Post-Graduate Degree Programme (CBCS)
in
ZOOLOGY

SEMESTER-IV

SOFT CORE THEORY PAPER

AQUACULTURE TECHNOLOGY
ZDSE(MN)T-410

SELF LEARNING MATERIAL

DIRECTORATE OF OPEN AND DISTANCE LEARNING
UNIVERSITY OF KALYANI
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Director's Message

Satisfying the varied needs of distance learners, overcoming the obstacle of distance and reaching the unreached students are the threefold functions catered by Open and Distance Learning (ODL) systems. The onus lies on writers, editors, production professionals and other personnel involved in the process to overcome the challenges inherent to curriculum design and production of relevant Self Learning Materials (SLMs). At the University of Kalyani, a dedicated team under the able guidance of the Hon'ble Vice-Chancellorhas invested its best efforts, professionally and in keeping with the demands of Post Graduate CBCS Programmes in Distance Mode to devise a self-sufficient curriculum for each course offered by the Directorate of Open and Distance Learning (DODL), University of Kalyani.

Development of printed SLMs for students admitted to the DODL within a limited time to cater to the academic requirements of the Course as per standards set by Distance Education Bureau of the University Grants Commission, New Delhi, India under Open and Distance Mode UGC Regulations, 2020 had been our endeavour. We are happy to have achieved our goal.

Utmost care and precision have been ensured in the development of the SLMs, making them useful to the learners, besides avoiding errors as far as practicable. Further suggestions from the stakeholders in this would be welcome.

During the production-process of the SLMs, the team continuously received positive stimulations and feedback from Professor (Dr.) Amalendu Bhunia, Hon'ble Vice- Chancellor, University of Kalyani, who kindly accorded directions, encouragements and suggestions, offered constructive criticism to develop it within proper requirements. We gracefully, acknowledge his inspiration and guidance.

Sincere gratitude is due to the respective chairpersons as well as each and every member of PGBOS (DODL), University of Kalyani. Heartfelt thanks are also due to the Course Writers-faculty members at the DODL, subject-experts serving at University Post Graduate departments and also to the authors and academicians whose academic contributions have enriched the SLMs. We humbly acknowledge their valuable academic contributions. I would especially like to convey gratitude to all other University dignitaries and personnel involved either at the conceptual or operational level of the DODL of University of Kalyani.

Their persistent and coordinated efforts have resulted in the compilation of comprehensive, learner-friendly, flexible texts that meet the curriculum requirements of the Post Graduate Programme through Distance Mode.

All the Self Learning Materials are self-writing and collected from e-book, journals and websites.

Director
Directorate of Open and Distance Learning
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SOFT CORE THEORY PAPER (ZDSE(MN)T -410)

AQUACULTURE TECHNOLOGY

Module	Unit	Content	Credit	Page No.
ZDSE(MN)T -410 (AQUACULTURE TECHNOLOGY)	I	Stock Improvement: Induced breeding and bundh breeding, sex reversal and sterility, Selective breeding, Androgenesis and Gynogenesis, Polyploidy, Hybridization, Shell fish reproduction: Endocrine control of reproduction, role of neurotransmitters.	**2**	
	II	Non-conventional aquaculture technology: Raceways and recirculatory system, Cages and pen culture, Wastewater aquaculture Organic aquaculture, Aquaponics and hydroponics, Biofloc culture.		
	III	Pheromones and reproductive behaviour, parental care. Regulation of seasonal reproduction: Role of environment (photoperiod, temperature, rainfall), Role of hypothalamo-hypophyseal system and pineal gland, role of peripheral endocrine system.		
	IV	Physiology of fish migration and behavior: Behavioral response to the environment. Circadian rhythm. Hormones in communications, pheromones, concept on fish behavior and regulatory mechanism		
	V	Coastal aquaculture: Status of coastal aquaculture in India,		

		Culture of prawn: major cultivable species, techniques of larval rearing, growout technology.		
	VI	*Culture of shrimp*: major cultivable species, Reproduction and rearing Grow out of shrimp		
	Total counselling session hrs.			

Unit I

Stock Improvement: Induced breeding and bundh breeding, sex reversal and sterility, Selective breeding, Androgenesis and Gynogenesis, Polyploidy, Hybridization, Shell fish reproduction: Endocrine control of reproduction, role of neurotransmitters

Objective: In this unit we will discuss about induced breeding and bundh breeding, sex reversal and sterility, Selective breeding, Androgenesis and Gynogenesis, Polyploidy, Hybridization, Shell fish reproduction: Endocrine control of reproduction, role of neurotransmitters.

Induced Breeding

Introduction:

The technique of induced breeding was first evolved in Argentina after producing pituitary extract by B. A. Hussay in 1930. Brazilian was the first country to develop a technique for hypophysation in 1934.In India, first attempt to induce breeding was made by Hamid khan in 1937 on Cirrhinus mrigala. Hiralal Choudhary applied this technique in minor carps like *Esomus danricus* in 1955.

What Is Induced Breeding?

Induced breeding is a technique where by ripe fish breeders are stimulated by pituitary hormone or any other synthetic hormone introduction to breed in captive condition. Then the carps being excited lay eggs in the pond water and the process is called induced breeding. This process of breeding is also known as hypophysation. Major carps are most important species from the point of view of their high food and nutritive values. Hence, they have kept attention of scientists and aqua farmers. They have peculiar habit of breeding in running waters of rivers and streams where they have large space for movement

Principle:

Environmental Factors

↓

Brain

↓

Hypothalamus

(Releasing Hormone)

↓
Pituitary Gland
(Gonado Tropic Hormone (FSH & LH))
↓
Gonads
(Gonadotrophic Hormones)
↓
Gamets
(Spawning)

1. Collection of Pituitary Extract:

Collection of the pituitary gland from freshly killed fishes is preferable. But it has been observed that the pituitary glands taken from five to eight days old ice-preserved fishes have also given successful results. The pituitary glands can be taken out from the posterior end of the cranium through the foramen magnum after cleaning the brain tissue. After the collection of the pituitary glands are kept in absolute alcohol for dehydration. After 24 hours, the alcohol is changed for further dehydration and de fattening. The glands are then weighed and preserve in fresh alcohol in dark-colored phials. It may be stored at room temperature or in a refrigerator. At the time of injection to carps for the induced breeding, the required quantity of pi tuitary glands are taken out of the phials and the alcohol is allowed to evaporate. The glands are then macerated with a tissue homogenizer either in distilled water or 0.3percent of saline water The gland suspension is then centrifuged and the supernatant fluid is drawn into a hypodermic syringe for the injection

2. Selection of Breeders:

Medium sized fully ripe and healthy fish of around 2 to 4 years of age is preferred for induced breeding. The weight should be 1 to 5 kg. Healthy male and female breeders should be identified and netted out before the breeding season and should be kept in spawning pools.

3. Method of Injection:

During the rainy season or cloudy, the extract of the pituitary gland of the same species which is prepared on the above said scientific process is injected in the muscle of the matured carps. Just before evening, per one female with two males of the approximate same body weight are to be injected the pituitary extract by hypodermic syringe. In case of male carps, the pituitary extracts are introduced once and in case of female carps it is introduced twice. At first, at the rate of 2 to 3 mg of pituitary extract per kg of body weight is introduced in the muscle of the caudal peduncle or near the dorsal fin of the female carp. The needle of the syringe is to be introduced between the scales but with an angle of 45° with the body. After six hours of first injection, the second injection is given to the same female at the rate of 5 to 8 mg of pituitary extract per kg of body weight. There is no need of injecting dose to the male breeder if it in a state of milt oozing.

4. Synthetic Hormones:

HCG (human chorionic gonadotropin hormone), Synahorin, Ovatide, Ovaprim. It is the new inducing hormone for fish and absolute substitute of pituitary extract though it's costly. Ovaprim is far superior to carp pituitary in inducing spawning in several species of carps. These synthetic drugs are better than the pituitary extract and easier to administrate. Only single dose injection is enough to induced craps.

5. Spawning

Then the carps, one female and two males are placed in a breeding hapa for spawning. Inside of the breeding hapa both the female and male carps are excited. After the excitation the female carps lays eggs. The eggs are externally fertilized by the spermatozoa(milt)that are discharged by the males.

6. Spawning Hapa

Hapa for larger fishes its size is 8′ x 3′ x 3′, but for the smaller fishes it is 5'x 3'x 3′.It isheld on four bamboo poles, one at each corner of the rectangular case. After that all the fishes are removed from the breeding hapa and then the eggs are collected by a net and are transferred to the inner part of the hatching hapa. After 14 to 18 hours, the spawns enter into the outer hapa and the induced breeding process completed. Then the spawns are collected from the outer hapa and transferred to the pond for nursery.

- ## Precautions for Induce Breeding

(1) To avoid diseases and parasitic infections,

(2) Breeders should be properly washed with $KMnO_4$ solution for a few minutes.

(3) Breeder should be protected from mechanical injuries during handling.

(4) Water condition should be favourable having temperature about 24 to 31°C and turbidity about 100 to 1000 ppm.

5)Flowing water with higher O_2 content is of great use.

(6) The intensity and duration of light also affect the induced breeding and spawning. Pituitary glands taken from the same or related species as the recipient species are said to be more effective.

- ## Advantages of Induced Breeding

i) A pure spawn of a desired species is made available. The spawn obtained from the rivers are not pure. They are mixed with the spawns of other species and sorting of pure seed from the mixed spawn is not possible.

ii) Desired species of carps can be cultured through the induced breeding.

iii) Large numbers of eggs are available from a fish through induced breeding.

iv) In the same season, a carp can be induced to breed more than once.

v) Transportation cost becomes very low as the carps can be breed in any desired pond.

vi) Between the different species of fishes hybridization can be done and it is possible to get hybrid variety of fishes.

Bundh Breeding

Bundh is a type of perennial and seasonal tank or impoundment where riverine conditions are simulated and where major carps are known to breed. After a heavy shower, the bundhs receive large quantity of rain water with washings from their catchment areas and provide large shallow areas that serve as spawning grounds for the fishes. The first bundh (dry bundh) was set up in Madhya Pradesh at Sonar Talliya in 1958. After this, persistent expansion of bundhs had taken place due to its simplicity of operation and high rate of success.

Types of bundhs

The bundhs are of two types viz. wet and dry bundhs.

1. **Wet bundhs**

These are also known as perennial bundhs. The wet bundh is a perennial pond located on the slope of a vast catchment area of undulating terrain with proper embankments having an inlet facing towards the upland and an outlet towards the opposite lower ends. During summer, only the deeper portion of the pond retains water containing breeders. The remaining portion is dry and is used for agriculture.

After a heavy rain a major portion of the bundh gets submerged with water flowing in the form of streamlets from the catchment area and excess water flows out through the outlet. The fish starts spawning in such a stimulated natural condition in the shallow areas of a bundh.

The outlet is protected by fencing to prevent the escape of breeders. The wet bundhs are comparatively much bigger in size than the dry bundhs. These are also known as perennial bundhs.

2. **Dry bundhs**

A dry bundh is a shallow depression enclosed by an earthen wall, which is locally known as a bundh. on three sides, and an extensive catchment area on the fourth. Bundhs get flooded during the monsoon, but remain completely dry for a considerable period during the remaining part of the year. These are seasonal rainfed water bodies, and are also known as seasonal bundhs. The topography of the land has a great role to play in the location and distribution of the dry bundhs. It is preferred to have undulated land because it provides a large catchment area and facilitates quick filling of the bundh even with a less rain, at the same time quick and easy drainage due to gravitation. In West Bengal, a catchment area of more than five times the bundh area is considered most suitable (Saha, 1977), whereas in Madhya Pradesh a ratio of 1:2.5 is considered essential (Dubey and

Tuli, 1961). In Bankura district of West Bengal, most of the dry bundhs are fed with water from storage tanks, constructed in the upland area.

Bundh breeding being practiced since a century, has been given a greater importance. Since last three decades particularly after it has been reviewed in Madhya Pradesh, it has gained importance to such an extent that in some of the states like West Bengal, Rajasthan and Andhra Pradesh, besides rivers, the contribution of spawn production from bundhs is quite significant, particularly the spawn from dry bundhs as this source yields 100% pure spawn. It is known for its simplicity and mass production at one time.

Site selection

The efficiency of the bundhs depends on many factors. The following criteria may be kept in mind when designing bundhs for fish breeding.

1. Extensive upland area from where, with heavy rains, considerable amount of rain water carrying soil and detritus enters the main pond.

2. The pond should have extensive shallow marginal areas which serve as ideal spawning grounds.

3. The soil should be of gritty nature which is considered to be the most suitable for the breeding of fishes.

4. Increase in oxygen contents of water which is due to the vast and shallow area of the pond.

The land should provide a place where a good-sized pond can be made with a small dam. The place with a flat area surrounded on three sides by steep slopes should be selected. The fourth side, where the area drains out, should be as narrow as possible. The side slopes should constrict to shorten this up the construction area or axis of the dam.

Catchment area

A water shed with more than fifteen hectares of hard land for every hectare of water surface in the pond is considered essential. If the soil is retentive in nature, then forty hectares of watershed for each hectare of surface water is a better proposition. The fields must not erode. If the water shed is found either too big or too small even then it may be possible to correct the situation by using diversion terraces. .If water is more, excess watershed may often be cut off and the water disposed off elsewhere. If more water is needed, a diversion terrace will increase the effective water shed.

Embankment

The embankment must be constructed at the low-level side. The slopes must be built on each side of the dam. On the lower side the slope should be 20%, i.e., two feet on horizontal distance for each foot of vertical rise. The upper or pond side slope requires more attention. If the fill material has a very high proportion of clay, it may safely be built to the 2 to 1 dimension. If it is loamy or silty or with any sand or gravel in it. this slope should be broadened out to 3 to 1. For one hectare pond, a minimum of 4 feet width is desired at the top and a free board of 2 feet is essential.

A spillway and sluice are a must in the bundhs also. The spillway or flood outlet is a surface drainage way that will carry surplus water during heavy rains. Without this, the whole dam may be lost by overlapping in some sudden monsoon cloudburst. It must be placed around one end of the dam in hard ground. When required the pond can be emptied completely with the help of sluice gates. Spillway and sluice should be provided with strong iron netting, so that the fishes may not escape from the breeding bundh.

Factors responsible for spawning

i. Heavy monsoon and flood are the primary factors responsible for spawning of Indian major carps.

ii. The strong current is necessary to influence the breeding intensity of carps.

iii. Low depth of water is quite sufficient for fish breeding.

iv. Molecular pressure of water particles and silt on the body of natural breeders has a stimulating effect for spawning in conjunction with rising temperature.

v. Monsoon floods from the hills, having a peculiar smell, specific chemicals and physical properties, were responsible for breeding of fishes in the bundhs.

vi. The availability of shallow ground was also considered to be a factor for spawning

vii. Temperature has no specific influence on spawning, but cloudy days accompanied by thunder storm and rain seems to influence the spawning.

viii. pH and oxygen content of water do not influence spawning in fishes.

ix. Bundhs having highly turbid waters with a distinct red colour, low pH between 6.2-7.6, 5-8 ppm of dissolved oxygen, low total alkalinity and 27-290 C temperature provide favourable conditions for spawning in bundhs.

Fish breeding techniques

Rohu, catla, mrigal, common carp, silver carp and grass carps are used to breed in bundhs. 100% pure seed can be produced in bundhs. Besides, more seed can be produced at a time. Once the bundhs are constructed, they can be used for many years to get more profits.

The brooders are collected in May and stocked in storage tanks where they are kept sex wise till the first monsoon showers. As soon as water accumulates in the bundhs, a selected number of these breeders are introduced into these bundhs and a constant vigil is maintained. In the earlier days no importance was given to maturity, sex ratio, etc. The techniques were improved later and the breeding was done with a better understanding of sex, ratio and number of breeders. Fully ripe females and males 1:2 in number and of 1:1 weight was introduced into the bundhs on rainy days. Successive spawning could also be achieved as many as 5 times in one season.

In the modern techniques few pairs of females and males are being injected with either pituitary, or HCG or ovaprim extract and are released in the bundhs. This process, "sympathetic breeding in dry bundhs" has been used in West Bengal. By this method of partial hypophysation all the limiting factors for spawning like rain, thunder, storm and current of water can be bypassed. It is reported that about 160-200 million spawns of major carps have been produced.

Fish in bundhs generally commence to breed during the early hours of the morning and continue to breed throughout the day. Catla prefer deeper waters, when compared to rohu or mrigal, which breed in shallow waters varying in depth from 0.5-1 metre. In wet bundhs, the brooder stock may be maintained throughout the year or replenished prior to the monsoons. The brooders are generally not injected with pituitary extracts but are stimulated to breed due to the current of rainwater from the catchment area, like in the case of dry bundh breeding,

Collection and handling of eggs

As soon as breeding commences, arrangements for collection and hatching of eggs are made. The eggs are collected by pieces of nylon net or mosquito netting, cloth or gamcha after lowering the water level and hatched in the double walled hatching hapas, ordinarily fixed in the bundhs. Collection of all the eggs is impossible, especially in case of wet bundhs, due to its larger areas. About 70% of eggs can be collected from the bundhs. In Madhya Pradesh, the hatching of eggs is carried out either in double-walled hatching hapas fixed in the bundh itself or in rectangular cement hatcheries measuring 2.4 x 1.2 xO.3 m. However, in West Bengal, the eggs are kept for hatching in specially dug out small earthen pits with mud plastered walls. The hatchlings are lifted from the pits by dragging muslin cloth pieces after 12 hours of hatching and are transferred to similarly prepared bigger earthen pits. The survival rate is about 35-40% in the hapas. It can be increased to 97% by using modern hatcheries.

Improved features of dry bundhs

The dry bundhs can be improved keeping in view the following points:

1. Selecting shallow sloping depressions and undulating terrain of sandy soils with maximum catchment areas
2. Constructing a small earthen bundh at the far end of the depression opposite to the catchment area so that water could be retained for a certain period. A maximum depth of 2 meters of water is maintained in the bundhs and a fine meshed wire netting protects any overflow water.
3. Since major carps generally breed almost at any place in the shallow bundhs, it may be advantageous to prepare spawning grounds at different levels so as to get them flooded at different water levels in the bundh. But, it is necessary to have the spawning ground away from the direction of the current.

4. A few storage tanks, cement cisternae or earthen ponds can also be provftfed adjacent to the bundhs to store the breeders temporarily prior to their introduction in the bundh.
5. Constructing a battery of 10-20 rectangular cement hatcheries measuring 2.4 x 2 x0.3m.
6. Constructing a small double storied building which could serve as an observation tower cum store cum shelter.

Sex reversal and sterility

Sex reversal is a redirection of sexual phenotype during embryonic development. Most aspects of sexual phenotype, including sex ducts and genitalia, depend on the presence of steroid hormones produced by the testis or ovary. The testis or ovary fate of the gonad is decided through a process called sex determination.

In aquaculture exogenous steroids given during the gonadal development period can control the phenotype overriding the expression of the genotypically determined sex. This process is commonly referred to as sex reversal. Androgens direct the development to males and estrogens to females.

Selective breeding

Selective breeding is a breeding programme that tries to improve the breeding value of the population by selecting and mating only the best fish (largest, heaviest, those with the desired colour, etc.) in the hope that the select brood fish will be able to transmit their superiority to their offspring. If this occurs, the next generation will be more valuable because the fish will grow faster, which will increase yields; the fish will grow more efficiently, which will lower feed costs; or all fish will have a more desired body colour, which will increase their market value.

all breeding approaches that can be used to improve yields are important and although they can be used either singly or in combination to achieve specific goals, this manual will describe only those procedures that can be used to improve fish by selective breeding.

The decision to conduct a selective breeding programme is a decision that must be made for each farmer or each fry/fingerling production center on a case-by-case basis. The decision to incorporate selective breeding into a farmer's work plan should not be a general decision made at a regional level. If it is, most of the selective breeding programmes will be failures, because selective breeding programmes require dedication, a certain level of sophistication, record keeping, and the investment of extra labour. Additionally, selective breeding programmes are not free; they also require the investment of money. Finally, these programmes usually do not produce immediate improvements. Improvements are usually not seen for at least one growing season, so a farmer must be able to incorporate long-term planning into his farm management programme, and he must be patient. As a result, within a region, only a small percentage of farmers or fingerling production centers should or will ever conduct selective breeding programmes.

Finally, common sense must prevail when choosing the most appropriate breeding programme. Even if a farmer has the ability and the desire to conduct a selective breeding programme, the biology of the species and the way it is grown should be carefully considered before the decision is made to conduct a selective breeding programme to improve growth rate. Even though most farmers would like to have faster-growing fish, in some cases greater yields can be achieved by improving other phenotypes via another type of breeding programme. For example, the biggest problem in tilapia culture is the fact that tilapia become sexually mature before they reach market size and, as a result, reproduce in the grow-out ponds. This uncontrolled reproduction means that a significant percentage of yield is unmarketable. Tilapia farmers may benefit from breeding programmes that can produce monosex male populations far more than from selective breeding programmes that might improve growth rate.

Androgenesis and Gynogenesis

- Androgenesis is a method for producing fish in which all the nuclear genetic information originates from the male parent (i.e., from the sperm) while the mitochondrial DNA is still maternally derived. Androgenesis is induced by gamma or ultra-violet (UV) irradiation of the egg to inactivate chromosomal DNA followed by fertilization with normal sperm. This results in a haploid zygote containing a single chromosome set. The normal diploid state is restored by applying pressure or temperature shock at the first cleavage division so as to duplicate the haploid set and restore the diploid condition. This procedure has been accomplished in only a few laboratories to date, e.g., in rainbow trout (Onozato 1992; Parsons and Thorgaard 1985) and amago salmon (*Oncorhynchus rhodurus*) (Onozato 1993). Recently, Thorgaard et al. (1990) used diploid sperm from tetraploid rainbow trout to fertilize gamma-irradiated ova, thus obviating the need for pressure shock treatment to suppress the first cleavage division. Survival of these androgenetic diploids was much better than those produced using haploid sperm. Fused sperm have also been used to produce diploid androgenetic rainbow trout (Araki et al. 1994). Potential uses of androgenesis include the regeneration of stocks from cryopreserved sperm, the development of identical groups of fish (*see* below), and the production of YY males for the production of monosex male salmonid stocks.
- Gynogenesis is a special form of sexual reproduction in which insemination is necessary but the head of the sperm penetrating into the ovum does not transform into male pronucleus; and the gynogenetic embryo develops at the expense of the ovum nucleus only. Consequently, the gynogenetic offspring are all females identical to the

mother. Reproduction of gynogenetic forms takes place when gynogenetic females' mate with males of the bisexual form of the same and related species.

Gynogenesis cannot be regarded as usual fecundation which is characterized by amphimixis. It is not identical with parthenogenesis either, though very close to it. Brachet (1917) wrote that gynogenesis was a bridge built by nature connecting fecundation with natural parthenogenesis.

Gynogenesis was first found in some species of free-living nematodes. It is now known to exist also in some other worms, insects, fish and amphibians. Most cases of natural gynogenesis were discovered in the past ten years. Natural gynogenesis occurs more often than believed, though compared to parthenogenesis it is extremely rare.

Two cases of natural gynogenesis are known in fish, namely in *Carassius auratus* (Cyprinidae) and in live-bearing *Mollienesia formosa* (Cyprinodontidae); of which the gynogenesis of *C. auratus* has been studied more thoroughly because of its importance in the artificial rearing of this species.

Application of Gynogenesis:

i. In female homogametic species all female population is produced,
ii. 50 to 100% inbred individuals can be produced in a single generation.
iii. This is useful for the production of female or mono sex exotic species for release into the natural environment without risk of reproduction.
iv. Combining gynogenesis and sex reversal it is possible to produce males with female genotype.

Polyploidy

A promising biotechnological tool for increased production of food from aquaculture and creation of sterile organisms is polyploidy. Polyploidy refers to a genetic state that can be produced artificially in fish and shellfish through manipulation of embryos. Polyploid individuals have extra sets of chromosomes beyond the normal 2, with triploids having 3 and tetraploids having 4. Although it is a lethal state for mammals and birds, polyploidy has shown some promising results in the field of aquaculture.

- Triploid fish and shellfish are viable and tend to be sterile due to a lack of gonadal development. This sterility allows for reproductive energy to be diverted toward somatic growth, resulting in higher growth rates for some triploid individuals.
- Although triploidy has been highly effective for enhancing growth in shellfish, results thus far in fish have shown variable, conflicting results, with reports of triploid fish growing slower, at the same rate, or faster than diploids.

- When meiotic phase II is inhibited after insemination of a normal egg with a normal sperm, the female nucleus with 2 sets of chromosomes and male nucleus with one set of chromosomes combine, yielding a triploid with 3 sets of chromosomes, while if the first cleavage is inhibited, a tetraploid with 4 sets of chromosomes by chromosome replication can be obtained.
- In polyploidy plant that contains more sets of chromosomes the plant itself or the fruits become larger, and the same phenomenon can be expected in animals. But in fish, the tendency to become large according to polyploidization and each volume is in proportion to ploidy. Therefore, these traits can be used to identify the ploidy.
- The triploid condition often causes sterility. Reproductive organs of normal aquatic organisms are large often accounting for more than 30% of the gross weight. Therefore, if sterilization by triploidization can be achieved, the energy used for formation of these reproductive organs can be applied to body growth.
- Sterile triploids of exotic species could be safely used where the introduction of such exotic species could otherwise lead to competition with native fish and suppression of the later.
- The induction of triploidy is a very useful technique to regulate and control populations of uncontrolled breeding species like tilapias, and the grass carp, which had been introduced into the exotic habitats. One such example is the introduction of grass carps into the reservoirs of the USA to reduce unwanted growth of macrophytes.
- Induction of triploidy basically involves applying shock treatment by heat, cold, pressure or chemicals to eggs soon after the sperm entry when the eggs are about to undergo the mitotic phase of meiosis.
- The shock treatment suppresses the separation of sister chromatids (anaphase II) thereby preventing the second polar body formation inducing the diploid condition instead of maintaining the haploid. With subsequent fusion of the diploid egg and haploid spermatozoa a triploid zygote result.
- The gonad of a triploid male is generally less developed than that of a diploid male. Spermiogenesis of triploids is disturbed by the irregular pairing of the three sets of chromosomes and if spermatogonia develop, they are aneuploid.
- Triploid females have under developed ovaries, resulting in a much higher carcass index than diploid females. Maturation is completely suppressed. Triploid males have partially developed testes and also a good carcass index.
- In the course of sexual maturation, triploids (especially females) of numerous species have shown to excel diploids in growth and some taste characteristics. Triploid individuals are expected to be functionally and endocrinologically

sterile due to their meiotic inhibition of gametogenesis and lack essential steroid hormones to support gonadal growth.

Hybridization

It is the technique of breeding of fishes between two species or genera which ordinarily do not breed.

- **Hybridisation in nature:**

Most fishes release their eggs and sperms in water and fertilisation are external. Fish hybridizes more frequently than tetrapodes so fertilization of closely related species which leaves in same water bodies, are common. Reservoir is the most important area where natural hybridization occurs frequently than rivers, because the area is not too large as rivers and scarcity of certain species with preponderance of others. Naturally hybridized fishes are found in following families – Esocidae, Catastomidae, Cyprinidae, Salmonidae, Poecillidae etc of about 56 families.

- **Technique of Hybridization:**

The hybridization is done actually by inducing the virgin fishes or small aged group fishes. The hybridized fish possess intermediate character of two species. This type of hybridization is also known as diploid hybridization. These hybridized fishes are capable to produce new fish up to F2 progeny. Inter specific and inter generic both type of hybridization is done in India.

Inter specific hybridization – Inter specific hybrids are generally producing by mating between two different species in same genus. In India mating female kalbasu and *Labeo rohita* is highly successful. Over 94% fertilisation was obtained. The growth rates of hybrids are superior to the parent Kalbasu. It attains maturity in two years. The hybrids also can be bred by hypophysation and can be obtained F2 generation. However, the fishes are selected by following process –

The brooders are selected in first maturity generally virgin.

One pair of males (rohu) and one pair of females are injected to induce them prior to breeding by hypophysation technique.

The breeders are kept separated for some times and then they are released in breeding hapa with suitable breeding conditions.

Endocrine control of reproduction

- **Endocrine Glands of Fish**

The glands that secrete their products into the bloodstream and body tissues along with the central nervous system to control and regulate many kinds of body functions are known as endocrine gland. In fishes various endocrine gland has been found associated with different tasks and functions.

Endocrine glands of fishes: Different types of endocrine glands are found in fishes; such as-

i. The pituitary gland or Hypophysis
ii. Thyroid Gland
iii. Adrenal gland
iv. Corpuscles of Stannius
v. Ultimobranchial Glands
vi. Urohypophysis
vii. Pancreatic islets
viii. Pineal gland

Fishes synthesize LH and FSH from anterior pituitary under the control of hypothalamus GnRHs to regulate early gametogenesis, steroidogenesis and ovulation/spermiation. Hence, puberty is governed by GnRH and certain gonadal steroids. GnRH release is controlled by several neurotransmitters and neuropeptides.

Role of neurotransmitters

Neurotransmitters are chemical messengers that your body can't function without. Their job is to carry chemical signals ("messages") from one neuron (nerve cell) to the next target cell. The next target cell can be another nerve cell, a muscle cell or a gland. Both glutamate and gamma-aminobutyric acid (GABA) are involved in pituitary hormone release in fish. Glutamate serves 2 purposes, both as a neurotransmitter and as a precursor for GABA synthesis.

Probable Questions:

1. Hypophysation Techniques2.Methodof Injectionin Major carps3.Advantagesof
2. Induced Breeding
3. What is bundh breeding?
4. Mention the types of bundhs in bundh breeding
5. What is wet bundhs?
6. Write any two advantages of bundh breeding.
7. Mention any two disadvantages of bundh breeding
8. Describe the wet and dry bundh breeding.
9. Explain the fish breeding techniques and factors responsible for spawning in bundh breeding
10. What is gynogenesis?

Suggested reading:

1. Nihar Ranjan Chattopadhyay: Induced Fish Breeding: A Practical Guide forHatcheries.
2. A Text Book of Fish Biology &Fisheries. By S S Khanna and H R Singh
3. FisheriesScience. Author, R. Santhanam
4. https://courseware.cutm.ac.in/wp-content/uploads/2020/06/session-5-1.pdf
5. Bardach, J. E. and Ryther, J. H. (1972). *Aquaculture*. John Wiley and Sons.
6. Beaumont, A. R. and Hoare, K. (2003). *Biotechnology and Genetics in Fisheries and Aquaculture*. Blackwell Publishing.
7. Jhingran, V. G. (1991). *Fish and Fisheries of India*.3rd ed. Hindusthan Pub. Corp. John Wiley and Sons.
8. Pillay, T. V. R. and Kutty, M. N. (2005). Aquaculture Principles and Practices. 2nd ed. Blackwell Publishing Ltd.
9. Chakraborti, N.M.; Chakraborty, P. P. and Mandal, S. C. (2010). *Biology, Breeding and Farming of Important Food Fishes.* Narendra Publishing House. New Delhi.

Unit II

Non-conventional aquaculture technology: Raceways and recirculatory system, Cages and pen culture, Wastewater aquaculture Organic aquaculture, Aquaponics and hydroponics, Biofloc culture

Objective: In this unit we will discuss about non-conventional aquaculture technology like Raceways and recirculatory system, Cages and pen culture, Wastewater aquaculture Organic aquaculture, Aquaponics and hydroponics, Biofloc culture.

Introduction

A **raceway**, also known as a flow-through system, is an artificial channel used in aquaculture to culture aquatic organisms. Raceway systems are among the earliest methods used for inland aquaculture. A raceway usually consists of rectangular basins or canals constructed of concrete and equipped with an inlet and outlet. A continuous water flow-through is maintained to provide the required level of water quality, which allows animals to be cultured at higher densities within the raceway.

A raceway in its simplest form is just a flume for carrying water. Raceways for fish culture are tanks which are relatively shallow and rely on a high-water flow in proportion to their volume in order to sustain aquatic life. Flow-through fish culture systems pass water through the systems once, provide waste treatment as required, and then discharge the water rather than treating and recirculating it. For successful aquaculture, the inflowing water must be within the temperature tolerance of the species being cultured and should match the optimal temperature for the target species as closely as possible. Oxygen is also provided by the incoming water and is removed by the fish as the water progresses down the raceway. In most raceway systems, dissolved oxygen is replenished by allowing the water to fall into subsequent tanks within the raceway. Dissolved metabolites from animals in the system are carried out in the effluent, while settleable particulate wastes can be captured by settling or less frequently by other means of filtration. Depending on the water chemistry, the depletion of oxygen and the accumulation of ammonia, carbon dioxide, or fine particulates can eventually become limiting to fish production within the system. No natural foods are generated in these systems, and nutritionally complete diets are an essential requirement for successful raceway aquaculture. Flow-through aquaculture systems require water exchange to maintain suitable water quality for fish production and rely on water flow for the collection and removal of metabolic wastes. Water for flow-through facilities is usually diverted from streams, springs, or artesian wells to flow through the farm by gravity. Water pumped from wells or other sources is more expensive and is seldom used. Water diverted from springs or surface sources for flow-through aquaculture is regulated by various public agencies, depending on the specific water laws of each state.

Flow-through systems are the most commonly used aquaculture production systems for the culture of rainbow trout Oncorhynchus mykiss and other salmonids in the United States. Other cold water fish species produced in flow-through systems include brook trout Salvelinus fontinalis and brown trout Salmo trutta. Flow-through systems are used for production of freshwater stages of salmon. Flow-through systems are also used on a limited scale for the production of warmwater fish such as catfish *Ictalurus* spp. and tilapia Oreochromis spp. Recently, flow-through systems have been used to produce cool water species such as yellow perch *Perca flavescens*, hybrid striped bass *Morone* spp., and several species of sturgeon Acipenser spp. Flow-through systems include linear earthen and concrete raceways and tanks constructed from other materials. Concrete raceways are the most common. Circular rearing tanks are also used in flow-through systems, most commonly for brood stock production. The typical raceway production system consists of a tank (rearing unit) or a series of rectangular tanks with water flow along the long axis. In an ideal raceway, water flow will approximate plug flow with uniform water velocity across the tank cross section.

However, friction losses at the tank-water and air-water boundary layers will cause water velocities to vary across the width and depth of the raceway. Greatest water velocities are at mid-depth, with slightly reduced velocities at the air-water interface and greatly reduced velocities along the raceway bottom. A defining characteristic of linear-pass raceways is a water quality gradient from the inflow to the out flow of the rearing unit during production, with best water quality at the inflow and deteriorating water quality along the length of the raceway as water flows toward the outlet. Circular rearing units are more thoroughly mixed and have relatively uniform environmental conditions throughout the tank.

- **Advantages of Raceway**

i. Per unit of space, raceway production is much higher.

ii. Raceways also offer a much greater ability to observe the fish. This can make feeding more efficient, and disease problems are easier to detect and at earlier stages.

iii. If disease signs are observed, disease treatments in raceways are easier to apply and require fewer chemicals than a similar number of fish in a pond (due to the higher density in the raceway).

iv. Raceways also allow closer monitoring of growth and mortality and better inventory estimates than ponds.

v. Management inputs such as size grading are much more practicable in raceways than they are in ponds, and harvesting is also easier.

- **Disadvantages of Raceway**

i. The disadvantages of raceways are primarily related to their need for large constant flows of consistent, high-quality water. Since such resources are not common, locating and securing a proper water supply is a major consideration.
ii. Commercial viability often requires that the water gravity flows through a series of raceways before it is released. This adds a requirement for an elevation of the water source and suitable topography for the gravity flow between raceways.
iii. Another limitation compared to ponds is the release of effluent. While ponds largely process wastes within the culture systems, raceways, with their low retention times, do not.
iv. Effluent releases from raceways are a larger consideration than they are for ponds.

Recirculatory Aquaculture System (RAS)

Recirculatory Aquaculture System (RAS) is a technology where water is recycled and reused after mechanical and biological filtration and removal of suspended matter and metabolites. This method is used for high- density culture of various species of fish, utilizing minimum land area and water.

It is an intensive high density fish culture unlike other aquaculture production systems. Instead of the traditional method of growing fish outdoors in open ponds and raceways, in this system fish are typically reared in indoor/outdoor tanks in a controlled environment. Recirculating systems filter and clean the water by recycling it back to fish culture tanks. The technology is based on the use of mechanical and biological filters and the method can be used for any species grown in aquaculture. New water is added to the tanks only to make up for splash out, evaporation and that used to flush out waste materials. The reconditioned water circulates through the system and not more than 10% of the total water volume of the system is replaced daily. In order to compete economically and to efficiently use the substantial capital investment in the recirculation system, the fish farmer needs to grow as much fish as possible in the inbuilt capacity. The management of recirculating systems relies heavily on the quantity and quality of feed and the type of filtration. Numerous filter designs are used in recirculating systems, but the overall goal of all filtration is to remove metabolic wastes, excess nutrients, and solids from the water and provide good water quality for the aquatic organisms. It is important to consider all factors when designing and investing in aquaculture systems.

However, in order to encourage small-scale fish farmers and entrepreneurs and also to facilitate fish production in urban and semi-urban areas where land and water are scarce, it is proposed to promote Backyard Recirculation Aquaculture Systems.

- ## Advantage of RAS

  i. Extended durability of tanks and equipment
  ii. Reduced dependency on antibiotics and therapeutants hence, advantage of getting high quality fish.
  iii. Reduction of direct operational costs associated with feed, predator control and parasites.
  iv. Potentially eliminate release of parasites to recipient waters.
  v. Risk reduction due to climatic factors, disease and parasite impacts
  vi. RAS production can promote flexibility in terms of location for farming, proximity to market.
  vii. Enable production of a broad range of species irrespective of temperature requirements.
  viii. Feed management is considerably enhanced in RAS when feeding can be closely monitored for 24 hrs.
  ix. Exposure of stock to stress on RAS can be reduced for some factors such as adverse weather, unfavourable temperature conditions, external pollution and predation.
  x. Enable secure production of non-endemic species.

- **Disadvantage of RAS**

  i. Constant uninterrupted power supply is required if electric power fails than backup of electricity is required
  ii. Capital cost of starting a recirculating aquaculture system is high as compared to ponds and raceways.

Cages and pen culture

Today **cage culture** is receiving more attention by both researchers and commercial producers. Factors such as increasing consumption of fish, declining stocks of wild fishes and poor farm economy has increased interest in fish production in cages. Many small or limited resource farmers are looking for alternatives to traditional agricultural crops. Aquaculture appears to be a rapidly expanding industry and it offer opportunities even on a small scale. Cage culture also offers the farmer a chance to utilize existing water resources in which most cases have only limited use for other purposes.

The right choice of site contributes significantly in the success of cage farm. Site selection is vitally important since it can greatly influence economic viability by determining capital outlay, by affecting running costs, rate of production and mortality factors.

- Site selection is a key factor in any aquaculture operation, affecting both success and sustainability.
- Circular cages of different diameter ranging from 2 m to 15 m, designed for the culture of fishes such as milkfish, mullet, cobia, pompano, sea bass, pearl spot, shellfishes such as shrimps, crabs and lobsters were experimented and demonstrated successfully in India by Central Marine Fisheries Research Institute (CMFRI).
- Stocking of right sized fish juveniles in adequate stocking density is another factor which determines the success of farming. The stocking density and size of stocked fishes varies with different species.
- Proper feeding of quality feeds, periodic monitoring and cleaning of cages contributes immensely to the success of cage farming.
- With proper management of cage erected at an ideal location can yield a production of 20-40kg/m ^{3} with various species of fishes.

Cage aquaculture involves the growing of fishes in existing water resources while being enclosed in a net cage which allows free flow of water. It is an aquaculture production system made of a floating frame, net materials and mooring system (with rope, buoy, anchor etc.) with a round or square shape floating net to hold and culture large number of fishes and can be installed in reservoir, river, lake or sea. A catwalk and handrail is built around a battery of floating cages. There are 4 types of fish-rearing cages namely: i) Fixed cages, ii) Floating cages, iii) Submerged cages and iv) Submersible cages. Economically speaking, cage culture is a low impact farming practice with high returns and least carbon emission activity. Farming of fish in an existing water body removes one of the biggest constraints of fish farming on land, i.e., the need for a constant flow of clean, oxygenated water. Cage farms are positioned in a such way to utilize natural currents, which provide the fish with oxygen and other appropriate natural conditions.

- **Advantages of Cage culture**

Cage culture has advantages which include:

i. Many types of water resources can be used, including lakes, reservoirs, ponds, strip pits, streams and rivers which could otherwise not be harvested.

ii. A relatively low initial investment is required in an existing body of water.

iii. Harvesting is simplified.

iv. Observation and sampling of fish is simplified.

v. Allows the use of the pond for sport fishing or the culture of other species.

vi. Less manpower requirement.

vii. Generation of job opportunities for unemployed youth and women.

viii. Additional income to fishers during closed seasons.

- **Disadvantages of Cage culture**

Cage culture also has some distinct disadvantages. These include:

i. Feed must be nutritionally complete and kept fresh.

ii. Low Dissolved Oxygen Syndrome (LODOS) is an ever-present problem and may require mechanical aeration.

iii. Fouling of net cage.

iv. The incidence of disease can be high and diseases may spread rapidly.

v. Vandalism or poaching is a potential problem.

vi. Navigation issues.

vii. Accumulation of unused feed and excreta will lead to water pollution as well as eutrophication.

viii. Change in water quality parameters.

ix. Conflicts within the local community.

x. Predation by aquatic mammals and birds.

xi. Escapement.

xii. Overcrowding of aquatic organisms in cages.

Pen culture

Pen culture is defined as raising of fish in a volume of water enclosed on all sides except bottom, permitting the free circulation of water at least from one side. This system can be considered a hybrid between pond culture and cage culture. Mostly shallow regions along shores and banks of the lakes and reservoirs are used in making pen/enclosure using net/wooden materials where fish can be raised. In a fish pen, the bottom of the lake forms the bottom of the pen. Pen has the advantage of containing a benthic fauna which serves as food for the fish and polycultue can be practiced in pens as it is in ponds. The environment in fish pen is characterized by a free exchange of water with the enclosing water body and high dissolved oxygen concentrations.

Advantages:

a. Intensive utilization of available space: Stocking density can be increased compared to that of a pond culture system.

b. Safety from predators: Within the enclosure the predators can be excluded. In the larger pens this would be more difficult, but in smaller pens this can be done as efficiently.

c. Suitability for culturing many varied species: Due availability of more space and the natural water system

d. Ease of harvest: In the large pens the harvest may not be as easy as in cage rearing but it more controllable and easier than in the natural waters.

e. The flexibility of size and economy: When compared with the cage, pens can be made much larger and construction costs will be cheaper than that of the cages.

f. Availability of natural food and exchange of materials with the bottom: Since, the bottom of the pen is the natural bottom, the pen cultured organisms are at an advantage that they can procure food/exchange materials from the natural bottom.

Disadvantages:

a. High demand for oxygen and water flow

b. Dependence on artificial feed

c. Food losses: Part of the feed is likely to be lost uneaten, and drifted away in the current, but the loss here would be less than in floating cages.

d. Pollution: Since a large biomass of fish are cultured intensively a large quantity of excrements accumulate in the area and cause a high BOD - also substances such as ammonia and other excreted materials, if not immediately removed/ recycled. They pollute the water and cause damages.

e. Rapid spread of diseases: For the same reason of high stocking density in an enclosed area, any disease beginning will spread very quickly and can cause immense mortality of stock and production decline.

f. Risk of theft: Since the fish are kept in an enclosed area, 'poaching' and thefts can take place more frequently than in natural waters, but perhaps less than those from cages.

g. Conflict with multiple use of natural waters: In locations where a pen is constructed, if the water is used for multipurpose like irrigation and recreational activities, such as swimming, boating etc. may lead to conflicts.

Wastewater aquaculture

Wastewater reuse for aquaculture has been practiced in many countries for a considerable period of time. It has the potential of wider application in the tropics. There is great diversity of systems involving cultivation of aquatic species, (mainly fish) and plants (mainly aquatic vegetables such as water spinach). Farmers and local communities have developed most reuse systems; the primary motivating factor has been reused of nutrients for food production rather than wastewater treatment, and with scant attention to either waste treatment or to public health. In most aquaculture systems, wastewater is not reused directly in aquaculture and the nutrients contained in the wastewater are used as fertilizer to produce natural food such as plankton for fish. These nutrients, mainly nitrogen and phosphorus, are also taken up directly by large aquatic plants such as duckweed, which is cultivated for animal feed, and aquatic vegetables such as water spinach and water mimosa cultivated for human food.

There are a number of constraints to wastewater-fed aquaculture and they need to be considered where the practice is considered an option. They include:

- lack of knowledge of aquaculture as a technical option in wastewater treatment and reuse.
- limited available sites in peri-urban areas where wastewater is available for reuse
- rapid urbanization in developing countries threatens the existing wastewater-fed systems
- rapid eutrophication from both urbanization and industrialization
- improved sanitation reduces the availability of night soil for agriculture and aquaculture.
- rapid industrialization contaminates nutrient-rich domestic wastewater with industrial wastewater.
- social and cultural acceptance of wastewater-fed
- climate - wastewater-fed aquaculture involves the farming of warm water organisms

Despite the constraints listed above, there is considerable potential for the reuse of wastewater in managed aquaculture in the tropics. A correctly managed system would limit public health risks and wastewater should never be reused without prior treatment if the produce (fish or aquatic vegetables) is intended for direct human consumption.

Organic aquaculture

The global fishery industries are in a stage of fishery resources depletion due to unsustainable fishing practices, large scale aquatic pollution, commercial exploitation of aquatic environment and destruction of primary breeding environment such as mangrove forests & coral reefs. Due to intensification of aquaculture practice all over the world, has in turn resulted in accumulation of high levels of antibiotics, PCBs, residues of pesticides and heavy metals causing a great damage to environment. Organic Aquaculture is the only solution to increase fish production in sustainable and environment friendly manner.

- "Organic aquaculture is production of high-quality foods in a stable aquatic ecosystem by managing the natural resources and environment without any negative effects and to secure the genetic diversity and richness of species in a native system."

- Current problem with the industrial aquaculture practice of fish harvested from wild as feed for the production of cultured fish, 3 tons of wild fish is used to produce feed for the production of 1 ton of farmed fish, so this depletes the natural stock available in wild. To increase production, fast growing exotic fish varieties are farmed this result in weakening of the native species and transfer of disease from farmed aquatic animals to wild fish is also major problem in the current aquaculture systems.
- Organic aquaculture is a method to reduce the abovementioned adverse effects of the industrial aquaculture practice. Organic aquaculture is most important in the sustainable and environmental friendly aquaculture production. This method of culture also farms the aquatic organisms in conditions similar to that of the natural environment. As in case with the other forms of food production industries there is some consumer interest in organic aquaculture. However, fi s h farmers have been slow to adopt the organic standard as many claim that modern aquaculture practices are already " organic " in principal but do not meet the strict legal standards.

2. Principles of organic aquaculture

The main principles of organic aquaculture are as follows:

i. Monitoring of environmental impact
ii. Natural breeding procedures without use of hormones and antibiotics
iii. No use of inorganic fertilizers
iv. Integration of natural plant communities in farm management
v. No synthetic pesticides and herbicides
vi. Feed and fertilizer from certified organic agriculture and fisheries
vii. Organic criteria of sustainability for fishmeal sources
viii. Absence of GMOs (Genetically Modified Organisms) in stocks and feed
ix. Stocking density limits
x. Restriction of energy consumption (e.g. regarding oxygenation)
xi. Preference for natural medicines
xii. Processing in approved organic facilities

Aquaponics and hydroponics

Aquaponics is a new type of complex farming system that involves growing plants and fish in the same environment. When you use this growing method, the waste from the fish is converted directly into nitrates by the surrounding bacteria. These nitrates are used as food for the plants, which then return the remaining water to the fish that are free of harmful contaminants, creating an effective and efficient growth cycle called the nitrogen cycle.

While the accumulation of waste is ultimately toxic to the fish in the tank, the bacteria introduced into the water convert the waste into useful nitrate before any fish are adversely affected. Aquaponics allows a harmonious ecological balance between animals, plants, and microorganisms, and is a sustainable circular zero-emission low-carbon production model and an effective solution to the agroecological crisis. While aquaponics is a simple method of farming and growing, you can use many different systems to implement this method, including everything from media beds and vertical towers to nutrient film technology.

Hydroponics is a popular way of growing plants without soil, also called nutrient culture. Using only chemical nutrients and water, this method grows plants without the use of soil. Although there are many significant benefits to growing plants using hydroponics, it is often used because of the consistency of results and the ability to produce high yields.

Hydroponics works by growing plants in a nutrient-rich, water-based solution. The roots of the plants are suspended directly in the nutrient-rich water, which allows them to obtain the substances they need to grow. At the same time, the rest of the plants will receive oxygen, which allows the growth process to continue without problems. There are many different types of hydroponic systems, most of which will alter the water flow and the way it reaches the plants.

Biofloc culture

Biofloc fish farming is one of the best available methods today, which is helping fish farmers to attain a wide range of objectives such as high output, low cost, sustainable growth, better income opportunities, less area, less maintenance cost, etc.

Species suitable for Biofloc Culture

- A basic factor in designing a biofloc system is the species to be cultured. Biofloc system works best with species that are able to derive some nutritional benefits from the direct consumption of floc. Biofloc system is most suitable for species that can tolerate high solids concentration in water and are generally tolerant of poor water quality. Some of the species that are suitable for BFT are:
- Air breathing fish like Singhi *(Heteropneustes fossilis)*, Magur *(Clarias batrachus)*, Pabda *(Ompok pabda)*, Anabas/Koi *(Anabas testudineus)*, Pangasius *(Pangasianodan hypophthalmus)*
- Non-air-breathing fishes like Common Carp *(Cyprinus carpio)*, Rohu *(Labeo rohita)*, Tilapia *(Oreochromis niloticus)*, Milkfish *(Chanos chanos)*
- Shellfishes like Vannamei *(Litopenaeus vannamei)* and Tiger Shrimp *(Penaeus monodon)*

Advantage of BFT

i. Eco-friendly culture system.

ii. It reduces environmental impact.

iii. Judicial use of land and water

iv. Limited or zero water exchange system

v. Higher productivity (It enhances survival rate, growth performance, better feed conversion in the culture systems of fish).

vi. Higher biosecurity.

vii. Reduces water pollution and mitigate the risk of introduction and spread of pathogens

viii. It reduces utilization of protein rich feed and cost of standard feed.

ix. It reduces the pressure on capture fisheries i.e., use of cheaper food fish and trash fish for fish feed formulation.

Probable Questions:

1. What is RAS?
2. State the advantage of RAS.
3. Mention the difference between Cages and pen culture.
4. State the advantages and disadvantages of Cage culture.
5. Write short notes on Wastewater aquaculture.
6. Write down the principles of organic aquaculture.
7. Define Aquaponics.
8. Name the species suitable for Biofloc Culture.

Suggested reading:

1. Beaumont, A. R. and Hoare, K. (2003). *Biotechnology and Genetics in Fisheries and Aquaculture*. Blackwell Publishing.
2. Jhingran, V. G. (1991). *Fish and Fisheries of India*.3rd ed. Hindusthan Pub. Corp. John Wiley and Sons.
3. Pillay, T. V. R. and Kutty, M. N. (2005). Aquaculture Principles and Practices. 2nd ed. Blackwell Publishing Ltd.
4. Chakraborti, N.M.; Chakraborty, P. P. and Mandal, S. C. (2010). *Biology, Breeding and Farming of Important Food Fishes.* Narendra Publishing House. New Delhi.
5. http://ecoursesonline.iasri.res.in/mod/page/view.php?id=35104

Unit III

Pheromones and reproductive behaviour, parental care. Regulation of seasonal reproduction: Role of environment (photoperiod, temperature, rainfall), Role of hypothalamo-hypophyseal system and pineal gland, role of peripheral endocrine system

Objective: In this unit we will learn about pheromones and reproductive behaviour, parental care of fish. Regulation of seasonal reproduction: Role of environment (photoperiod, temperature, rainfall), Role of hypothalamo-hypophyseal system and pineal gland, role of peripheral endocrine system.

Pheromones and reproductive behaviour

Pheromones are chemicals that pass between members of the same species which have inherent meaning. Because most fish pheromones are mixtures, and their actions can be complex, behavioral assays are required to identify them. This chapter describes a few strategies and two specific methods (one for measuring attraction and another for sexual arousal) that can serve this purpose in fishes that live in nonflowing water such as the carps.

Pheromones are natural chemical substances generally used for communication between animals. In fish, pheromones play roles in fish aggregation, shoaling, social interactions, kin recognition, prey detection, migration and signalling the presence of predators, individual identification, group cohesion, territorial markings, sex attraction, and synchronization of reproductive processes. Pheromone molecules used by aquatic animals are water-soluble and their diffusion rate can be 10,000times lower than in the air.

- **Different fish pheromones**

Pheromones are structurally identified as a variety of low-molecular-weight metabolites, such as bile salts, F-series prostaglandins, amino acids, and gonadal steroids.

❖ **Sex steroids.** They are hormones produced from cholesterol and found in gonads (ovaries or testes). It includes estrogens, androgens, and progestogens. Estrogens possess an 18-carbon estrane skeleton, androgens possess a 19carbon androstane skeleton, and progestogens a 21-carbon pregnane skeleton. These steroids and their derivatives act as reproductive pheromones in many teleost fishes. In Goldfish (*Carassius auratus*), sex steroids and prostaglandins, help inter- and intra-sexual.

❖ **Prostaglandins.** Prostaglandins are group of lipids, derived from arachidonic acid. There are 4 series namely, Eseries, I-series, D-series, and Fseries. In some fishes, female uses F-series prostaglandins to trigger sexual behaviour and leak prostaglandins into the water immediately a over ovulation.

❖ **Bile salts.** They are diverse group of steroids derived from cholesterol in vertebrates. The bile salt's structural diversity includes 27-carbon bile acids, 24-carbon bile acids and 27-carbon bile alcohols each with C-3, C-7 or/and C12 hydroxylation. The 27- carbon bile alcohols predominate in lampreys, hag fish, cartilaginous fishes and amphibians, and 27-carbonbile acids in reptiles and early evolving birds. Bile salts are act as a potent odourants for many fishes. Bile salts can be sensed by Arctic char (*Salvelinus alpinus*) and other salmonids that help in migration.

However, the role of the bile acid as sex pheromone in sea lamprey, discovered through bioassay-guided fractionation, underscores the unpredictability of nature.

• **Other identified Fish pheromones**

i. Tetrodotoxin (TTX, 1) - It is a potent neurotoxin. It attracts sexually mature males in grass pufferfish (Fugu niphobles), upon release with ovulated eggs into the water.

ii. Tetrahydrofuran diols [petromyroxols and isopetromyroxols] are potent odourants released by larval sea lamprey, indicating fatty acids may also function as pheromones.

• **Applications of pheromones aquaculture**

i. Induction of Maturity and Reproduction: Effective stimulation of sexual maturity with pheromones, could not only reduce the need for injections but may also improve the quality and, survival of resultant larvae and synchronization or timing of sexual maturity.

ii. Delaying Precocious Maturation: Early puberty is a problem for the aquaculture industry in many species due to the consequent allocation of energy reserves to the gonads rather than muscular growth. There may also be negative effects on appearance and flesh quality, thus reducing marketability. In aquaculture, cod tend to spawn at an earlier age than in the wild, presumably due to increased food intake and consequent deposition of lipid and protein reserves. If chemical communication can modulate the onset of puberty, then the high densities of fish in aquaculture are likely to exacerbate this problem.

iii. Sex Determination: In sequential hermaphroditic species, the proportion that changes sex may depend on social conditions. Sex pheromones could be used to sort males from females, and thereby reduce handling and associated stress. Pheromones could be used to attract those of the sex required in a similar way that invasive species may be trapped.

iv. Welfare of animal: Stress reduces food conversion efficiency and growth rates in fishes, so it is possible that monitoring cortisol in the water may be indirect way of assessing the level of stress in a tank of fish.

v. **Using pheromones to facilitate trapping:** Trapping is done for simply remove organisms, and/or to collect animals. It is a low-cost trap. Naturally, pheromone application should be considered together with the use of other attractant cues such as sound or light to get the best possible result. F prostaglandins from female could be considered for use in male trapping regimes. Similarly, male odours, androstenedione should be considered for use in to attract and remove females.

vi. **Using pheromones to disrupt movement and migration:** Migratory fish species such as the lampreys and chars appear to use pheromones to find spawning grounds from some distance. It is conceivable that pheromones could be used to divert migrations of invasive fishes to regions unsuitable for spawning or habitation.

Behaviours During Reproduction

The reproductive behaviour of fishes is remarkably diversified: they may be oviparous (lay eggs), ovoviparous (retain the eggs in the body until they hatch), or viviparous (have a direct tissue connection with the developing embryos and give birth to live young). All cartilaginous fishes—the elasmobranches (*e.g.,* sharks, rays, and skates)—employ internal fertilization and usually lay large, heavy-shelled eggs or give birth to live young. The most characteristic features of the more primitive bony fishes is the assemblage of polyandrous (many males) breeding aggregations in open water and the absence of parental care for the eggs. Many of the species in this group, such as herrings, make what appear to be completely chaotic migrations to their breeding areas. Actually, however, each of these huge spawning aggregations is made up of small, coordinated parties consisting of one female and one or more males. On the other hand, a number of fishes are monogamous, form pairs, and care for the eggs or young. In courtship behaviour, in which they utilize all potential stimuli including sound, chemical, and electrical stimuli, the range and complexity of their displays are not exceeded by any other vertebrate group.

Although the sexes are usually separate, hermaphroditism is much more common among the bony fishes than in any other group of vertebrates. The reasons for this condition are both physiological and ecological. Whereas the developing gonads of all other vertebrates have an outer and inner layer of tissue, those of bony fishes have a simple origin that lacks any male or female elements. In terms of the evolutionary process, this type of development is likely to be more adaptable to pressures that favour hermaphroditism. When, because of one or several interacting factors, a population density reaches a low point in some species, reproduction may be limited to a low probability of contact with another sexually active individual. In such situations (*e.g.,* very deep-sea habitats, tide or stream pools) the evolution of even temporary self-fertilizing hermaphrodites would have the greatest advantage.

One form of hermaphroditism fairly common in bony fishes is the protogynous type, in which the individual functions first as a female and later as a male; it is much more frequent than the reverse situation (protandrous hermaphroditism). The selective reasons for the predominance of the former are presumably associated with the relationship between smaller body size in females and the greater energy requirements needed to produce eggs. In addition, in some promiscuous mating systems, it may be selectively advantageous to be a male when the body size is large and the individual experienced, rather than small and young. Most sea basses, parrot fishes, and wrasses have this sort of hermaphroditism.

Parental care of fish

Fish as a group pay little parental care to their eggs and young. Most of them are content to ensure fertilization of their eggs but bestow little attention on them. This lack of parental behaviour is correlated with production of great numbers of eggs and sperm. There are, however, some notable exceptions in which the eggs and young are guarded with great solicitude mostly by the male parent (Fig. 10).

1. Nest Building:

Some fishes prepare crude nests for egg laying. At first a suitable place for preparing the nest is selected and some species may defend the place till death. Males of many species like the Darters (Etheostoma), sunfishes and cichlids, prepare a shallow basinlike nest for laying eggs by females. The stones and pebbles are removed from such nest and male keeps close watch over the eggs till hatching.

i) Unprotected nest: A few species, however, leave the nest unprotected. Many freshwater fishes prepare crude nest with aquatic vegetation where eggs are laid. Protopterus and Lepidosiren prepare deep hole into which the females lay eggs. Males protect the nest till development is complete. Amia calva (bowfin) prepare a crude circular nest among aquatic vegetation.

ii) Crude nest: The fertilised ova are protected by male who keeps guard over the nest till the young ones are hatched. The young ones are allowed to leave the nest in a body under the protection of father. Both the male and female of some cat fishes of North America prepare a crude nest in the mud for egg-laying. The nest is sometimes provided with protective cover of logs, stones, etc.

2. Coiling round eggs. In Pholis, one of the parents possibly the male guards by coiling round the eggs, rolled into a ball or sphere until they hatch.

3. Attachment to body. The male of the New Guinea fish, Kurtus entangles the egg mass on a hook like process on head until they are hatched.

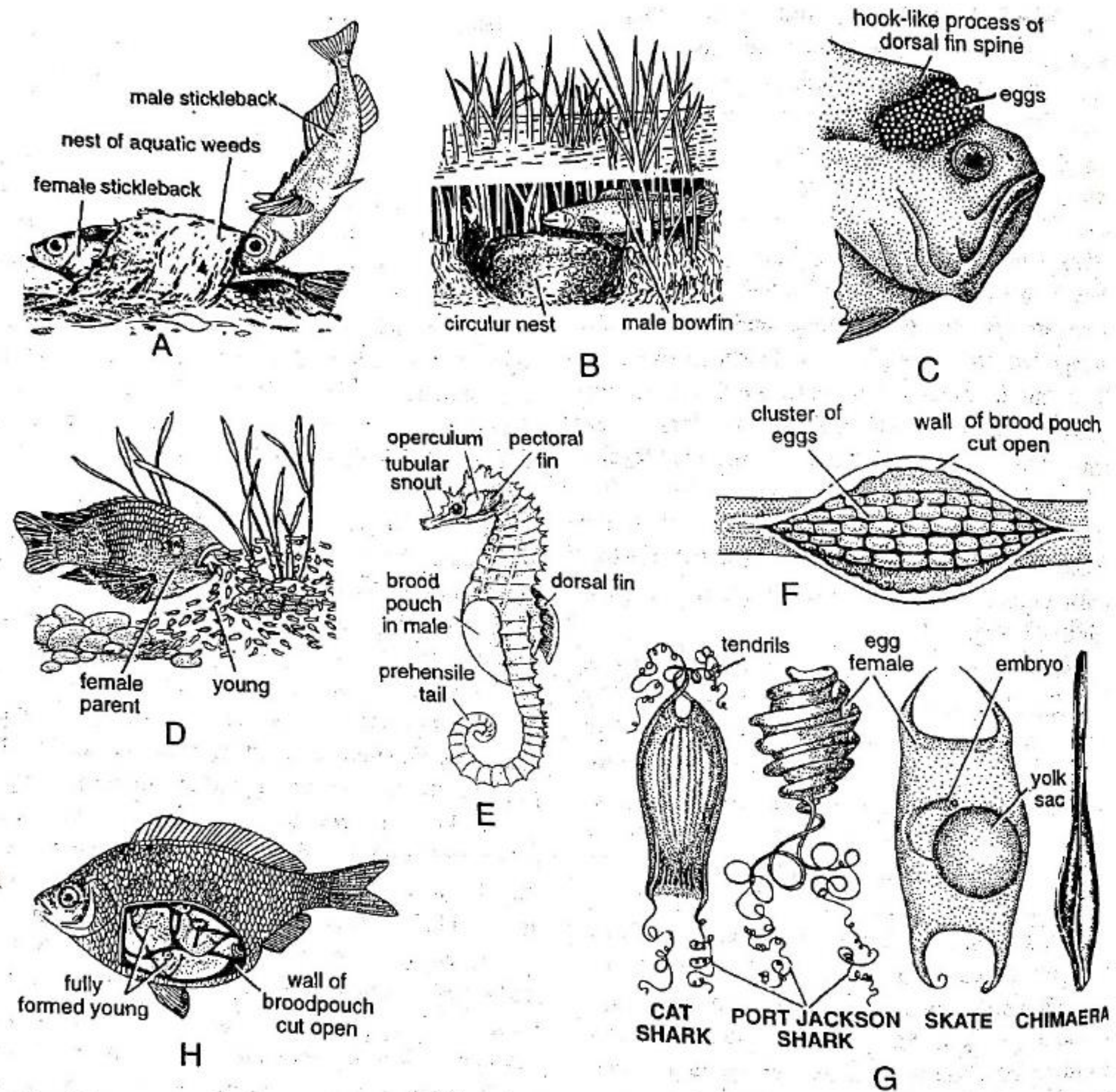

Fig. 10. Some interesting examples of parental care in fishes. A—Male stickleback (*Gasterosteus aculeatus*) muzzles female at the base of tail to stimulate her to lay eggs in a nest of dead aquatic plants. B—Male bowfin (*Amia calva*) guarding over circular nest. C—The male Australian *Kurtus* incubates eggs on its forehead. D—Very young of *Tilapia mossambica* take refuge in female parent's buccal cavity in times of danger. E—A male *Hippocampus* carrying brood pouch. F—Brood pouch of male *Syngnathus* opened to show eggs. G—Mermaid's purses for eggs. H—Body cavity of *Cymatogaster aggregatus* cut open to shown fully formed young ready for hatching.

4. Integumentary cups. In the siluroids, Aspredo and Platystacus, the fertilized eggs are pressed into the soft spongy skin of belly of the female. Each egg becomes attached by a stalk into a cup-like depression of integument and carried until hatching.

5. Shelter in mouth. There are several species of mouth-brooding fishes. The fertilized eggs are carried in the mouth cavity by males in the catfish Arius and by females in the Cichlid, Tilapia. The very small young also take refuge in the parental buccal cavity in times of danger.

6. Brood pouches. In the sea horse, *Hippocampus* and pipe fish *Syngnathus*, the female transfers eggs into a brood pouch on the belly of male to be kept until hatching takes place.

7. Mermaid's purses. Oviparous sharks (e.g. *Scyllium*) lay fertilized eggs inside protective homy egg capsules or mermaid's purses, which remain anchored to see weeds by their long tendrils. The young hatch out after rupturing the egg case.

8. Viviparity. A few species of fishes are viviparous, such as the dogfish, *Scoliodon* and the surf fish *Cyamatogaster aggregatus*. Fertilization and development are Both internal. Developing embroys are nourished mostly by a yolk sac placenta and the young are born with the characteristics of the adult. Viviparity provides maximum protection and represents the highest degree of parental care.

Regulation of seasonal reproduction: Role of environment (photoperiod, temperature, rainfall)

The different stages of gonadal development are also aliened by their diet and environmental factors like photoperiod, temperature, rainfall etc. These environmental clues received by brain that stimulated to produce gonadotropin releasing hormone (GnRH) and it stimulate pituitary.

- **Ecological Factors:** Often ecological factors are associated with timing so that food availability is optimal for the larvae. Some ecological factors important to spawning are temperature, photoperiod, tides, latitude, water depth, substrate type, salinity, and exposure.

Temperature: An important factor in determining geographical distributions of fishes. Although little is known about the mechanism by which temperature controls maturation and spawning in fishes, for many marine and freshwater fishes the temperature range in which spawning occurs is rather narrow, so that in higher latitudes the minimum and maximum temperature requirement for spawning is often the limiting factor for geographical distribution and for the successful introduction of a species into a new habitat. For example, Pacific halibut (*Hippoglossus stenolepis*) are found spawning primarily in areas with a 3-8^{0}C temperature on the bottom and therefore do not spawn in Puget Sound, although the adults are caught in the northern areas of Puget Sound. In fact, even in highly migratory tuna, spawning is restricted to water of specific temperature ranges.

Photoperiod and Periodicity: The day length (photoperiod), in some cases at least, is thought to influence the thyroid gland and through these the fishes' migratory activity, which is related to gonadal development (maturation). In the northern anchovy, by combining the effects of temperature and day length, continued production of eggs under laboratory conditions was brought about by keeping the fish under constant temperature conditions of 15^{0}C and a light periodicity of less than 5 hours of light per day (Lasker personal communication). In high latitudes, spawning is usually associated with a definite photoperiod (and temperature), which dictates seasonal pulses of primary production in temperate regions to assure survival of larvae. In low latitudes, where there is little variation in day length, temperature, and food production, other factors may be important such as timing with the monsoons, competition for spawning sites, living space, or food selection. Reproductive periodicity among fishes varies from having a short annual reproductive period to being almost continuous. There is a tendency for the length of the reproductive period to shorten with increasing latitude. Thus tropical fishes spawn nearly continuously, whereas subarctic fishes spawn predictably during the same few weeks each year. Presumably times of spawning have evolved so larval development will coincide with an abundant food supply. Within spawning seasons, fish may spawn on a daily or monthly tidal cycle or on a diel cycle, or in association with some other environmental cue, such as a change in daylength, temperature, or runoff. A notable instance of spawning periodicity associated with the tidal cycle is the California grunion (*Leuresthes tenuis*), which spawns intertidally at the peak of the spring high tides (Walker 1952). Within species, spawning times may vary with latitude: Generally, in species that spawn as daylength increases, spawning occurs earlier in the year in lower latitudes than at higher latitudes. In species that spawn as daylength decreases, spawning takes place earlier in the year at higher latitudes than at lower latitudes.

Role of hypothalamo-hypophyseal system and pineal gland

The hypothalamic neurosecretory system of the marine fish is made up of two nuclei 1) the nucleus praeopticus and 2) the nucleus laterlistuberis, which are paired. The hypothalamo-hypophysial tract extends posteriorly from each body, and they penetrate into the pituitary gland to fuse to form one structure. The pituitary gland is a master endocrine gland that originates embryologically from the two sources. The first ventral down-growth of a neural element from the diencephalon known as the infundibulum which joins with another, an ectodermal up-growth (extending as Rathke's pouch) from a primitive buccal cavity. Both of these outgrowths are ectodermal in origin and enclose mesoderm in between them, which later on supply blood to the pituitary gland, originating from the inter-renal carotid artery. This gland is placed below the diencephalon (hypothalamus), behind the optic chiasma and anterior to saccus vasculosus, and is connected to the diencephalon via stalk or infundibulum. So, the pituitary gland, which is made up of adenohypophysis and the neurohypophysis, is connected to the hypothalamus by a short stalk that have neurosecretory fibers projecting from the brain to the pituitary in fishes. The infundibulum size varies according to the species. Generally, in cyclostomes it is smaller but increases in bony fishes, with prominence in groove or depression of para-sphenoid bone receiving the gland. The pituitary gland is oval shaped and is dorsoventrally compressed. The size of male glands is smaller compared to those of females.

In case of vertebrates, the hypothalamus receives various internal and external environmental signals and integrates it to regulate the pituitary (hypophysis). In teleost the hypothalamus-pituitary-gonadal (HPG) axis predominantly regulates reproduction. The posterior part of the pituitary is neurohypophysis which has a rich supply of neurosecretory fibers that release vasotocin and isotocin. It is glandular and originated from the ectoderm. The anterior part of pituitary is adenohypophysis, have various pituitary endocrine cells secreting pituitary hormones, which include FSH, LH, thyroid-stimulating hormone (TSH), growth hormone (GH), prolactin (PRL), adrenocorticotropic hormone (ACTH), and somatolactin (SL). It is a nervous part which originates from the infundibular region of the brain. Both these parts are closely associated with each other.

The pituitary gland is divided into two parts:

(a) Adenohypophysis:-. Adenohypophysis is divided into

1) Pro-adenohypophysis – Rostral pars distalis :- Present dorsal to the mesoadenohypophysis in the form of a thin strip.

2) Mesoadenohypophysis – Proximal pars distalis: - Present almost in between the rostral pars distalis and pars intermedia.

3) Metaadenohypophysis – Pars intermedia: - Present at the distal tapering end of the pituitary gland.

(b) Neurohypophysis:-. Pituitaries are broadly categorized as platybasic and leptobasic. In platybasic form e.g. Eel, the neurohypophysis contains the flat floor of the caudal infundibulum that sends processes into disc-shaped adenohypophysis. In leptobasic, the neurohypophysis has a fairly well developed infundibular stalk and the shape of adenohypophysis is globular or egg shaped.

In fish, hypothalamic hormones which regulate pituitary functions are directly transported to the respective pituitary endocrine cells by neuronal fiber projections to the adenohypophysis. Neuronal processes which are immunoreactive to various hypothalamic hormones project into the pituitary.

Hypothalamic hormones are produced from the nerve terminals to act directly on nearby target cells.

Teleost is a good model to study hypothalamic control of the pituitary endocrine cells because of direct innervations from the hypothalamus to the adenohypophysis and the segregation of endocrine cells in the pituitary. Unlike typical vertebrate hypothalamohypophysial portal vascular system for transport of neurohormones to pars distalis.

There is relation between the distribution of hypothalamic neuronal fibers and the endocrine target cells in the adenohypophysis of teleosts e.g, fiber terminals of GnRH neurons are found in the proximal pars distalis, where LH and FSH cells are present, which justifies the role of GnRHin GtH secretion. Neurons synthesizing several neuropeptides and neurotransmitters e.g. GnRH, GABA, neuropeptide Y, dopamine, and PACAP have project their fibers to the pars distalis to modulate the release of GtH and other pituitary hormones. The brain regions contain two hypophysiotropic nuclei known as the nucleus preopticus (NPO) and the nucleus lateralis tuberis (NLT), which control teleostean adenohypophyseal functions. In most teleosts, both NPO and NLT form the major neuronal systems that innervate the pituitary to control different endocrine cells.

But, some extra hypothalamic areas e.g. Olfactory system and the telencephalon have also send neuronal projections to the pituitary. In the preoptic area (POA)- hypothalamus, the anterior and posterior subdivisions of the nucleus preopticus periventricularis (NPP) is the regions which have various peptide hormones and neurotransmitters e.g. dopamine that control of GtH secretion in the pituitary.

Pineal gland

This gland is located near the pituitary gland and it is a photo neuroendocrine gland. Generally, in fishes this gland is absent or rudimentary in adults, but parapineal anlage usually shows some early ontogenetic development. However, a parapineal-like parietal eye of lizards has been found in at least one adult teleost. In other groups of fishes, a well-developed parapineal body is found only in non myxinoidea cyclostomes. The main hormone secreted by pineal gland is indole hormone melatonin, a hormone produced from amino acid tryptophan. Melatonin (N-acetyl-5-methoxytryptamine) biosynthesis starts with conversion of tryptophan into 5-hydroxytryptophan via tryptophan hydroxylase (TPOH) enzyme. Hydroxytryptophan is then decarboxylated by enzyme aromatic amino acid decarboxylase to produce serotonin. Converts serotonin is converted into N Acetylserotonin by Arylalkylamine N-acetyltransferase (AANAT) and then N Acetylserotonin is methylated by hydroxyindole-0-methyltransferase (HIOMT) enzyme to produce melatonin. Melatonin is generally produced during the dark because light inhibits its production. So, this gland controls the rhythmic activity in the fish. This gland conveys information to the brain by a neural pathway. The pineal organ is made up of the pineal gland and the parapineal organ. In fish the entire system e.g. the photodetector, the circadian clock and melatonin synthesizing enzymes is present in the pineal organ.Three types of cells are mainly present in the pineal gland e.g. pinealocytes (photoreceptor cells), glial (supporting) cells and second order neurons (ganglion cells).The blood vessels supply blood to all parts of the pineal gland without penetrating into the parenchyma of the gland. The pinealocytes contain photopigment so they are photosensitive and they undergo morphological changes in response to changes in photoperiod. In fish the melatonin diffuses directly into the bloodstream after synthesis. The hormone melatonin controls reproduction through pineal-hypophysis pituitary-gonadal axis. Treatment with melatonin during preparatory phase causes decrease in ovarian weight and arrested ovarian recrudescence. The gold fishes which are pinealectomized in spring and then exposed to long photoperiod conditions result in ovaries regressed and plasma gonadotropin levels were significantly depressed. The melatonin has inhibitory effect on thyroid hormone in fishes during gonadal development and maturation which is required for the sex steroidogenesis in the process of reproduction. The pineal gland regulates metabolism of carbohydrate by changing the insulin responsiveness e.g goldfish. The function of Melatonin is to control the reproductive seasonality by stimulating the final stages of sexual maturation and by synchronizing the oocyte maturity with optimal timing of spawning. It also affects estradiol levels in mature carp females and indirectly affects the secretion of GtH II by hypothalamic stimulatory (GnRH) centers.

Role of peripheral endocrine system

Peripheral endocrine glands do include the parathyroid and the ultimobranchial glands, both derived from pharyngeal endoderm and the source of calcitonin (CT), but these glands are not present or they have not been described in detail in any of the groups of fishes under consideration in this volume.

Probable Questions:

1. Name different types of pheromones in fishes.
2. Mention the applications of pheromones aquaculture.
3. What is Nest Building in fish? State its utility.
4. How photoperiod helps in seasonal reproduction in fish?
5. Write short notes on pineal gland.

Suggested reading:

1. Beaumont, A. R. and Hoare, K. (2003). *Biotechnology and Genetics in Fisheries and Aquaculture*. Blackwell Publishing.
2. Jhingran, V. G. (1991). *Fish and Fisheries of India*.3rd ed. Hindusthan Pub. Corp. John Wiley and Sons.
3. Pillay, T. V. R. and Kutty, M. N. (2005). Aquaculture Principles and Practices. 2nd ed. Blackwell Publishing Ltd.
4. Chakraborti, N.M.; Chakraborty, P. P. and Mandal, S. C. (2010). *Biology, Breeding and Farming of Important Food Fishes.* Narendra Publishing House. New Delhi.

Unit IV

Physiology of fish migration and behavior: Behavioral response to the environment. Circadian rhythm. Hormones in communications, pheromones, concept on fish behavior and regulatory mechanism

Objective: In this unit we will discuss about physiology of fish migration and behavior: Behavioral response to the environment. Circadian rhythm. Hormones in communications, pheromones, concept on fish behavior and regulatory mechanism

Fishes migration

- In ecology, it is an animal behaviour of mass movement of animals from one place to another.
- The purposes for migration vary accordingly with the types of animals.
- Migratory behaviour of fish is a regular phenomenon. Their journey is purposed mainly for feeding and reproduction.

Types fish migration on the basis of needs:

1. **Alimentary or Feeding migration:** migration for search of feeding ground. It occurs when food resources get exhausted.
2. **Gametic or spawning migration:** it occurs during breeding season in search for the suitable spawning ground.
3. **Climatic or seasonal migration:** migration in search for suitable climatic condition.
4. **Osmo-regulatory migration**: migration for water and electrolytes balance from sea to fresh water and vice-versa.
5. **Juvenile migration:** it is larval migration from spawning ground to the feeding habitats of their parent.

<u>Types of fish migration</u>

The migration of some fishes is a regular journey and is truly an innate animal behaviour. Fish migration are classified into following types:

1. Diadromous migration:

- it is the migration of fish between sea and fresh water.
- As we know, most of the fishes are restricted to either fresh water or sea water. Changes in habitat may causes osmotic imbalance in those fishes.

However some fishes regularly migrate between sea and fresh water and have perfect osmotic balance, they are the true migratory fish.

- This migration is of two types-

i. Anadromous migration:

- it is the migration of marine fishes from sea to fresh water for spawning.
- Fishes spend most of their life living and feeding in sea.
- They only migrate during breeding season to the river for spawning ground.
- Eg. *Salmon, Hisla, Lamprey* etc.
- Salmon migrates for breeding during winter from sea to river. While migrating, some physiological changes occurs:
- – stops feeding during journey
- – changes colour from silver to dull reddish brown
- – gonads mature
- They select suitable spawning ground and make a saucer-like nest in which female lays eggs and male releases smelt over them. Juvenile larva hatched out from the egg known as Alevins. Alveins then transform into parr and metamorphosed into adult when return to the sea.

ii. Catadronous migration:

- It is the migration of fresh water fishes from river to sea during breeding season for spawning. Eg. Eel (*Anguilla* spp)
- Both European eel *(Anguilla anguilla* or *Anguilla vulgaris)* and the American eel *(Anguilla rostrata)* migrate from the continental rivers to Sargasso Sea off Bermuda in south Atlantic for spawning, crossing Atlantic Ocean.
- Before and during migration some physiological changes occur in their bodies:
- – deposit large amount of fat in their bodies which serves as reserve food during the journey
- – Colour changes from yellow to metallic silvery grey.
- – Digestive tract shrinks and stops feeding
- – Eyes get enlarged and vision sharpens. Other sensory organs also become sensitive.
- – Skin serves respiratory organ.
- – Gonads get matured and enlarged.

- The lay eggs in suitable spawning ground and are fertilized by males. After spawning they die. The larva hatch out and develop into young ell and finally return to river.

2. Potamodromous migration:

- it is fresh water migration of fresh from one habitat to another for feeding or spawning.
- Eg. Carps, catfish

3. Oceanodromous migration:

- It is the migration of fish within sea in search of suitable feeding and spawning ground.
- eg. *Clupea, Thummus, Tuna*

4. Latitudinal migration:

- it is the migration of fish from north to south and vice-versa.
- It is a climatic migration.
- Eg. Sward fish migrate north in spring and south in autumn.

5. Vertical migration:

- it is a daily migration of fish from deep to the surface and vice-versa for food, protection and spawning.
- Eg. Sward fish usually move vertically downward to greater depth for food.

6. Shoreward migration:

- it is the migration of fish from water to land. However, it is a temporary migration.
- Eg. Eel migrate from one pond to another pond via moist meadow grass.

Significance of fish migration

- to find suitable feeding and spawning ground
- for protection from predators
- survive from extreme climatic conditions
- increases genetic diversity
- it is an adaptational characters for survival and existences

Physiology of fish migration

Migration, like reproduction and other phases (as molting in birds), is part of the life cycle and depends on a complex internal rhythm that affects the whole organism, particularly the endocrine glands (glands of internal secretion) and the gonads. Migration must thus be viewed in relation to the entire annual cycle.

Each year birds return to particular areas to breed, and remain there until the members of the brood can care for themselves. There is no relation between the reproductive and migratory stimuli, yet the two phenomena, although independent, are nevertheless stimulated by the same factor.

A physiological study of certain migrants has revealed that metabolic patterns usually change prior to migration, and fats accumulate in the body tissues. The whitethroat (*Sylvia communis*) weighs an average of 12 to 13 grams (about 0.4 ounce) during the breeding season, 16 to 19 grams (about 0.6 ounce) in the autumn, and 20 to 24 grams (about 0.8 ounce) in the winter. Food consumption increases with the autumn molt, reaching a peak at the beginning of the migration season. These fundamental physiological changes, chiefly under the control of the thyroid gland, are correlated with migratory activity. Such fluctuations are not observed in nonmigratory species.

Variations in metabolism and related phenomena are controlled by an endocrine gland, namely the pituitary gland, which is located in the lower part of the brain and acts as a command post, sending out instructions in the form of secretions called hormones. That the pituitary has a cycle independent of environmental factors is demonstrated by the regularity with which phases such as reproduction occur from year to year in the lives of some birds, and by the diverse response of various species and populations to the same environmental factors. That the pituitary is, however, influenced by environmental factors, such as variations in day length and the intensity of the Sun, has been demonstrated experimentally.

Gonadal development and the deposition of fat, for example, are influenced by the pituitary, which responds to increasing day length in springtime by accelerating the rate of gonadal development. The pituitary thus governs the development of gonads and, in addition, affects all metabolic processes, including development of the thyroid gland, so as to prepare the animal physiologically for migration. If only the pituitary and variations in day length were involved, migration would be triggered at definite times, because the pituitary cycle is fixed, and photoperiodism is a highly predictable phenomenon; such a lack of flexibility, however, would inevitably cause migrant populations to suffer catastrophes because ecological conditions are irregular—meteorological events, such as the arrival of spring, and biological phenomena, such as flowering, foliation, hatching of insects, and availability of food, are highly variable from year to year. The pituitary thus serves only to prepare the bird for flight; the proper ecological conditions, on the other hand, are necessary to initiate it. The availability of food is an important factor. Temperature and weather conditions also have an influence—a sudden period of cold weather during autumn may induce the immediate departure of many migrants.

Sensitivity to changes in the weather and other environmental conditions varies markedly among species. Some, such as the woodcock, snipe, lapwing, starling, and lark, rely on surrounding conditions to initiate their spring and autumn migrations, and the patterns of their flight depend on temperature and barometric pressure. Others, such as the swift, cliff swallow, Baltimore oriole, and short-tailed petrel, are less weather dependent, and, since the dates of their arrival and departure are not regulated by the weather, they occur with remarkable regularity each year.

The factors that stimulate migration in animals other than birds are not yet well understood. Ecological conditions play a great part in the migratory activity of mammals, who react to general food shortage by moving to another region. Whale, for example, leave the Antarctic region as winter modifies the oceanographic conditions. Seals disperse when the food supply in the area of their breeding colonies is depleted. Environmental factors are of primary importance in the migration of fishes and marine invertebrates. Annual movements of water masses change physical conditions such as temperature and salinity; biotic conditions are influenced accordingly.

Circadian rhythm

Circadian rhythmicity in behaviour and metabolism is a ubiquitous phenomenon in biology, documented in such diverse species as unicellular organisms, plants, invertebrates, and vertebrates. The reason is quite clear: the survival of all of these organisms depends on adapting to the regular changes of their environment, defined mostly by the 24-hour period of earth's rotation relative to the sun. Importantly, the organisms can immensely benefit from predicting when the day or night comes and, with it, changes in illumination, temperature, or food availability. Anticipating these environmental changes allows organisms to adjust all of their metabolic and behavioural processes in advance and to do everything “on time.” Hence, biological clocks have evolved, and even in the absence of any environmental cues they autonomously oscillate with a circadian (*circa* = about, *dia* = day) period.

The intrinsic period of circadian clocks can be somewhat shorter or longer than 24 hours and can be adjusted (reset) to the environment by gradually shifting the oscillation phase until it coincides with the environmental cycle and then stabilises (entrains). Such entrainment can be induced by different environmental cues, called *zeitgebers* (“time givers”) or *synchronisers*. Light appears to be the strongest of these synchronisers and, as a result, a large amount of data characterising light-dependent intrinsic oscillations has been collected over the years. In addition, other critical environmental parameters changing daily or annually (such as environmental temperature, food availability, and predation risk) can also affect the phase of intrinsic clocks and, in some species, may even play a more important role than light.

The circadian system of fish follows the same general design as in other vertebrates and invertebrates; they show circadian rhythms of activity, food intake, and some physiological parameters.

A principal circadian hormone, melatonin, and melatonin-producing organs, the pineal gland and retina, also play a central role in the circadian rhythms of fish and their entrainment to changing environments. Rest in fish is under both circadian and homeostatic control, showing distinct behavioural and pharmacological features of sleep. A sleep like state can be induced in fish by different hypnotic agents and melatonin, further suggesting that rest in fish is analogous to sleep in higher vertebrates.

Hormones in communications

Fish commonly use reproductive hormones (steroids and prostaglandins) both as endogenous signals between reproductive tract and brain and as exogenous signals (hormonal pheromones) that synchronize gamete maturation and/or spawning interactions between and among conspecifics. This dual function for hormonal products not only extends traditional concepts that sex hormone actions are limited to reproductive synchrony within the individual, but also implies we are unlikely to achieve a comprehensive understanding of reproductive function in any fish without knowledge of both the endogenous and exogenous actions of its hormones and related released compounds. Such knowledge is beginning to accumulate for several species (e.g. goldfish, Atlantic salmon), but even here is far from complete. Moreover, because hormonal pheromone studies have focused on oviparous gonochorists with relatively simple reproductive strategies, we know nothing about the potential hormonal pheromone functions of the numerous species with sequential hermaphroditism or alternative male strategies, or the possible changes in pheromone function associated with the numerous transitions from oviparity to viviparity. Given the insights we have gained from studies of traditional species, it seems certain that expanding hormonal pheromone research to non-traditional species exemplifying the diverse nature of fish mating systems will similarly enrich our understanding of fish reproductive function.

Probable Questions:

1. What is catadromous migration?
2. What is the anadromous migration?
3. Discuss the physiology of fish migration.
4. Describe circadian rhythm in fish.

Suggested reading:

1. Beaumont, A. R. and Hoare, K. (2003). *Biotechnology and Genetics in Fisheries and Aquaculture*. Blackwell Publishing.
2. Jhingran, V. G. (1991). *Fish and Fisheries of India*.3rd ed. Hindusthan Pub. Corp. John Wiley and Sons.

3. Pillay, T. V. R. and Kutty, M. N. (2005). Aquaculture Principles and Practices. 2nd ed. Blackwell Publishing Ltd.
4. Chakraborti, N.M.; Chakraborty, P. P. and Mandal, S. C. (2010). *Biology, Breeding and Farming of Important Food Fishes.* Narendra Publishing House. New Delhi.

Unit V

Coastal aquaculture: Status of coastal aquaculture in India and *Culture of prawn*: major cultivable species, techniques of larval rearing, grow out technology

Objective: In this unit we will learn about status of coastal aquaculture in India and Culture *of prawn*: major cultivable species, techniques of larval rearing, grow out technology

Status of Coastal Aquaculture

- India has a coast line of 6517 Km (mainland), a continental shelf of about 40 million hectares and brackish water area of about 1.7 million hectares.
- The east and west coast of India are productive and are suitable for undertaking mariculture, while the edges of the seas offer scope for large scale culture of organisms such as oysters, mussels and seaweeds.
- The open seas could be used for suspending rafts and cages for the culture of finfish and shellfish.
- Despite the huge potentials, the development of coastal aquaculture in India has been rather confined to brackish water shrimp culture in the maritime states.
- In fact, the country has a rich tradition in shrimp culture, as various traditional practices were followed in different regions to grow and harvest shrimps in its natural habitats.
- Taking a cue from the traditional practices, scientific systems have subsequently been evolved to culture shrimps in protected and manually controlled regimes. Presently, over 1,67,500 ha area is under shrimp farming in various coastal states, out of which as much as 50,000 ha is still adopting traditional practices.
- Presently there are about 350 hatcheries in India with a built-in capacity of 14 billion seed per annum to supply quality seeds of both shrimp and scampi. Broodstock collectors, nauplii producers, nurseries, water quality analysis laboratories, PCR Labs etc are also functioning to support the operations.
- Another vital sector for the sustainable development of coastal aquaculture is the feed and feed inputs. Over 30 domestic feed mills are supplying shrimp feed to the farmers, apart from the imported brands. Various forms of other inputs such as probiotics, immunostimulants, Zeolite, BKC etc are also marketed to help successful crops.

- The shrimp farms in the country have been periodically affected by white spot syndrome viral disease and the farmers are adopting various management measures to prevent crop loss and ensure sustainable production levels.
- The Marine Products Export Development Authority (MPEDA) of Government of India has been playing a major and significant role for promoting coastal shrimp and scampi cultivation in the country, as shrimps constitute the major revenue earner in the export market.
- The revolution in coastal shrimp culture started when MPEDA established two modern shrimp hatcheries in the east coast, with overseas technological tie-up. Subsequently, scientific commercial shrimp farming practices were also demonstrated to farmers through pilot projects. This sector, which has witnessed a sudden upsurge with large-scale development, faced several challenges from environmentalists, lawmakers, financiers, etc. apart from in-house problems such as the onslaught of diseases.
- However, the situation got stabilized and now streamlined with the enactment of the Coastal Aquaculture Authority Act facilitating statutory and regulatory control over coastal farms. Small and marginal farmers largely run the shrimp culture sector in India. In order to empower these farmers, MPEDA has mooted the concept of forming "Aquaculture Societies" in various farming villages, through a project undertaken by MPEDA in association with the Network of Aquaculture Centers in Asia-Pacific (NACA), Bangkok on Shrimp Disease Control and Coastal Management in India.
- Aquaculture societies are expected to improve the socio-economic condition of the small scale and marginal farmers by assuring them sustainable production levels through adoption of Better Management Practices (BMPs) to reduce the risk of diseases and improve production and productivity.
- The country is estimated to have about 1.2 million ha.of areas, suitable for undertaking brackish water aquaculture. However, the development so far, has been only about 15% of the available area, and the scope for further expansion is therefore enormous.
- In order to regulate the development of coastal aquaculture in an environmentally and sustainable manner, the Coastal Aquaculture Authority (CAA) has been authorized by the Government of India to license the aqua farming activity in the coastal region for which, the norms and guidelines are already framed by the CAA. This Authority, although national in character will be working through the state governments for the governance of coastal aquaculture sector.

What is prawn?

Prawns are belonging to the phylum arthropoda, class Crustacea is considered by most people a fish. But it is not a fish; it is an aquatic Crustacea of economic importance. The prawn is a good source of protein and constitutes highly nutritive diet for human beings. Due to its nice taste, it is a cherished food-item throughout the world.

What is Prawn culture?

Generally, the larval forms of prawn is allowed to enter the different types of the culture fields, rear them there and to capture them for marketing. And this is the system which is called the prawn culture.

Habit, Habitat and food of Prawns

Before going for the prawn culture, we should have some knowledge about the habit, habitat and food of prawns. Prawn inhabits all sorts of water, much as in sea-water, estuaries and fresh-water. They are generally living at the bottom of water and are avoiding sun-rays. The marine and brackish water species spawn in sea. The hatchlings are incapable to swim, so they are drifted along with the current to the coastal waters or estuaries where they undergo development till they reaches the juvenile stage. The post larvae feed upon the dead organic matter of plants and animals and upon small benthonic organisms.

The juvenile prawn has to enter the sea. The fresh-water species like *Macrobrachium* sp. spawn in fresh-water, then they are drifted to estuaries and after attaining the juvenile stage swim back to fresh-water. Prawns are consuming the organic substances, microscopic animals and plants as their food material. Among the animals, minute insect, snail, larvae of mollusca and echinodermata as well as aquatic weeds, algae, moss etc., are taken as their food material.

Fresh Water Prawn (*Macrobrachium malcolmsonii*), the second largest fast-growing prawn occurs commonly in Indian rivers, draining into Bay of Bengal. They are cultivated under monoculture as well as polyculture systems. Under monoculture systems production levels of 750-1,500 kg prawns/ha/ 8 months are achieved. Further, it is a compatible species for polyculture along with Indian Major Carps and Chinese carps, which may yield 400 kg prawns and 3000 kg carps/ha/yr. Since the seed requirement for the commercial farming of this species is not met from the natural resources, large-scale seed production under controlled conditions for year-round supply is extremely important. The technologies of large-scale seed production and grow-out culture have led to increased awareness of the farmers and entrepreneurs for diversification of their culture practice.

- **Broodstock Management**

Broodstock and berried females are essential component for continuous operation for seed production. The gonadal maturation of the species differs greatly in nature depending on the agro-climatic conditions. In the Ganga, the Hooghly and the Mahanadi

River systems, the maturation and breeding start from May and continue till the end of October, whereas in the Godavari, the Krishna and the Cauvery systems it commences from April and continue till November. Under pond conditions, sexual maturity generally occur after attaining a maximum size of 60-70 mm. Berried females are recorded year-round in most of the ponds. The ratio of berried females in total population is found to be higher during August-September and during this period they carry good quantity of eggs (8000-80,000). Prawns breed 3-4 times in a season. Successful community breeding and year-round seed production under captive conditions is possible by employing air-lift bio-filter re-circulatory system.

- **Spawning and Larval Rearing**

Mating takes place immediately after pre-mating moult in matured female and spawning occurs few hours after mating. Incubation period of eggs lasts between 10-15 days depending upon the water temperature of 28-30°C. However, at lower temperature, the incubation period is prolonged to more than 21 days. Hatching of fully developed 1st zoea takes place through the body stretching of the zoea, which breaks the eggshell and comes out from the egg and starts swimming as plankton.

Different larval rearing technologies viz., static, flow-through, clear or green water, closed or semi-closed, with or without circulation systems of larval rearing of prawn species under hatchery conditions have been developed with varying degrees of success. The green water technique has been claimed to increase the post-larval production by 10-20% over other techniques and provide a quality seed. But higher mortalities are generally encountered due to rise in pH and uncontrolled algal bloom. Further, increase in numbers of adult Artemia, due to abundance of feed in green water, contributes to accumulation of ammonia in the culture medium. The production of post-larvae (PL) in large numbers is possible following airlift bio-filter re-circulatory system. The larvae passed through 11 zoeal stages before attaining PL within a period of 39-60 days at salinity and temperature ranging from 18-20‰ and 28-31°C, respectively, with the production density of 10-20 PL/l.

Parameter		Range
Temperature	:	28-30°C,
pH	:	7.8-8.2,
Dissolved Oxygen	:	4.4 to 5.2,
Total hardness	:	3000-4500 ppm
Total alkalinity	:	80-150 ppm
Salinity	:	18-20‰
Ammonical nitrogen	:	0.02-0.12 ppm

Bio-filter equipped with air-lift re-circulation has shown promising results in maintaining favorable water quality in different rearing media with enhanced rate of post-larval production. The water quality parameter generally influences the growth, survival and metamorphosis of the developing larvae and it should be maintained optimally for getting better survival (Table.1).

- **Larval Feeding**

Various feed items viz., Artemia nauplii, zooplankton especially cladocerans, copepods, rotifers, flesh of prawn and fish, molluscan meat, earthworms, tubificid worm, egg custard and cut pieces of goat/hen viscera are used during larval rearing. Among these Artemia nauplii have been recognized as an excellent larval food for the prawn larvae. At the beginning, freshly hatched Artemia nauplii are provided to the 1st stage zoea at 1 g/30,000 larvae twice daily up to 15 days or till they attain stage VI. Thereafter, the feed is given once daily along with egg custard and mussel meat/tubificid worm four times daily.

- **Harvesting of post-larvae**

Harvesting of post-larvae of prawn is rather difficult due to their crawling habit. Therefore, both turn-down and drain siphoning of water are commonly used for harvesting. But due to longer duration for attaining post-larval stage the above methods are neither useful nor safe. Further, the presence of post-larvae in the larval tank affects the growth and survival of advanced larvae due to competition for food and cannibalism. Hence, the need for an ideal device for regular harvest of post-larvae from the rearing unit is very much essential. String shell is therefore devised and is successfully used for phase wise harvest of post-larvae during larval rearing. Post-larval survival and production rates, following air-left bio-filter re-circulatory system, are in the range of 10-20 PL/l.

- **Post-larval Rearing**

Optimum growth, production and survival of prawns can be achieved in grow-out ponds on stocking the nursery reared juveniles rather than stocking directly with the freshly metamorphosed post-larvae. Post-larvae slowly adopt themselves to freshwater. Optimum growth and survival of healthy juveniles during post-larval rearing is achieved at salinity of 10parts per thousand.

Post-larval rearing can be done both in well-prepared earthen ponds with adequate aeration facility and inside the hatchery following bio-filter re-circulatory system. Stocking density, feed and water quality management play the major role in raising healthy juveniles during rearing. Stocking density between 10-15 PL/l is ideal. Among various feed items, egg custard along with chopped freshwater mussel meat have been established to be more effective in maintaining good growth. Water quality parameters, viz., water temperature, pH, dissolved oxygen and dissolved ammonia in the ranges of 27.5-30ºC, 7.8-8.3, 4.4-5.2 ppm and 0.02-0.03 ppm, respectively are considered to be favorable for better survival.

- **Grow-out Culture**

Grow-out system of prawn is normally comparable to that of freshwater fish farms. As the prawns can migrate from one pond to other due to its crawling habit, it is necessary to have the pond embankment 0.5 m higher from the water level. Sandy-clay Pond bottom is considered to be favourable for better growth. Undrainable ponds may be treated with conventional piscicides for eradication of predatory and weed fishes. Stocking density of 30,000 to 50,000/ha is recommended for semi-intensive monoculture farming. Ponds with the facility of water exchange and aeration can be used for intensive farming where stocking density could be increased to 1 lakh/ha. Temperature is the most important factor which directly controls the growth and survival of prawns. Temperatures above 35°C or below 14°C are generally reported to be lethal and 29-31°C is optimal.

Male prawns grow faster than females. Mixture of groundnut oil cake and fish meal in the proportion 1:1 is used as supplementary feed. A production of 750-1200 kg/ha in six months of rearing are achieved under monoculture with the stocking density of 30,000-50,000. In polyculture, M. malcolmsonii at a stocking density of 10,000-20,000/ha along with carps at density of 2,500-3,500 nos/ha, a production of 300-400 kg prawn and 2000-3000 kg carps can also be raised.

Probable Questions:

1. State the status of Coastal Aquaculture.
2. Name species of prawn cultured in India.
3. Discuss the prawn culture method.
4. State the brood stock management of prawn culture.

Suggested reading:

1. Beaumont, A. R. and Hoare, K. (2003). *Biotechnology and Genetics in Fisheries and Aquaculture*. Blackwell Publishing.
2. Jhingran, V. G. (1991). *Fish and Fisheries of India*.3rd ed. Hindusthan Pub. Corp. John Wiley and Sons.
3. Pillay, T. V. R. and Kutty, M. N. (2005). Aquaculture Principles and Practices. 2nd ed. Blackwell Publishing Ltd.
4. Chakraborti, N.M.; Chakraborty, P. P. and Mandal, S. C. (2010). *Biology, Breeding and Farming of Important Food Fishes.* Narendra Publishing House. New Delhi.

Unit VI

Culture of shrimp: major cultivable species, Reproduction and rearing Grow out of shrimp

Objective: In this unit we will discuss about Culture of shrimp: major cultivable species, Reproduction and rearing Grow out of shrimp.

Introduction

Shrimp is one of the exports earning commodities and the main source of shrimp is the marine catches. India is considered to be one of the world leaders in shrimp production. The marine shrimp production seems to have been stagnant over a couple of decades and has remained restricted with minor fluctuations in annual catches. During eighties the culture of shrimps has been a popular venture to increase production and earn more foreign exchange as the Indian shrimps were in greater demand in the world markets.

- ### Biology of Indian Shrimp

Indian shrimps (prawns) constitute the penaeids for culture practices and before they are taken to the culture farms, it is pertinent to have certain knowledge on its biology. In general, the penaeid shrimps have a tendency to migrate into brackish water areas, such as estuaries and

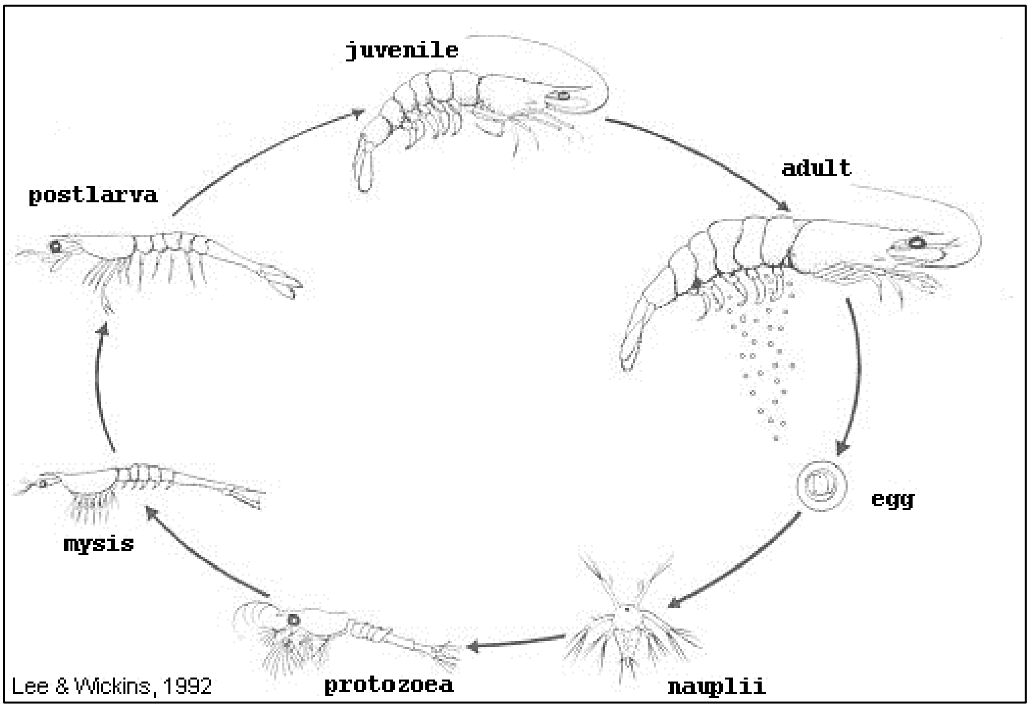

Fig. 11.1: Life cycle of shrimp

backwaters and after attaining adolescence they migrate back to the sea for breeding and spawning. The nursery and adult phases get completed in the sea itself. Adult female shrimp releases over lakhs of eggs and the fecundity range varies from species to species. The eggs hatch out in sea water medium and the larvae pass through different stages, such as nauplius, protozoea (3 stages), mysis and postlarvae. Though you have studied in detail the life cycle of shrimp in Block 2, let us recall it by Fig 11.1.

- **Cultivable Species for Shrimp Culture**

The important species of shrimps which could be economically cultured in India are the following:

1. White shrimp (*Penaeus indicus*)
2. Tiger shrimp (*Penaeus monodon*)
3. Flower shrimp (*Penaeus semisulcates*)
4. Banana shrimp (*Penaeus merguiensis*)

Other species:

5. Kuruma shrimp (*Penaeus japonicusy)*
6. King prawn (*Penaeus latisulcatus*)
7. Red tail prawn (*Penaeus penicillatusi)*

Metapenaeus species like M dobsoni and M monoceros are also cultured in traditional farms

- **SHRIMP FARMING SYSTEMS**

Growing of shrimps in enclosed water body is called as shrimp culture. In natural conditions it grows in the sea, estuaries and brackishwater areas. In the enclosed system proper management measures have to be undertaken for upkeep of the environment to optimum levels for better growth and survival of the species. Shrimp farming systems are classified by stocking densities (the number of seed stock per hectare) and are called as 'extensive' (low stocking density) 'semi-intensive' (medium stocking density), intensive (high stocking density) and super-intensive (highest stocking density). As densities increase, the farms get smaller, the technology gets more sophisticated, capital costs go up and production per unit of space increases dramatically. Based on the management practices, the farming systems are classified into the following:

i) Traditional

ii) Extensive

iii) Semi-intensive and

iv) Intensive

I. Traditional System

In traditional culture system, the shrimp young ones/postlarvae along with fish larvae and other organisms coming along with the high tide, are trapped when the adjoining ponds gets inundated. The trapped organisms are prevented from escaping by installing suitable screens in the sluice. The grown-up ones are harvested periodically. This system is followed in Kerala and West Bengal, otherwise, it is termed 'paddy cum shrimp culture' and referred to as 'pokkali fields' in Kerala and 'bheris' in West Bengal respectively. This kind of farming is practised traditionally in the other stages like Karnataka and Goa. The shrimp production under this system is unpredictable owing to indiscriminate stocking of both desirable and undesirable varieties of shrimp and fish species including predatory ones. The shrimp grows in these fields with natural food production and no supplementary feeding is done. Water quality management is also not practicable. The production from traditional system is about 300 to 500 kglha/annum.

II. Extensive System

The extensive system is considered to be an improved method of traditional farming. The culture ponds are constructed with less expenditure and an average area ranging from 1 to 5 ha and selective stocking of species, postlarvae or juveniles of *P. monodon* and *P. indicus* collected from natural sources or from hatchery, done with the density from few thousands to 1 lakh/ha, with or without supplementary feeding. Extensive shrimp farming (low-density) is conducted in the tropics, in low-lying impoundments along bays and tidal rivers, often in conjunction with herbivorous fish. Impoundments range in size from a few hectares to over a hundred hectares. When local waters are known to have high densities of larval shrimp, the farmer opens the gates, impounds the wild larvae and then grows them to market size. Overall, however, stocking densities are quite low, not over 25,000 post larvae per hectare. The tides provide a water exchange rate of 0 to 5% per day. Shrimp feeds on naturally occurring organisms, which may be encouraged with organic or chemical fertilizers. Construction and operating costs are low and so are yields. The water quality is checked periodically depending upon the rise or fall in level by pumping out upto 10 to 15%. The average production from this extensive culture or so called improved extensive system ranges from 1 to 1.5 tonneslha/annum. Since it is illegal in many countries to build new shrimp farms in tidal and mangrove areas, almost no new extensive shrimp farms are being constructed today.

III. Semi-Intensive Culture System

Semi-intensive culture is a scientifically managed system. Conducted above the high tide line, semi-intensive farming introduces carefully laid out ponds (2 to 30 hectares), feeding and pumping. Pumps exchange from 0% to 25% of the water a day. With stocking rates ranging from 100,000 to 300,000 postlarvae per hectare, there is more competition for the natural food in the pond, so farmers augment production with shrimp feeds. The ponds with size ranging from 0.2 ha to 0.5 ha, selective stocking with fast growing hatchery produced seed like P. monodon/P. indicus with high density of I to 3 lakhlha. Supplementary nutritious feeds; either indigenous or imported are given as per schedule worked out. Water quality is maintained by exchanging 10-20% daily and aeration is provided with air blowers or paddle wheel aerators atIeast 4 number/hectare. The average production from semi-intensive culture is expected to be 4 to 5 tonnes/ha crop in 3 Y2 to 4 months culture period.

IV. Intensive Culture System

Intensive culture is carried out in ponds constructed from 0.03 ha to 0.1 ha in size. Intensive shrimp farming introduces small enclosures (0.1 to 1.5 hectares), high stocking densities (more than 300,000 post larvae per hectare), around-the-clock management, heavy feeding, waste removal and aeration. Selective stocking with quality shrimp seed from hatchery produced @ 10 lakhs/ha, maintaining water quality by exchange of25%-30% a day, with mechanical aerators/paddle wheels, feeding the shrimp with nutritionally balanced diet, are the main criteria for intensive culture. The production from this system could be expected from 10 to 20 tonnes/ha/crop. It is relatively easy to convert intensive farms to other species. Intensive farms frequently cause environmental problems. Extensive and semi-intensive culture systems have been making rapid strides in production of shrimp. White shrimp *P. indicus* and tiger shrimp *P. monodon* have proved to be economically suitable for culturing in brackish water ponds. Under extensive or improved extensive system the juveniles of P. indicus @ 50,000 to 1,00,000 and P. monodon 30,000 to 50,000 could be stocked. Intensive farming is always not encouraged despite high returns as it develops high risk due to pollution, disease leading to high mortality.

• Factors Affecting Shrimp Farming System

1. Water Quality

The quality of water is one of the important factors for better growth and survival as also for production. The temperature of the water affects the metabolism and indirectly growth rate. The hydrogen-ion concentration (pH) also plays a prominent role in water quality problem. pH is an indicator of the presence of metabolic photosynthetic activity and fertility of the pond water. pH of pond water in the range of 6.5 to 8.5 is considered to be the most ideal for shrimp culture. Very high-level value of pH is too fertile and likelihood of development of plankton bloom and toxicity of ammonia will be increased. Very low pH also leads to poor growth of plankton and less oxygen production.

2. Aeration

Shrimp farmers use tidal flow and diesel pumps to maintain stable water quality conditions and to renew the dissolved nutrients that sustain healthy algal blooms in their extensive and semi-intensive ponds. This process introduces freshly oxygenated water and helps flush out wastes. To further increase oxygen levels, some semi-intensive farms and most intensive farms use paddlewheel and aspirating aerators, electrical/mechanical devices that add oxygen to the water. They are used at night and early in the morning when oxygen levels are at their lowest. Shrimp flourish in the currents created by the aerators. Low pressure air has found many applications in the sewage treatment business and is likely, over time, to find more applications in shrimp farming.

3. Disease

Diseases represent the biggest obstacle to the future of shrimp farming. Farms and hatcheries have few defenses against rampaging protozoa, fungi and bacteria, but it's viral diseases that pose the greatest threat. Good water quality and lower stocking densities appear to be the best defense against all diseases. When pathogen populations are low, a shrimp's defenses are normally capable of preventing disease, but when stressed by questionable water quality and high stocking densities, shrimp fall prey to "shell-loving" bacteria, fungi and viruses.

4. Bird Predation

Migrating flocks of birds can land on a shrimp farm and quickly consume most of the shrimp. Almost everywhere birds are protected by law and efforts to scare them away are usually futile. Noise cannons, rockets and scarecrows work for a while, but the birds soon learn to ignore them.

5. Pollution and The Environment

Whenever large numbers of semi-intensive and intensive shrimp farms concentrate on the same river, estuary or bay, their rich effluents, primarily shrimp waste products, uneaten feed and dead algae and bacteria, lower the quality of the surrounding water, overwhelm the environment and create conditions which favours shrimp pathogens. Moderate amounts of effluents from shrimp farms have a beneficial effect on the environment, enriching it without overwhelming it. In some cases, shrimp farm effluent has improved the local fishery. The mangroves and mangrove species that surround many shrimp farms thrive on moderate amounts of nutrients from shrimp farms.

6. Shrimp Farm Management

All the unwanted organisms, predators should be destroyed before stocking the pond. Crabs are a menace to the culture ponds. It is always better to stock the ponds in dim light and avoid sunny days. Excess stocking may lead to overcrowding and lead to mass mortality. The availability of natural food may be examined and the parameter on water quality checked periodically. In case the shrimps are moving irregularly during day time, the water exchange may be done at once. Aerators should be used to maintain the optimum oxygen level. Supplementary feeding may be done during early morning and evening hours and recommended dose only to be applied. Otherwise, it will lead to pollution and development of diseases resulting in high morality.

Probable Questions:

1. What is shrimp?
2. Discuss the life cycle of shrimp with diagram.
3. Name two cultivable Indian species of shrimp.
4. Discuss about semi-intensive shrimp farming.

Suggested reading:

1. Beaumont, A. R. and Hoare, K. (2003). *Biotechnology and Genetics in Fisheries and Aquaculture*. Blackwell Publishing.
2. Jhingran, V. G. (1991). *Fish and Fisheries of India*.3rd ed. Hindusthan Pub. Corp. John Wiley and Sons.
3. Pillay, T. V. R. and Kutty, M. N. (2005). Aquaculture Principles and Practices. 2nd ed. Blackwell Publishing Ltd.
4. Chakraborti, N.M.; Chakraborty, P. P. and Mandal, S. C. (2010). *Biology, Breeding and Farming of Important Food Fishes.* Narendra Publishing House. New Delhi.