days. These studies indicate that fish meal can be replaced by soy protein without compromising weight gain or feed efficiency in the fry of *Mugil cephalus*.

Arlinghaus *et al.* (2003) undertook a study on the digestibility measurements in juvenile tench (*Tinca tinca*) by using a continuous filtration device for fish faeces. The digestibility of macronutrients by tench was investigated using sieving method of faeces collection and chromic oxide. The mean apparent digestibility of coefficients of net feed efficiency was estimated by nearly 78.2% in tench.

Narejo *et al.* (2003a) conducted an experiment to study the effect of different feeds on growth, survival and production of freshwater and mud eel, *Monopterus cuchia* reared in cemented cisterns (I .25m, 2 each) over a period of twelve months from July 2000 to June 2001. Three different feeds namely F1 (live small fish), F2 (dead small fish) and F3 (pallet feed, 30% protein) were applied to treatment I, II and HI respectively. Each cistern was stocked with ten fish having mean initial body weight of 30.5 ± 4.25g, each treatment was triplicated. Highest weight gain of 71.20 ± 3.78g was obtained in treatment II followed by treatment I (46.46 ± 2.30g) and lowest 26.10 ± 2.40g in treatment III. On the basis of better growth, survival rate and production, it was concluded
that dead small fishes are suitable for the culture of *Monopterus cuchia*.

Somashekar *et al.* (2003) conducted various experiments to find out the comparative usefulness of floating aquatic weeds incorporated feed for carp fry. *Pistia straiotes* and *Lamna major* as major ingredients and dried silkworm pupae powder as minor ingredients were used and growth was compared with conventional feed (rice bran and ground nut oil cake in the ratio of 1: 1. The average growth of carp fry grown on *pistia* leaf based feed (PF) was marginally superior to that obtained with *Lemna* based feed (LF) and CF (Conventional feed).

All and Janney (2004) worked on the effects of feeding on growth and body composition of *Clarias gariepinus*. They conducted eight week feeding trial. Three fish meal and soybean meal based diets having protein 28, 35 and 40% fishes were fed according to restricted feeding regime. Growth rate and feeding efficiency did not differ significantly (p>0.05) between fish fed with diets containing 35 or 40% protein but was lower (p<0.05) for diet containing 28% protein. Whole body composition, liver lipid and liver glycogen did not differ significantly. Their study revealed that the response of African catfishes to change in dietary levels was not influenced by feeding.

Raj *et al.* (2004) studied the food and feeding habits of *Mystus montanus* inhabiting Tambaraparani River fed systems based on the analysis of gut. Index of preponderance adopted for determining the percentage occurrence and volume of food items indicated that the fish is an omnivorous bottom feeder.

Yang *et al.* (2004) conducted the experimental studies on the effect of replacement of dietary fish meal by meat and bone meal and poultry byproduct meal on the growth and feed utilization of gibel carp, (*Carassius auratus gibelio*). The authors concluded that meat and bone meal (MBM) or poultry byproduct meal (PBM) could be replaced upto 500g Kg’ of fish meal protein in diets for gibel carp without negative effects on growth while 150 g Kg’ replacement
by meat and bone meal protein improved feed utilization.

Ali and Jauncey (2005) made an eight week feeding trial in a recycling water system at 28± 1°C to investigate the effect of dietary protein to energy ratios (P/E ratios) on the body composition, digestive enzymes activities, blood plasma metabolites and histology of intestines and liver in African catfish *Clarias gasiepinus*. Six fish meal based diets of two protein levels (33 to 43%) each with three lipid levels (4, 8 and 12%) resulted in P/E ratios ranging from 15.5 to 21.3 mg protein K'T gross energy (GE). The diets were fed to 20 fish (per 30-L tank) in triplicate at the rate of 5% of their body weight per day adjusted fortnightly. Higher lipid deposition in whole body and liver were observed with increasing dietary lipid level at each protein diet and were higher for the lower diets. No significant differences were observed in digestive enzyme activities (protease and lipase) of intestine and liver of fish fed with varying P/E diets in response to experimental diets. No significant differences were detected on plasma concentration (glucose, triglycerides and cholesterol) plasma amino acid level and histology of liver at different P/E ratios. The authors concluded that response of whole body composition, digestive enzymes, blood plasma and histological condition of intestines and liver is not influenced by varying dietary P/E ratios.

Cai *et al.* (2005) conducted a study to determine the effect of diet processing and replacement of fish meal by detoxified caster bean meal on growth performance, body composition. Three replacing levels (0, 40 and 100%) of fish meal protein were replaced by detoxified castor bean meal. Significant decreased specific growth, feed conversion efficiency ratio and feed intake was observed. Phosphorous excretion was reduced because of lower intake of apparently absorbed phosphorous and higher apparent digestibility coefficient.

Paul *et al.* (2005) conducted an experiment to evaluate the use of
mustard oil cake as a dietary protein source for medium carp (*Puntius gonionotus*) fry. Mustard oilcake was incorporated at 0, 20, 30 and 40% which substituted 0, 23, 35 and 46% of total dietary protein. The study indicated that mustard cake can be incorporated up to 40% in the diet of *Puntius gonionotus* without any adverse effect.

Rao and Kumar (2005) performed an experiment on performance of squilla meal incorporated diet on the juveniles of *Labeo rohita*. Taking 25% protein level traditional diet as the control diet, the performance of squilla meal incorporated formulated diets of 25 and 30% protein levels were tested. Observations revealed that from among the two formulated diets, the one with 30% of protein performed better.

Zhou *et al.* (2005) performed an experiment in floating cages to determine the potential use of defatted soybean meal (roosted and solvent extract) as a partial replacement of fishmeal in the isonitrogenous diet for juvenile *cobia* with an initial average weight of about 8.3g. Diets were formulated to include 0, 100, 200, 300, 400, 500 and 600g kg\(^{-1}\) (diets D0, D10, D20, D30, D40, D50 and D60 respectively) of fish meal protein being substituted by defatted soybean meal without methionine supplement. Decreased weight gain was observed when the replacement level of fish meal protein was increased from 400g kg\(^{-1}\) to 500g kg\(^{-1}\) and the D60 diet was the lowest in all groups.

Awasthi *et al.* (2006) developed a new approach for gut analysis of fishes *Cyprinus carpio* L. fishes were fed with algal species. The intact guts and gut contents of 25 fishes were transferred directly to five different solid nutrients mediums to study the species of algae consumed by the fish. The method adopted was found to be simpler, accurate and more convenient compared to conventional technique for gut analysis.

Adamek *et al.* (2007) performed culture of Siberian sturgeon in
concrete ponds with natural water temperature regime during the growing season. They separated fishes in two groups with supplementary feeding using trout pellets (FF) and control variant (CF). Specific growth rates calculated were 0.26 and 0.16% per day in length and 0.53 and 0.18% per day in weight, respectively. They concluded that index of preponderance for artificial feed was only 3.53. However, its role in the growth performance and condition of Siberian sturgeon in pond culture was very important.

Shah et al. (2008a) made an attempt to find out the effect of different concentrations of feed ingredients on the growth and survival of *Schizothorax curvifrons* in captivity and concluded that feed formulations containing Soya protein upto 15% can be incorporated in the feed of *Schizothorax curvifrons* without any side effects.

Shah et al. (2008b) conducted an experiment on food and feeding habits of an endemic fish, *Schizothorax curvifrons* in Kashmir valley, India. Index of Preponderance was adopted for determining the percentage occurrence of different food items. Gut analysis indicated that algae are the main food items followed by zooplanktons.

2.2. Breeding Biology

Kyle (1926) worked on the fecundity of marine fishes and reported 1460 million ripe eggs in the ling and 8-10 million eggs in the cod and conger, but in a large specimen of sunfish the number goes on high as 160 million.

Khan (1938) was the first who attempted induced breeding of the major carps. He did not meet with any success when he injected *Cirrhina mrigala* with mammalian pituitary gland.

Jones (1946) has consolidated different works on Indian fishes. In
Notopterus chitala the number of eggs vary from 300-500; in Barbus conchonius the egg number varies from 150-300; while in Carassius auratus there are 2,000 to 70,000 eggs depending on the size of fish.

Pincher (1948) had reported 1.5 million eggs in a 22 pound carp; only 500 in a 3 pound minnow, 155,000 in a 3-pounds perch; 595,000 in a 32 pounds pike; 18,000 in a 22 pounds salmon; and only 4,000 in a 4 pounds trout.

Chaudry (1963) induced the major carps to breed successfully in a pond by pituitary gland treatment at a mature stage.

Henderson (1963) studied the influence of light and temperature on the reproductive cycle of the eastern brook-trout (Salvelinus fontinalis) has indicated that the gonadal response to the same conditions of light and temperature vary according to the phase of gonadal development. She also stated that a short photoperiod coupled with low temperature during the spring months induced a precocious onset of the secondary growth phase, but retarded the subsequent growth rate of the developing ova, particularly in the terminal phase. She concluded that a short photoperiod may stimulate one phase of reproductive cycle and retard another. Ovarian development according to her was retarded by short photoperiods in late summer, when the fish had been exposed to short photoperiods during spring and early summer.

Bhatnagar (1964) conducted a study on the spawning and fecundity of Bhakra reservoir fishes and calculated that Schizothorax richardsonii spawns twice a year, once from July to August and second in December and January.

Das and Malhotra (1964) undertook a study on the occurrence of corpus luteum in Kashmir teleost fish Schizothorax niger. The authors concluded that membrane propria remains intact throughout the stages of transformation and the
only the size of the theca cells increases. It was further concluded that the only layer left to give rise luteal cells are the granulosa (or follicular epithelium) cells that are budding directly, or in the form of cell pearls, are originating from the cells of granulosa layer.

Qayyum and Qasim (1964) studied the biology of some fresh water fishes of India and concluded that the seasonal changes occur in the weight of gonads.

Malhotra (1965) studied the seasonal variation in morphology of the ovaries of a Kashmir fish *Schizothorax niger* and concluded that breeding season of the fish is from January to March. He (Malhotra 1967) also studied the relation between the ovarian cycle and feeding of *Schizothorax niger* and *Botia*, and showed that during the maturation of gonads feeding slackened in these fishes.

Malhotra in (1970) undertook a detailed study on the breeding biology of *Schizothorax niger* from Kashmir. He observed the breeding season of *Schizothorax niger* starts from middle of April to middle of June. On the basis of histological studies of the oocytes, the studies on the diameter of oocytes and gonadosomatic index indicated that breeding season depends upon the optimum external factors like food, temperature and light, both for the parent as well as the off springs.

Jyoti and Malhotra (1972) studied the fecundity of *Schizothorax niger* from Dal lake and stated that *Schizothorax niger* breeds once in a year. The peak spawning was observed from March to May.

Sexena (1972) determined the stages in gonadal development and spawning time of *Rita rita*. He studied ova diameter of 110 specimens and recorded more than one spawning in *Rita rita* in a season usually between May-September.

Bishat and Joshi (1975) worked on the seasonal histological changes in
the ovaries of a mountain stream teleost, *Schizothorax richardsonii* and concluded that species spawns twice initially in July-August and again in December-January in Bakhra reservoir.

Guraya *et al.* (1975) studied the morphological and histological changes of the cat fish (*Mystus tengara*) ovary during its reproductive cycle in natural and confined waters. This fish is oviparous and breeds once during the rainy season. They recognized seven phases in ovarian cycle based on morphological changes in the ovary. They were: immature, preparatory, maturing, pre-spawning, spawning, depletion and recoupment. They worked out that ova diameter and gonadosomatic index are maximum in July and minimum in November and December.

Raina (1977) conducted a study on the fecundity and spawning behavior of *Schizothorax esocinus* Heckel from Dal lake of Kashmir. Fecundity estimates were made on 26 mature fishes. The relationship between the logarithm of the egg number to length and weight of the fish were found to be, \( F=0.350L^{-1.12} \) and \( F=7464W^{1.737} \). Fecundity was found to be related to both body length and body weight. The spawning season was found from April to the end of June in the surrounding snow fed streams of the lake.

Jhingran and Sehgal (1978) conducted a study on cold water fisheries in India and observed that *Schizothorax richardsonii* spawns once but in different periods at various elevations depending upon elevation in different rivers/streams of Himachal Pradesh.

Malhotra *et al.* (1978) studied the ovarian cycle and spawning season of *Ophicephalus punctatus*, from Jammu region of J & K state. The oocyte showed six well differentiated stages of maturation and the fish had a prolonged spawning season extending from May to August.
Shrestha and Khanna (1979) studied the gonadosomatic index and histology of the ovary in Japanese fish *Schizothorax richardsonii* and *Schizothorax plageostomus*, concluded that the fish spawns twice a year, once from mid September to October and secondly in March.

Sunder *et al.* (1979) analysed the maturity stages in *Schizothorax niger* by ova diameter.

Qadri *et al.* (1983) worked on the breeding biology of *Schizothorax richardsonii* in snow fed water bodies of Kashmir valley and concluded that the species is typically early summer spawner.

Baloni and Tilak (1985) undertook a longitudinal study on the breeding behaviour of *Schizothorax richardsonii* from Nanital and concluded that the fish spawns only once in a year and the peak spawning period is from late October to December.

Raizada (1985) worked on breeding, development and culture prospects of the Himalayan barbell, *Schizothorax plageostomus*. They concluded that Schizothoracine is an important group of fishes in cold waters of Himalayas. Since the fish is in high demand locally in J&K, but exploitation or unrestricted bag limit besides killing through illegal means including use of explosives and poisoning, affecting adversely the fishery. They also concluded that restoring the population of *Schizothorax plageostomus* through other than natural means is now gaining importance.

Mihelakakis and Kitajima (1995) studied the spawning of the Silver Sea Bream, *Sparus sarba* in captivity. Two types of eggs were reported buoyant and sunken, fertilization rate of buoyant eggs and percentage of abnormally developed eggs were estimated daily. There was no correlation between water temperature and spawning and viable hatch and spawning period, at the
same incubation temperature in all cases. The total number of eggs released during the spawning period was estimated at 18.1 million in group A and 10.8 million in group B. Mean egg diameter tended to decrease during the spawning season along with the increasing water temperature.

Fleming (1998) studied the breeding system of Atlantic salmon (*Salina solar*), they find out that female breeding success is largely dependent on egg production, access to breeding territories, and nest quality and survival. By contrast, male breeding success is largely determined by access to ovipositing females. They also concluded that spawning populations of Atlantic salmon are not static, as they exhibit spatial and temporal variability in spawner density, sex ratio, age at maturity and body size. Events both natural and anthropogenic affect this variability and ultimately shape the breeding system.

Grier *et al.* (1998) studied the testicular maturation and regression in the common snook. Histological criteria, particularly differences between continuous and discontinuous germinal epithelia were used to distinguish five classes of annual reproductive cycle. The five classes were: regressed, early, mid and late maturation and regression.

Dadzie *et al.* (2000) studied the reproductive biology of the silver pomfret, *Pampus argenteus* in Kuwait waters. The reproductive activities were monitored by observing the seasonal distribution of maturity stages and variation in seasonal fluctuations in the gonadosomatic index (GSI). Two spawning peaks were observed the first in May and the second in August. The males were found to mature early compared to females.

Liley *et al.* (2002) examined aspects of the fertilization dynamics of rainbow trout (*Oncorhynchus mykiss*) that may play a role in determining reproductive success of males of different age and status competing for
spawning. There were no differences in the gonadosomatic indices and relative yields of milt of adult and precocious male rainbow trout collected from a wild population. They also examined that short gamete longevity and the speed with which fertilization occurs indicate that the timing and position of sperm release may play a critical role in determining the reproductive success of males in competition for spawning with a single female.

Kumar et al. (2003a) studied the annual reproductive cycle of male Rohu, *Labeo rohita* in Tarai region of Uttaranchal. Testicular development of *Labeo rohita* under ambient environmental conditions was associated with increasing day-length and temperature, where as testicular maturity and spermeogenesis during spawning phase seem to be correlated with the lowering of water temperature, attributed to rainfall. The primary spermatogonial cells and spermatocytes, a few lobules with spermatozoa and spermatids were observed in preparatory phase. The peak of spermatogenesis having active interstitial lyding cells was recorded during prespawning phase. During spawning phase, most of the testicular lobules were packed with sperm masses along with a few secondary spermatocytes and spermatids. Decreased interlobular space with some inactive interstitial cells was noticed during post spawning phase. The histological changes in liver showed augmented biosynthetic activities corresponded with testicular growth and maturation and changes in hepatopancreatic cells were suggestive of energy mobilization Kumar et al. (2003b) conducted a comparative study on the fecundity of some fresh water fishes of India. The fecundities of three species of fresh water fishes varied from 167,940 in a specimen of Wallago attu (weighing about 4994 gms) to 12,000 in *Rita rita* (weighing about 3178 gms). Thus the authors concluded that the number of ova produced is directly proportional to the size of the fish both in length and weight.
Joshi (2004) worked on artificial breeding and rearing of *Schizothorax richardsonii* and concluded that the species is an annual spawner and breeds between September to October, exhibiting migration to nearby streams for spawning. Overall survival rate of 80.0 to 85.0% from fertilized egg to fry (22.0-24.5°C) and 35.0 to 45.0% from fry to fingerlings was recorded during the experimental trials conducted under farm conditions. Fry attained total length between 75.0 to 100mm (weight 4.0 to 6.0g) with a cumulative survival of about 45% within a rearing period of one year.

Macchi *et al.* (2004) worked on the reproductive biology of the Argentine hake, *Merluccius hubbsi*, inhabiting the Patagonian waters at south of 41°S was studied by using histological analysis of the ovaries. The samples were collected during the reproductive season from December 2000 to March 2001. Argentine hake is a batch spawner with indeterminate annual fecundity that spawns from end of spring to summer with a main reproductive peak in January. They also worked out that from December to February the number of eggs produced by unit weight of hake did not change. In March the relative egg production decreased significantly coincided with an increase of atresia.

Brett *et al.* (2005) worked on induced spawning, larval development and rearing of two indigenous Malaysian mahaseer, *Tortamboria* and *Tor douronensis*. Sexual maturity in captivity was successfully induced using hormone treatments.

Madan (2005) studied the reproductive biology of snow trout *Schizothorax richardsonii* from River Gaula and concluded that the species spawns twice in a year (July-October) and January-February. This statement was based on the evidence of ripe fishes characterized with high bgonadosomatic index. The fecundity ranged from 2248 to 8726 in fishes of 160-245mm total length and 40-110gm weight. The relation between fecundity and fish length, fish weight and ovary weight were also attempted.
Singh et al. (2005) worked on seasonal ovarian cycle in fresh water teleost, *Labeo rohita* based on histological changes, and correlative variations in liver. They divided ovarian cycle into five phases i.e. resting, preparatory, pre-spawning, spawning, spawning and post-spawning regression. They examined that histological changes in liver showing augmented biosynthetic activity during preparatory and pre-spawning phases seemed well co-related with the gonadal development. They also worked out that increasing water temperature and day-length apparently were favorable for the gonadal development in *Labeo rohita*.

Musallam et al. (2006) studies the fecundity and gonadosomatic index (GSI) of the Omani-Indian oil Sardine, *Sardinella longiceps* and observed a significant linear regression between fecundity and total length of the fish. The GSI analysis indicated that the fish shows two major spawning peaks, March-April and August.

Joshi (2006) performed an experiment on Brood stock rearing and artificial breeding of *Schizothorax richardsonii*. A total of 80 fishes (female 28, male 52) with a total biomass of 15.2kg were stocked in the pond at a stocking density of 0.5 k/gm Body length and corresponding weight of the stocked females ranged between 210 to 325mm and 100 to 340 g and that of the males between 170 to 250mm and 50 to 150g respectively. Continuous flow of water was maintained at the rate of 10-30 liter per minute in the ponds. The stock was fed with a laboratory compounded wet diet comprising 32% crude protein. The ingredients used for feed formulation were Soya flour (38%), groundnut oil cake (20%), and rice polishing (2%). The stock was fed minimum at lower temperature and gradually raised as per increase in ambient temperature. Among the stocked fishes, a survival of 88.75% has been recorded after 1 year, in which it was comparatively higher in males than females. Out of 80 fishes reared in pond, 18 females and 41 males attained gonadal maturity during breeding.
season. The natural spawning in *Schizothorax richardsonii* also occurs during the month of September in the nearby streams located in similar altitudes.

Mcquaid *et al.* (2006) estimated the size at onset of maturity (SOM) for both male and female Nephrops from primary sexual characteristics and morphometric traits. SOM estimation was based on histological examination of the gonad ranged from 15.1mm carapace length (CL) in males to 22.9mm CL in females. Nephrops morphometric maturity, or change in allometric growth of body parts, was estimated from appendix masculine and cutter claw lengths in males and abdomen width in females from two sites in the Irish Sea. Two regression techniques were used to estimate morphometric maturity. Estimated SOM from morphometric characteristics ranged from 23.2 to 27.6mm carapace length in females and from 25.9 to 31.0 mm carapace length in males. Spatial variation in SOM was observed in Nephros from different parts of the Irish Sea.

Murua *et al.* (2006) sampled sexually mature female hake *Merluccinus merluccinus* with hydrated ovaries in order to find out seasonal variation in egg production and batch fecundity. The batch fecundity was positively related to total length. The relative batch fecundity varied significantly among months and years, but not between areas. They concluded that relative egg production varied from high value in January to March to a low egg production between April and October.

Yamaguchi *et al.* (2006) studied the reproductive cycle, sexual maturity and diet reproductive periodicity of White croaker, *Pennahia argentata* (Sciaenidae), in Ariake Sound, Japan. The reproductive biology of White croaker was studied by measurement of gonadosomatic indices (GS!) and histological examination of ovaries. Ovaries were classified into one of the five maturity stages based on histological data, i. Immature/ resting stage ii.
Developing stage iii, maturing stage iv. Ripe / spawning stage, v. spent stage. The spawning season lasts from April to September but most activity was observed from May to August. The authors observed that the post ovulatory follicles co-existed with yolk stage oocytes in histological sections of ovaries indicating that white croaker is a multiple spawner, spawning more than once in a single spawning season.

Kaul (2007) studied the fecundity of Schizothorax esocinus in relation to its length-weight. A linear relationship was observed between fecundity and somatic weight, and fecundity and total weight. The relationship between fecundity and standard length followed a power law with an exponent of 2.426 ± 0.153. Faster increase in fecundity was observed in older fishes compared to smaller fishes.

Shah et al. (2007) conducted an experiment on the seasonal variation of blood glucose level in Schizothorax esocinus and Schizothorax curvifrons and observed a significant relationship between glucose level and temperature. They further concluded that blood glucose level increases during the breeding season.

Solomon and Ramnarine (2007) worked on gonadal development and spawning of white mullet, Mugil curema in the Gulf of Paria, Trinidad, West Indies, was investigated using both macroscopic and histological techniques. They concluded that prolonged spawning may be an indication of the lack of population synchrony rather than prolonged spawning by a single individual. Peak spawning occurs in June/July and it is a hypothesized that it is in response to the start of the rainy season.

2.3. Age and Growth

Graham (1929) surveyed a literature on age determination of fish during 1899-
1926 has dealt within detail the consecutive factors that lead to the formation of check marks on the hard parts and discussed the techniques for evaluating the age in fishes.

McConnell (1952) studied the opercular bones as an indicator of age and growth of carp, *Cyprinus carpio* L. He investigated that the opercular method is superior to several other methods of determining age and growth. Past growth was calculated with a logarithmic monograph. Expected number of annuli on opercular bones of known age of carp, agreement of ages assessed by length frequency mode and those assessed from opercular bones of the same fish, agreement between ages assessed by scales and opercular bones and increase in age with increase in size were accepted as evidence of validity of the opercular method.

Das (1964) conducted a study on the scales of freshwater fishes of India. The author tried to find out the age of fishes by using scales. The annuli have been found in a more or less satisfactory state in all the species of fishes studied.

Das and Fotedar (1965) found double concentric winter and summer zone in the scales of *Cyprinus carpio ,specularis*.

Dhar (1967) studied the age and growth in some Kashmir fishes by scale method and confirmed with hard parts.

Ramakrishna and Alikunhi (1967) studied the growth and propagation of common carp (*Cyprinus carpio*) in India. The authors' concluded that when eggs from the same batch are hatched under different conditions and the different media, the length of hatchlings varied markedly. When hatched in cloth hapas fixed in a pond, and in tap water in trays in the laboratory, the length of the hatchlings varies.
Monchizuki (1979) examined the age and growth of two Japanese representatives of the Scombropidae, *Scombrops boops* and *Scombrops gilbertia* by means of otolith reading. Examination of marginal growth of the otolith showed the availability as annual rings of the outer margins of hyaline zones formed in the period from November to January. Growth of the two species was expressed by the Von Bertalanffy's equation based on the estimation of standard lengths at the time of annual ring formation.

James and Kincaid (1982) made a comprehensive study on the survival, growth and catchability of Rainbow trout of four strains. Fingerling rainbow trout (*Salmo gairdneri*) of genetically different strains survived, grew and were caught at different rates by anglers and in gill nets after release from a hatchery into a one hectare pond. When two domestic strains were compared, more fish of the strain genetically selected for fast growth were caught per unit of angling effort than fish of strain not selected of the characteristic. When fish of a natural and domestic strain were released together, survival was higher in the natural strain, but growth was slower.

Toshio (1984) examined age composition, growth, sex ratio and gonad development of *Salmo gairdneri* and *Salmo mykiss* in the North pacific. The author suggested that they are significant differences in anadromy by sex between both species. The differentiation of mature and immature forms of the fish was estimated from the seasonal changes in the gonad weight distribution.

Johal and Tandon (1992) attempted a study to find age and growth of carp, *catla catla* from northern India. 229 fish specimen were collected from Gobindsagar reservoir and 223 were collected from river Harike in north India for age determination by using scales. Strong linear relationship was observed between total fish length and lateral scale radius. High growth rate
was observed in riverine fishes compared to fishes inhabiting in stagnant water bodies.

Kimura and Kiriyama (1993) studied the embryonic, larval and juvenile development of the labrid fish, *Halichoeres doecilopterus* in the laboratory conditions. The eggs, measuring 0.60 - 0.77mm in diameter, were pelagic and spherical with a single oil globule (0.12-0.16mm in diameter). The newly hatched larvae, measuring 1.46 -1.70 mm total length, had 8-11+16-18 myomers. A conspicuous melanophore appeared in the dorsal finfold 8h after hatching. The yolk was completely absorbed 3 days hatching, at 2.52-2.72 mm total length.

Singh and Sharma (1995) conducted a study on the age and growth of Himalayan teleost *Schizothorax richardsonii* (Gray) from Garhwal hills of Indian. Scales were used for age determination and calculation of growth parameters. A linear relationship was observed between length and lateral scale radius. The annuli formation was observed in August September which coincided with spawning. The growth constant parameter indicated that the fish enters in old age in the fifth year of life.

Negil (2002) analysed growth pattern and variation in some morphometric characters of sympatric hill stream teleost. In males and females *Barilius bendelisis* and *Barilius vagra* parameters showing most significant linear regression in relation to total length, snout length and least depth of caudal peduncle. On the basis of morphometric analysis, *B. bendelilis* with 54.5% of genetically controlled characters in males and 50% in females shows relatively wider distribution and greater tendency of subspeciation than *B. vagra* with 63.9% genetically controlled characters in males and 59.1% in females.
David and Pancharatna (2003) conducted an experiment on the age determination of Indian Whiting, *Sillago indica* using otolith and ring count. Length-weight relationship, condition factor and relative condition factor were also calculated in the experiment. The results revealed that length-weight relationship follows cube law $\text{W} = \text{L}^{3.74}$ suggesting the isometric pattern of growth of this fish $K$ and $Ka$ increased up to 190mm (when otolith showed 3 growth rings) and then decreased giving a clue about the size and age of attainment of sexual maturity in this fish. Otoliths obtained from different sized fishes revealed the presence of 1-5 growth rings.

Francis (2003) used otoliths for estimation of age of fish which is a widely accepted and valuable technique for validating annulus counts. They analyzed whole otoliths and also the otolith cores. They used more than one otolith per sample so as to provide sufficient sample mass, in order to avoid sample heterogeneity in otolith age and mass growth rate.

Kosygin and Waikhom (2003) worked on length-weight relationship and fecundity of Cyprinid fish, *Semiplotus manipurensis* from Manipur. The length-weight equation for the fish was calculated as $\log \text{W} = 3.1508895 \log \text{L} = 5.1984116$. The average value of relative condition factor "Kn" was found to be 1 indicating a general good condition. The regression equation between the length and weight was calculated as $Y = -90.78644 \pm 1.0268877X$. Fecundity varied from 18298 to 20573 which showed that the fish is a prolific breeder.

Narejo *et al.* (2003b) studied the length-weight relationship, relative condition factor (Kn) and morphometric and merestic counts of freshwater spiny eel, *Mastacembalus armatus* (Lacepeda) from district Mymensingh, Bangladesh. The fish collected for the experiment were of 14.8 - 47.5cm length and 8.0 - 139.4g weight. The length weight relationship of *M armatus* was
described as log $W = -2.30 +2.72 \log L$ for males, log $W = -2.38 + 2.78 \log L$ for sexes combined. The mean relative condition factor ($K_n$) values ranged from 0.83 to 1.31 for males, 0.80 to 1.29 for females and 0.76 to 1.30 for combined sexes. The morphometric measurements of various body parts and meristic counts were recorded for males and females separately.

Sandhya and Shameem (2003) estimated the length-weight relationship of 723 *Liza macrolepis* fishes collected from unpolluted water bodies of Gasthani estuary and polluted waters of Vashakapatnam Harbour. The results of the study indicated a high regression coefficient value ($b$) for mullets collected from unpolluted waters as compared to those from polluted waters. The relative condition factor indicated higher mean $K_n$ values in the fishes of unpolluted waters than of polluted waters.

Udupa (2003) compared the length-weight relationship in fishes using dummy variables. Regression analysis was used to fit multiple linear regression equation of log weight $n$, log length by including dummy variables.

Venkatesha Moorthy *et al.* (2003) made an experiment on the age and growth of blue spot mullet, *Valamugil seheli* from Manglore. Length-weight relationship, condition, age and growth and mortality rates of *Valamugil seheli* from Manglore region were studied during April 1998 and March 1999. The combined length-weight relationship derived was log $W = -1.4257+2.6207 \log L$ and growth rate was found to be allometric. Seasonal variation in condition factor showed higher values from September to December while the mean values of $K$, showed an increasing trend with size. Studies on age and growth revealed that males grow faster than females and the Von-Betalanffy growth equation was $L_t = 601.76$ for males and $L_t = 534.53$ for females. The instantaneous total, natural and fishing mortality were found to be 1.5060, 0.9713 and 0.5347 for males and 1.3384,
0.9004 and 0.4380 for females respectively.

Brouwer and Griffiths (2004) worked on the age and growth of *Argyrozona argyrozona* and investigated the methods based on both otoliths and mark-recapture data. Transverse sagital sections from the Tsitsikamma National Park showed clear opaque and translucent growth increments. Marginal growth zone analysis and mark recapture of chemically tagged fish (oxytetracyclin) revealed that these were deposited on an annual basis: opaque in summer and translucent in winter. The first translucent check was shown by daily increment counts to mark the completion of the first annulus. They also concluded that mark-recapture is also used to calculate growth of species.

Khan (2004) studied the age and growth, mortality and stock assessment of *Euthynus affinis* (cantor) from Maharashtra waters. The size range of *E. affinis* in the drift gillnet fishery recorded was 26 to 75cm. Total mortality co-efficient (z) was estimated by the catch curve method for the period 1996-2000 which varied between 2.04 (1996) to 2.86 (1998).

Papandroulakis *et al.* (2004) investigated growth performance and food intake capacity of juvenile fish of wreckfish (*Polyprion americanus*) while as gametogenesis was studied in adult fish. Three groups were created from 19 individuals, which were collected during neustonic sampling; using fish aggregated devices, in association with floating objects and during tuna fishing with drift nets from Greece, Italy (Ionian Sea) and the Altanic coast of France from September 1999 to March 2001. Food consumption varied during the rearing period according to developmental stages and the rearing condition. The food conversion ratio ranged between 0.9 and 2.5 on dry weight basis during the period of study. Gametogenesis was monitored in a separate stock of 15 individuals (11.7+ 3.7 kg) by biopsies while blood samples were taken for steroid estimation. Increase in oocyte diameter was observed in females from
August to January, while plasma estradiol levels also increased from October to March. However, either egg or sperm were collected from the stock. Young wreck fish presented a high growth rate in captivity thus supporting the feasibility of the species for rearing.

Saker *et al.* (2004) undertook a study to find out the relationship of morphometry and length-weight of *Megalaspis cordyla* from Mumbai coast. Allometric growth and high interdependence was observed. The condition factor of the population was found to fluctuate between 0.7 to 1.2.

Jena *et al.* (2005) conducted an experiment on evaluation of growth and survival of Indian major carp fry in aerated vis-à-vis non-aerated ponds under different stocking densities. Out of eight ponds, four were provided with mechanical aeration, where as remaining four ponds without aeration served as control. Fry of Catla, Rohu and Mrigal were stocked in equal proportions at four densities ranging from 0.15 to 0.6 million/ha. The mean growth and survival of fry in aerated ponds were considerably higher than non-aerated ponds at each density. The biomass production, specific growth and the feed conversion ratio also showed significantly better performances in aerated ponds over the control ponds.

Joshi *et al.* (2005a) conducted a study on *Schizothorax richardsordi* from hatchling stage up to the five years in ponds. The fry were stocked at a stocking density of 10 m$^{-2}$. The water flow in the ponds was maintained at 1520L per minute for the first year and 20-50 L per minute afterwards. The fry were fed on a laboratory compounded wet artificial diet containing 32% crude protein at the rate of 5-10% of the body weight per day during the 1st year and 3-5% later on. The feeding schedule was maintained according to ambient water temperature. The stock was fed at low and it was gradually increased. The feed ingredients were Soya flour (38%), groundnut oil cake (20%), fishmeal
(20%) and vitamin-mineral premix (2%). The finally powdered dry feed was soaked in water to make small balls, which were kept in enamel coated feeding trays, on pond bottom twice a day. The fry were regularly sampled for observation of gain in length, weight and survival. After one year of rearing in the ponds the fish recorded a growth of 76-105mm from the initial length of 9.5-13.5mm. The increment in weight was 3.8-6 g (average 5.2g) from the initial weight of 0.021-0.032g. The body length was 160-262mm (average 204mm) with a corresponding weight of 51.5-91g (average 72 g ) at the completion of 5 years.

Joshi et al. (2005b) conducted an experiment on the rearing of rainbow trout, *Oncorhynchus mykiss*. The experiment revealed that fish can attain an average growth of one kg by year. The brood stock raised in this experiment were successfully bred and the seed produced was reared under farm conditions at the water temperature range of 4.0 to 18.0 ºC.

Mello and Rose (2005) worked on seasonal growth of Atlantic cod *Gadus morhua*. Water temperature, partial fullness index and gonado-somatic index explained between 31 and 52% of the monthly variability in growth. They also worked out that the rapid increase in somatic mass during June and July occurred despite cold water temperatures and moderate to high gonado-somatic index. The findings of their study suggested that when food was not limiting factor, growth tended to increase even when Atlantic cod occupied colder waters, but when food was limiting the opposite may have occurred.

Rao et al. (2005) conducted a study on the length-weight relationship and condition factor of *Liza parsia* in relation to industrial pollution. The authors concluded that the length-weight relationship and condition factor were significantly less in the polluted harbor and coastal waters, compared to those from Gosthani waters.
Majhi et al (2006) worked on growth performance and production of organically cultured grass carp *Ctenopharyngodon idella*. The aquatic fern Azolla was grown and fed to grass carp, and was found to be preferred feed by grass carp and daily growth increment was recorded. They concluded that the utilization of organic Azolla through grass carp is one of the best options for production of the fish biomass from the aquatic habitat.

Bascinar et al. (2007) worked on growth, feed conversion ratio of Black sea trout (*Salmo trutta, Labiax pallas*). They evaluated the daily feeding frequencies of 360 fishes. Three feeding treatments (F1, F2 and F3) were applied to three tanks. They concluded that Black sea trout fed once a day grow slower than those fed two or three times a day, but the FCR was the best than other groups.

Gerritsen and McGrath (2007) used length-weight relationship of fish to estimate the biomass of length distributions and indices of condition. They examined length-weight relationship of 1334 haddock (*Melanogrammus aeglefinus*) and 1186 whiting (*Merlangius merlangus*) collected on a ground fish survey in the waters around Ireland in 2004. The length-weight regression showed a significant area effect but no significant difference existed between the sexes. The condition indices showed a moderate spatial structure for both species.

Ismen et al. (2007) they estimated the age, growth, reproduction and feeding of common guitar fish (*Rhinobatus rhinobatus*) using 225 specimens. Females made up of 43% and males 57% of the individuals. The total length of females ranged from 22.2 to 81 cm, and of males from 220-120 cm. They derived age data from vertebrae readings and also used to estimate growth parameters. They concluded that males matured at 68 cm total length and females at 69 cm total length. The stomachs contained mainly crustacean.
Phelps et al. (2007) studied precision of five structures for estimating age of common carp, they analysed that otoliths have been validated as an accurate structure for estimating age of common carp, *Cyprinus carpio*. They estimated age using scales, vertebrae, opercula's, pectoral fin rays and otoliths. Although pectoral fin rays gave accurate age estimates however it still requires evaluation. Accurate fish ages are important for growth analysis, age structure analysis and mortality rate. They concluded that otoliths have gained favour over other body structures because of their lack of resorption and because their growth is a cellular rather than by calcification.

Shah et al. (2008c) conducted an experiment on length weight relationship of *Schizothorax esocinus* in cold water bodies of Kashmir valley India and concluded that maximum body weight occurs just before spawning period.

It could be seen from the above literature that the food and feeding habits, breeding biology and age and growth have been studied by a number of workers from time to time. Though there are reports in case of *Schizothorax* but there is no detailed information so far on the feed formulation and rearing of this indigenous fish from our valley. So, the present work was undertaken to fill this gap and it is hoped the preparation of artificial feed will help in rearing this fish under controlled conditions which will help in preventing the decline of this fish by producing fully viable seed ready for release into rivers and lakes of the valley.