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Seasonal Variation of Fish Reproduction : A Review

Kousik Roy
Department of Zoology, Polba Mahavidyalaya (Affiliated to The University of Burdwan), Polba, Hooghly, West Bengal, India

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ABSTRACT

In the present study demonstrated the morph anatomy, seasonal reproductive cycle of gonad and hormonal regulation of fish reproduction. A study on reproductive biology is much more needed for fisheries development. The annual reproductive cycle of most fishes divided into four different phases: preparatory, prespawning, spawning and post spawning. The ovarian development is generally observed in three patterns, i.e. synchronous, group synchronous, and asynchronous according to the size and distribution of oocytes. The gonads are divided into different stages according to the maturity and seasonal variation due to histological observation. The gonadosomatic index (GSI) is varied in different season and peak in monsoon season in most of the fishes. The fecundity of fishes fluctuated according to the fish species, environmental conditions, length, age, genetic potential location etc. The relative fecundity is the number of the standing stock of advanced oocytes at any time associated to body weight. Mainly two important environmental factors, photoperiod and temperature are responsible for fish reproduction. The hormonal regulation of fish reproduction is controlled through brain-pituitary-gonadal axis.

Keywords : Seasonal variation, Gonads, GSI, Fecundity, Fish reproduction, Hormonal control

I. INTRODUCTION

Fish is the major source protein for human consumption and economically important for income and employment generation. Fisheries production needs to be increase to meet the increasing demands due to increasing population bloom and enhancement in per capita fish consumption. According to FAO (2012), fish represented 16.6 % of the animal protein to the world population's intake and 6.5 % of all protein consumed. FAO (2014) indicated that the world food fish aquaculture production expanded at an average of 6.2 % per year during the period of 2000-2012. Fish biodiversity comprising of about 50%

of vertebrate species has immense ecological importance.

Studies on reproductive biology of fish are essentially needed and a basic requirement to plan a better conservation and management strategies of fishery resources (Muchlisin et al., 2010), and for assessing the influences of environmental variability on the dynamics of fish populations (Schlosser, 1990). The reproduction biology is an important topic now, beside for conservation purposes, information on reproduction biology is also useful to select the candidate of fish target from the wild for diversification of fish species in aquaculture industry (Muchlisin, 2013). The reproductive tactics of a fish species is common to individuals of within species, while the reproductive strategies are varies in response to fluctuations in the environmental parameters (Roff, 1992).

II. BACKGROUND DESCRIPTION

A. Male reproductive organ

The male gonad of fish comprise of paired elongated testes which displays numerous species variations particularly in morpho-histological structures. Morpho- anatomy and histological features of the testes of fish have been described for many fish species (Billard et al., 1982). The testis is enclosed by tunica albuginea made up of dense collagen connective tissue and elastic fibres. The connective tissue fibres from the peripheral stroma project inside the lumen of the testes to form large number of seminiferous lobules (Sathyanesan, 1960). The seminiferous lobules undergo changes in accordance to the maturity cycle. With advancing to the maturity the interlobular septa are thinned out and rapture resulting confluence with each other to facilitate passage of sperm through common duct (Srivastava and Rath, 1969). The seminiferous lobules contain germinal cysts. The germinal cysts contain germinal cells at different stages of development. Resting or primary spermatogonia are the largest germinal cell in testis Secondary spermatogonia resemble to the primary spermatogonia being only difference in smaller size and radiating chromatin thread (Abu Hakima, 1987). Secondary spermatogonia produce primary spermatocytes by mitotic division and these cells possess hyaline cytoplasm and centrally placed nucleus. Primary spermatocytes enter into meitic division and result the formation of secondary spermatocytes and spermatids successively. Small round spermatids transform into mature spermatozoa by the process of spermiogenesis (Abu Hakima, 1987). Interstitial Leydig's Cells are distributed singly or in small groups in between the lobules (de Vlaming, 1974). The testicular lobules contained another type of cell which is homologus or atleast analogus to the sertoli cells of higher vertebrate. The sertoli cell has flattened and elongated dense nuclei and surrounded the germinal cysts as their cytoplasmic processes contribute to the formation of the wall of germinal cysts. Sertoli cells are found in contact with the basal lamina also they are present at the periphery of the testicular tubules (Koc et al., 2012).

B. Annual reproductive cycle of male fish

The annual spwaner fishes show the different states of maturity of their gonads in their annual reproductive cycle. Hyder (1970) described the annual reproductive cycle of Tilapia leucusticta into three principal phases such as I) Quiescent phase characterised by the lowest GSI, small lobule and mainly spermatogonial cells ii) recovery phase with the appearance of all the cell types and iii) maximum maturity phase with peak GSI, sperm filled large lobules. He suggested that temperature and sunlight play the major role on gonad maturity. Four stage of maturity of testis has been recognised by Sanwal and Khanna (1972) based on histomorphological features. They detected the major cell types as spermatogonia and primary spermatocytes in stage –I (November to February), secondary spermatocytes and spermatids in Stage-II (March–May), sperm in stage-III (June to

August) and residual sperms and spermatogonia in stage-IV (September to October). On the basis of gonadal volume, GSI and annual percentages composition of different spermatogenic cells testicular cycle of many fish were divided into resting maturing, pre spawning, spawning and post spawning phases (Htun-Han, 1978). The maturity stages of testis of Mystus tengara has classified into five annual stages on the basis of morphological development that was stage I (Immature), stage II (Maturing), stage III (Mature), stage IV (Ripe), stage V (Spent) (Gupta and Banerjee, 2013). The maturation of testes of G. oyena can be classified into eight stages, i.e. immature, developing virgin, maturing, mature, ripe, spawning, spent and developing recovery (EL-Boray, 2001). Ali and Kadir (1996) has categorized the maturity stage of T. thynnoides into four stages i.e. immature, maturing, ripening and spent. Although Nichol and Acuna (2001) has classified the maturity stage of female yellow fin sole into five stages i.e. immature, maturing, hydrated, and spawning and spent. Marcano et al. (2007) has applied a single method of macroscopic to determining the maturity stages of the gonad of Oxydor assifontesi and it was categorized into six stages i.e. virgin, immature, maturing, mature, spermiated or ovulated and spent or spawned. Furthermore, Grandcourt et al., (2009) have observed the reproductive biology of grouper Epinephelus coioides and classified female gonad into six stages i.e. immature, undetermined inactive, mature resting, mature ripe, mature running ripe, and spent. Gonad developmental of R. tawarensis has been divided into five maturity stages on the basis of macroscopic evaluation which were immature, develop, mature, ripe and spent (Muchlisin, 2014).

C. Female reproductive organ

The female reproductive system of teleosts is highly variable reflecting the wide range of reproductive patterns including viviparity. The ovary consisting of oocytes, follicle cells supporting tissues or stroma and vascular as well as nervous tissue (Nagahama, 1983). Ovarian wall is three layered - outer thin peritoneal, middle thick albuginea and inner germinal epithelium which project into ovarian cavity in form of ovigerous fold. Ovigerous fold is the seat of oocyte development (Howell, 1983). The ovary of teleosts is mostly contains a hollow, lymph-filled space which opens into the oviduct, and into which the eggs are shed (Romer et al., 1977). Three types of fish ovary may be found, such as gymnovarian, secondary gymnovarian and cystovarian. In the first type, the oocytes are discharged directly into the coelomic cavity and then enter the ostium, then through the oviduct and are eliminated. Secondary gymnovarian ovaries shed ova into the coelom from which they go straight into the oviduct. In the third type, the oocytes are transported to the exterior through the oviduct (Brito and Bazzoli, 2003). Gymnovaries are the primitive condition which is found in lungfish, sturgeon, and bowfin. Cystovaries are found in most teleosts, where the ovary lumen has continuity with the oviduct (Guimaraes-Cruz et al.,2005).

The ovaries of adult fish occur as paired structures close to the body cavity on either side of the dorsal mesentery. The ovarian development is generally observed in three patterns, i.e. synchronous, group synchronous, and asynchronous (de Vlaming, 1982).

I. Synchronous pattern: All of oocytes develop and ovulate in unison and there is no replacement from early stage, and a single size distribution in the ovary (West, 1990), for example in common carp (Cyprinus carpio).

II. Group synchronous pattern: This group has minimum two populations of oocytes at any developmental stages. This pattern permits for multiple, distinct ovulatory events that naturally follow seasonal, lunar, or diurnal cycles (Redding and Patino, 1993). This pattern was recognised in some fishes for example rainbow selebensis, Telmatherina

celebensis (Nasution, 2005), white mullet Mugil curema (Solomon and Ramnarine, 2007).

III. Asynchronous pattern: This pattern contains oocytes at all stages of maturity without dominant populations. The ovary appears to be a random mixture of oocytes at every imaginable stage, allowing for prolonged or continuous ovulation (Murua and Saborido-Rey, 2003), for instance pounting, Trichopterus luscus (Normando et al., 2009).

Synchronous pattern of fishes are known as total spawner where the whole clutch of yolked oocytes ovulates at once and the eggs are shed in over a short period of time. Fish with asynchronous ovulator is known as batch spawner or multiple spawner, where only a portion of the yolked oocytes is spawned in each batch, generally through the hydration process (Murua and Saborido-Rey, 2003). Batch spawning is a tactic to release eggs over an extensive period of time increasing the survival probability of offspring (Lambert and Ware, 1984). Additionally, a group synchronous pattern is known as a fractional multiple spawners, distinct ovulation events that typically follow seasonal, lunar, or diurnal cycles (Redding and Patino, 1993).

D. Maturational stages of oocytes

The process of oogenesis was categorized according to oocyte location and size, staining characteristics, number of nucleoli and presence of the follicular layer and the distribution of cytoplasmic inclusions. The reproductive biology of Labeo victorianus was classified into six stages i.e. oogonia, chromatin nucleolar oocytes, perinucleolar oocytes, primary yolk vesicle oocytes, secondary yolk vesicle oocytes and tertiary yolk vesicle oocytes (Rutaisire and Booth, 2004). Various authors have been categorized the process of development of egg into different phases in order to demarcate the degree of changes involved therein. The basic classification of different phases proposed by various authors based on the changes in size and structure of nucleus and cytoplasmic inclusions of the developing oocytes. Two phases of development, a primary and a secondary growth phase have been described by Bullough (1939) while eleven development phases have been described by Shackley and King (1977). Erickson et al. (1985) described the successive changes in oocytes as perinucleolar stage cortical alveoli stage, vitellogenesis, yolk coalescence, hydradation and follicular atresia stage. Goodall et al., (1987) described the developing oocytes in Sillago cilicta as primary oocyte, early yolk deposition oocytes, vitellogenic oocytes and hyaline oocytes. Greeley et al., (1968) categorised the cell types of ovary as oogonia, perinucleolar growth phase cortical alveolus (Yolk vesicle) oocytes of early, intermediate and late stage, vitellogenic oocytes of early and late stage, maturation phase of pre GVBD and post GVBD, ovulated eggs and atretic follicles. Mayer et al., (1990) studied in details the reproductive cycle of female D. labrax and categorised the oocyte development into two phase primary growth phase and secondary growth phase. Oocytes of primary growth phase are recognized as oogonia chromatin nucleolar stage early and late perinucleolus stage while the oocytes under secondary growth phase are lipid vesicle stage-I and stage-II, primary, secondary and tertiary yolk granule stage. Murayama et al., (1994) proposed the name of developing oocytes oogonia, primary oocytes, primary yolk vesicle stage, primary yolk globule stage, migratory nucleus stage, final maturational GVBD and atretic stage. Janssen et al., (1995) studied on Pleuronectes flessus and described the cell types of ovary as oogonia, chromatin nucleus stage, early and late perinucleolar stage yolk vesicle stage, yolk granulestage and vitellogenic stage. Bromage and cumaratunga (1988) suggested that the ovarian cycle of fish complete in five steps i) Oogonial proliferation ii Oogenesis and folliculogenesis iii) primary growth of oocyte (Pre-vitellogenesis) iv) secondary growth of oocyte

(vitellogenesis and v) tertiary growth or maturational step.

E. Annual reproductive cycle of female fish

The vast majority of fishes show periodic reproductive behaviour. The annual cycle of developing ovary has been conveniently divided into various stages or phases and the division is primarily based on the condition of maturity of the ovary. The International Council for the Exploration of Seas (ICES) has recognized seven maturity stage or phases first and second as immature, third and forth as maturing fifth as mature, sixth as ripe and seventh as spent. However, since then, different workers adopted different methods of classification while describing the various stages of gonad maturity. The weight of the ovaries was increased of Puntius filamentosus from immature to the ripe condition through six maturity stages such as, 1. Immature 2. Early maturing 3. Late maturing 4. Mature 5. Spent 6. Recovery spent (Manna et al., 2010).The maturity stages of ovary of a freshwater catfish Mystus tengara are divided into five stages which are as follows: Stage I (Immature), Stage II (Maturing), Stage III (Mature), Stage IV (Ripe), and Stage V (Spent) (Gupta and Banerjee, 2013). The ovarian developmental of Puntius filamentosus are divided into five stages such as immature, early maturing, advanced maturing, ripe and spent (Palaniswamy et al., 2012).The annual ovarian maturation cycle of Barbus grypus divided into three maturity periods: previtellogenic, vitellogenic and maturation (Dorostghoal et al., 2009). The development of ovary of Labeo victorianus was divided into five stages according to their size and shape, such as Juvenile, regressed, maturing, ripe and spent juvenile ovary was thick, straight, translucent, strap like; regressed ovary was straight, flaccid, yellowish; Maturing ovary straight, ova visible through the capsule and ovary increases in size and starts forming lobes (Rutaisire and Booth, 2004). The maturity stages of ovary of Puntius sophore was divided to seven maturity stages based on colour, shape and size which was as follows: Stage I, Stage II, Stage III, Stage IV, Stage V, Stage VI and Stage VII (Banik and Saha, 2013). The ovaries of Pampus argenteus can simply be classified into eight stages according to the standard terminology based on the gross structure of the ovaries which are as follows: virgin, resting, developing, maturing, gravid or ripening, running or spawning, partially spawned, and spent. Gross examination of ovaries produce that the maturity stages of Alosa fallax fallax was classified into seven according to its development macroscopically, those was immature/resting, early development, maturing, ripe, spawning, partial spent, spent (Pina et al., 2003).The process of ovarian development of Labeo victorianus was divided into five different stages macroscopically based on shape and size of ova as follows: juvenile, regressed, maturing, ripe and spent. The reproductive status of female Liza ramada have been divided into two main group that was immature period (first growth phase) and maturation period (second growth phase) while immature period again divided into three stages such as oogonia, early perinucleolar stage and late perinucleolar stage, like as maturation period has been classified into five stages i.e. vaculization stage, yolk granule stage, vitellogenic stage, germinal vesicle migration stage, mature yolk stage and lastly atretic oocyte. The stages of oocyte development of Rutilus frisiikutum were classified as previtellogenic, vitellogenic, and maturational phases based on the histological observation of the ZR structure (Heidari et al., 2009). The previtellogenic phase again divided into two stages, namely the primary oocyte and the perinucleolus. Histological study observed that the reproductive biology of female wild carp, Cyprinus carpio classified six different maturity stages (Sivakumaran et al., 2003). Histological examination studies considered essential for identifying details within the maturation cycle such as: maturing females, partially spawned fish, postovulatory follicles (POF) and atretic oocytes (Marshall et al., 1993). In mature

ovaries, the cytoplasm of the largest oocytes was full of yolk granules and lipid droplets. Just prior to spawning, the hydration process remains until ovulation, when the follicular epithelium surrounding the oocyte breaks and the egg is released. The follicular cells then form strings, which are folded in the space left by the egg (Sivakumaran et al., 2003). The mean diameter ranges of oocytes in sectioned material belonging to microscopic Stages II–VI were 58–410, 73–1 014, 441–1570, 733–1627 and 893–1772μm, respectively (Sivakumaran et al., 2003).The ovarian follicles existing oocytes at five stages of maturation (I– V), followed by two further stages (i.e. ovulation and degeneration stages) in adult female Bulatmai barbell (Eagderi et al., 2012).

F. Gonadosomatic index (GSI)

The seasonal change in the gonadosomatic index is one of the criteria for determining the degree of maturation of gonads in teleosts. The method of studying the spawning season is to follow the seasonal changes in gonadal weight in relation to body weight, expressed as the gonadosomatic index (Ahirrao, 2002). Gonads undergo regular seasonal cyclic changes in weight; particularly in females indicate the spawning season (Dadzie et al., 2000). Gonadosomatic index is one of the important parameter of the fish biology that gives the detail idea about the fish reproduction and reproductive status of the species and help in ascertaining breeding period of fish, (Shankar and Kulkarni, 2005). Gonadosomatic index is described as the ratio of gonad weight to body weight. Some researchers are calculated GSI of different fishes cardinal fish, Apogon lineatus (Kume et al., 2000), while, Brown-Peterson and Warren (2001) have used the total weight with excluded the gonad weight in their assessment. The study of the gonadosomatic index expressed appropriate annual cyclic changes in paired ovarian weight. The values of GSI in Catla catla did not show any significant variations over the months of October through April. In the month of May and onward a progressive increase in the value of GSI was noted until July when it was peak. After July month the gonadal weight was gradually fall thereafter to repeat the cycle (Dey et al., 2004). The highest values of gonadosomatic index in rainy season showed accumulation of large quantity of yolk in ripe ova and reached at peak in this season. Some investigators established similar observation on the other fishes (Alam and Pathak, 2010). The GSI was increased in with advanced developmental stages of ovaries were also reported in Puntius filamentosus (Manna et al., 2010), Puntius dukai (Joshi and Joshi, 1989), Barbus longiceps (Stoumbondi et al., 1993). Gonadosomatic index used to identify the spawning season (Jacob and Nair, 1983). The seasonal changes might greatly influence the maturation of ovary resulting successive variations in the gonads and body weights (Lincoln et al., 1980). Gonadal development and maturation observed in major carp Labeo rohita was affected positively by increasing day length and temperature (Singh et al., 2005). Bhatt (1968) reported that the highest weight of the ovary of H. fossilis occurs during breeding period. GSI were measured maximum from March to June and that reduced in the subsequent months in female Schizothorax esocinus (Raina, 1976). Similar results have been observed by Thakur (1978) who noted the maturity and spawning and spawning behaviour of Clarias batrachus and recorded the highest GSI value during the months between June-July of the female individual. The female grey mullet, Liza subviridis exhibited the spawning period from June to September characterised by the highest GSI (Chan and Chua, 1980). The GSI has been found maximum in June and minimum in November in Mystus vittatus (Azizullah and Salahuddin, 1984). Treasurer, (1990) found that GSI of female E. lucius were higher than that of male. GSI reached maximum immediately prior to spawning and it decline after spawning. The clear relationship was expected between mean GSI and reproductive stages in female wild carp Cyprinus carpio when gonads were staged macroscopically

(Sivakumaran et al., 2003). In females, GSI values were low with ovaries identified to Stages I–II, reflecting their immature status, and slowly increased in fish with ovaries assigned Stages III–IV, according with the maturation of the ovary. The GSI in Stage V ovaries presented substantial changes due to some individuals having already shed an unknown number of oocytes, ensuing in loss of ovary mass (partially spent). Seasonal maturation of ovaries of female wild carp Cyprinus carpio starts in August and continues through to March (Sivakumaran et al., 2003).

G. Fecundity

The fecundity is important for studies of population dynamic and life history of fishes (Kapoor and Khanna, 2004). Fecundity is defined as the total number of mature eggs existing in ovary of a fish before spawning (Alam and Pathak, 2010). Usually fecundity is defined as the number of ripening eggs found in the female just earlier to spawning (Bagenal, 1978).The information of fecundity is of great value in fish culture (Bhatt et al.,1977) as it can be used to evaluate the abundance and reproductive potential of the spawning stock (Sarker et al., 2002). Fecundity fluctuates from one species to another, depending on the environmental conditions, length, age, genetic potential location etc. (Alam and Pathak, 2010) and even among the individuals of the same species depending on various factors like size, age, nutrition and environmental condition, etc. (Alam and Pathak, 2010). The total number of advanced yolky oocytes matured per year, known as potential annual fecundity (Hunter et al., 1992). Annual realized fecundity is the exact number of eggs finally released. Generally, annual realized fecundity is lower than potential annual fecundity, because some of the eggs were not able to be liberated and residual in the ovary and being reabsorbed (Murua and Saborido-Rey, 2003). The absolute fecundity is the standing stock of advanced yolky oocytes at any time (Hunter et al., 1992), while the batch fecundity is the number of eggs spawned in each batch, and the sum of batch fecundities is the understood annual fecundity. The annual population fecundity is the number of eggs that all the females in a population spawn in a breeding season (Bagenal, 1978). Finally, the relative fecundity is the number of the standing stock of advanced oocytes at any time associated to body weight (or the number of oocytes per gram body weight).

Fecundity can be divided into two types on the basis of oocytes recruitment strategy i.e. determinate and indeterminate fecundity. The total fecundity prior to the onset of spawning is considered to be equivalent to the potential fecundity is called determinate fecundity. After improving for atretic losses, the number of eggs released per female in a year is called the realized annual fecundity. In batch spawning species the number of yolky oocytes residual in the ovary decreases with each spawning even (batch) due to the standing stock of yolky oocytes is not replaced during the spawning season (Hunter et al., 1992). While, indeterminate fecundity is refers to species where potential annual fecundity is not fixed before the onset of spawning and non-yolky oocytes stay to be matured and spawned during the spawning season (Hunter et al., 1992). The fish with this pattern, the standing stock of previtellogenic oocytes may mature and be recruited into the yolky oocytes stock at any time during the season (Hunter and Goldberg, 1980). Naturally, fish with synchronous and group-synchronous pattern indicates that annual fecundity is determinate (Hunter et al., 1992; Greer-Walker et al., 1994).

There are six methods to estimate the fecundity of fish i.e. gravimetric, volumetric, stereometric, dissector, auto- diametric, and combination among gravimetric, volumetric, and automated particle counting methods (Murua et al., 2003). Among available methods, the gravimetric is a popular method due to low cost and time consumed, fast and

easy to carry out. The gravimetric has been used in some species of fish, for example; Thynnichthys thynnoides (Ali and Kadir, 1996), Atlantic sturgeon, Acipenser oxyrinchus (Van-Eenennaam et al., 1996), snakehead Channa striata, Bloch (Ali, 1999), Baltic cod Gadus morhua (Kraus et al., 2000), bagrid catfish Mystus menurus (Muchlisin et al., 2006) and Atlantic stargazer Uranoscopus scaber (Coker et al., 2008), while the volumetric has been utilised for American eel, Anguilla rostrata (Barbin and Mc Cleave, 1997), spotted sea trout Cynoscian nebulosus (Brown-Peterson and Warren, 2001), Rasbora tawarensis (Muchlisin et al., 2011).

H. Environmental regulation in fish reproduction

The environmental constituents changes at different times of the year to account for the different seasons and occasions this facts are used in timing the reproductive function of a species. The environmental machineries which influence the reproductive function of a fish species in a broad sense comprise day length or photoperiod, temperature, rainfall, food supply, nutrients and some other factors like salinity of water, water current, turbidity, flood, lunar rhythms or periodicity and some chemical property of the ambient waters which are, pH, dissolved oxygen, total alkalinity, specific conductivity and others (Chaudhuri, 1997). The annual changes in the duration of the solar day has been showed to be the primary and regular variable that individually, or in combination with other environmental component(s), impel the 'driving function' in determining the sexual periodicity in most of the fish species (Lam, 1983; Koya and Kamiya, 2000).

Annual fluctuations in photoperiod and temperature are considered as the primary environmental factors that regulate the reproductive cycle in fishes (Lam, 1983). Significance of photoperiod and temperature on the regulation of annual gonadal cycle had been examined in various species of fishes. Studies revealed that the nature of influence of photoperiod and temperature on the reproduction of fish is species specific. The development of gonads are dependent on day length in case of some fishes (Lam and Munro, 1987), although others respond to the variation in temperature (de Vlaming, 1974), and some of the fishes gonadal development occurs thought both temperature and day length (Koya and Kamiya, 2000). It has been considered that photoperiod plays a major role in the regulation of gonadal development in fishes living in bright light adjacent the surface of water (Lofts, 1975).

I. Hormonal control of fish reproduction

It is well known that the reproductive activities in all vertebrates are controlled mainly by the endocrine system via brain-pituitary-gonadal axis (Choi et al., 2010). Estradiol 17-β (E2) is regulated in the neuroendocrine feedback control in the brain-pituitary-gonadal axis throughout the reproductive cycle (Yadetie et al., 1999). The gonad development, steroidogenesis and ovulation is controlled by the pituitary gonadotropins FSH (GTH-I) and LH (GTH-II) hormones (Yadetie and Male, 2002). Few studies have been reported that, FSH mediated vitellogenesis and spermatogenesis, where LH initiated final maturation of oocyte and spermination in fishes (Choi et al., 2010). It is reported that estradiol-17β (E2) has a positive feedback control on LH and a negative feedback control on FSH levels in immature or juvenile salmonids (Yadetie and Male, 2002).

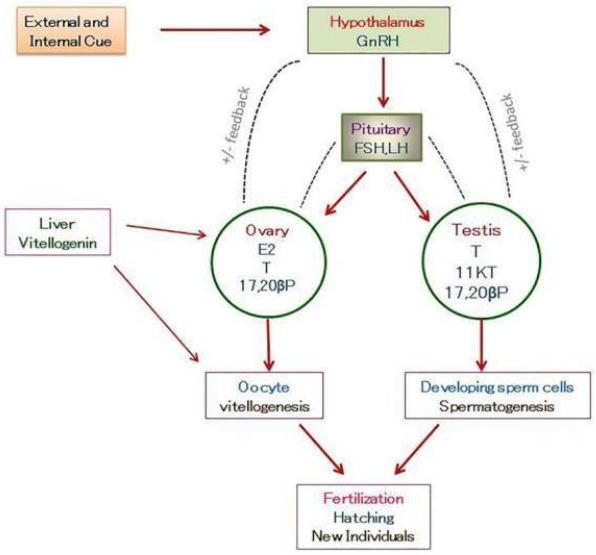

Figure: Schematic presentation of brain-pituitary-gonadal axis in the regulation of fish reproduction.

III. CONCLUSION

The research of reproductive biology of fish is crucial topic for better conservation and fishery management. The annual reproductive cycle of gonads is divided into several stages including different phases and the division is primarily based on the condition of maturity of the gonad. The reproductive cycle of most of the fishes especially carp comprises of different sequential events in the gonads depending upon the regulatory system and environmental cues. Mainly, on the basis of germ cell pattern of gonad, the annual reproductive cycle is divided into four different phases: Preparatory, pre-spawning, spawning and post-spawning phases. Each reproductive phase comprises specific characteristic feature and timing is the most important for specific phases. The timing of different reproductive phases in an annual cycle in any seasonally breeding animal, including fish, is very acute for a species and the success of reproduction is dependent on the maximum survival of the offspring. Gomadosomatic index (GSI) is another important parameter to know the reproductive status as well as breed periodicity of a fish species. The highest value of GSI is indicated that peak reproductive season in any fish species. Determination of fecundity is essential tool for studies of population dynamic and life history of fishes. Fecundity of organisms fluctuates from species to species due to the environmental conditions, length, age and genetic potential. The reproductive activities in all vertebrates are under controlled by brain-pituitary- gonadal axis. Most of the hormones such as 17-β estradiol, testosterone, FSH and LH plays an important role for hormonal balance through neuroendocrine feedback control mechanism.

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