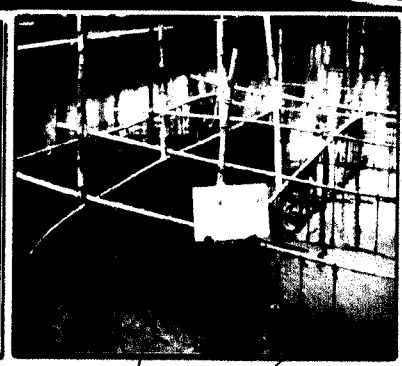
POSTGRADUATE PROGRAMME IN MARICULTURE

M.F.Sc. Mariculture

Lecture Outline
Volume I



भाकृअनुप
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INDIA

CULTURE OF CRUSTACEA

(MC-501)

M.F.Sc. (Mariculture) I

Central Marine Fisheries Research Institute

Cochin

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Lecture No. 1 Mary K. Manisseri

Global status of crustacean aquaculture

Shrimps fresh water, brackishwater and marine eco-systems some species cultivated in Southeast Asia for five centuries or more mostly trapping and confinement of young prawns in brackish water ponds 1934 Fujinaga spawning and partial rearing of *P. japonicus* sugpo prawn or giant tiger prawn *Penaeus monodon* is most preferred biological characteristics such as colour, larger size, faster growth rate, tolerance to wider range of salinity and temperature, availability of seeds etc. make the species most preferred.

Aquaculture practices popular in Philippines Taiwan Thailand India Indonesia Israel China Japan Australia United States etc. The white shrimp *Penaeus vennamei* is widely cultured in Latin American countries, especially Mexico and Ecuador *Penaeus orientalis* in S. Korea *P. japonicus* and *P. monodon* in Australia West German scientists tried culture of the sand shrimp *Crangon crangon* intensive culture of *P. japonicus* started in Japan hatchery and farming technology standardized high demand and attractive prices in India and Southeast Asian countries *P. monodon* culture is tried even in freshwater systems the recent outbreak of viral diseases has been a setback in most of the countries stress indicated as one of the reasons efforts are on to contain the epidemic.

Lobsters are low-volume high-value products prices go up to Rs.1300/- per kg for large-sized ones temperate and topical regions with different species United States and Europe *Homarus americanus* and *H. vulgaris* India has several spp. sand lobster *Thenus orientalis* in the northwest and southeast regions fattening of *Panulirus polyphagus* a popular practice Bhavnagar *P. ornatus* is the largest species in India fishery available along the southeast coast Mud crab *Scylla tranquebarica* larval cycle succeeded cannibalism poor survival fattening of water crabs juvenile to market size production trends.

Major species used in aquaculture

Penaeus monodon (black tiger prawn) – *P. indicus* (Indian white prawn) – *P. semisulcatus* (UAE, India) (Green tiger prawn) – *P. merguiensis* (banana shrimp) (Southeast Asian countries) – *P. chinensis* (Chinese fleshy prawn) (China, Korea) – *P. vennamei* (White leg shrimp) (North and South America) – *P. stylirostris* (Blue shrimp) (Ecuador, Panama). *P. japonicus* (Kuruma shrimp) (Japan, Australia) – *P. esculentus* (Brown tiger shrimp) (Australia) – *P. setiferus* (Northern white shrimp) (America) – *P. penicillatus* (Red tail shrimp) (China, Taiwan) – *Metapenaeus* spp. (China, Southeast Asian countires, Pakistan, India) – availability and adaptability of the species play a major role in selection – demand in the industry and price structure are important – genus *penaeus* is widely preferred because of the larger size and faster growth rate.

P. monodon is cultured in most of the countries along with the native species – simple and standardized hatchery and farming technologies promote shrimp farming when compared to farming of other crustaceans – import of species which are not native to the region is also noticed – *P. vennamei* in demand in Asian countries – care should be taken – proper quarantine measures – effect if any on native species to be studied.

Culture of lobsters – temperate species more successful than tropical – attempts to culture both varieties – species with shorter larval period preferred – hatchery techniques yet to be standardized in many cases – *Panulirus homarus* (Scalloped spiny lobster) – *P. polyphagus* (muddy spiny lobster) – *P. ornatus* (ornate spiny lobster) – *P. cliphas* (long-legged spiny lobster) – *Jasus edwardsii* in Australia – *Homarus americanus* (American lobster) – *H. vulgaris* (European lobster) – *Callinectus sapidus* (American blue crab) – *Cancer irroratus* (rock crab) – *Cancer borealis* (Jonah crab) – *Portunus pelagicus* (blue crab) – *P. trituberculatus* in Japan – *Scylla tranquebarica* (mud crab).

Lecture No. 3

Mary K. Manisseri

Farming technology and production trends

From traditional to semi-intensive - intensive - ultra-intensive traditional - passive flooding - catch and hold - collecting natural seeds - sorting - transportation - availability - different sizes of seeds - supplementary feeding - Pokkali culture in India - sluice gates - extensive culture - hatchery technology - induced breeding - spawning in captivity - larval rearing - availability of required species and seeds in large numbers - seeds of the same brood - "specific-disease-free" spawners and seeds to overcome the problem of viral diseases.

From the hatchery to the nursery - acclimatization to lower salinities in case of species which spend their juvenile phase in brackishwater - feed pellets of different sizes to be made available for the hatchery and nursery phases - supplementary feeding for sub-adults and adults - feeds of different composition and nutritional values - crop holidays and rotation of crops practised to overcome the threat from viral diseases - introduction of new species in the place of traditionally used species - development of hatchery and farming technologies for the newly introduced species - protection and promotion of the locally available species - appropriate technologies for different species in different localities - optimum range of water quality parameters for different phases of each species.

Stocking density increased in semi-intensive and intensive culture - feeding - water quality management - disease management - pumping water and mechanical aeration - concrete tanks or other facilities - tidal exchange of water in some cases - ultra-intensive grow-out systems - large concrete tanks - false bottom for some species - stocking rate - 0.1 to 10 no/m^2/crop - 3 to 10 no/m^2/crop - 15 to 50 no/m^2/crop - 50 to 100 no/m^2/crop - production - <0.3t/ha/yr - 0.5 to 2.5t/ha/yr - 5 to 15t/ha/yr - 30 to 100 t/ha/yr - reduction of stocking density advised for reducing stress.

Seed production of *Portunus trituberculatus* in Japan

Introduction swimming crabs secondary crop in the traditional fish ponds in Asia *Portunus trituberculatus* distribution Japan, China, Taiwan and Korea.

In Japan pond rearing of crabs is negligible - 'Saibai gyogyo' programme - objectives of fishery restocking history of the programme modern hatchery techniques well advanced in Japan national network of hatcheries - Japan Sea Farming Association - prefectural centres semi-governmental and private hatcheries JASFA Tamano - Okayama Fukui-etc.

Broodstock management capture of spawners small bottom trawlers - fixed or floating gill nets crab pots season transportation conditions and stocking density - maintenance of broodstock facilities required Indoor concrete tanks - stocking and management of the broodstock crabs outdoor tanks feed used - monitoring egg development temperature manipulation condition of the egg mass - handling of berried crabs incubation days changes in the eggs hatching procedures - time of hatching hatching rate selection of larvae larval rearing stages - production facilities rearing tanks sea water water quality management - water circulation.

Microbiological treatment of water extraneous organisms in the rearing tank - counting and stocking food feeding regimes feeding schedule in different hatcheries culture of *chlorella* culture of microbial flock culture of rotifer - culture of artemia provision of shelter for megalopa survival and production - harvest and transport major constraints prospectives postlarval restocking programme locations and sites procedures experimental production of *Scylla serrata* seedlings in Japan

Lecture No. 4

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Historical background of shrimp culture practices in India

Extensive culture – traditional farming – catch and hold method – no selective stocking – fast growing species along with others – no supplementary feeding – harvesting at intervals – problem with predators – no eradication – no artificial aeration – tidal exchange of water – Pokkali farming is an example – sluice gates – special variety of rice – organic debris in the system – practised for the past few centuries.

Among the species cultured generally were *Penaeus indicus* and *Metapenaeus dobsoni* – seeds of *P. monodon*, *M. monoceros* etc. in lesser numbers – *P. indicus* was preferred for traditional farming – larger size and faster growth rate – demand in the export market – attractive prices – hardy species – seed availability from the shallow brackishwater ponds, canals and creeks – omnivorous and detritivorous – cost of supplementary feeding negligible – leaving the organic debris of pokkali cultivation in the water amounted to organic farming – lesser stocking density avoiding stress though income also was not very high – polyculture with good quality fishes – culture practices without aeration, pumping of water, expensive compounded feed etc. reduced the cost of production making the income attractive.

With the advent of scientific knowledge – additional stocking along with natural stock – seed collection – surf collection – sorting for the required species – however, no selective stocking – supplementary feeding with locally available food stuff – use of tidal water – harvesting based on lunar phase – from extensive to modified extensive – semi-intensive culture practices – availability of hatchery produced seeds – compounded feed for various stages – artificial aerators – pumping of water – the practice of eradication – liming the pond – drying the pond wherever possible – crop holidays – much popularised.

Culturable species of shrimps

Preferred biological characteristics:

Large-sized species – penaeid species preferred generally – most of the non-penaeids smaller in size – prices and profit depend on size – many *Metapenaeus* spp also culturable – penaeids show faster growth rate – makes management easier – number of crops per year can be more – more profitable.

Seed and feed availability:

Natural seed availability – availability of standardised hatchery technology – breeder availability – culture of live feed organisms – availability of proper compounded feed – affordable costs – locally available feed.

Adaptability:

Local species – tolerance to wider range of salinity – temperature – other environmental parameters – easier water quality management – hardy species.

Disease resistance:

Important factor in the present context – resistance to diseases – availability of "specific-pathogen -free" breeders, seeds and feed – principle of "rotation of crops".

Marketability: Species with greater demand in domestic and international markets.

Preferred species:

Penaeus monodon *P. indicus* *P. semisulcatus* *P. merguiensis* *P. japonicus* *P. vennamei* *P. chinensis* *P. stylirostris* *P. esculentus* *P. setiferus* *P. penicillatus*

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Life cycle of shrimp

Larval phase:

Larval phase – marine – eggs hatch in seawater – stages of nauplii –stages of protozoea stages of mysis – post larvae

Juvenile phase:

In most of the species brackishwater – shallow ponds, creeks, canals, backwaters – availability of food – omnivorous in food habit – faster growth rate during this phase – brackishwater systems – shelter – early juveniles often seen among the vegetation along both the sides of the canals – many species prefer shallow regions during the juvenile phase – larval growth in seawater – sub-adults migrate back to the sea for maturation .

Adult phase:

Sexual maturation in sea – adult phase fully spent in marine water – spawning – rematuration – repeated spawning

Life cycle of some of the species fully marine – *P. semisulcatus* – juvenile phase in shallow coastal region with aquatic plants – adult phase and breeding – deeper waters – *Parapenaeopsis stylifera* – juveniles – shallow coastal waters – adult phase – deeper waters.

"Short-distance" migration – part of life cycle in most of the Indian species such as *Penaeus indicus, P. monodon, P. merguiensis, Metapenaeus dobsoni, M. monoceros* etc – "long-distance" migration due to other biological or environmental parameters has been demonstrated in case of *P. indicus*

Maturity stages in shrimp

Immature stage – ovaries thin – translucent – unpigmented – confined to abdomen – oocytes – small spherical ova – clear cytoplasm – conspicuous nuclei.

Early-maturing stage – anterior and middle lobes developing – dorsal surface light yellow to yellowish green – opaque yolk granules in cytoplasm of ova – ova larger.

Late-maturing stage – ovary light green – visible through exoskeleton – anterior and middle lobes fully developed – maturing ova opaque due to yolk.

Mature stage – ovary dark green – clearly visible through exoskeleton – ova largest – peripheral regions transparent – size close to planktonic eggs – last stage before spawning – rod-like peripheral bodies.

Spent-recovering stage – after extrusion of eggs – gonad reverts – immature condition – similar to the first stage – size of the shrimp – hairy pleopods – growth a continuous process – stages arbitrary – sizes < 0.08 mm – 0.08 to 0.24 mm – 0.18 to 0.3 mm – 0.22 to 0.38 mm - < 0.096 mm.

A thorough knowledge of the maturity stages of shrimp – necessary for broodstock development and maintenance – it is helpful that ovaries in late-maturing or mature stages are visible through the exoskeleton in live prawns, held against light – very often fully mature specimens are directly purchased from the fishermen who take enough care to bring them live and healthy with frequent water exchange – stress such as fall in temperature, salinity etc. would lead to delayed spawning – viability of eggs also may get affected – rematuration in captivity is possible – proper feeding and good water quality management essential.

Shrimp : male reproductive system and secondary sexual characteristics

Heterosexual – male generally smaller in size – brighter in colour – endopodites of the first pair of pleopods are modified to form petasma – endopod of the second pleopod also bears an accessory structure called appendix masculina – another structure called appendix interna – carideans. The male reproductive system conssits of a pair of testes – situated in the thoracic region lying above the posterior half of the dorsal surface of hepatopanereas and beneath the pericardinal sinus and heart – irregular in shape – each testis consists of three lobes – the anterior, the middle and the posterior – the anterior lobes of both the testes joined in the middle – just below and behind the posterior lobe is situated an accessory gland.

Vas efferens – from each testis – join to the proximal part of vas deferens which runs downwards and backwards – in its course – receives ducts from the accessory gland also – distal part of vas deferens thicker – has a wider lumen – called terminal ampoule – opens on the coxa of the last pair of thoracic legs – the terminal ampoule is a sac-like structure with a thick muscular coating – contains spermatophores and a white thick fluid.

Histologically, the testis has two different regions – one with bigger germ cells and the other with smaller glandular cells – generally, the spematophores are oval, transparent sac-like structures – in *Parapenaeopsis stylifera* spermatophores measure about 0.06 mm in breadth and 0.3 mm in length – in each spermatophore sperms are arranged in transverse compact rows varying from 6 to 8 in number – sperm elongated and cylindrical in shape with a very short tail – the membrane at the tail end produced into a thin spine-like process – head piece slightly smaller than the body – the whole spermatozoan appears to be enclosed in a thin transparent membrane.

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Shrimp: female reproductive system and secondary sexual characteristics

The female reproductive system consists of paired ovaries, oviducts and a single thelycum – the sternal plates in between the last three pairs of thoracic legs modified to form thelycum which serves as a receptacle where the spermatophores are deposited.

The mature ovaries are paired organs situated dorsally, extending from the base of the rostrum to the last abdominal segment – they are bilaterally symmetrical and partly fused – each ovary consists of three lobes – the slender anterior lobe occupies the anterior region just behind the rostrum – the middle lobe has 6 or 7 finger-like lateral lobules which entirely fill the area between the anterior region and the posterior border of the carapace – the posterior lobes extend the length of the abdomen.

The ovaries are united by two commissures – one at the base of the anterior lobes and the other at the tip of the posterior lobes in the sixth abdominal segment – the thin oviducts start from the tips of penultimate lobule of the middle lobe on either side and run downwards to external openings placed in the coxae of third walking legs.

Histologically, the ovary is surrounded by a thin membrane called capsule – followed by a thick layer of connective tissue – inner layer of germinal epithelium distributed only in certain areas called the "zone of proliferation" – the remaining area is the follicular region containing immature ova – immature ova are found in the centre while the mature ones are seen at the periphery – at the time of spawning the follicular cells undergo degeneration – the number of eggs produced varies with the size of the prawn in a logarithmic manner – about 50,000 to over 12 lakhs – fecundity: total number of ova in a mature ovary calculated from the weight of the ovary and the number of eggs in a weighed sample.

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Shrimp : digestive system, hepatopancreas

Shrimp - mouth parts – mandibles – tear the food material – other mouth parts – hold the material while tearing – oesophagus and stomach of penaeid prawns are lined with chitin and form the "stomodeum" – the short oesophagus runs vertically into the anterior chamber of the proventriculus – a system of grooves present on the floor of the anterior chamber enabling secretions from digestive gland to be passed forward and mixed with food – dorsally on each side of these folds which are armed with setae and spicules, there are rows of stout denticles which constitute the "gastric mill" used to grind the food.

The posterior proventriculus – partly embedded in the digestive gland – divided into a dorsal channel which leads directly into the midgut and a ventral "filter-press" which permits the finest food particles to pass directly into the digestive gland – the filter press has paired openings leading directly into the simple, blind-ending tubules which comprise the hepatopnacreas – short and straight intestine – feeding for more time.

The hepatopancreas is compact in shape – forms 3 to 4% of the total body weight – discharges functions of liver, pancreas and intestinal glands of higher animals - functions include secretion of digestive enzymes, absorption, digestion, storage etc. – the walls of the tubules are made of a single layer of epithelium – different types of cells – embryonic (E) cells – fibrillar (F) cells – vacuolar (B) cells – storage (R) cells – lumen – short midgut – peritrophic membrane – hind gut – longitudinal muscles – faecal pellets - major role played by hepatopancreas – cases where certain viral diseases are spread through food – how the system accepts and propagates.

Lecture No. 11

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Shrimp : food and feeding habits

Penaeid shrimps in general have been described as "omnivorous scavengers" or "detritus feeders" – browse on epi-flora and epi-fauna of the substrata – mixed diet suggested to be better – estuarine mud support a rich growth of bacterial colonies, microalgae and filamentous algae – micro-fauna enriched by protozoa, copepods, ostracods, nematods, etc. – polychaetes, and larvae of other organisms and sand particles are also seen in stomach contents – selective feeding by different size groups has been suggested in some species – species like *P. japonicus* obligatory nocturnal feeder.

Shrimps are known for caprophagy – this nature makes propagation of several diseases especially the viral diseases easier – also known for cannibalism – this nature poses a bigger problem in farming – this is more so in the case of crabs – compounded feeds are also tried in farms – feeds of different nutritional values are made for different stages of prawn – attempts are made by several agencies to formulate high quality feeds using locally available raw materials.

The stages of feeding – stomach full – partially filled – empty – some species nocturnal in habit – some burrowing – all these to be taken into account – different methods to assess food and feeding in shrimp – occurrence method – the number of prawns in which each food item occurs is listed as a percentage of the total number examined – number method – the total number of individuals of each food item as percentage of the total number of organisms found in all the specimens examined – dominance method – number of prawns in which each food item occurs as the dominant food stuff, expressed in percentage – volume and weight methods – the volume or weight of each food item or of the total food in each individual as percentage of the total body weight – fullness method – demonstrates seasonal variation in food intake using an arbitrary estimate of the fullness of the stomachs – order of preponderance – points method – allotting points according to the size and number of each food organism and expressing as percentage composition of the food of all the individuals examined.

Lecture No. 12

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Natural shrimp seed distribution and abundance, methods of collection.

Penaeid shrimp preferred – seed availability – traditional farming – life history includes a brackishwater phase in most species – the fast growing juvenile phase – post-larvae enter the brackishwater system – shallow ponds and canals preferred – this system is rich in organic debris with good algal growth.

Surf-collection of post-larvae attempted – available in large numbers – collection using velon screen or nets of smaller mesh size – sorting – transportation – acclimatization – practical difficulties – because of the availability of hatchery produced seeds, this method is not practised now-a-days..

Collection of early juveniles from brackishwater canals, creeks and ponds – collection manually done from shallow regions – velon screen or nets of smaller mesh size used – sorting the required species and sizes difficult – seeds belonging to different size groups only will be available – keeping in happas which would serve the purpose of acclimatization and also storage until the seeds are purchased by farmers or their agents – not practical when compared to hatchery production of seeds – availability seasonal – wastage of a number of less preferred shrimp and fish seeds which is extremely harmful to the environment – needs more manpower and effort.

Seeds of *Penaeus monodon* and *P. indicus* collected and stocked in traditional farms – seeds of smaller-sized shrimps such as *Metapenaeus dobsoni* constitute more than 50% of the shrimp seeds in the brackishwater systems in India – trapping is the most favoured method of collection – still followed in traditional system such as "Pokkali" farms in Kerala – also attempted in perennial farms practising modified extensive farming.

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Long-term impact of exploitation of seeds from natural sources on the fishery; Sea-Ranching of Prawns

Collection of prawn seed from natural sources – shallow brackishwater canals creeks – ponds – collection using nets and velon screens – sorting for desired species the rest of the seeds of other prawns, fishes etc. thrown out – affects the ecosystem – the balance will be upset when collection is on a large scale – adverse effects were noticed in the case of seeds of *Penaeus monodon* along the Kakinada coast – hatchery production is more practical and advisable – the traditional method of trapping of natural seeds making use of the tidal influx and sluice gates is more profitable as there is no manual sorting or selective stocking

Sea ranching to augment natural production – large scale production of seeds in the laboratory or hatchery – larval rearing – post-larvae – nursery phase – acceclimatisation – release in large numbers to the sea – to increase the natural stock – expected to achieve usual growth rate – successful entry in the fishery – richer returns – successfully attempted in case of *Penaeus japonicus*.

India – sea ranching of *P. semisulcatus*, a local species – attempted at Mandapam some species undertake long-distance migration – *P. indicus* migrates from the southwest coast to the southeast coast of India – this has been proved by biological studies and tagging experiments – any improvement in the returns would be visible in cases where the species does not take long-distance migrations.

Exploitation of juvenile phase of penaeid species is widely practised along our coasts – large quantities of *Penaeus indicus*, *Metapenaeus dobsoni*, *M. monoceros*, *M. brevicornis*, etc. are landed by stake nets, cast nets and small shore seines – a modified gear is used along the coasts of Tuticorin and Mandapam landing tons of juvenile *P. semisulcatus* from the shallow coastal waters with rich growth of seaweeds – this is a threat to the marine penaeid prawn fishery.

Lecture No. 14

Mary K. Manisseri

Problems and future outlook of crustacean culture

Shrimp culture - maximum attention - hatchery technology standardized - compounded feed available for different levels - disease is the major challenge today - viral diseases literally wiping out farms - the problem was worse in southeast Asian countires - Monodon baculovirus affecting most of the preferred shrimp species - large scale mortality at the hatchery level itself - total loss of the stock experienced - mortality occurring within days of infection - affecting the low-lying areas more - white spot disease in India - crop holidays - drying of ponds - resistant species to be popularized - disease leading to heavy economic loss - "specific-pathogen-free" spawner and seeds should be supplied to the farmers - water quality management to be given more attention - stress of any kind especially high stocking density to be avoided.

Hatchery technology to be standardized in case of lobsters and crabs - larval rearing - nutritional aspects - great demand - fattening profitable - should not affect natural resources - lobster resources face depletion - attempts should be made to standardize the hatchery technology - India has not yet succeeded in rearing the larvae of lobsters to the PL stage in laboratory. In case of mud crabs, the larval cycle is completed but the survival rate is too low - More studies to be carried out in this direction - moulted crabs landed are exported or kept in ponds for a few weeks for hardening. Crabs of smaller sizes also are used for fattening - spiny lobster *Panulirus polyphagus* in Bhavnagar - fattening cannot be promoted in a big way as this would adversely affect the natural stocks.

Sustainable aquaculture to be ensured - conserve natural resources and biodiversity - achieve least degradation of environment - techniques and technologies to be appropriate to a situation and site - foster minimal social disruptions and conflicts - provide for community needs.

Lecture No. 15

Mary K. Manisseri

Shrimp culture: prospects in India

Culturable species of shrimp – *Penaeus indicus*, hardy, large-sized prawn, contributing to good fishery along the Indian coasts – major attraction of traditional farmers – post-larvae and juveniles available in good numbers in the brackishwater region – hatchery technology standardized – larval cycle completed in about 8 to 10 days if environmental parameters are favourable – *P. monodon*, the most-favoured species fishery along the east coast – *P. merguiensis* – large sized penaeid prawn – fishery along the central west and central east coasts – hatchery technology known.

P. semisulcatus – fishery along the southeast coast of India – large-sized – good demand in export industry – hatchery technology standardized – juveniles caught in large numbers from shallow coastal waters along the coast of Tuticorin and Mandapam – *P. japonicus* – fishery along the Maharashtra coast – available in stray numbers along the east and west coasts – brightly coloured and large-sized – good demand in the export industry – wild shrimp fetching higher prices when compared to cultured shrimp – *P. penicillatus* – also a large-sized prawn – larval cycle comparable to that of *M. monodon* and *P. indicus*.

Metapenaeus spp – present in large numbers – *M. monoceros* – a large-sized prawn – fishery along both the west and east coasts, especially along Andhra and Orissa coasts – *M. affinis* comparable to *M. monoceros*. *M. dobsoni* – a smaller-sized prawn available in very large numbers along both the coasts – a major item in the capture fisheries – larval cycle comparable to penaeid prawns – hardy with juvenile phase in the brackishwater – tons of juveniles getting landed from the brackishwater ponds, canals, etc. – *M. brevicornis* comparable to *M. dobsoni* – smaller size and slower rate of growth make the *Metapenaeus* spp less attractive for aquaculture – those landed from the wild are used both in the internal and export markets.

Lecture No. 16

E.V.Radhakrishnan

Reproductive biology of lobsters

Lobster fishery species distribution general biology

Reproductive system of clawed and spiny lobsters - Male reproduction - maturity indicators of maturity - Male reproductive system Morphology - Anatomy - Formation of spermatophore - spermatozoa - Androgenic gland - Androgenic hormone .

Female reproductive system maturity - indicators of maturity - Ovarian development- maturity stages - Vitellogenesis - Resorption - Secondary sexual characters - Courtship - Mating behaviour - Multiple mating - spermatophore deposition - spermatophore sturucture Egg extrusion Egg attachment - Relationship between mating and oviposition - Incubation - Fecundity - egg development - egg loss - Hatching

Captive breeding - Control of reproduction in the American lobster - Reproductive hormones - Role of environmental factors - Reproduction in spiny lobsters - Environmental and hormonal factors - Broodstock - Maturation and spawning - Eyestalk ablation - Effect of EA on male and female - Reproduction - Gonadosomatic index - Reproductive metabolism - Broodstock holding system Flow-through system - Recirculation system - Stocking density - environmental requirements - Feed - Fresh and prepared feeds Broodstock diets - Reproductive cycles in captivity.

Lecture No. 17

E.V.Radhakrishnan

Recent advances in seed production of lobsters

Life cycle of Nephropid, Palinurid and Scyllarid lobsters – Larval biology of clawed and spiny lobster

Larval stages and instar - Functional morphology of larval digestive system.

Larval culture system for American lobster larvae - Hatchery techniques – Feeding - Water quality management

Different larval culture systems for spiny lobsters –Earlier attempts – Recent advances - Design of culture tank – Japanese (model) tank – Advantages – Modifications – Greenwater system – clear water system – Larval food – feeding behaviour - Water quality management – Salinity, pH, ammonia, COD, Heavy metals, microflora - Constraints, *Puerulus* culture – Larval diseases of clawed and spiny lobster -

Commercial seed production - Future prospects and constraints

Larval rearing of Scyllarid lobsters – Rearing conditions – Larval stages – Environmental factors.

Lecture No. 18

E.V.Radhakrishnan

Problems in hatchery technology development of lobsters

Breeding of American lobster – Biannual cycles – Prolonged maturation and egg incubation – Maturation and spawning by environmental manipulation – Short larval cycle – Feeding – Cannibalism

Breeding of spiny lobsters - natural breeders - Collection and transport of egg-bearing lobsters – Microbial infestations – Broodstock development – Holding – Maturation – Spawning – Egg quality – Influence of nutrition – Environment control – Feeds – Water quality management

Prolonged larval phase – Larval feeds – Live feed – Artemia nauplii – Feed requirement for different stages – Influence of photoperiod and light intensity - Artificial feed development for lobster larvae – Water quality management – Probiotics, larval diseases.

Advantages and disadvantages in seed production of clawed and spiny lobsters - Commercial seed production prospects and future strategies – Restocking .

Lecture No. 19

E.V.Radhakrishnan

Lobster grow-out systems, grow-out of juveniles

Culturable species Biology Moulting Growth Maturity Social behaviour Gregariousness nocturnal behaviour Solitary nature

Grow-out techniques for the American lobster Grow-out system – Stocking - Feeding – Growth – Water management – Harvest – Economics – Problems in commercial culture Cannibalism Slow growth Acceleration of growth in thermal effluents.

Grow out techniques for spiny lobsters – Collection of puerulii – Methods - Feasibility Juveniles/sub-adults – Collection Transportation – Quarantine

Grow-out of puerulii and juveniles to commercial size Grow-out system Cage, indoor system - Intertidal ponds – Food – Fresh feeds – Storage – Artificial feeds - Availability Stocking – Shelter – Environmental requirements – Feeding schedules Food conversion efficiency – Water quality management – Hormonal manipulation for growth enhancement – Eyestalk ablation – Food consumption – Growth – Survival Diseases - Future prospects - Economics.

Fattening - Short term fattening for value addition Market demand – Price structure Seed supply Seed transportation Stocking - Artificial feeds – Feed Feeding behaviour Feed consistency water management Harvesting Commercial prospects Product quality

Constraints No hatchery technology - Dependence on wild seeds – Seasonal-limited quantity - Long term impact on lobster fishery

Lecture No. 20

E.V.Radhakrishnan

Live transport and marketing of crustaceans

Collection – Transportation – Suitability – Market demand – Species – Size – Price structure – Competition

Physiology – Stress – Oxygen requirement – Mortality – Transportation in containers – Live lobster holding – Biological factors – Bacteria – Starvation – Temperature

Live lobster export in dry package – Temperature acclimatization – Slow cooling – Dip method – Problem of excretory wastes – Packaging materials – Packing techniques – Export – Problems in live lobster packing and export – Risk factors

Overseas markets – Status of export – Processing methods for whole-cooked lobsters and export – Export of other lobster products – Chilled, frozen tails etc.

Suitable species – Research information on respiratory physiology – Stress induced mortality – Stress – Indicators, bacterial load – Current status – Market needs – Market overview.

World markets for live prawns – Competitive advantage – Cultured prawns – Handling – Storage – Temperature acclimatization – Packing materials – Packing techniques and export – Quality issues – Image and perception – Consistency in export – Marketing in Japan – Price – Prospects for export from India.

Lecture No. 21

E.V.Radhakrishnan

Sustainable exploitation and conservation of lobster resources

Management of lobster fishery.

Introduction – overview of lobster fishery - Location – Time frame of fishery

Stock status of the fishery – Northwest coast – Southwest coast, Southeast coast – Deep sea lobster fishery.

Export of lobsters – countries – Live lobster marketing and export – other lobster products

Management objectives – Issues in management – current management measures in India – lobster fishery in other countries.

Suggestions for future management – Protection of egg-bearing lobsters – Ban on capture and export of juveniles and egg-bearing lobsters – Minimum legal size - Awareness creation among fishermen, traders and exporters – 'V' notching and releasing of egg-bearing lobsters – breeding period and seasonal closure – establishment of sanctuaries – Ban on destructive gears

Conservtion and protection issues – Artificial habitats for fishery enhancement – Breeding and searanching of lobsters – Research for management – CMFRI's effort – sustainable exploitation and management of lobster fishery in India.

Lecture No.22

A. Laxminarayana

Shrimp spawner collection and transport

Sexual dimorphism – petasma – appendix masculina – thelycum – gonophores – impregnation – spermatophores – maturity stages of female shrimp.

Spawning season – collection of spawners – trawl net operation – selection of spawners – colour of ovary – median, lateral and posterior lobes of the ovary – checking of impregnation.

Transport of spawners – immobilization – reduced oxygen requirement – change of water – for shorter-period transportation.

Longer-period transportation – aerated with battery operated aerators – polyethylene bags filled 2/3 portion with oxygen – ice blocks to reduce the temperature – bring to hatchery – disinfect – acclimatize to room temperature – keep for spawning.

Air-lifting spawners to other places according to demand – maximum demand for *Penaeus monodon* – maximum availability of the species in India along the Andhra coast – price of a single spawner sometimes goes up Rs.25000/- or more – mature specimens are in demand in other states – larvae and post-larvae are also air-lifted from the hatcheries to other places according to demand – transportatiaon of shrimp larvae in the first stage (nauplii) seem to be easier as the larvae in this stage do not feed – mature females of other species such as *P. indicus* also are in demand.

Lecture No.23

A. Laxminarayana

Shrimp broodstock management

Source of broodstock – sea – brackishwater – grown from postlarvae to adult size in ponds – pond size – shape – water depth – stocking density – culture period – feeds and feeding – aeration – water exchange – survival rate.

Sex ratio – latency period – effect of breeding season on maturation – rematuration and spawning.

Physical facilities used for broodstock maintenance – marine pens – flow-through systems – recirculating systems.

Marine pens – bamboo pens – sheltered bags – net made of nylon webbing – feeding – shrimp in the net hauled up periodically for examining – maturity stages.

Flow-through system – seawater from a well on the seashore pumped continuously through the system – feeding.

Recirculating system – sub-gravel filters – bacteria in gravel bed – oxidize toxic ammonia into nitrate – feeding.

Advantages and disadvantages of each system.

Important aspects as far as shrimp hatcheries are concerned: due care to be given to water quality management, environmental parameters and feeding – variation of environmental parameters to intolerable limits would lead to resorption of ova in the ovary – in the case of larvae moulting will be delayed under such conditions.

Lecture No.24

A. Laxminarayana

Induced breeding of shrimp under controlled conditions

Reproduction of penaeid shrimps – closed thelycum penaeids – open thelycum penaieds – maturity – spawning.

Maturation in captivity – man-made earthern ponds – cement tanks – raceways – seawater ponds – land-based – maturation tanks – running seawater facility – tank with sub-gravel filters.

Factors influencing maturation – light – temperature – pressure – water quality – pH and inorganic carbon – ammonia and nitrite – food – stress – mating process – artificial insemination – in vitro fertilization – diseases and injuries.

Environmental manipulation is known to have profound influence on the process of maturation in shrimp – among the various parameters pH seems to be very important – feeding is also considered as an important factor as far as maturation is concerned – stress delays maturation and spawning – eye-stalk ablation which would regulate the hormonal contents is also practised in some hatcheries – techniques of induced maturation, rematuration and artificial insemination have been attempted in some penaeid species of commercial importance.

Lecture No.25

A.Laxminarayana

Induced breeding of shrimp through hormonal intervention

Egg production - under control of neurosecretory centres - eyestalk - X-organ sinus gland complex - gonad inhibiting hormone (GIH) - inhibiting vitellogenesis - brain and thoracic ganglia - gonad stimulating hormones (GSH) - promote vitellogenesis - mechanism of action of hormones - principle of eyestalk ablation.

Bilateral eyestalk ablation - initial mortality – no spawning - regression of ovaries - electron microscopic studies - reason for lack of success with bilateral ablation - other neurosecretary hormones present in the eyestalk - their functions -

Unilateral eyestalk ablation - methods of ablation - scissor cutting – incisors of eyestalk and squeezing the contents of the eyeball - electrocauterisation - advantages and disadvantages of each method.

Shrimp breeding through environmental and dietary interventions.

pH - as factor influencing maturation of penaeid shrimps - in captivity - Induction of maturity by pH - regulation

Role of nutrition in brood stock management - nutritional requirements of broodstock shrimps- prostaglandins - long chain polyunsaturated fatty acids - fresh feeds - feeding rate - shrimp breeding through dietary intervention

Lecture No. 26

A. Laxminarayana

Traditional shrimp farming methods – extensive and modified extensive farming.

Definition of Traditional, shrimp farming. Bheries of West Bengal, Pokkali fields Kharlands – ghazan fields. Rotation of crops - paddy and shrimp/fish. Repair of bunds – fixing of wooden sluices – transportation of shrimp/fish seed during high tide trapping of seed – culture period – harvesting – production – Advantages and disadvantages of the system.

Definition of extensive system – size of ponds – water depth – fertilization of ponds – plankton blooms – stocking density – feeding – water exchange – culture period – production.

Definition of modified extensive culture – size of ponds – scientifically designed – separate inlet and outlet – pond preparation – eradication of predators, liming - fertilization with organic and inorganic fertilizers – stocking density - feeding with compounded feed – water exchange – use of aerators – culture period – production.

Both naturally collected and hatchery produced seeds are used in traditional and extensive systems – sorting is rather difficult in the case of naturally collected seeds resulting in a multi-species stock – even in case of seeds belonging to the same species, size range would be different because the seeds may not belong to the same brood as in the case of hatchery produced seeds – production is less in the traditional and extensive systems – the modified extensive system is more scientific and production is also quite encouraging.

Lecture No. 27 A. Laxminarayana

Semi-intensive, intensive and Ultra-intensive grow-out systems

Definition of semi-intensive - shape of ponds - depth - elevated site-ponds well prepared – eradication of predators – liming - fertilization - stocking density 1,00,000 to 1,50,000 ha. – water exchange 25 to 30% - 4-6 aerators per pond – high energy prepared feed given – generators provided – production level 2.5 to 5 tons/ha/crop – advantages and disadvantages of the system.

Definition of intensive system – shape and size of ponds – depth – preparation of ponds – high stocking density – feeds and feed management, aerators – water exchange high – high production – high investment – risks involved – advantage and disadvantage of the system – not adopted in India.

Definition of ultra-intensive grow-out system – size and shape of ponds – depth – very high stocking density – completely feed-based – generator – very high investment – high risk – very high production – not adopted in India – advantages and disadvantages of the system.

Selection of specific-pathogen-free breeders and seeds important – proper care should be taken during transportation – acclimatization to the system is necessary – regular monitoring of important environmental parameters such as temperature, salinity, pH and ammonia and frequent water exchange also needed – proper feed to be given in adequate quantities following a feeding schedule – regular monitoring to ensure health of the stock – frequent sampling to monitor the rate of growth.

Shrimp Farm Management.

Water quality parameters – temperature – salinity – dissolved oxygen – pH and alkalinity – turbidity – nitrogen metabolites – water colour – transparency – redox potential.

Techniques for maintaining good water quality – water exchange – water cultivation aeration – liming – therapeutants and other chemicals – removal of metabolic waste.

Pond preparation – feed management – factors influencing feed management – natural feeds – benthic layer – "Lab-Lab" – phytoplankton and zooplankton – fresh feeds – survival rate – feeding rate – feeding frequency – feeding tray – observation on feeding.

Fertilizers and chemicals used in shrimp farms – shrimp diseases – causes – diagnosis – prevention – treatment – disease control programme in shrimp farms.

Care should be taken from the beginning – site selection – availability of spawners or seeds of the required species to be ensured – water quality and environmental parameters of the region to be surveyed.

Methods for eradication of predators and fertilization of farms to be eco-friendly – "organic farming" to be given importance – it should be ensured that the spawners or seeds collected are specific-pathogen-free.

Enough thought to be given to the possibilities of poly-culture – crop holidays and rotation of crops using suitable species – avoiding stress from stocking density.

Shrimp farming in different maritime states, export

Shrimp farming development in different states - shrimp farming in Kerala Karnataka Goa Maharashtra Gujarat West Bengal Orissa Andhra Pradesh Tamil Nadu.

Area under culture in different maritime states systems of culture in different states species cultured production from different states.

Changes in the system of culture due to Supreme Court verdict - disease problems. Shrimp farming system recommended by the Aquaculture Authority environmentally friendly and sustainable shrimp farming contribution of cultured shrimps to exports.

Export of marine products frozen shrimp continues to be the largest item in terms of value shrimp contributed to 30% in volume and 70% in value of the total export of marine products from India during 2001-02 decline in international price of Black Tiger shrimp by 22.5% during the year however, 14% increase in shrimp export mainly from aquaculture farms.

Export of live lobster and shrimp showed positive growth quantity of frozen shrimp exported during 2001-02 was 1,27,709 t as against 1,11,874 t during the previous year, fetching a price of Rs.4140 crores. Japan continued to be the largest market for Indian marine products value-wise share for Japan was 30.56% during the year, USA 23.86%, European Union 19.31% and China 10.03%.

Chennai, the largest port with a share of 26% in value and 10% in volume share of Kochi 17% in volume and 15.6% in value. Ministry of Commerce and Industries fixed an export target of US $ 1250 million for 2001-02, the actual export was US $ 1253.35 million.

Shrimp production trends:

Shrimp production trends – global level – production by species – contribution of various species to the total production.

Production in the eastern hemisphere – Thailand – China – Indonesia – India – Philippines – Vietnam – Taiwan – Malaysia – Iran – Australia – New Caledonia and Others – percentage of production – hectares in production – kilograms per hectare – number of hatcheries – number of farms.

Production in western hemisphere – Ecuador – Brazil – Nicaragua - Venezuela – Panama – United States – Others.

Trends of production in different maritime states of India – Kerala – Karnataka – Goa – Maharashtra – Gujarat – West Bengal – Orissa – Andhra Pradesh – Tamil Nadu.

In India about 1,57,400 ha went into production of brackishwater shrimp – yielded 102,940 t of shrimp with a farm gate price of about Rs.3,170 crores, during 2001-02 – showing a 6% increase over the previous year's production – about 36,640 ha of freshwater farms yielded about 24,230 t of scampi – showing 46% increase over the previous year's production.

Contribution of cultured shrimp to the total shrimp export from India during 2001-02 was 58.6% in quantity and 85.8% in value. The major product form of frozen crab exported from India during 2000-01 – cut swimming crab (3219 t).

Lobster resources – landed by trawlers and indigenous gear – fattening is also practised – export during 2000-01 in live condition: 146 t – chilled: 57 t and frozen: 1352 t – species involved: *Panulirus homarus, P. polyphagus, P. ornatus, P. versicolor, Thenus orientalis, Scyllarus sordidus* and *Puerulus sewelli*.

Seed Production of Penaeid shrimps- General aspects

Introduction – history of seed production – major countries – candidate species selection of suitable species – seed availability – distribution, season etc – identification characteristics – penaeid and non-penaeid larvae.

Biology of prawns – penaeid prawns lay eggs in the open sea – postlarvae migrate towards coastal areas, estuaries, backwaters – juvenile phase – adults migrate back to sea – maturation and spawning – males do mature in backwater – *Penaeus indicus* – *P. monodon* – *P. semisulcatus* entire life history in marine environment – male sexual organ petasma – female – thelycum – non-motile sperms – moulting and mating – time lay between mating and spawning.

Viable sperm throughout the intermoult period – multiple spawnings – process of spawning – time of spawning – fertilization – fecundity – characteristics of fertilized eggs – size of the egg – size of perivitelline space in different genera – egg development – rate of egg development – hatching.

Nauplius – pear shaped body with 3 pairs of appendages – medium eye – no mouth – substages and their identification characteristics – duration of each stage – nauplii count – feeding stage, protozoea – large carapace, slender thorax and abdomen – other morphological characters – 3 substages – feeding requirement.

Mysis – substages – distinguished only by small increase in the size of the larvae – length of pleopods – behaviour of larvae in each stage – feeding appendages – mouthparts of the protozoea and mysis adopted for filter feeding – other modification for filter feeding – metamorphosis of mysis into the postlarvae – postlarvae capable of capturing prey

Lecture No. 32

Josileen Jose

Basic requirements of a shrimp hatchery and its operation

Introduction – design and layout of a hatchery – factors to consider – criteria for suitable site selection – species to be cultivated – appropriate facilities to be constructed – technical know-how – production target – capitalization – design and construction criteria – hatchery size – lay out – specific guidelines.

Location of sea water suction – effluent discharge points – pump house – generator housing – air blower room – effluent treatment – settlement – chlorination – storage tanks.

Location of different sections in the hatchery complex – algal culture tanks – larval rearing tanks – access to the larval rearing tanks – spawner and hatching facilities – packing and storage area.

Types of tanks – broodstock holding tank – larval rearing tanks – algal culture tanks – chlorella – rotifer tanks – transition tanks – nursery tanks – brine shrimp hatching tanks – shape of the tanks – bottom slope – materials – water depth.

Seawater supply system – aeration system – freshwater supply system – electrical system – main building and other facilities – algal laboratory – spawning and hatching area – counting and packing area – store room – office room etc.

Estimation of hatchery facilities – size of algal tanks – larval rearing tanks – nursery tanks – total water requirement etc. Hatchery operation – spawning to postlarval development – shut down period – larval feeding – spawner feed schedule – lighting in larval rearing tanks – larval shifting and rearing.

Lecture No. 33 Josileen Jose

Maturation / rematuration system for shrimp hatchery

Introduction – development of broodstock – selection of animals – size of the animals – maturation/rematuration systems – concrete tanks – fibre glass tanks.

Induced maturation techniques – environmental manipulation – temperature – salinity – pH – ammonia – nitrite – nitrate – feed – feeding schedule.

Eyestalk ablation – different methods – size of the animals – electro-cauterisation – ablation procedures – requisites – principle behind electro-cauterisation – advantages over other methods.

Regular observation on eyestalked animals – development of ovaries – stocking density in maturation system – male to female ratio – chances of moulting after ablation – full development of ovaries – transfer of gravid females for spawning – spawnings followed by ablation.

Management of broodstock system – water quality parameters – salinity – temperature – pH – dissolved oxygen – light intensity – different feeds – feeding schedule.

Recruiting system for rematuration – type of tank – materials required – air-lifting system – system set up – in situ biological filter – total water available for recirculation – recirculation per day – pH adjustment – spawner care.

Techniques of rearing penaeid shrimp larvae, seed transport

Introduction – history of culture – pioneering efforts of Hudinaga with *Penaeus japonicus* - hatchery systems – Japanese system or community culture system – fertilized or large tank hathery system – characteristics of the system – hatchery tanks – cement/ concrete tanks – size range and shape of the tank – indoor or outdoor.

Aeration systems – agitators – preparation of tanks – spawner introduction – stocking of spawners – spawning – hatching – tank fertilization – larval stages – feeding – water exchange – modifications by different workers – advantages and disadvantages.

Galveston system – closed system / unfertilized system – Galveston lab – different components of closed system – modification by different workers – Cook (1969) – Cook and Murphy (1969) – Aquacop (1975) – algal concentrations – rotifer and artemia concentration - nauplii stocking density – advantages and disadvantages.

CMFRI techniques – low cost technology – spawning – larval rearing techniques – cylindro-conical tanks – management – water quality parameters.

Kerala Fish. Tech: different aspects of rearing – management.

Nursery rearing techniques: Japanese system – cylindro-conical tanks – concrete tanks – earthern ponds – net cages (floating and fixed types) – shapes and sizes of the tanks, ponds and cages – stocking density – feeding – preparation of nursery ponds.

Shrimp seed transportation – nauplii transport – suitable areas – concept – requirements – advantages – disease and nauplii transport.

Shrimp farming in pens – raceways – status – production.

Lecture No. 35

Josileen Jose

Hatchery and nursery management

Successful functioning based on management – adequate technical know-how and expertise – major areas which need proper management – selection of site – design, lay-out and construction – other infratructure facilities – seawater intake and pumping – water storage for steady supply of good quality water.

Collection of spawners from the wild – selection of spawners – broodstock management – facilities for spawning – rearing of larvae – food and feeding schedule – uninterrupted aeration facility – supply of electricity – freshwater availability.

Appropriate stocking densities – larval tanks – nursery tanks – seed collection – packing – transportation – maintenance of hatchery equipments.

Most important – water quality management – reason – provision of clear seawater one of the major prerequisites – removal of organic and inorganic particles – filtration and recycling systems – sedimentation – filtration – disinfection – recirculation – biological filtration – biological – mechanical – chemical filtration – first step in biological filtration – mineralisation – nitrification – denitrification – filters – effective filters – rapid sand filters – sand vaccum filters or pressure filters – backwashing of filters.

Water quality parameters to be analysed – methods – temperature – pH – light intensity – salinity – dissolved oxygen – phosphate – nitrite – nitrate – ammonia.

Lecture No. 36 Josileen Jose

Feeds for the hatchery

Introduction – important species of phytoplankton – Mixed algal culture dominated with *Chaetoceros* spp. – *Chaetoceros* mass production – innoculum collection – chemicals used – duration of culture – cell concentration – counting – addition to rearing system – new culture – *Chlorella* – *Nannochloropsis* – culture – growth phase – batch culture – semi-continuous culture – GNOC method – chemical method – problems.

Zooplankton – selection of suitable species – qualities of the feed – rotifer – size range – L type – S type – SS type – distribution and availability – life cycle – life span with respect to temperature – optimum range of salinity – pH – asexual reproduction – sexual reproduction – mass production techniques – yeast based – microalgae based – comparison of different algae – nutritional qualities of rotifer – methods of culture – batch culture – semi-continuous culture – advantages – disadvantages – ground nut based culture – chemical method – prevention of contamination in long term culture – methods of harvesting.

Moina – life cycle – size range – propagation – methods.

Artemia – adult artemia – feeds of artemia – geographical distribution – size range – different strains – qualities of cyst – selection of suitable strain – hatching efficiency – T_0 incubation – T_{90} incubation time – hatching techniques – decapsulation methods – qualities of artemia as feed – collection of artemia nauplii – feeding strategies – enrichment techniques – nutritional value of artemia.

Artificial feeds – prawn egg custard – preparation – storage – feeding intervals – particle size – advantages and disadvantages.

Lecture No. 37 Josileen Jose

Important species of crab, their taxonomy and life cycle

Introduction – species of commercial importance – taxonomy of the species – features of the family portunidae – sub family portuninae – important genera – *Scylla* - *Portunus* – *Charybdis* – *Lupocydus* – *Thalamita* – different species of each genera.

Classification of *Scylla* spp. by different workers – Estampador's classification – Keenam *et al.* – Kathirvel & Srinivasagam – Joel-Sanjeevaraj – Radhakrishnan and Samuel etc. – major reports by other Indian workers.

Scylla and *Portunus* spp. external anatomy – carapace – spines along the sides of the carapace – antennae and antennule – walking legs – swimming legs – structure and function of chelate legs – function of pleopods – morphometry – carapace width and length.

Ecology and life history – habitat – juvenile phase – adults – spawning – incubation period – development – pre-cleavage – cleavage - blastula-gastrula – naupliar stage – Meta nauplia – pigmented eye – heart beat – pre-zoea- hatching – zoeal stges – megalopa.

Crab instar – adult crab moulting and growth – stages in moult – pre-moult – moulting – post moult – intermoult – reproductive biology – differences between male and female – reproductive system in females – ovaries – spermatheca – oviduct.

Male reproductive system – paired testes – vas deferens – ejaculatory ducts – spermatophores – size at maturity – determination of maturity in males and females – courtship and mating – sperm transfer – fecundity.

Lecture No. 38 **Josileen Jose**

Crab Farming in the Indo-West Pacific region

Introduction – important species of mud crab – demand and scope of the mud crab aquaculture – culture practices – sources of seeds – natural habitat – distribution and availability in India – season in different maritime states – gears – status of hatchery seed production.

Culture practices – grow-out culture – fattening – site selection – design and construction of ponds – pond preparation – draining – sun drying – application of lime – eradication of unwanted species – application of organic manure – filling with water – use of *Gracilaria* in crab ponds.

Stocking – feeding – water management – monitoring growth – sampling – harvesting techniques – time of harvest – post harvest sorting of mud crabs – different grades in the market.

Handling after capture – longevity of crab outside sea water – packing – packing materials – packing of juveniles – in algae – wet cotton – in woodshavings – adult crab – different methods for live transport – latest methods – Vivier truck.

Quality of holding water – salinity – oxygen – temperature – handling equipment – "Ice wrap" – benefits description and working – uses – packaging refrigerant use – storage and handling – Marketing – important markets – export economics of mud crab farming.

Important species of USA – *Callinectes sapidus* – *Cancer magister* – *C. borealis* – *C. irroratus* – *Mithrax spinosissimus* – present status – culture.

Lecture No. 39 **Josileen Jose**

Crab Seed production

Introduction – status of seed production – important species – *Scylla* spp. *Portunus* – *Callinectes* – *Cancer* - important attempts in India, Malaysia, Philippines, Thailand, Australia and other countries.

Brood stock development – management of brood stock – procurement of wild spawners – availability of berried crabs – selection of desired size – conditions during transportation – management of holding tanks – incubation period – colour changes during incubation – hatching tank – time of hatching – requisites for hatching – conditions for hatching – selection of active zoeae for rearing – total zoeae estimation – stocking density in larval rearing tanks – larval stages – zoeal stages – megalopa – crab stages.

Different feeds used during different larval stages – feeding schedule – live feeds required for various stages – *Chlorella/Nannochloropsis* culture – rotifer culture – artemia nauplii production – management of larval rearing tanks – water exchange – larval moultings – duration of each zoeal stage – megalopa stage – crab instars – behaviour of larvae in each developmental stage – cannibalism – "clinging" of megalopa – additional substratum/materials/shelters used for megalopae and early crab stages – effect of hydrological conditions on larval growth, development and survival – survival rate – scope of the hatchery technology.

Nursery rearing – concrete tanks – ponds – other methods – feeds and feeding schedule – management of nurseries – larval stages of important species – *Scylla* spp. *Portunus pelagicus* – Species from USA

Major constraints and problems in seed production – high larval mortalities – cannibalism – carnivorous diet – differential growth rate – failures in moulting – prospectives and suggestions.

Culture of Mollusca

(MC-502)

Post Graduate Programme in Mariculture
Central Marine Fisheries Research Institute
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7. Dr. Shoji Joseph Scientist (Senior Scale)

Lecture - 1

Molluscan Mariculture

Overview of Molluscan Culture (1)

History of Molluscan culture : History- need for culture – dwindling stock- over fishing - disease out break – transplantation-Southeast Asia- Japan – China- Taiwan- Europe- Canada- America —research significance

Trends in world production of farmed molluscs:

Average annual production – contribution to total world aquaculture production – trend over a decade - Production of the major groups of molluscs - bivalves- gastropods –cephalopods- production from Asia- major contributors

Bivalve Production – Total world production- Contribution to molluscan production - Major species – clams and cockles : inflated ark - blood cockle- common edible cockle- globose clam- smooth mactra- Japanese hard clam— grooved carpet shell- Japanese carpet shell- Pullet carpet shell- butter clam- Pacific little neck clam- northern hard clam- Venus clams- razor clams - gaper cockles-

Oysters- Chilean flat oyster- European flat oyster- Shell loving oyster- Pacific cupped oyster- mangrove oyster- American cupped oyster- Portuguese cupped oyster – Hooded oyster- Sydney cupped oyster- Slipper cupped oyster- Cortez oyster- Cupped oyster

Faculty - Dr.K.K.Appukuttan / Dr.K.S.Mohamed

Lecture - 2

Molluscan Mariculture

Overview of Molluscan Culture (2)

Mussels -Korean mussel- Chilean mussel- blue mussel – green mussel- Mediterranean mussel – Australian mussel – Choro mussel- Horse mussels- South American rock mussel – brown mussel – New Zealand mussel – Cholga mussel – Sea mussels

Scallop – Yesso scallop- great Atlantic scallop- Australian southern scallop – Peruvian calico scallop- Queen scallop-

Gastropods — abalones – Perlemoen abalone – blacklip abalone- horned turban- Periwinkles- Stromboid conchs- –*Trochus- Babylonia- Chichorius- Rapana* – endangered species- sea ranching -regulations- conservation need

Cephalopods- Pharaoh cuttlefish- *Sepiella inermis- Loligo duvauceli - Octopus vulgaris-* – Octopus- neuron – behavioral studies- recent developments - cephalopod culture - cuttlefishes- squids- production level- Sea ranching – stock enhancement - countries - constraints

Pearls – Global pearl production- *Pinctada margaritifera - P. maxima - P. fucata - P. mazatalanica* – trends in trade of marine pearls – leading countries – Tahiti – Japan – Australia – China – Akoya trade

Faculty - Dr.K.S.Mohamed/Dr.V.Kripa

Lecture – 3

Ecology and biology of pearl oysters

Distribution – *Pinctada fucata* – *P. margaritifera*- *P.maxima* - tropical – subtropical – intertidal- deeper areas – Persian Gulf – Red sea – Philippines – Japan – China – Korea – Myanmar – Indonesia – Papua New Guinea – French Polynesia – Cook Islands – Australia – Gulf of California – Mexico – Panama – Venezuela

Ecology – Gulf of Mannar – Palk Bay – Paars – calcareous algae – sponges – hard substrata – Gulf of Kutch – Khaddas – Intertidal – Southern Kerala – Andaman and Nicobar – Lakshadweep Islands – productive paars – assostaited fauna sponges – starfish – other molluscs – alage – predfatory fishes – Balistes – serranids – rays – skates – boring polychates – sponges – predatory gastropods

Biology – life history - growth rates in different regions – west coast – east coast – semienclosed bays - food and feeding - reproduction- gametogenesis - season – periodicity - spat fall - intensity – survival – fishery

Faculty- Shri.T.S.Velayudhan

Lecture - 4

Theory of Pearl

Pearl Culture Technology: Pearls in ancient times - Natural pearl – organic or inorganic nucleus – parasites – adults – larvae – decaying parts of plants – grains History of pearl culture – Chinese pearls -Pearl production in Japan – pearl sac theory- Kokichi Mikimoto - formation of pearl – outer eplithelium of mantle – mantle – nacre – extra pallial fluid – mother liquor – muco protein – acid mucopolysaccrides – calcium carbonate – inorganic ions – aspartic acid – serine – glycine – alanin residues – first mineral lamella – inter crystalline matrix – size – shape – nature of aggregation of crystals- physiological condition of oyster – seasonal changes - development of cultured pearl industry

Pearls from India : History – ecology – depth- substrata- natural predators- pearl banks – main paars – Gulf of Mannar –Palk Bay – Gulf of Kutch - pearl fisheries- fishing method – production – stock depletion- revenue– reasons for closure of fishery – recent fishery

Pearl producing molluscs: Taxonomy – shell structure - Conchiolin layer- prismatic layer – nacreaous layer - identifying characters- *Pinctada fucata* – *P.sugillata* – *P. margaritifera- P.maxima* –*Pteria sp-* freshwater mussels – *Hyriopsis schlegeli* – *Cristaria plicata* – *Quadrula* – *Parreysia corrugata* – *Lamellidens marginalis* – gastropds - *Haliotis* – *Strombus* – *Trochus* – *Turbo*- distribution - utilization – mother of pearl – shell craft

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Lecture - 5

Pearl oyster Surgery

Selection of oysters: Size – health - boring intensity – gonad condition - Preparation of oysters - conditioning – menthol crystals – hinge down tight packing – pegging - Graft oyster selection – tremadode infection - significance – Graft tissue – donor oysters- – parts of mantle – size of graft – eosin

Surgical instruments – graft cutting and trimming – opening and regulating the valves – knife – scissors – forceps – spatula – scalpel – oyster stand – shell speculum – retracteor – foot puller – lancet cum graft lifting needles – nucleus lifting needles -

Nucleus – source – *Triogonia* – *Pleurobema* – *Megalonais* – phylogenic affinity – chemical composition – binding strength – heat resistence - size – specific qualities of nucleus- Nucleus implantation - position of implantation – single and multiple implantation

Convalescence – flow through system- density - Post operative culture Harvest-collection of pearls cleaning- polishing -sorting - grading- size – luster – iridescence- flaws – colour – shapes-Transplant of harvested oysters for reuse.

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Lecture - 6

Pearl oyster farming

Selection of culture site - Ecological conditions of the culture site -Primary productivity -Temperature -Salinity -Depth- Current – water inflow – siltation – nature of sea bottom – presence of industrial and domestic pollutants – sheltered bays – calm coastal waters -

Grow out systems: Different cages - iron rimmed - lantern cages – sandwich cages – square lantern cages – netlon – nylon fish net – plastic baskets – size of cage – durability – corrosion – fouling intensity – predation – clogging - Stocking density - Grow out systems- Racks - Rafts- Long line culture – advantages – limitations

Onshore systems – cement tanks – water flow – aeration – feeding intensity – stocking density – water exchange – water quality management

Farm management: – bamboo – casuarinas –floats – anchors – farm houses - Maintenance -Periodical cleaning- thinning - stocking – labour -Monitoring - fouling –season- intensity based on depth- location - boring – sponges- polydorid worms – control – fresh water treatment – replacement of grow out structures

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Lecture – 7

Pearl Culture in India

Pearl culture and CMFRI : Technology development- ICAR- role of CMFRI – Tuticorin Research Center - Pearl culture programs in Tamil Nadu – Kerala Pilot project – shortfalls – Gujarat – resource availability - Lakshadweep – Andaman and Nicobar Islands – training programs – short term -long term – beneficiaries

Commercial Pearl culture: Tamil Nadu Fisheries Development Corporation- Southern Petro Chemicals Limited - Krusadi Island –Industrial programs- Village linked -Valinokkam Bay programme- farmers involvement – production – incentives- draw backs- - problems - commercial pearl farms – M.S.S.R.F programme – supply of nucleated pearl oysters – spat – NATP on Pearl mariculture

Prospects – higher growth- nacre deposition – colour – luster –Problems – Location – resource management – resource availability – protection of farms - production rate- size of pearls – mother oyster stock improvement – pathology problems – pearl culture environment – techniques of surgery – biominerilisation of nacre- tissue culture – options for organizational set up – decentralized systems – village level units – pearl farmers cooperatives – input supply - arrangements for security – ouput management – policy support – quality of pearls – demand – international market

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Lecture - 8

Recent developments in Pearl Culture

Types of pearls- *Pinctada fucata* - Japanese Akoya - Chinese Akoya- oriental pearls – *Pinctada margaritifera* – black pearls – *Pinctada maxima* – mother of pearls - keisi- biwa pearls – winged pearl- golden pearls-fresh water pearls-difference between luster and orient – blister pearl – free pearl - pearl without nucleus

Global market-Japan - size of pearls- value –Trends in pearl production-Major pearl producing countries - Japan – Australia- development of stock – natural pearl spat collection – hatchery – cooperative societies – financers – entrepreneurs - Tahiti – South east Asia

Recent developments– mabe pearls – selection of oysters - images-materials- shell powder – plastic beads – acrylic - location of insertion – pouches - grow out period- polishing - make up pearls- alkaline base – ouil base – acid dye – straight dye – seeping – trade ethics – neutron bombardment – manganese – black pearls - fresh water mabes-large pearl production in India – new designs of cages and rafts

By products – Seed pearls – medicines – pearl powder – pearl liquid – stimulant – tonic – aphrodisiac – laxative – sedative – emetic – nutritive – antacid – Class C pearls - Pearl calcium tablet – pregnancy – pearl shell medicine

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Lecture – 9

Tissue culture in Pearl Oyster (1)

Marine invertebrate tissue culture – tissue culture in agriculture – medicinal fields- origin and importance – tissue culture in fresh water organisms – marine invertebrate tissue culture – recent field of research – work on pearl oyster and other marine organisms – countries involved in marine invertebrate tissue culture – aim and importance of the work – set up of tissue culture laboratory – office - cum – record room- preparation room – dressing room – operation room – pass box – animal sterilization room

Instruments - Placement of instruments – deep freezer – pH meter – electronic balance – magnetic stirrer – hot plate – refrigerator – water purifier – water bath – centrifuge – autoclave – pipette washer in the preparation room – laminar flow hood – refrigerated centrifuge – vacuum pressure pump – CO2 incubatyer – inverted binocular microscope – computer and its accessories.

Procedure - Preparation of balanced salt solution for marine molluscs (MMBSS) – composition of MMBSS – preparation of supplementary salt solution and its composition – preparation of culture medium and its composition – sterilization by filtration – selection of antibiotics – dosage of antibiotics preparation of tissue extract and its procedures

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Lecture – 10

Tissue culture in Pearl Oyster (2)

Preparation - Depuration of test animals – U.V. chamber – reservoir tank – sterilization tank – steriliastion of test animals – use of 70 % ethanol – opening of oysters – removal of mantle tissue – washing in sterile sea water – treatment of tissues in antibiotic solution – preparation of explant tissues – incubation of culture containers in CO_2 incubater – explant cultures and organ culture in TD flasks and Petri dishes – medium change

Study on cell proliferation – granular, agranular and fibroblast cells – cell types – cell migration – formation of psedop[odial network – forming of organic matrix – grouping of cells – formation of cell sheet – secretion of crystals – *deposition of crystals on organic matrix – aragonite and calcite crystals*

Collection of mantle cells – subculture of cells – preservation of cells in refrigerator (- 15 ^{o} C) – deep freezer (-70 ^{0} C) – liquid nitrogen (- 196 ^{O}c) preparation of dimethyl sulphoxide (DMSO) and glycerol – the cryoprotectants – cell revival – procedures – creation of cell bank – application of tissue culture techniques in *invitro* pearl production - possibility of manipulation of techniques.

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Lecture - 11

Bivalve hatchery and nursery

Hatchery facilities – selection of hatchery site – Hatchery-building – Seawater supply system – air supply system – power supply system – conditioning room for broodstock maintenance – microalgal culture system – infra structure facilities.

Induced breeding of oysters- Selection of oysters – spawning techniques – natural and induced spawning – Thermal stimulation – chemical stimulation – mechanical stimulation and biological stimulation – effect of NaOH, TRIS buffer, hydrogen peroxide – injection of NH_2OH.

Larval development - Fertilization, cleavage, morula, blastula, gastrula, trochophore, veliger stages – method of estimation of larvae and stocking – feeding protocol – development of larvae – veliger – umbo – eye-spot stage – pediveliger – plantigrade and spat – standardization of larval rearing techniques

Nursery Rearing – estimation of spat – fabrication of cages – velon screen cages – fruit baskets - spat/juvenile rearing in the farm – site selection – depth – water flow – siltation - mortality rates - growth and survival – predation - percentage production of seeds

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Lecture - 12

Larval feed

Microalgae – different species – microalgal culture – batch culture – continuous culture – semi continuous culture – advantages

High density microalgal production – carbon dioxide media – semi continuous – continuous systems – advantages – economics

Microalgal substitutes – preserved algae – dried algae – algal pastes – artificial diets – microencapsulated diets

Bacteria as feed – probiotics - What are probiotics- Types of aquatic probiotics- modes of action – biocontrol agents- probiotics in live feeds- bio encapsulation

Probiotics in molluscan larviculture - Probiotics in diatom culture-

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Lecture -- 13

Global Mussel Farming

Aquaculture characteristics of mussels – low in the food chain - fecundity – free living larvae – rapid growth rate – byssal attachment – capacity for reattachment - natural seed availability – resistant to diseases – nutritious as human food.

Global Mussel Resources: *Mytillus galloprovincialis* - *M. smaragdinus*- *M. edulis*- *Perna canaliculus*- *Perna perna*- *P. viridis*- *P. indica* – geaographic distribution in the world and in India

Global Mussel Farming – Spanish Galician rafts – Italian - French – Dutch – China – Korea – Singapore – Malaysia – New Zealand – Canada – Greece – Chile – Argentina – Thailand - Philippines

Taxonomy – morphological shell characters – adductor muscle scars – ligament - general anatomy – mantles – ctenidia – labial palps – foot – visceral mass – alimentary canal – pericardium - reproductive organs.

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Lecture - 14

Biology and Ecology of Mussels

Life history – fertilization – embryo – larval development – factors affecting larval development – salinity - temperature – food – settlement – metamorphosis – larval dispersal and recruitment

Growth - Spat – growth rates – adult - growth rates – factors affecting growth – salinity – temperature – current - density – food availability – exposure in intertidal populations

Food and feeding – filtration rates – ingestion rates – pseudofaeces – particle size – Seston – neuston – factors affecting feeding

Reproduction - sexes – male – female – reproductive organs – gametes – seasonal maturation – factors affecting reproduction – fecundity – spawning – condition index – variation with season

Mussel bed community – associated fauna – community diversity and associations – commensalism- Pinnotheres

Faculty – Dr.K.S.Mohamed

Methods of Mussel Farming

Historical back ground – Bouchot culture in France -Galician rafts in Spain

Site selection – water quality – salinity – temperature – dissolved oxygen – pH – productivity – current velocity – tidal amplitude – pollution – trace metals – bacterial – organic – sewage – algal blooms – social factors – market availability – seed availability – conflicts with other aquatic habitat users

On bottom culture system: Preparation - sowing- harvest- advantages- limitations

Off – bottom culture system - Fixed method -Stakes and poles – *Bouchots* - spacing of poles- seeding- Rope web method- production- harvest- advantages- disadvantages

Suspended method on ropes: Rack - bamboo- casuarine pole – spacing- single beam- tripod- crossbeam- - parallel beam – construction- disadvantages –boring- PVC poles - Rafts - wooden – bamboo- design – square- rectangle- aluminum ; buoyant materials -floats- oil barrels- FRP coated Styrofoam – durability - mooring systems -Anchors- Yachtmans- Danforth- Mushroom- Nothhill – Navy- Anchor lines- Anchoring - Longlines - Structures - designs- floats – anchors- anchoring systems

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Lecture - 16

Seed Collection, Seeding, Grow out and Harvesting

Seed collection: Natural mussel beds- season- tide - Implements – cleaning - sorting; spat collectors - natural – bamboo poles – stakes – coir fibres – synthetic – polypropylene – polyethylene – polycoco – evaluation of spat collectors – efficiency – local availability – durability – Initial cost - seasoning - setting of collectors- prediction of spatfall - hatchery production of seed – conditioning – thermal stimulation – larval rearing - transportation- acclimatization

Seeding method : Material – nylon rope- Flexible plastic strips- coir rope; seeding – density - covering – cotton biodegradable cloth - mesh tubing - stretchable stocking - stocking method - stitching - filling – new device – automation – advantages - limitations

Grow-out - thinning – farm management – periodic checks of growth – predation – algal blooms – replacement of farm structures

Harvest: Condition factor – preparations - methods – manual – automation – declumpimg – debearding - shucking - steaming – storage- markets

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Lecture - 17

Post Harvest

Harvest: Harvest of produce –mechanical – manual – jet washing – removal of silt – removal of debris mussel – removal of byssal threads – mechanized – Declumping of oysters - avoid damage to shell – jet washing

Depuration – Need for depuration- in situ depuration – relaying- location of depuration stations

Depuration units-Disinfectants – UV light –chlorine- ozone- water change – running water systems- water change – duration – stocking density –lay out – water source – water treatment – controlled storage- washing – culling – depuration tanks – laboratory -

Preservation - icing – freezing – canning – smoking – drying

Bivalve products -Live oysters -mussels- clams- Fresh shucked- sun dried – pickled – frozen- marinated – smoke cured – pickle – export

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Lecture - 18

Economics of Mussel Farming

Economics of Rack and rope culture In estuary: Area – number of seeded ropes- culture period - Fixed cost - bamboo – PVC – seeding material; Operational cost – cotton netting- seed- canoe hiring- seeding charges- harvesting charges- transportation; Income – production; Comparison of old and new methods – Net profit - Benefit

Economics of Raft and rope culture In open sea: Fixed cost - bamboo – aluminum poles – floats- anchors - seeding material; Operational cost – cotton netting- seed- canoe hiring; labour - mooring - seeding charges- harvesting charges- transportation; Income – production.

Economics of longline culture In open sea: Fixed cost - main lines – floats- anchors - seeding material; Operational cost – cotton netting- seed- canoe hiring; labour - mooring - seeding charges- harvesting charges- transportation; Income – production.

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Lecture - 19

Commercialization of Mussel Culture In India

Mussel Farming – Initial trials- demo farms- estuarine farming - open sea culture systems- Training programmes - Availability of finance – JRY – SJRY – DWCRA – TRYSEM – BFFDA – ADAK – NABARD - Subsidies- Local governing bodies - Women Self Help Groups - Commercial farms – Maharashtra - Rack – Raft - long line - comparison

Location testing programs – participatory approach – Kerala – Padanne – Cheruvathur - Kadalundi – Korapuzha – Elathur – Dharmadom – Chettuva- Narakkal – Andakaranazhi – Ashtamudi – Paravur – Thangassery - Karnataka – Mulky – Baindur – Karwar - Andhra Pradesh – Kakinada – Bhuminipatinam - Tamil Nadu – Ennore – Pulicat - Collaborative programs – KKV – Maharashtra - Ratnagiri - Juve -

Production – annual increase in farmed mussel production in India

Marketing – Direct – Indirect (IFP, BFFDA, Commission agents)

Problems – seed availability – finance - market – new products – prospects

Impacts - Employment opportunities – resource utilization – village level socioeconomic development

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Lecture – 20

Biology and Ecology of Oysters

Taxonomy – identification characters -shell characteristics adductor muscle scar -- oviparous – incubation -*Crassostrea* – *Ostrea*- *Saccostrea* - shell composition - Biochemical composition of meat

Anatomical features – Adductor muscle - Mantle – mantle cavity- branchial cavity - alimentary system-- labial palps- mouth-intestine- stomach – crystalline style- rectum - branchial system- ctenidia- gonad

Food – phytoplankton – seston- particle selection and rejection- filtration rates- factors affecting physiological processes- pseudofecaes -

Life history- growth- xenomorphism-environmental factors – reproduction - sex reversal – hermaphoditism – spawning – factors affecting maturation and spawning- periodicity – larval development- factors affecting spat settlement – light –salinity-inclination – current- predater

Condition index - definition- methods used for determination of CI- volume method – cavity method - significance

Ecology – natural habitat – zonation - biocenosis- oyster reefs- associated fauna

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Lecture – 21

Oyster Farming Methods

History – harvest from wild - utilisation –factors responsible for stock depletion- overexploitation – disease out breaks – slow recovery of natural beds- transplantations of fast growing oysters- *Crassostrea gigas- Crassostrea virginica- C.angulata*- Global oyster farming – United States of America-Europe- Australia- China-Korea- Japan- Malaysia

Edible oyster resources in India - – Commercially Important edible oysters – *C. madrasensis, C.gryphoides, C.rivularis, Saccostrea cucullata*, Taxonomic characters - distribution – region wise – zonation – life history

Farming: Site selection – Environmental factors- salinity – tidal amplitude – currents- phytoplankton- turbidity – pollution- Socio economic- water usage- Different methods of culture – rack – rack and tray – rack and ren- Spat collection– different types of spat collectors – tiles- oyster shells-split bamboo – sticks - Preparation for spat collection – Deployment of Cultch – Nursery rearing- management - predators – size related predation - fouling - Harvesting Condition factor- Depuration- Shucking- Utilization of oyster shells.

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Lecture – 22

Fouling and Boring Problem in Oyster Culture

Foulers: - Effects of fouling- spat settlement – post harvest – market value – foulers- Algae- *Chaetomorpha- Ulva*, *Enteromorpha*, *Gracilaria*, *Cladophora*, *Polysiphonia*- Porifera- *Haliclona* sencrusting – solitory- Colenterata- Bryozoa- moss animals- Annelida – Bivalves- Crustacea - *Balanus amphitrite* Chordata- *Botrylloides nigrum*, *Symplegma sp*, *Diplosoma listeranum*, *Lisscolinum abdominale* seasonal variation-intensity – area wise- estuarine – open sea- mangroves - depth – impacts on oyster culture industry- Hiroshima Bay

Borers: - Harmful effects- quality – shell – main bores- Algae- *Hyella caespitosa*, *Mastigocoleus testarum* –Sponges – *Cliona celata*, *C.vastifica*, *C.carpenteri*, *Aka minuta*, Annelids- *Polydora* – intensity – season – agewise - Bivalves *Lithophaga sp.*

Predators:- Flatworms- oyster leeches - Gastropods- drills- *Cymatium martinanium* - Accessory Boring Organ –ABO- band –over-pulley- intensity of destruction- Pacific coast of US- Crustacea- juvenile predation- baits- Echinoderms- Fishes –*Chilomycterus schopfi*, *Gobiosoma bosci*, *Opsanus tau*, *Rhinoptera bomasis*, *Paralichthys dentatus*, *Diodon hystrix*, *Raja spp.*prey *Pogonias cromis*, *Dasyatis dipterurus* -Birds-, *Nyroca marilla* , *Nyroca affinis* , *Melamita deglandi* - Size related predation-

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Lecture – 23

Parasite and Disease Problems in Oyster Culture

Parasites- Helminth parasites – *Bucephalus- Protoeces – Acanthoparyphium- cestodes- Tylocephalum* - Crustacean parasites- *Mytilicola*- red worm- Molluscan – *Boonea impressa* -harmful effects – condition index- gonad – sex reversal- quality

Diseases: - Viral diseases- gill disease- ovacystosis - Fungal diseases – shell disease- *Ostraoblabe implexa*- Bacterial diseases- larval vibriosis - Juvenile oyster disease (JOD)-summer disease – environment- selective breeding

Protozoans:- Delaware Bay disease *Haplosporidium nelsoni* , MSX disease -SSO disease- *Haplosporidium costale* Digestive gland disease- Bonamiasis- *Bonamia ostreae*, Dermo disease- *Perkinsus marinus* Other protozoan parasites – main reasons for disease out breaks - precautions

Control of Fouling Organisms – Suction devices- mopping- flaming – scraping – chlorinated hydrocarbons-dip treatments- rock salt solution - freshwater - Biological controls

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Lecture - 24

TOT Programmes in Oyster Culture

Oyster Farming – Initial trials- Lab to land programs- Tuticorin -Pilot project - NABARD - demo farms- estuarine farming –Training programmes - Availability of finance – JRY – SJRY – DWCRA – TRYSEM – BFFDA – ADAK – NABARD - Subsidies- Local governing bodies - Women Self Help Groups - Commercial farms –

Location testing programs – participatory approach – Kerala – Dharmadom – Chettuva- Narakkal – Panambukad – Dalawapuram - Ashtamudi – Paravur – Kayamkulam - Karnataka – Mulky – Karwar - Andhra Pradesh – Kakinada – Bhuminipatinam - Tamil Nadu – Adayar - Athankarai - Muttukadu - Tuticorin - Ennore – Pulicat

Production – Income- Marketing – Direct – Indirect – economic development – annual production - - Ashtamudi Lake – Kayamkulam- Harvest melas- Marketing – problems- prospects

Collaborations: Integrated Fisheries Project Cochin-Brackish water Fish Farmers Development Agency – Aquaculture Development Agency of Kerala - NABARD- Fisheries Departments- BFFDA- local panchayats

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Lecture - 25

Clam Farming

History of clam culture –Taiwan – Japan- North America - major species- cultured - *Mya arenaria- Mercenaria mercenaria- Artica islandica- Spisula solidissim- Tapes phllipinarium- Venerupis (=Tapes japonicus) Anadara granosa - Panope generosa* geographical areas

Anatomy and ecology : General anatomy - modification of foot- burrowing - non burrowing forms - food - filtration rates- ecological requirements - substrate preferences- sandy – clayey.

Site selection: Physical – waves –currents- intertidal exposure- substrate characteristics- Water quality – Temperature- salinity- oxygen- suspended solids- red tides- Pollution –industrial- domestic- Biological environment – competition- disease- predation- primary production

Seed Collection – Collection method – sorting- planting parameters – seed size- seed - Density- protective device- burial depth- season- harvest size

Nursery rearing – Post set maintenance- Field nursery systems- onshore nursery systems- comparisons- up flow -commercial application

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Lecture - 26

Clam culture in India

Clam resources of India: Major clam resources: *Paphia malabarica- Villorita cyprinoids- Meritrix casta- .M. meritrix-, Marcia opima-, Geloina bengalensis- Solen kempi* - species identification- present status of utilization

Biology of candidate species: Substrate preference- ydrographicrequirements- growth rate- spat fall season- growth rate.

Culture Systems: On bottom culture - Preparation of ground- fencing- stocking - net covering thinning - advantages Off bottom culture: Construction of rack- trays- stacking- advantages

Clam culture: Pen enclosures - *Anadara granasa* – split bamboo fencing- Andhra Pradesh - *Villariata cyprinoides* – Kerala- open system – net covering – netlon fence - *Meritrix casta* - Tamil Nadu- Karnataka- Semiculture -*Paphia malabarica- Villorita cyprinoides*- grow out period- production

Sea ranching: Global overview- experiments in India - *Paphia malabarica* -, *Meritrix casta* – Ashtamudi Lake – Estuaries of Tamil Nadu

Culture Constraints: Site - Biological - environmental limitations- social – economic- production

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Lecture - 27

Clam culture management

Diseases of Cultured clams : Prokaryote pathogens- Bacteria - blue bodies – NIX- Viruses- Neoplasms- Eukaryote pathogens – Fungi- amoebae- protozoa - Gas bubble trauma- shell deforming disease

Parasites: Internal –Copepods- trematods - nematode- External – gastropod

Pests – Fouling and boring organisms – amphipods- tunicates- polychates- sponges-Organisms within the mantle cavity – Clam leeches- pea crabs

Predators – Predators of larval - juvenile and adult clams-Annelids- crabs- lobsters- gastropods- cephalopods- starfishes-birds- fishes

Management: Predator control – Mechanical- chemical- biological methods

Integrated culture: Clam /Cockle and seaweed culture in South East Asia

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Lecture - 28

Giant clam culture

Giant Clams : Resources – *Tridacna gigas- T. derasa- T. squamosa- T. maxima- T.crocea- Hippopus hippopus- H.porcellanus-* description- distribution and life history- Symbiosis- zooxanthellae- Country status – Australia- South east Asia

Giant clam mariculture – Habitat requirements- Nursery Systems - Ocean nurseries-protective containers – prawn trays- boxes- lines- covers- Grow – out systems - protected - unprotected substrates- growth-survival.

Conservation programmes: Reef reseeding - quarantine systems-Cooperative programs

Utilization : Adductor muscle-shell-seed- aquarium specimens- live whole clams-soft tissue

Giant clam resources of India – Lakshadweep- Andaman and Nicobar Islands-species-stock

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Lecture – 29

Economics of Oyster and Clam Farming

Economics of Rack and ren culture in estuary: Area – number of rens- culture period - Fixed cost - bamboo – PVC – ren; Operational cost — canoe hiring- harvesting charges- transportation; Income – production; Comparison of old and new methods – Net profit - Benefit

Economics of Rack and tray culture in estuary Rack and tray Fixed cost - bamboo – cages; depreciation - Operational cost – maintenance – labour- harvesting – total cost - transportation; Income – production – net profit – unit cost of production

Economics of clam culture in estuary: Area – seed stocked- culture period ; Operational cost — cost of seed- split bamboo – netlon - canoe hiring- harvesting charges- transportation; Income – production– Net profit - Benefit

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Lecture - 30

Scallop Farming

Scallop resources: *Pecten maximus- Chlamys opercularis- C.varia- C. purpurata- Patinopecten yessoyensis-* biology- life history.

Spat collection : Scallop hatcheries – induced spawning, larval rearing, nursery culture: natural spat collection – spat monitoring- plankton hauls- trial spat collectors- sample analysis- spat settlers -spat bags- humbug bags-setting of collectors- harvesting- spat handing- sorting of species

Methods of farming : Hanging culture –long line- rafts- pearl nets-lantern nets-Japanese types- removable stocking-ear hanging- rope culture-pocket nets-hog ringing-plastic trays- bottom culture

Factors affecting production- Stocking densities - net mesh size- net-changes- tidal flow- current- growth- mortality- foulers-borers- diseases-predators.

Harvest: Harvesting methods- post harvest-products- markets

Diversification: Alternate farming with mussels- oysters-clams.

Business structures – partnerships-cooperatives- associations- equipment pool

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Lecture – 31

Abalone Farming

Abalone Resources – *Haliotis rufescens - H.fulgens -H.discus hannai - H.ruber - H.iris*-description, Country status – Japan- Korea- Australia

Life history: Food -growth rate- gonad indices- fecundity -Induced maturation and spawning: Rearing containers- gamete stripping- desiccation- thermal shock- UV irridated seawater- Hydrogen peroxide- gamete viability.

Larval development: Development of larval stages - larval density- settlement of larvae- Antibiotics- transporting larvae- comparison of larval -characterlstics- egg diameter- pigmentation- photoaxis

Settlement: Preparation of settlement plates- settlement behavior and metamorphosis- induction of settlement – diatom and mucus induction- GABA-larval biology

Marketing : Storage- transport- international trade- abalone products- frozen-canned-cocktail abalone- shell – seed- alternative medicines

Market : Depuration - export products- quantity- nations- trend

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Lecture – 32

Sea ranching of molluscs

Sea ranching : need for ranching – area- resources – bivalves – gastropods - cephalopods

Gastropods- abalone – area of ranching - Ownership- seed- liberation- predators- poachers- recovery – impact – Trochus- Strombus

Pearl oyster – *P.fucata* – veliger – pedivelider- spat – paars- impact revival of beds- collection per diving hour - edible oyster – clams -

Clams- resource depletion – enhancement – giant clams- seed production – hatchery- net enclosure- on bottom- monitoring

Oysters – Reef destruction- spawning stock – artificial cultch – reef building - impact – natural recruitment – fish habitats

Cephalopods – Japan - twigs- natural spawning ground- egg collection – protection – recruitment – hatchery - para juveniles- ranching – fishery assessment

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Lecture - 33

Farming of *Xanchus, Trochus, Strombus*

Xanchus pyrum : Distribution - biology –reproduction- egg capsules- rearing- tagging –recapture – egg cases – wild collection – hatching rate – larval rearing – juvenile rearing tagging

Trochus : Ecology- size at maturity-fecundity- spawning – fertilization- larval development - settlement, grow out- reseeding-prospects for aquaculture development - problems.

Strombus gigas : Ecology- growth- predators- spawning- larval development, metamorpnosis- collection of egg masses- metamorphosis- larval rearing- induction of metamorphosis- culture of macroalgae-grow out

Conservation : Reseeding- management implications.

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Lecture – 34

Abalone and Whelk Seed Production

Whelk resources: *Babylonia spirata- B.zeylanica* – Identification- distribution- life history

Brood stock: Maintenance- feed- water quality-substrate- spawning- egg capsules- hatching- Larval rearing: Larval development – trochophore- pelagic stages- settlement -larval feed- biology- settlement- Water quality-stocking density- larval feed

Juvenile rearing: Feed- growth rate- indoor culture method

Abalone: Resources in India - distribution- hatchery technique

Seed Production : Raft system- juvenile rearing on diatom plates- multilayered structure - intermediate culture - transportation of juveniles- early –juvenile stage cultivation- weaning.

Grow out : on land farming- ocean floor rearing- containment rearing- nutrition- natural food-artificial feed- parasites- predators- disease and abiotic disorders

Faculty – Dr.V.Kripa

Lecture – 35

Cephalopod culture

Species cultured : *Symplectoteuthis ovualanensis – Sepiella inermis – Sepia pharaonis* - Stock enhancement – Japanese systems - breeding grounds- egg collectors – transportation – incubation - survival

Hatchery Brood stock collection – transportation - rearing - stocking density – spawning act – mortality –water quality – feed

Egg laying – incubation – hatching rate - development – rearing- young ones - feed – water quality – growth- mortality – maturation – F2 generation

Live feed development – zooplankton – artemia- problems

Cephalopod culture in India – species cultured – *Sepia pharaonis* – *Sepeilla inermis* – *Symplectoteuthis ovulalanensis* - experimental culture – present status – problems – prospects

Faculty – Dr.Shoji Joseph

Lecture - 36

Genetic application in bivalve mariculture

Chromosomal engineering-- Haploid number of Chromosomes- ploidy manipulation – thermal – pressure – chemical shock – triploid zygote- aneuploids-triploidy – tetraploidy-Advantages of triploid - Interspecies hybridization – M.edulis - *Crassostrea* species- *Ostrea* species

Quantitative genetics and selective breeding – traits of interest - polygenic – variance of traits – genetic component – environmental component – additive – non additive – heritability – single gene characters – characterization of stocks - Edible Oyster - *C . virginica- C.rhizophorae-C.gigas- C.anulata- Crassostrea gigas – Ostrea edulis- Saccostrea cucullata*- genetic parameter estimates—selection- inbreeding – heterosis- heterzygosity- Environmental variability and growth rate – farm trails

Stock improvement - Pearl oyster – Selective breeding – selection – shell characteristics- nacre – growth – depth- gonad

Faculty : Shri.T.S.Velayudhan

Lecture – 37

Remote Setting of molluscan larvae

Remote setting concept – larval transport – low temperature - reduced metabolic rate – low tranrsport stress – anaerobic metabolism - moist conditions in absence of seawater - pediveliger - survival rates - background and history – why RS was developed – reasons – commercial requirement – low spat fall - disadvantages of transporting spat settled on cultuch - Loading and unloading cultch- shipment charges

Pre transport – Filtering larvae – packing – transport – general hatchery – farm site

Setting Tank Conditions: - Setting conditions - Temperature - Salinity - Post-Settlement Handling –Requirements for tank operation-- Larvae density - Vexar bags - French pipe - Shell chips - Chinaman Hats- Survival

Feeding: - Artificial foods and dried algae- Recommended algal feeding rates- Aeration - preparation- set inducers

Remote setting of bivalves – oysters – clams – scallops – Remote setting experiments in India -*C. madrasensis* – *Pinctada fucata* - influence of temperature - setting rate - aeration – prospects – problems

Faculty ; Dr.V.Kripa

Lecture - 38

Harmful Algal Blooms

Global overview: - Toxic Algae causative factors – Coastal aquaculture- eutrophication- climatologically condition- translocation- major blooms recorded and causative facters- species involved and economic losses

Types of blooms: - Harmless discoloration blooms - non-toxic blooms – species involved *Chaetoceros concavicornis- C.convolutus- Heterosigma akashiwo* – blooms that change water quality - hypoxia- water quality- fish kills- impact on food webs- larval settlement- recruitment –*Notiluca*-Ceratium dens- *Lingulodinium spp- Prorocentrum micans- Protoperidinium- Rhisolonenia*- Toxic blooms -

Motality modes –starvation – nutritional mismatch – size mismatch – excess prey density – Mechanical – bumping – particle irritation – physical – viscosity barrier- gelatinous barrier- mucoid layer reduction – Anoxia- NH_4 toxicity – phycotoxin- alleopathic- ambush predation

Taxonomic Principles: - Toxic Dinoflagellates- Gymnodinoids – Notilucoids- Peridinoids- Gonyaulacoids-Dinophysoids-Prorocentroids- Haptophytes- Diatoms- Raphidophytes- Cyanobacteria- cyst

Faculty : Dr.V.Kripa

Lecture - 39

Shellfish poisoning

Characteristics of phycotoxins- Brevetoxin- Na+channel activater – Ciguatoxin- Na+ Channel activater- Saxitoxin- Na+ Channel blocker – Domoic acid- Neural depolarization- - enzyme Inhibiters- *Pfiesteria* toxin - neurotoxicity

Paralytic shellfish poisoning PSP: - Causative organisms- *Alexandrium acatenella- A.catenella- A.tamarense*- Symptoms - mild - extreme case – treatment - permissible limit in products- toxin levels

Diarrheic shellfish poisoning DSP- Causative organisms- *Dinophysis acuminate- D.acuta*- Symptoms - mild - extreme case – treatment– retention levels- Amnesic Shellfish Poisoning (ASP)- Causative organisms – *Pseudonitzschia australis- P.mutiseries*- Symptoms -mild - extreme case – treatment

Neurotoxin Shellfish Poisoning (NSP)- Causative organisms- Symptoms-mild - extreme case treatment

Management of shellfish resources- Monitoring programs- epidemiological issues– closures- intoxification- retention levels – clams – oysters- mussels- scallops- detoxification – regulations- satellite monitoring – long term monitoring- programs - precautions- awareness – public health

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Lecture – 40

Bivalves as biofilters

Statement of Problem : Qualities of bivalves as biofilters

- Filtration rate- size of the species- environmental conditions =water movement - particle size – concentration - density - phytoplankton - suspended solids

Integrated farming- Oysters as Biofilter in Aquaculture - oysters and shrimp culture - *Crassostrea virginica- Peneus monodon- Peneus japonicus* increase in shrimp yield- survival rate of oysters - meat percentage-growth rate - higher condition indices – clam and shrimp – scallop and seaweed- cockle and seaweed- pearl oyster and seaweed- oyster and fish

Model Systems sedimentation – microseiving- integrated fish –mollusk-seaweed system total nitrogen budget fish yield- N introduced in the feed-bivalve yield –seaweed- settled feces - suspended and dissolved discharge back into the sea - benthic species -detritus consuming bivalve - bait worms

IF in India - Feasibility of integrated shrimp aquaculture with bivalve farming in India. mussels and oysters - shrimp - *Peneus monodon* - *Etroplus suratensis*

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Lecture - 41

Bivalve farming and Environment

Environmental Impact Assessment of Bivalve farming: Stocking density – carrying capacity – currents- biomass – filtration – clearance – pseudofaeces -On bottom culture – clam – oyster - culture – raking – clearing -- burrowing shrimp eradication- pesticide - changes in benthic community structure- variation in prey – predator levels- effect on migratory populations- artificial substrates

Suspended culture – oyster – mussel – diseases- Total suspended matter – currents- phytoplankton - filtration – sedimentation - biodeposition – variation in sediment structure - perennial culture systems – seasonal culture – management measures

Bioaccumulation - concept of mussel watch – sentinels - trace metals- bioaccumulation levels- retention- sources of pollution- variation with size – gender - ecosystems- stress – permissible limits – lethal levels- sublethal levels – microbial levels- permissible limits- significance in site selection for edible bivalve farming

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Lecture – 42

Molluscan culture and Public Health

Health issues – mussels as vecters – water borne diseses – contaminent – significance in aquaculture development and product marketing

Infections - Bacterial infections – Faecal contamination – Salmonella sp. Shigella sp. Clostridium – non pathogenic *Escherichia coli* – Species of bivalves involved – *Aulacomya ater* – *Mytilus* sp. diseases – Gastroenteritis – Hepatitis A – Cholera – Typhoid – Dysentary - Viral infections – probability cited – polio viruises – Allergy

Monitoring and Regulations - international shipment – quality control – constant surveillance – sanitary and processing facilitles – trade in live fish – United NationsProgramme (UNEP) – reference methods – marine pollution studies – National Shellfish Sanitation Programme(NSSP) in USA – Interstate Shell fish Sanitation Conference (ISSC) – Regulatory authorities – Shellfish programs – Microbial standards – approved – conditionally approved – prohibited

Hazard Analysis and Critical Control Point (HACCP) – identification of hazards - growing areas – harvesting – processing – marketing – determination of critical control points – application of HACCP

Quality – decline in shellfish borne diseases - - increased public awareness programmes –reassess usefulness of indicator organisms- standardize depuration protocols – uniform means of testing and reporting of contamination levels

Faculty – Dr.V.Kripa

M.F.SC. MARICULTURE

LECTURE OUTLINE

COURSE No. 503

CULTURE OF FINFISH AND SEA CUCUMBER

Course Teacher : Dr. L. Krishnan
Faculty Members : Dr. G. Gopakumar
Smt. Grace Mathew
Shri. A. Raju
Dr. K. K. Joshi
Smt. P.S. Asha

Topic: Marine and Brackish Water Finfish Culture of the World

Aquaculture –Definition- Advantages of Aquaculture-as converters of primary foods- source of low-cost protein- as industry and trade-sea ranching and restocking-waste utilization and conversion.

World aquaculture scenario- present production and annual growth rate-top ten species and their production- Different countries and their aquaculture practices- China, Italy, Africa, Japan, India, Israel, Cambodia and Indonesia.

Aquaculture practices-importance of site selection-source of water-environmental condition-fertility of ponds- ownership-co-operative societies-

Different types of transplantations- from poor to better growing grounds-from hatchery reared fish-trapped and held until ready for harvest-intensive practices of fertilization and water quality management-complete control of stocking.

Different types of Aquaculture systems-Marine-brackish water-freshwater-land based systems-water based systems-descriptions of extensive system, semi intensive system and intensive system.

Important species cultured in brackish water and marine-descriptions of pond, cage, and pen culture systems- Definition of natural breeding and induced breeding.

Lecture No.2 K.K.Joshi

Topic: Finfish Culture Practices in the World

Mullet culture - countries were culture practiced - Israel, Philippines, Italy, Hong Kong, Cyprus, Greece, and Taiwan. Description of polyculture of mullets in Israel - Intensive culture of mullets - Definition of Valliculture - Potential of mullet culture.

Important characters of milkfish - euryhaline - high growth rate - high fecundity - description of Tambak culture in Indonesia - polyculture in Philippines.

Define Floating net cage culture - example of Japanese yellow tail - feeding – prorogation.

Description of running water culture of eels - prospects of eel culture - as high demand - restocking purpose - propagation in captivity - Culture practices in Western Europe.

Description of Sea bass culture - importance of the species - fast growth rate - wide distribution - bred in captivity - Culture practices in Thailand - ponds and net cages - prospects - development of hatchery technique - high cost of thrash fish. -

Definitions of Monoculture - Monosex culture - Polyculture and integrated farming - examples for different culture practices - Recent advances in Marciculture - Importance of integrated farming - scope of Mariculture as industry.

Culture of Pacific Salmon - over fishing and pollution lead to culture - Important species cultured – Chinook Salmon - Coho salmon - Sokeye Salmon - Salmon hatchery - Problems and prospects

Topic: Major Species Cultured in the World

Mullets - Biological characters - *Mugil cephalus* in Taiwan, Italy, Israel, Mediterranean - IndoPacific.

Milk fish - Biological characters - *Chanos chanos* in Indonesia, Philippines, Taiwan, Africa, Bangladesh, Malay, Cambodia, and Australia

Groupers - characters - *Epinepehulus malabaricus* - *E.tauvina* - *E.salmoides* in Thailand, Hong Kong, Philippines, Indonesia, Singapore

Japanese Yellow tail - *Seriola quinqeradiata* in Japan – floating net cage culture.

Sea bass - *Lates calcarifer* in Thailand - fast growth rate - grow to large size - can breed in captivity.

Pacific salmons - different species of *Onchorhynchus* in California.
Eel - *Anguilla japonica* in Japan, Western Euorpe - Mahimahi - *Coyphaena hippurus* in Florida -

Pompano culture - *Trachinotus carolinus* Florida and Georgia - salinity tolerance.

Black bass - *Microtperus dolomien* in Europe - Pike - *Esox lucius.*
Tilapia - *Oreochromis mossambicus*, *O.niloticus*

Topic : Characteristics and Criteria for Selection of Species for Mariculture

Description of desirable biological characteristics - food and feeding - Foraging efficiency - selection of food items - FCR - growth rate - grow out period.

Reproductive habit - breeding and maturity - feed for maturation - breeding in captivity -

Requirements of the eggs and larvae - price –availability throughout the year - tolerance to environmental changes - susceptibility to disease - suitability to polyculture.

Description of economic attributes - supply of fry - price of fry - grow out period - price of adult - impact on local market -

Grow out cost - suitability to small - scale farming - suitability to commercial farming - stock enhancement - adaptation to artificial feeds.

Compatibility with other species - flesh qualities - larval survival.

Economic attributes - supply of fry - price of fry - grow out period - price of adult - cost of feed - market acceptability - consumer preference.

Lecture No.5

K.K.Joshi

Topic: Status of Finfish Culture in India

History of finfish culture - Brackish water culture - Mariculture experiments in India - Species cultured in India - Mullets - Monoculture - polyculture - stocking density - production - breeding programmes - prospects of mullet culture in India - Milk fish - Cultured practices - stocking density - production - breeding - prospects.

Grouper culture experiments - *Epinephelus tauvina* - *E.malabaricus* - *E.merra* - sex reversal - induced breeding - Future prospects of mariculture.

Cultivable finfishes of India - Mulltes - *Mugil cephalus* - *Lisa parsia* - *L.tade* - *L. macrolepis* - *Lates calcarifer* - *Chanos chanos* - *Etroplus suratensis.*

Ornamental fishes - prospects and problems - Parrot fish - Butterfly fish - Damsel fish - Angel fish.

Lecture No.1

Prepared by : A. Raju

TOPIC: EGG INCUBATION, LARVAL REARING AND MASS SEED PRODUCTION

- Spawning – Natural & Induced spawning – Natural spawning by environmental and nutritional manipulation – Induced spawning through hormonal induction – hormone pellets.

- Fertilisation – Natural & artificial – Natural fertilisation – spawning of male and female and fertilisation - Artificial fertilisation – stripping - dry and wet method – dry method – eggs & milt released in succession in dry container and mixed before adding water – wet method – released simultaneously – mixed in volume of water.

- Collection of fertilised eggs – size – washing – transfer for incubation – definition of incubation – incubation units – type of equipments – shape and size – advantages and disadvantages – preparation of units – stocking density of eggs – milkfish, grey mullets, seabass, groupers, snappers, etc.

- Process of egg development – different stages – Morula, blastula and gastrula – water quality – water exchange – aeration – embryo formation – hatching – period of incubation – characteristics of hatchlings – larval collection –rearing phase – primary and secondary phase – Primary phase – indoor & outdoor concrete tanks; Second phase - larger tanks or net cages – stocking densities – rearing units – water quality – water exchange.

- Larval food – types of food – rotifer, moina, copepod, artemia – feeding regime at different stages – rearing duration – nursery rearing – rearing facilities – ponds and cages – stocking size and densities of different species.

- Mass seed production – hatchery facilities – broodstock maintenance – maturation and spawning, fertilisation and hatching, larviculture, feeding – live feed culture – phyto & zooplankton, larval growth, survival and production.

Lecture No.2 Prepared by : A. Raju

TOPIC: POND PREPARATION, SEED STOCKING RULES, FEED AND WATER QUALITY

- Definition of pond – size for culture – types of ponds – ravine ponds, excavated ponds, levee ponds – repair works – set right of bunds and slopes.

- Removal of organic matter, vegetation, predatory and unwanted organisms – removal of vegetation – manuals. Methods of eradication – drawing and drying – effect and advantages – application of toxic substances – types of toxic substances – lime, mahua oil cake, ammonia, etc – rate of application – lethal effect on organisms.

- Improvement of bottom soil – porous soil – protection – impervious materials – clay puddle lining, brick lining or plastic lining – advantages – methods – acidic soil – application of quick lime – rate and effect, Fertilisation – inorganic and organic fertilisers – application method – common fertilisers – Inorganic: Quick lime, slaked lime, lime stone, nitrogenous fertilisers, Organic: cowdung, chicken manure – dosage and effect.

- Water supply – sources – tidal effect and pumping – exchange rate – maintenance of water depth – hydrological parameters.

- Stocking of seeds – methods – acclimatisation – size and stocking densities – stocking time – carrying capacity – effect of low and higher stocking – optimum stocking – determination of carrying capacity.

- Feeding – types of feed – feeding method – feeding ratio and rate – effect in fish ponds feed conversion ratio – metabolic wastes – carbon dioxide, ammonium, phosphate and other organic and inorganic substances – their effect on water quality.

- Harvesting – method – estimation of production and survival.

Lecture No.3 Prepared by : A. Raju

TOPIC: FINFISH SEED RESOURCES – NATURAL SEED RESOURCES – THEIR REGIONAL AND SEASONAL ABUNDANCE METHODS OF COLLECTION, ACCLIMATISATION AND TRANSPORT OF SEED.

- Seed – major criteria for culture both quality and quantity – called as fry and fingerlings. Fry – below 20 mm, fingerlings – above 20 mm and up to 100 mm – seed of different cultivable finfish – feeding behaviour.

- Sources – two ways – seed production & quality, seed procurement & quality. Seed production & quality – stimulation of natural condition – bunds – dry and wet bunds – artificial induction – induced breeding. Seed procurement and quality – natural resources – potential grounds – shallow coastal waters, estuaries, tidal canals, burrow pits, coastal lagoons and mangrove swamps.

- Milkfish: Euryhaline – breed marine condition – fry enters in inshore waters. North coast of Java & temperate region of Indonesia : - Oct-Nov and Apr-May – peak – Philippines – round the year – peak: May-June. Indonesia – March-May & Sep-Dec – high tide period. Taiwan – Apr-Aug (peak : Apr-Jun) – India – East coast - from Vizag southwards through East Godavari – Pamban area lake – Feb-June & Oct-Nov Pulicat lake – Feb/Mar-Oct (peak – April & September). Nets – Sweep nets, scoop nets, shore seines, tidal filter nets, skimming nets & dip nets , drag nets.

- Mullet : - Important species – *Mugil cephalus*, *M. macrolepis*, *M. parsia* and *Rhinomugil corsula* – Distribution - Contai coast, Sunderbans, Hooghly – Maltah estuary, Mahanadhi estuary, Chilka lake, Pulicat lake and Islands of Gulf of Mannar. Season – round the year – Nets – Hapa nets, small dip nets, filter nets, pouch nets, Khadujal, sccop nets, short bagged dragnets, beach seine.

- Seabass: - distribution – lower stretch of Hooghly – Maltah estuary, Chilka lake, Sundarbans, Tamil Nadu – Muthupet saline swamps and Tamirabarani river mouth Tuticorin, Pulicat lake. Season May-October. Nets – Hapa nets (common gear), Shooting nets in Kakdwip (West Bengal).

- Groupers : Southeast Asian Countries – Sep-Jan – Seine nets – coastal waters – Triangular net cage with wooden pieces and fine nylon netcage – Hook & Line, bamboo traps, dip nets – India Dec-Mar – drag nets – traps.

- Etroplus: *E. suratensis* – backwaters, estuaries, tidal creeks, lagoons, brackishwater. Season – Kerala – May-Jun & Nov-Feb - Peak Jan. Madras – Nov-Feb – Chilka lake – Dec-Feb & Apr-May.

- Transport of seed – transfer of catch – white basin – removal of debris & unwanted organisms – counting & sorting – transfer to small basin – add freshwater – milkfish – mullet – plastic bags – oxygen filled – transport – salinity range 10-15 –ppt – Stocking density – depends size of seed.

Lecture No.4 Prepared by : A. Raju

TOPIC: GROW-OUT SYSTEM IN CULTURE, TRADITIONAL AND IMPROVED FARMING PRACTICES.

- Definition of culture system – two groups – Natural waters: inland seas, lakes, rivers, lagoons, mangrove swamps – artificial or man made facilities: ponds, pens, cages, raceways, silo – pens and cages are developed in natural waters.

- Three categories – extensive, semi intensive and intensive systems – extensive: culture in large enclosed water bodies – without supplementary feed – depend natural feed – pond productivity – improved fertiliser. Advantage: less water, labour, oxygen depletion, less investment. Disadvantage: weed control, fish size large are , difficult harvesting. Semi-intensive: improved extensive – widespread – supplementary feeding. Eg. Fish farming of Southeast Asia.

- Intensive: culture in ponds, cages, pens, tanks, raceways, silos, recirculating system – formulated feed or trash fish – high priced fishes – groupers, snappers, seabass, salmon species selection – stocking manipulation and environmental condition. Advantage: - greater control of size fish, less area, hygiene improved, simplified harvesting, vegetation & disease control, partial harvest. Disadvantage: - more water, feed of labour, increased danger oxygen depletion, parasites and disease more common.

- Pond system – types – holding ponds, spawning ponds, rearing pond, growing pond, catch out pond – definition – size – usage. Cage and pen culture systems : definition – site selection and location – materials – size and shape – types – advantages and disadvantages.

- Substrate system – definition – advantages and disadvantages. Culture system with reference to water movement – static (lentic) or flowing (lotic) – static: ponds as culture units – flowing: tanks, raceways, silos and cages – rearing chambers. Mono and polyculture systems – definition – species selection – advantages.

- Traditional farming – impoundments, paddy fields, shallow coastal lagoons – candidate species – production. Improved or modern farming – fish farm – intensive culture – candidate species – yield.

Lecture No.1 Prepared by Grace Mathew, P.S

Topic: Hatchery technology for production of seed

Introduction.

-Pre requisites of a marine finfish hatchery to ensure stable and affordable supply of disease free, good quality seed

- facilities for broodstock management, spawning, incubation of eggs and larval rearing essentially required

-Availability of spawners - wild caught or reared in captivity

-Mature female and male broodfish

-spawning tanks - indoor, outdoor tanks, with flow-through sea water system, re-cirulating sea water system.

- suitable stocking rate

- **Spawning**
- natural or spontaneous spawning - environmental manipulation
- induced spawning through hypophysation
- spawning behaviour and synchronization of spawning
- fertilization of eggs as soon as they are released -
- viable transparent eggs containing single oil globule float on the surface
- non-viable unfertilized opaque eggs that sink
- viable buoyant eggs collected
- egg collection by overflow method or sieving out
- number estimated

- **incubation**
- incubation tanks- incubation and hatching time
- no. of hatched out larvae and hatching rate estimated

- **larval rearing**
- stocking in larval rearing tanks
- providing green water
- providing right quantity aeration
- development of suitable live feeds; ratio of volume of phytoplankton to zooplankton
- screened live feed provided before mouth opening
- water management and feed management
- enrichment of live feeds
- critical stages in rearing the larvae
- weaning the larvae to inert food

Lecture no.2 Prepared by Grace Mathew, P.S.

Topic : **Broodstock development and management**

Introduction

Marine finfish breeding

- captive breeding
- what are brood stock
- brood stock by conditioning the adults collected from wild
- by rearing from fingerlings
- in open sea net cage - in onshore ponds , tanks etc.
- Broodstock development in different systems
- flow-through water system, re-circulating sea water system.
- Stocking density

- **Female and male broodstock**
- Size at first maturity
- sexual dimorphism - protogynous hermaphrodites
- sex inversion - natural sex inversion and through hormonal application

- **Water quality management for broodstock**

  Hydrographical parameters necessary for broodstock

  - water exchange frequency
  - renewal of sea water - in re-circulating sea water in grouper broodstock tanks-monitoring of DO, pH ,Temp, salinity , nitrogenous wastes etc.

Broodstock feeding and nutrition

- feeding frequency and feeding regime
- main food items- trash fish, live feed- formulated feed
- feed enrichment - supplementary feeding
- requiremnt of PUFA in the diet

- removal of waste food - cleaning etc.

Broodstock health and hygiene

- proper cleaning of waste food and faecal matter
- strict adherence to water quality and replenishment of water
- removal of nitrogenous wastes
- exposure to pathogens and stress
- disease treatment - use of antibiotics etc.

Lecture No. 3 Prepared by Grace Mathew, P.S

Topic: Breeding under controlled conditions, through environmental and hormonal interventions.

Introduction

- Ability to control sexual maturation
  - controlled spawning of culturable species
  - enable fry availability at the right seasons
  - methods of controlled breeding
  - availability of wild broodstock
  - culture conditions of spawners
  - conservation, selection and in-breeding of the spawners
  - broodstock management techniques
  - control of matuaration of gonads
  - induced spawning
  - environmental manipulation
  - genetic manipulations
  - egg and sperm quality
  - cryopreservation of gametes.

Environmental manipulation

- control all stages in gonad development
- effect of temperature on gonad maturation
- use of modified light or photoperiod regime for breeding at the right time
- ability of fish to spawn more than once a year

Induced spawning

- Induced spawning through hormonal intervention

- hypophysation - for final maturation or release of eggs and sperm
- use of pituitary extracts and HCG, LHRHa etc
- disadvantages
- Synthetic hypothalamic releasing hormones
- inducing final maturation,ovulation and spawning
- synthetic analogues of GnRH- LHRHa/GnRHa - long lasting action

Lecture No.4 Prepared by Grace Mathew, P.S

Topic: Methods of induced spawning

Introduction

-Induced spawning - hypophysation

- enable breeding of fish that do not spawn in captivity
- bring about final maturation and release of ripe gametes
- use of fish pituitary extracts and HCG
- problems are purity, specificity, availability, potency etc.
- use of synthetic hypothalamic releasing hormones
- synthetic analogues of GnRH- LHRHa/GnRHa
- long lasting actions than naturally occurring hormones.

Methods of administration

- injecting in water or saline
- implant slow release pellet
- intramuscular or intra peritoneal, oral
- Im - easy standardized
- using fine needle - dosage
- Ip - large needles inject suspension
- more viscous soln.
- enter the circulatory system in minutes
- metabolised soon.
- implantation - intraperitonially or intramuscularly.
- slow release and long lasting

LECTURE NOTES FOR M.F.Sc. PROGRAMME IN MARICULTURE

MARINE ORNAMENTAL FIN FISH CULTURE

Lecture No. 1

Prepared by G.Gopakumar

Marine ornamental fin fish culture – General aspects.

A lucrative global ornamental fish trade with an annual turn over of about 450 million dollars in vogue – marine aquarium technology has advanced due to the development of an array of gadgets – Indian scenario – major groups of marine ornamental fishes – distributed in coral reef areas – natural stocks and present status – indiscriminate exploitation can lead to destruction of reef habitat – eco-friendly exploitation of natural stocks – trap fishing, diving and selective hand netting – conditioning methods – use of physical, chemical and biological filters – need for development of hatchery technologies for sustainable production.

Marine ornamental fishes reared in captivity – maximum number of species from family Pomacentridae – constraints in marine ornamental fish breeding – no sexual dimorphism – difficulty for development of broodstock in captivity – complex patterns of sex change – problems in larval rearing such as suitable water conditions and live feed – protogynous and protandrous hermaphroditism – patterns of sex reversal – monogamy and polygamy – monogamy is associated with protandrous hermaphroditism – polygamy is associated with protogynous hermaphroditism – sex reversal by suppression and induction – suppression by aggressive dominance, induction by sex ratio induction or size ratio induction – gonadal growth and development – final maturation and spawning – types of breeding – egg scattering, egg attaching, mouth brooding and giving birth to young ones, examples of each type of breeding and their significance.

Prepared by G.Gopakumar

Present status of marine ornamental fish breeding and culture

Hatchery technologies of clownfish and damselfish – clownfish protandrous hermaphrodite – one mated pair grows ahead of others and suppresses the growth of others – spawns throughout the year – potential to reverse sex – if functional female dies, the next male becomes a female and select the next male down the line – criteria for selection of pair – age is the most important factor – advisable to develop broodstock from sub-adults – sexual dichromatism – size can be a criterion for determining males and females – behaviour is another criterion for selecting males and females from adults or sub-adults – the utilization and manipulation of a combination of environmental factors such as light intensity, light duration, wave length of light, temperature, water current, water quality, nitrogen, phosphate, P^H, tank size, type of food and habitat for induction of gonadal maturation and spawning – broodstock diet is the main key to successful spawning – broodstock diet directly reflects in the number of eggs laid, fertilization rate, hatch rate and the viability of hatched larvae – live feeds are extremely important as broodstock feeds – pairs should be routinely checked for skin disorders – egg pigmentation has a direct relationship in the success of hatch and larval survival – culling of pairs required when a pair is not productive – larval rearing by providing adequate stable environment and providing live feeds of proper size and nutritional quality – breeding of damselfishes – some are protogynous hermaphrodites – some are dioecious – species that are protogynous hermaphrodites are polygamous with male dominance – larvae are smaller than clownfish larvae – the major problem of larval rearing is the availability and mass production of suitable live feeds.

Lecture No.3

Prepared by G.Gopakumar

Problems and prospects of marine ornamental fish culture.

Two key bottlenecks limit the expansion of marine ornamental fish aquaculture – control of maturation and spawning – identification of appropriate live feed for larval first feeding – information regarding size and age at first maturity, patterns of pair formation, spawning seasons and periodicity available only for a few reef fishes – rearing tank size and shape are important elements – broodstock water quality and nutrition are typical parameters – hormonal induction of final maturation and spawning not widely used in ornamental fishes – natural spawning and induced spawning through hormone administration in the diet is more appropriate – an area of continuing concern is the need for a wide assortment of suitable live feed organisms, for first feeding of larvae – development of methods to mass culture them and evolving feeding schedules – quality of water, water depth, water movements, etc. also play crucial roles in larval rearing – most critical requirement is to prevent head-butting syndrome – larvae swim towards light reflected from the sides or bottom of the tank and dash at the sides of tank and die – green water technique widely practiced to avoid this phenomenon – light intensity has to be sufficient for the larvae to easily detect and capture feed – light source must be indirect to avoid reflection.

Hatchery production and culture of marine ornamental fish more economically feasible – price per unit value high – clownfishes and damselfishes offer immediate scope – intensive research on broodstock development, breeding and larval rearing of marine ornamental fishes needed to develop technologies for more species – this can pave the way for the development of a hatchery reared marine ornamental fish trade in the country.

Lecture No: **2** Prepared by **P.S. Asha**

Topic : **Breeding and seed production of sea cucumbers**

Need for hatchery production and sea ranching-over fishing -depletion of stock-stock enhancement- re-seeding- History of breeding – *H.scabra, H.spinifera*- Hatchery operations-collection and maintenance of brood stocks-breeding seasons- biopsy for sex determination-socking density-spawning induction-methodologies- drying under shade- subjected to powerful jet of water-thermal stimulation- stripping- addition of powdered feed- etc.,

Spawning behaviour- male and female identification-Fertilization and early development- characteristics of blastula-gastrula-dipleurula- early, late auricularia- doliolaria-pentactula- size range- metamorphosis- development-larval rearing – larval stocking density- water quality management- types of feed –micro algae- feeding regime- enumeration of survival and growth rate-settlement induction- Algamac-algal extract preparation-Environmental factors-effect of temperature-salinity and pH on larvae- Nursery rearing-algal powder-Juvenile grow out- stocking density- survival and growth-Predators and their control.

Lecture No:1 Prepared by **P.S. Asha**

Topic : **Resources of sea cucumbers**

Taxonomic Position of Phylum: Echinodermata- Characteristics of Sub phylums- Pelmatozoa and Eleutherozoa- Characteristics of five classes of phylum Echinodermata- holothuroidea- echinoidea- asteroidea- ophiuroidea and crinoidea- Characteristics of five orders of class holothuoidea– aspidochirota - elasipoda- dendrochirota – molpadonia- apoda – Tentacles-types - peltate-dendritic- digitate- pinnate. –Habitat specifications- surf zone-fugitive-and fossorial

External morphology- habitat and general characteristics of holothurians - Characteristics of two families of order Asphidochirota- holothuridae and stichopodidae - Commercially important sea cucumbers (12 numbers)- Family: Holothuridae- Genera- *Actinopyga*- species egs. *Actnopyga miliaris*- *A.echinites*- *A.mauritiana*-Genera-*Bohadschia*-species egs. *Bohadschia argus, B.marmorata*,-Genera *Holothuria*- species egs. *Holothuria scabra, H.spinifera, H.nobilis, H.atra* Family: Stichopodidae- egs. *Stichopus. chloronotus, S.variegates, Thelenota ananas.*

Spicules – Definition- functions- Types of spicules- One dimensional egs– Buttons- (smooth-nodose-ellipsoid)- Miliary granules- Rosettes-'C' & 'S' shaped Fenestrated plates- Rods-(smooth & spiny) – Wheel- Anchor plates- Baskets- Two dimensional- egs- pseudo table- and table with arched disc.

Lecture No: **3** Prepared by **P.S. Asha**

Topic : **Present Status and future prospects for sea cucumber culture & Processing of sea cucumbers**

History of sea cucumber culture- culture of *Apostichopus japonicus*- China and Japan- pond culture- *H.scabra* –Indonesia-pen culture- Kamunolsland near Simji -cage culture- - *Parastichopus californicus*-British Columbia-suspended enclosure. *H.scabra*- India- first attempt in Port Blair—Culture attempt in prawn farms- growth rate at Minota aqua farm- Pablo prawn farm – Eastern aqua farm - Types of cages- rectangular iron cage-- velon screen cage- netlon cage - old one tonne tank- concrete rings- and concrete tanks with flow through system- Bottom substratum characteristics- organic carbon content- sediment particle size- presence of hydrogen sulphide- methane & nitrogen.etc.

Beche-de-mer- definition –origin of words-Industry-species used for processing – criteria- Difference in processing steps-Value of beche-de-mers-high valued *H.scabra* - medium valued *H.spinifera* - low valued *H.atra*-Processing steps-collection-cleaning-de-gutting- boiling- Uses of beche-de-mer- aphrodisiac qualities- curative properties- Bio- chemical composition.

COURSE MC 504

SEAWEED CULTURE AND UTILIZATION

LECTURE OUTLINE

COURSE TEACHER

REETA JAYASANKAR
SENIOR SCIENTIST
C.M.F.R.I
COCHIN

LECTURE OUTLINE FOR THE COURSE MC 504-(1+1)

SEAWEED CULTURE AND UTILIZATION

MC-504 Dr. N.Kaliaperumal

Lecture-1 Time-1 h

Topic – Resource and distribution of seaweeds in India and World

What is seaweeds – systematic position of marine algae in plant kingdom – classification of algae – classification of seaweeds – green algae, brown algae, red algae and bluegreen algae – criteria for classification of marine algae – importance of seaweeds – distribution of seaweeds in east and west coast of India – places where rich seaweed beds occur – localities of Indian coast where agar, carrageenan and algin yielding seaweeds occur – areas where majority of agar and algin yielding seaweeds grow – species with continuous distribution on the Indian coast – species having discontinuous distribution with luxuriant growth – life span and growth behaviour of seaweeds – peak growth periods of seaweeds – factors influencing growth of seaweeds- Seaweed resources survey conducted in different maritime states, Lakshadweep and Andaman-Nicobar islands – standing crop of seaweeds in intertidal, shallow and deep waters – total number of marine algae recorded from Indian waters – species of commercial importance – commercial exploitation of seaweeds in India-quantities of seaweeds exploited from natural seaweed beds - species harvested and their major landing centers – time-table for commercial exploitation of seaweeds - Countries where seaweeds grow abundantly – role of temperature and substratum in the geographical and local distribution of seaweeds – number of marine algal species reported from all over the world – seaweed resources of the world – total annual seaweed production in the world.

MC-504

Dr. N. Kaliaperumal

Lecture-2

Time-1 h

Topic –Taxonomy and identification of economically important seaweeds, their morphology and anatomy

Taxonomy of marine algae - Key characters (morphological and anatomical characters) for identification of different species of economically important seaweeds – green algae – *Ulva, Enteromorpha, Caulerpa, Codium* (edible seaweeds) - brown algae –*Sargassum, Turbinaria, Cystoseira, Hormophysa* (algin yielding seaweeds) – red algae – *Porphyra* (edible seaweed) – *Gelidiella, Gracilaria, Gelidium, Pterocladia* (agar yielding seaweeds) – *Hypnea, Acanthophora, Laurencia* (agaroid yielding seaweeds) – *Sarconema, Asparagopsis* (iodine yielding seaweeds) -Morphology – Filamentous forms – unbranched filaments – *Lyngbya, Phormidium, Chaetomorpha* – branched filaments – *Cladophora, Ectocarpus, Acrochaetium* – *Siphonaceous* forms – *Valonia, Bryopsis, Codium, Halimeda, Caulerpa* – Parenchymatous forms – *Ulva, Enteromorpha, Dictyota Sargassum, Laminaria* – Complex parenchymatous thalli; uniaxial forms – *Centeroceras, Ceramium* – multiaxial forms *Corallina, Spyridia*- Anatomy - prokaryotic algae - eucaryotic algae - mesocaryotic algae - cell wall – cytoplasm – chloroplast – pyrenoids – mitochondria – golgi bodies – endoplasmic reticulam – nucleus – chromosomes.

MC-504

Lecture-3

Dr. N.Kaliaperumal

Time-1 h

Topic –Present status of seaweed culture in India and other countries

In India - experimental scale cultivation of seaweeds by vegetative propagation method – culture of agar yielding seaweeds *Gelidiella acerosa* on coral stones in the subtidal area at Ervadi – field culture of the agarophyte *Gracilaria edulis* in the nearshore area of Mandapam on long line ropes and nets – culture of the agaroid yielding seaweeds *Hypnea musciformis* in inshore waters of Mandapam – in different environmental conditions – polyculture of *Gracilaria* spp in ponds with shrimp – experimental culture of agarophyte *Gracilaria edulis*, *G.corticata*, *G.foliifera* and carrageenophyte *Kappaphycus alvarezii* in the nearshore area of Narakkal (Cochin) and Calicut by reproductive and vegetative propagation methods – onshore culture of *Gracilaria edulis* under culture shed – tissue culture of seaweeds – pilot scale culture of *Kappaphycus alvarezii* in the nearshore area of Mandapam - In other countries – commercial scale cultivation of seaweeds – cultivation of *Porphyra* (edible red alga), *Enteromorpha*, *Monostroma* (edible green algae), *Undaria*, *Laminaria* (algin yielding brown algae) in Japan and China – Culture of carrageenophytes *Eucheuma* and *Kappaphycus* and edible green seaweed *Caulerpa lentillifera* in Philippines – culture of *Macrocystis* (alginophyte) *Hypnea* and *Chondrus* (carrageenophytes) in the Unites States – culture of *Gracilaria* spp (agarophytes) in Taiwan.

MC-504

Lecture-4

Dr. N. Kaliaperumal

Time-1 h

Topic – Uses of seaweeds

Uses of seaweeds – manufacture of phytochemical such as agar, carrageenan, alginates – production of other chemicals mannitol, bromine, iodine, laminarin furcellarin – protein rich seaweeds *Ulva*, *Enteromorpha*, *Codium*, *Monostroma* (Green algae), *Laminaria* *Undaria* *Macrocystis* (brown algae) *Porphyra*, *Gracilaria* *Eucheuma*, *Laurencia* and *Acanthophora* (red algae) for human consumption in the form of soup, solid, vegetable porridge – iodine rich seaweeds *Asparagopsis taxiformis*, *Sarconema* spp for controlling goitre disease caused by enlargement of thyroid gland – Human consumption of many protein rich seaweeds such as Ulva, Enteromorpha, Codium and Monostroma (green algae), Sargassum, Hydroclathrus, Laminaria, Undaria, Macrocystis (brown algae); Porphyra, Gracilaria, Eucheuma, Laurencia and Acanthophora (red algae) in the form of soup, salad, vegetable and porridge -preparation of seaweed meal as animal feed – fresh and cast ashore seaweeds as manure for land plants directly or compost form – seaweeds as a source for production of fuel gas – liquid seaweed fertilizer from seaweeds – its use as foliar spray for inducing faster growth and yield in leafy and fleshy vegetables, fruits, orchards, horticultural plants – use of seaweeds as medicine – seaweeds as a source for production of bioactive compounds

MC-504 Dr. N.Kaliaperumal

Lecture-5 Time-1 h

Topic –Methods of seaweed cultivation (onshore and field)

Methods of seaweed cultivation – Two basic methods for cultivation of seaweeds one by means of vegetative propagation method using fragments from mother plants and the other by reproductive method using different kind of spores as swarmers, zoospores, monospores, tetraspores and carpospores - Different culture techniques adopted for various economically important seaweeds in different countries by vegetative propagation method- fixed off bottom culture, floating raft /cage culture, bottom culture, greenhouse culture, spray culture, raceways culture and tissue culture - Reproductive method for the commercial scale cultivation of edible red alga *Porphyra* and green algae *Enteromorpha* and *Monostroma*;- agar yielding red algae *Gracilaria edulis* and *Gracilaria cylindrica* - algin yielding brown algae *Laminaria*, *Undaria* and *Macrocystis* in different countries-Culturing of vegetative fragments in the nearshore areas of the sea by inserting them in the twists of ropes, tieing to nylon twine or polypropylene straw, broadcasting the fragments in outdoor ponds and onshore tanks - Species cultured by vegetative propagation methods; *Eucheuma*, *Kappaphycus*, *Hypnea*, *Gelidiella*, *Gracilaria*, *Pterocladia*, *Chondrus*- Production and economics of commercial scale cultivation of agar yielding red seaweed *Gracilaria edulis*.

MC-504 Dr. N.Kaliaperumal

Lecture-6 Time-1 h

Topic: Seaweed culture by vegetative method, Production and Economics

Vegetative method – Culture of *Gelidiella acerosa* on coral stones in the subtidal area on coral stones – inserting fragments of *Gracilaria* spp, *Hypnea musciformis*, *Acanthophora spicifera* in the twists of long line ropes and nets and culturing them in the nearshore areas of the sea – culture of fragments *Eucheuma* and *Kappaphycus* on nylon monolines and in slotted polythene bags in inshore waters and open sea – culture of *Gracilaria* spp, *Caulerpa lentillifera Hypnea* spp in the ponds by uniformly broadcasting the fragments at the bottom of the ponds – onshore cultivation of *Gracilaria, Hypnea, Chondrus* in brick tanks, fiberglass tanks, plywood tanks – culture of fast growing strain *Gracilaria* N Br 10 in raceways- Production/annum – production/unit area- production/meter- *Gelidiella acerosa* –*Gracilaria edulis* at Mandapam and Minicoy respectively –*Hypnea musciformis* –*Acanthophora spicifera* in the sea and pond respectively- Economics – for commercial scale cultivation of agar yielding seaweed *Gracilaria edulis* in one hectare area of the sea for one year – recurring expenditure (seed material, coir rope nets, casuarina poles, wages etc.) – net profit

MC-504 Dr. N.Kaliaperumal

Lecture-8 Time-1 h

Topic – **Methods of preparation of liquid seaweed fertilizer, seaweed food products and recipes**

Liquid seaweed fertilizer – collection of brown seaweed *Sargassum* – drying and cleaning – pulverizing into fine powder – soaking in water – cooking in autoclave at 60 ° C for 2 hours- filtering through muslin cloth – centrifuging by an industrial centrifuge – filtrate dried to thick viscous liquid in hot air oven at 60 ° C or dried to powder-Seaweed food products and recipes- Seaweed jelly – boil cleaned dried seaweed *Gracilaria edulis* in water– stir frequently – filter through organdy cloth into a vessel – add sugar, lime juice, food essence and food colour to taste in hot condition – mix thoroughly – pour into trays – allow to set – keep in refrigerator for 30 minutes- Seaweed jam – prepare sugar syrup – add seaweed powder *Ulva lactuca* – boil for 15 minutes – stir frequently – add edible colour and essence- Seaweed pickle – take cleaned fresh seaweed *Gracilaria edulis* – cut into small pieces – soak in vinegar for 2 days – remove from vinegar – add gingelly oil, chilli powder, mustard, fennugreek powder – season with asafoetida – add peeled garlic – mix thoroughly and bottle-Salad – clean the fresh seaweeds of *Caulerpa racemosa*, *C.sertularioides*, *Codium* spp, *Gracilaria verrucosa*, *G.eucheumoides*, *Hydroclathrus clathratus*, *Laurencia papillosa* – wash in fresh water – add chapped tomatos, carrot, onion, chilly and ginger – mix thoroughly- add salt to taste- Seaweed masala – cut fresh green seaweed *Ulva lactuca* and onion into pieces – garnish them in low fire with oil, mustard and curry leaves – add chilly powder, coriander powder, turmeric powder, salt, ginger and tomato pieces – mix well-Seaweed wafer – boil cleaned dried seaweed *Gracilaria edulis* in water – filter through organdy cloth – add rice paste, chilly paste and asafoetida powder – add sesamum seed and cumin seed – mix well – cook together – dry the paste in open sun in small lump on cloth – fry in oil Seaweed porridge – boil dried cleaned *Gracilaria edulis* in water – grind it into fine paste – boil the paste in water – add sugar and milk – mix thoroughly – add cashew nut, raisins and cardamom.

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Lecture- 9 Time –1h

Topic: Reproduction in seaweed

Introduction - General classification of Plant kingdom – Acotyledon- Monocotyledon- Dicotyledon- Cryptogamae- Phenerogamae- Thallophyta- Bryophyta- Pteridophyta- Algae- Fungi- Classification of Algae based on reproductive parameters- General characterstics of algae- common features- Reproduction in algae-Types of reproduction –Vegetative – fragmentation- cell division- formation of hormogonia- Budding- propagules- Stolons- Adventitious branches- Asexual reproduction- zoospores- Flagella in zoospores- their attachment to the spores- Number of zoospores- types of zoospores- mitospores- meiospores- neutral spores - aplanospores- hypnospores- autospores- endospores- Monospores- - paraspores- androspores- hormospores- akinets or modified zoospores--- Dispersal of spores Sexual reproduction- Different types of spores – different types of reproduction Isogamous- Anisogamous- Oogamous- Hologamy- Plurilocular sporangia- unilocular sporangia, concentacle- receptacle- carpospores- typical example of reproduction in phaeophyceae and Rhodophyceae- formation of gamets- antheridia and oogonia- fusion -Parthenogenesis

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Lecture-10 Time –1h

Topic: Life cycle in seaweed

- General outline about the life cycle in algae- Haplotic life cycle- diplontic life cycle- diplohaplontic life cycle-Isomorphic diplohaplontic- heteromorphic diplohaplontic - haplobiontic- triphasic life cycle- Life cycle in Phaeophyceae with some examples-Life Cycle in Rhodophyceae with example- Life cycle in Chlorophyceae with example- Alternation of generation-Isogeneratae-Heterogeneratae- cyclosporae- Concept about conceptacle/Receptacles and their development--Life cycle of Fucales (a typical example)-Development of reproductive parts in Fucus- -Types of Oogonia in Fucales- Fucus type-Ascophyllum type- Pelvitia type- Heterophycus type-Cystoseira type-Sargassum type- Formation of conceptacle in Fucales –Ostiole- Paraphyses-Periphyses- Formation of antheridium -Formation of antherozoids

MC-504 Dr. Reeta Jayasankar

Lecture-11,12 & 13 Time –3 h

Topic: Seaweed Physiology

-General Introduction -Classification of algae based on their pigment constituents- Different types of pigments – Chlorophyll a, b, c, d, e- general structure of chlorophyll- distribution in different types of algae- carotenoid- carotene-leutin-zeaxanthin-anthraxanthin- Xanthophyll- peridinin- phycobiloprotein- phycoerythrin – phycocyanin - allophycyanin- Role of pigments in photosynthesis- Importance of natural pigments-- Structure of chloroplast --Electromagnetic spectrum- distribution of seaweed ght at different depth-Inside Chloroplast-Light harvesting antennae-Photosystem I and Photosystem II- Reaction centers- Electron transport chain- redox potential- resonance transfer in the reaction center—Photosynthesis-Photolysis of water- S State formulated by Kok,1970 - Light reaction-Energy absorption-Fluorescence and phosphorescence-Studies on fluorescent kinetics-Energy trapping-Resonance transfer -Generation of ATP and NADPH-Cyclic and Non cyclic photophosphorylation- Plastoquinone pool -Dark reaction-history of isotope carbon for tracing the intermediate product- Pentose phosphate pathway-enzymes associated with it- energetics of calvin cycle-C4 pathway- Crassulean acid metabolism- Photorespiration- Methods of estimating photosynthesis-Light and dark bottle method-Biomass and pigment constituents-^{14} C tracer-Fluorescent kinetics-Artificial electron donor and acceptor-Factors affecting photosynthesis- Essential nutrients and their uptake-Carbon metabolism-Anabolic pathaway-Catabolic pathaway-Translocation -Storage polysaccharides-Integration of metabolism

-Further reading -The Physiological Ecology of Seaweeds Edited by C.S. Lobban, Paul.J.Harrison and Mary Jo Duncan

-Physiology and Biochemistry of Algae Edited by Ralph A. Lewin, Univ of California

MC-504

Lecture-14

Dr. Reeta Jayasankar

Time –1h

Topic: Seaweed culture by reproductive method

General Introduction about reproduction and types of spores involved in culture- Tetraspores-Carpospores-Zoospores-Conchospores-Reproduction of *Gracilaria* from carpospores-Reproduction in *Laminaria*-Reproduction in Porphyra-**Video show** to the students on *Gracilaria*, *Laminaria* and *Porphyra* culture-- Selection of site and methods of cultivation of *Gracilaria*- Preparation of raft and other cultch material required for cultivation-- spore liberation- growth of spore by ocular meter- regular monitoring of growth- percentage of survival- period of transplantation- method of transplantation- culture condition in east and west coast of India- natural collection of spores- regular monitoring of germling stage in the field- regular monitoring of growth of plant- crop growth rate-Factors affecting the growth of *Gracilaria* cultured from spores-Optimum environmental parameters for growth of seaweed-Period of cultivation and necessary care during cultivation-Methods of Harvesting, period of harvest, drying, packing etc

MC-504

Dr. Reeta Jayasankar

Lecture-15 **Time –1h**

Topic: Physiology of seagrasses and method of studying biomass and productivity

General introduction- Seagrass, their habitat and the available species in India- standing stock and productivity- Comparative criteria and units- Methods of estimating seagrass productivity- Use of carbon isotope- Infrared gas analyzer- use of oxygen electrode- light and dark bottle method- Hantsch slack oxygen electrode- Chlorophyll estimation- Fluorescence kinetics- quadrate studies-Comparison of standing stock--Physiological studies-salinity tolerance-Photoperiod responses- Temperature response-Mechanism of photosynthesis-Other physiological response-

Further reading Seagrass Ecosystems –a scientific perspectives edited by C.Peter McRoy and Carla Helfferich, Inst of Mar. Sci, Alaska

MC – 504

Lecture – 16&17

Dr. P. Kaladharan

Time –2 h

Topic: Zonation and Factors influencing growth and distribution of Sea weeds.

Introduction: Definition of zonation- difference between distribution and zonation. Algal zones and distribution pattern- need to study zonation and factors influencing growth and distribution of seaweeds.

Factors: types of factors- external stimuli (stress)- physical, chemical ,biological and edaphic factors

Physical – Light- diffusion of light over water column -light energy- photons- photoperiod- short day and long day weeds- heliophytes and sciophytes Temperature- tropical and temperate zones, climatic zones- temperature and growth and biomass production. Current- Tide etc.

Chemical – Salinity- tolerance limit of seaweeds- stenohaline- euryhaline seaweeds- dissolved oxygen- dissolved nutrients- silicates, phosphates, nitrates- trace metals and minerals- dissolved ions- pH etc.

Biological – Epiphytes – competition for nutrients, and light- photosynthesis- shading by epiphytes and periphytons- predators- grazing - associated flora and fauna.

Edaphic - Sediment nature –composition of sediments- texture- microbial population - weeds attached to sediment- affinity to substratum etc.

Terminologies(Defnition and examples): Litoral, Neritic, Benthic, Supra litoral, Tropical,Temperate, Subtropical, Euryhaline, Stenohaline, Sciophyte, Heliophyte, Short day & Long day weeds, Endemics.

Further reading- M. J. Dring 1982. The Biology of Marine Plants, Edward Arnold, UK – Page 119 – 155.

MC - 504

Dr. P. Kaladharan

Lecture - 18

Time –1h

Topic: Tissue culture of Seaweeds.

Introduction : Aims and objectives of seaweed tissue culture - totipotency- regeneration -seaweed biotechnology - scope of seaweed tissue culture - methods of seaweed tissue culture - facilities, infrastructure required - explants – media - glass wares — equipment etc.

Growth promoters - morphogenetic substances, auxins, gibberlins and cytokinins

Sterilization - Survival and Sterilization- survival index - sterilants - chemical and physical means- antibiotivcs-radiation

Cell culture - protoplast isolation- separation- filtration /centrifugation

Protoplast culture – osmoticum – micronutrients- Brownian movement- protoplast as seed stock

Protoplast fusion – electrofusion –microporation -somatic hybridization – cell fusion system - scope of protoplast fusion- merits and demerits of protoplast fusion

Further reading.

1 Introduction to Applied Phycology : Ed.I. A.Katsuka, SPB Academic Publishing 1990. The Hague 647-668.

2 Kaladharan P. 1998 In Proceedings of the First National Seminar on Trends in Nature Biotechnology. Edr. S. Lazarus and Prakash Vincent 83-88.

MC - 504 Dr. P. Kaladharan

Lecture – 19 Time –1h

Topic: Methods of Preparation of Seaweed meal, Seaweed as feed/fodder and manure.

Introduction: Utilization of seaweeds and seaweed products- recent advances -harvesting methods - cleaning – epiphytes - epifauna, debris etc. drying – air drying, bleaching (natural method)seaweed meal – pulverising and storing.

Animal feed - fodder – digestibility - advantages of seaweed fodder – silage – ensilation – advantages of feed supplements -feed preparation – source of fibre – source of binder - feed for cattle - poultry and aquaculture

Manure -basal application -seaweed meal and seaweed factory discharge- effect of basal application on vigour and yield - mulching, compost - foliar application - liquid seaweed fertilizer, (LSF) - methods of LSF preparation- their Uses.

Further reading

1. Chapman V.J. and O.J. Chapman 1980, Seaweeds and their Uses. P. 30 – 241.
2. Training course manual on Seaweed culture, Processing and Utilization - TTC; CMFRI, Kochi June 1998 pp 36.

MC - 504

Dr. P. Kaladharan

Lecture - 20

Time –1h

Topic:Taxonomy and identification of different species of sea grasses – their ecology and biology.

Introduction : Differences between sea grasses and seaweeds - major characteristics of sea grasses- flowering plants – submerged angiosperms – Importance of seagrasses to coastal ecosystem – nursery grounds - swim-in restaurants.

Taxonomy – morphology - anatomy of seaweeds – flowering – pollination- fertilization - seed dispersal – underground stem and root system- sand binders

Identification of tropical species of sea grasses

Nutrient uptake - phenology -growth and meristems – rhizomes – leaves - leaf sheaths – ligules- flowering - hydrophily - seeds

Economic importance of seagrasses- utilization of seagrasses – edible grasses – ethnobotanic information - grazing by turtles, dugongs, holothurians

Ecology of sea grass meadows - restaurants for marine fauna – shelter – breeding and rearing grounds – primary production – carbon fixation -wasting disease

Further reading: Hand book of Seagrass Biology : An Ecosystem Perspective Ed. R. C. Phillips and C. P Mc. Roy, Garland STPM Press, PP 345.

MC-504

Dr. C.P.Gopinathan

Lecture-21

Time-1 h

Topic –Seagrass ecosystem

- General introduction for seagrasses
- Distribution
- Systematics
- Species diversity in Indian coast
- Morphological characterstics
- Functions of seagrass ecosystem
    - Primary productivity
    - Nursery ground
    - Feeding ground
    - Shelter
    - Food resource
- Importance of seagrass bed for marine turtle and marine mammals

M.F.SC. MARICULTURE

LECTURE OUTLINE

COURSE No. 505

ECOLOGY OF CULTURE SYSTEMS

Course Teacher : D. PREMA
Faculty Members : C.P. GOPINATHAN
G.S.D. SELVARAJ
T.S.NAOMI
REETA JAYASANKAR
MOLLY VERGHESE
IMELDA JOSEPH
A. NANDAKUMAR
GEETHA ANTONY

CONTENTS

Water quality parameters in mariculture systems (Part I)

Water quality – definition – water quality monitoring - importance - water quality parameters related to maricultre – physical – chemical

Physical factors : Temperature – absorption of solar energy at sea surface – factors affecting - vertical temperature profiles - formation of thermal stratification – typical profile – thermocline – definition - stability of the stratification

Measurement of temperature at surface, sub surface depths – instrument used – protected reversing thermometer – mechanism of recording temperature – accuracy of measurements

Factors affected by changes in temperature – physical – density, viscosity of water, solubility of gases, chemical – biological processes in the sea

Light – importance of the parameter – penetration of light (IR and Visible portion of the spectrum) to different depths – basis of degree of penetration – factors affecting – euphotic zone

Instruments for measuring light penetration – Secchi disc, transparency meter

Water quality parameters in mariculture systems (Part II)

Salinity – definition –unit – ratio of constant composition of in sea water – average salinity of sea water – factors causing variations in salinity – evaporation, precipitation, fresh water discharge from rivers – salinity tolerance – stenohaline and eurihaline forms

Salinity measurements – determination of chlorinity – titration method – Knudsen's equation – use of "standard sea water"
Determination of electrical conductivity of sea water – application of the relationship between conductivity and salinity – use of Salinometers – Refractometers – principle

pH – definition – principle system regulating pH in water – factors affecting variations in pH of sea water – environmental, biological – pH range of sea water – factors affecting marine organisms

pH measurements – use of pH meters – calibration - procedure

Turbidity – causes of turbidity – plankton blooms, concentration of humic substances, suspended particles of clay – problems due to turbidity

Turbidity measurements – estimation of total suspended solids (TSS) in sea water - unit - use of Nephelometer – unit of turbidity (ntu)

Water quality parameters in mariculture systems (Part III)

Chemical factors : Alkalinity - What is alkalinity - sources – unit of alkalinity - predominant basis contributing to alkalinity – effects due to high alkalinity

Determination of alkalinity – titration method – steps involved – phenolphthalein alkalinity - total alkalinity

Total hardness – what is total hardness – unit of expression – causes of hardness in water – polyvalent metallic ions – natural hardness – limestone – effect of hardness in water

Estimation of total hardness – titration method – principle

Dissolved oxygen – importance of the parameter – solubility of oxygen in water – factors influencing solubility - oxygen exchange across the sea surface – photosynthetic production of oxygen – dissolved oxygen stratification in culture systems

Estimation of dissolved oxygen in water – titrimetric method - Winkler method – sampling and storage – procedure

Water quality parameters in mariculture systems (Part IV)

Inorganic salts - major dissolved nutrients in sea water – phosphorus, nitrogen and silicon - their role in aquatic productivity – availability of nutrients at different layers – factors influencing concentration – light, temperature, water movement, river influx, extend of productivity - nutrient utilisation - process of photosynthesis – nutrient regeneration process - replenishment of surface layers – factors influencing – physical

Methods of estimation – orthophophosphate, nitrate, ntrite, silicate – principles - instruments involved

Bio-chemical oxygen demand (BOD) – what is meant by BOD - factors affecting BOD - purpose of BOD tests – water pollution investigation

Determination of BOD in samples – direct method , dilution method - preparation of dilution water - dilution scale – basis for dilution

Chemical Oxygen Demand (COD) - usefulness of COD tests - principle involved

Estimation of COD by different methods – digestion method – heat dilution procedure for brackish waters

Circulation and mixing pattern in coastal water bodies

Coastal Water bodies - regions included– their characteristic features - factors affecting – discharge of continental materials – biological productivity

Major circulation processes in the region – causative factors inducing circulation and mixing - thermohaline circulation – wind action at surface – effects of tidal currents

Thermohaline circulation : factors causing – evaporation, surface cooling - convective flow – effect on density of water masses – sinking process

Wind driven circulation : water movement – effect on coastal waters – upwelling - sinking

Tidal currents : factors causing formation of tides – oscillation and period – spring tide - neap tide

Factors affecting circulation and mixing – effect on thermal barriers - oxygenation of deeper layers – nutrient replenishment in surface layers - primary productivity of the euphotic zone – dilution of coastal pollution – influence on living organisms

Monsoon and its effect on coastal water bodies

Monsoon – origin of terminology – monsoons over India – causes of monsoon – wind patterns along the shores of the Indian Ocean - components determining the origin and development of monsoons - seasonal variations in sea surface temperature (SST) – variations in air-sea interaction

Phases of monsoon – wet phase - duration – average rainfall – dry phase– what is monsoon failure – monsoon forecasting – different ranges of forecast - effect of monsoon on physical and chemical properties of coastal water bodies

Upwelling – factors causing the phenomenon – upwelling process – upwelling areas – upwelling along the West Coast of India – causative factors – wind and current pattern during upwelling – period, intensity and duration of the process – effect on water properties – influence on coastal productivity

Mud banks – characteristic features – formation of mud banks – major locations of formation along the south west coast of India – reasons for tranquillity – properties of mud banks – physical - chemical

Coastal Ecosystem Analysis: Part-I. An overview

Introduction - Ecology - Ecosystem

The Environment - Hydrosphere - Atmosphere - Lithosphere - Biosphere

Coastal Zone - Continental shelf (classification) –Inshore - offshore waters - Neritic - Littoral zones

Inshore waters - Extent (upto 50 m depth contour)

Indian coast (area) - 0.193 million km^2 (42% of Continental shelf)
- East coast: 78,500 km^2 (41%)
- West coast: 1,14,500 km^2 (59%)

Estuary-13% of global coastline - Factors governing formation and life-span of estuary

Estuarine ecosystems - Mangroves, salt marshes, backwaters and lagoons

Tides - Spring tide - Neap tide - Full moon tide - New moon tide -Tidal amplitude - Role of tides

Diurnal studies - High and Low tide data

Types of Estuaries - Classification
- Prichard (1967)
- Mc Hugh (1966)
- Hansen and Ratray (1966)
- Nair and Thampi (1982)

Hydrodynamics of estuaries - Formation of mudflats and mangroves

Station fixing and sampling techniques

Coastal Ecosystem Analysis : Part-II. Structure and Functions

Boundaries - Physical and Ecological

Coastal Ecosystems: Marine zone –Estuarine zone - Mangroves - Salt marshes - Lagoons and Atolls - characteristics

Organic cycle: Within the phytomass - Within the Ecosystem - Outside the Ecosystem

Ecological Reservoirs (storage of organic matter): Living tissue - Detritus - Dissolved form (solution)

Organic carbon compounds in nature - (0.05%) - Storage: Fossil – detritus - biomass

Biomass: Primary - secondary - tertiary levels

Food-chain and Food-web – description - Trophic cycle (Food-chain) in the sea - Detrital Food-web in the Mangroves / Estuarine system

Organic cycling in the Mangrove ecosystem - Factors governing organic cycling

Different Types of Culture Systems

Introduction – characteristics - Freshwater – Estuary - Open sea - Salt pans

Pond culture – types - Freshwater - Perennial ponds - temporary ponds - Holding pond - Rearing pond - Growing pond - Excavated ponds - Levee ponds - Factors considered before building a pond - Preparation and management of fish culture ponds - Ecology of fish pond – factors affecting ecology – physical - chemical - biological

Culture in Brackish water ponds - Traditional culture practices - in impoundments - in paddy fields - in small shallow coastal lagoons

Other culture systems – features - Raft culture - Rack culture - Cage and Pen culture systems – advantages - disadvantages - Raceway and Tank culture – method – open system – closed system – advantages - disadvantages - Culture in salt pans – features - Sewage fed fisheries – features - Monoculture - Polyculture - Extensive and Intensive culture practices

Lecture 10

Prepared by Shri G.S.D. Selvaraj

Dissolved Oxygen and pH in Culture Systems

Dissolved Oxygen - The most critical factor - Sources of addition (Physical and biological) - Sources of removal (Physical, chemical and biological)

Solubility - Role of Temperature and Salinity - Supersaturation

Factors influencing dissolved Oxygen and pH

Diurnal fluctuation - Culture systems

Seasonal fluctuations - Coastal waters (winter-summer-monsoon)

How to check dissolved Oxygen - Sampling techniques

Coastal waters - At lowest and highest tides
- At bihourly intervals
(Diurnal and Tidal cycle studies)

Culture ponds - Early morning and late afternoon
- BOD / COD Tests

Determination of Compensation depth

pH & Dissolved Oxygen range and optimum in Culture Systems

Main causes for Oxygen depletion in Culture ponds

- Respiratory loss
- Phytoplankton depletion
- Eutrophication (aftereffect)
- Bacterial oxidation processes

Factors governing dissolved Oxygen in the Culture ponds - Primary Production - Feed - Seed density - Illustrations and Precautions

Biological Oxygen Demand (Net BOD) in Coastal Waters

BOD = Biological/Biochemical Oxygen Demand

- A derivative of Oxygen measurement
- Role of dissolved oxygen in coastal waters
- To determine water quality and healthy survival of organisms

Oxygen user levels : Primary, Secondary & Tertiary

Primary level : Phytoplankton and Bacteria

Oxygen requirement for Tertiary / culture organisms

Drawbacks of existing methods to assess O_2 level:

- BOD estimation (drawbacks)
- COD estimation (drawbacks)

Net BOD estimation at primary-Secondary production level:

(Modified Light and Dark bottle Oxygen Technique)

L-I value (12 hrs) = 12 light hours of the day

D-I value (12 hrs) = 12 night hours of the day

[(L-I) + (D-I)] 12 hrs = Net BOD value per 24 hrs

Water quality Test : + value = good; - value = Not good

Result: More realistic to the environment

Net BOD - An index to water quality

Carbon dioxide - Bicarbonate-Carbonate Buffer System in the Sea

Inorganic Carbon in the sea

CO_2 = 1%; HCO_3^- = 90%; CO_3^{2-} = 9%

Organic Carbon compounds on Earth = 0.05%

Fossil = 64%; Detritus = 32%; Living mass = 4%

Carbon dioxide - Most oxidised state of Carbon

Link between organic and inorganic forms of Carbon

Sources of CO_2 in sea water

Role of CO_2 (Photosynthesis & Respiration)

Carbon dioxide Cycle: - Within phytomass
- In the ecosystem

Factors influencing Bicarbonate - Carbonate buffer system

- Diurnal variation
- Photosynthesis and respiration
- Excess photosynthesis depletes HCO^-_3 pool
- Hydrolysis of carbonate ions and release of OH^- ions - pH rise
- Phytoblooms - pH rise (afternoon)
- Respiration - pH fall (at night)
- Reversible buffer action - At night

Precaution : Excess bloom – pH rise - stress to organisms

Regulate photosynthesis = Equilibrium

Nutrient Cycles in Coastal Ecosystems: Part- I. Nitrogen Cycle

Nitrogen store house - Living tissue
- Detritus/sediment
- Dissolved form

Cycle of Nitrogen - Within the phytomass (Part)
- Within the Environment (Rest)

Phytomass : Uptake of inorganic form and release of organic form

Environment: Recycling of organics to inorganics

Source: Inputs from neighbouring environments (River and Sea to Estuary)

Nitrogen cycle: Involves four processes - Parabiosis

(i) Nitrogen Fixation: (Incorporation in the cell) (uptake, assimilation, deposition, Utilisation) (eg) Mangrove vegetation

Nitrogen fixing bacteria
- *Acetobactor* (Aerobic)
- *Clostridium* (Anaerobic)
- *Rhizobium* (Symbiotic)

(ii) Ammonification: (Reduction process) : Breaking down of organic N. compounds to simpler forms of Ammonia

(iii) Nitrification: (Oxidation process): Ammonia to Nitrite:
- *Nitrocystis*
- *Nitrococcus*
- *Nitrosomonas*

Nitrite to Nitrate: *Nitrobacter*

(iv) Denitrification: (Reduction process) - (in oxygen deficit environment)

Nitrate to Nitrite (Heterotrophic bacteria)

Nutrient Cycles in Coastal Ecosystems: Part-II. Phosphorus Cycle

Sources - Input from land drainage/rivers

- Input from the Sea during high tide
- *In situ* production by recycling process

Transport - Through Flood flow

- Through tides
- Through migration of organisms

(Removal - Biological and non- biological processes)

Storage - Living tissue, Detritus, dissolved form

- Soluble and insoluble forms
- Organic and inorganic forms

Inorganic phosphorus :	(i) Orthophosphate	- 1%
	(ii) Hypophosphate	- 87%
	(iii) Phosphate	- 12%

(96% of phosphate and 44% of Hypophosphate are present as ions (with Calcium & Magnesium)

Phosphate recycling: Faster than Nitrogen cycle

- partly within the phytomass

(uptake of inorganic P. and release of organic P by excretion and death)

- rest within the environment by microbial action

(In shallow waters/culture systems, recycling occurs mostly in sediments)

- Recycling faster in summer months

By decomposition, zooplankton releases phosphate faster than phytoplankton cells - Role of Protozoans in Phosphorus regeneration.

Phosphorus cycle - Not fully understood. (More research envisaged)

Lecture 15 Prepared by Shri G.S.D. Selvaraj and Smt. Molly Varghese

Organic Production in Coastal Ecosystems

Organic production - Primary, Secondary and Tertiary production

Store house - Living tissues, detritus, dissolved form

- Primary production - (Basic source)
- Methods for estimation of primary production

Sources : River, Sea and *in situ* production

POM and DOM: POM: > 0.45 µm (SPM and Detritus)

- SPM = Living and Non living-Seston (Dry wt in mg / l)
- Primary production (g.C/m^3/day) - Conversion factor
- Secondary production (g.C/m^3/day)-Conversion factor
- Factors influencing primary & secondary production
- DOM : < 0.45 µm (Dissolved organic matter)

Role of Mangroves and other macrophytes

Mangrove ecosystem - Highly productive

Pitchavaram Mangroves : organic production

SOM = 340 million tonnes/year

DOM = 0.1 million ton/year

Factors influencing sedimentation : (physical, chemical and biological)

Estuarine systems : *In situ* production = > 80%

Sedimentation increases organic load

Humus - Fat of the soil

Estimation: Organic Carbon in sediment (%)

DOM estimation: (i) Dry combustion method

(ii) Wet oxidation method

Removal of DOM: Biological and Non biological

Functions of DOM: Growth, behaviour, mating etc.

Harmful effect: (eg) pollutants

Primary Production

Primary production – definition – significance in fisheries – methods of estimating primary production – light and dark bottle oxygen technique – advantages - ^{14}C technique – principle - Chlorophyll *a*, *b*, and *c* estimation – principle and procedure - Determination of total cell counts - principle - rates of primary production in various ecosystems – estimation of potential resources based on primary production – significance of primary production in mariculture.

Factors influencing Primary Production

Physical - chemical - biological factors - effect of monsoon – eutrophication – definition of the problem – natural – artificial - Red tide - toxic algal blooms and harmful effects - Causative organisms - Factors influencing - Harmful effects - Water quality management in algal culture systems - benthic production - Methods of estimation and assessment of potential resources

Primary (Photosynthetic) Production in Aquatic systems
Part-I. Gross Primary Production (L&D O_2 Technique)

Introduction - Methods to determine phytoplankton production
- Cell counts
- Chlorophyll estimation
- C^{14} Technique
- L & D bottle Oxygen Technique

Merits and demerits of different methods

Advantage of Oxygen Technique - Simple and widely used - Provides rate of primary production - Provides gross and net values

Gross primary production = L-D per 12 hrs.

Net primary production = L-I per 12 hrs.

Photosynthetic quotient and conversion factor

Derivation: mg. C. / l = g. C. / m^3

Optimum incubation time - Sea (3 hrs)
- Estuary (2.5 hrs)

Respiratory loss = I-D value

Column production estimation in the sea

Estimation of primary production in Culture ponds

Validity of L-D for G.P.P (L and D bottle components after incubation)

Primary (Photosynthetic) Production in Water
Part-II. Net Primary Production (L&D O_2 Technique)

Introduction - Parameter to assess water quality and potential fishery resources

Light and Dark bottle Oxygen Technique

N.P.P. = G.P.P. minus Respiratory loss by phytoplankton

i.e. (L-I) = [(L-D) - (I-D)]

Factors influencing I-D value: - Respiration by phytoplankton
- Respiration by micro zooplankton
- Bacterial reactions (oxidation - reduction processes)

Validity of L-I values for NPP in primary production experiments

Light bottle components (after incubation)

Factors influencing Light bottle samples (coastal waters)

Result: N.P.P. value is masked (by bacterial interference)

Rectification : Improvement of Formula for N.P.P

Determination of Respiratory loss by phytoplankton during photosynthesis

N.P.P. = 80% of G.P.P = 0.8 (L-D) 12 hrs

Water quality Test = % of L-I in L-D value

> 75%	= Best quality
50-75%	= Better (Replenishable)
25-50%	= BOD more (Water exchange advised)
<25%	= Not good

Methods of estimation of primary production of macrophytes.

Estimation of biomass by quadrate method and analysis of frequency, Density, abundance and percentage of cover in a particular distribution - Estimation of photosynthetic pigment during different period of growth – Chlorophyll-carotenoid-phycoerythrin-phycocyanin-allophycocyanin- their structure-qualitative characterization-Rate of oxygen evolution - Using standard oxygen electrode - Light and dark bottle method – DO of the benthic macrophytes-Polarographic method –Estimation of DO of seaweed and microalgae-Rate of respiration-Need for dark adaptation of the algae- Infra red gas analyzer (IRGA)-insitu photosynthetic activity- Rate of CO_2 utilization – use of stable isotope-Measurement of production through $^{14}CO_2$ techniques using enzyme RUBP carboxylase -Short term exposure - Long term exposure - Use of GM counter - Liquid Scintillation counter –identification of the intermediate compound-Specificity of PSI and PSII photosystem by mild detergent treatment- Efficacy of both the system- methyl viologen test and DCPIP reaction-Use of artificial electron donor and electron acceptor - Using inhibitor like KCN, Sodium azide and herbicide in the electron transport chain - Fluorescent kinetics and quantum yield- Use of Oscilloscope – slow kinetics and fast kinetics

Classification of major phytoplankton organisms

Diatoms – taxonomy – identification – features – cell characteristics – structure – reproduction – significance as feed

Dinoflagellates – taxonomy - identification – features - structure – cell characteristics – reproduction – significance - Red tide - Harmful effects to the aquatic organisms

Silicoflagellates – taxonomy - identification – features - structure – cell characteristics – reproduction - significance

Coccolithophores - taxonomy - identification – features - structure reproduction - significance

Blue Green Algae - Role of blue – green algae – structure – reproduction - Red tide - Harmful effects to the fauna

Nannoplankton - Organisms – Importance in hatcheries – Role of phytoplankton in food chain

Classification of macrophytes in coastal water bodies

Coastal vegetations - environmental influence on coastal vegetation, exposure to seawater - tidal amplitude - distance from the sea - topography - soil condition-Marine algal vegetation in littoral and sub littoral area – Chlorophyta- Phaeophyta- Rhodophyta- important characteristics for classification- branching pattern- morphology of the thallus- reproductive structure- pigment constituents- apical structure- dichotomy- distribution of marine algae in different depth- light an important factor influencing vertical distribution- Algal vegetation of salt and brackish water –salt tolerant variety- estuarine variety- aquatic weed – floating- submerged- partially submerged- Vegetation in sand dunes – Xerophytes distribution-characteristic features -Specialized vegetation associated with drift-line - Vegetation in shingle beaches - Vegetation in coastal cliffs – Mangrove

Classification of Zooplankton

Introduction - Marine Habitat - Drifting life of the environment - Classification – Phylum–Class– Order – Family. Characteristic features of common zooplankters. **Phylum Protozoa-**S.phylum Sarcomastigophora - Class Chrysomonadina Order Dinoflagellida - *Noctiluca, Ceratium, Peridinium* - Class Rhizopoda- Order Foraminiferida -*Globigerina*- **Phylum Coelenterata (Cnidaria)** -Class Hydrozoa - Order Hydroida - *Obelia, Liriope* Order Siphonophora, *Physalia, Porpita.* Class Scyphozoa –*Aurelia*-**Phylum Ctenophora**–Class Tentaculata– Order Cydippida– *Pleurobrachia*- **Phylum Bryozoa** – Cyphonautes **Phylum Brachiopoda** – Lingula&Pelagodiscus **Phylum Phoronida** – Actinotrocha **Phylum Chaetognatha** – *Sagitta enflata*- **Phylum Annelida** – Class Polychaeta (Bristle worms) – *Tomopteris*- **Phylum Arthropoda** - Class Insecta- Class Crustacea – S.class Cirripedia- Order Thoracica- Families Balanidae & Lepadidae- S.class Ostracoda- S.class Branchiopoda- Order Diplostraca- S.order Cladocera- *Evadne, Penilia* - S.class Entomostraca- Order Copepoda -S.orders Calanoida, Cyclopoida and Harpacticoida- S.class Malacostraca- Super Order Peracarida- Order Mysidacea- Order Amphipoda- Order Isopoda- Order Tanaidacea- Family Tanaidae- Super Order- Eucarida- Order Euphausiacea -Order Decapoda – S.order Natantia- Tribe Penaeidea- Family Penaeidae – *Penaeus, Metapenaeus* Family Sergestidae – *Lucifer, Acetes*- Tribe Caridea – S.order Reptantia – Families Palinuridae & Scyllaridae (lobsters) S.order Anomura–S.order Brachyura –S. order Hoplocarida –Stomatopods - **Phylum** Mollusca –Class Gastropoda- Order Heteropoda – Order Pteropoda –Class Lamellibranchiata **Phylum Echinodermata** – Larval forms - Class Asteroidea– bipinnaria-brachiolaria- Class- Echinoidea- echinoplutei - Class Ophiuroidea–ophioplutei Class Holothuroidea –auricularia-doliolaria - pentacularia

Phylum Chordata – S.phylum Urochordata (Tunicata) Class Thaliacea, Order Doliolida –*D. gegenbauri*- Order Salpida –*S. democratica*- Order Pyrosomida, *P.atlanticum.* Class Copelata (=Larvacea=Appendicularia) *Oikopleura, Frittilaria*

Factors influencing zooplankton abundance & distribution

Introduction - Lower trophic level consumers - principal herbivorous component - spatial & temporal changes - biological & physico-chemical conditions of the marine environment

Factors affecting zooplankton abundance – Physico chemical - Temperature – thermocline – moulting – spawning - Light – vertical migration - Salinity – tolerance - Dissolved oxygen level – optimum - Water movement - Tidal currents - Upwelling - Turbidity – Biological - Food variability – scarcity – predation - competition - Environmental preferences – Multiple strategies

Marine ecosystems – Life cycle – Holoplankton - meroplankton - tychoplankton - larval behaviour and abundance - faunal assemblages in relation to the habitat

Estuarine ecosystems - Circulation pattern – grazing - patchy distribution - tolerance - riverine discharge - environmental stress – biotic & abiotic factors of importance - prey–predator interactions - seasonal changes in community structure

Assessment of Secondary production (Part I)

Introduction - The linear food chain concept - trophic levels - primary – secondary - tertiary consumers - production - secondary production definitions

Basis for production measurements - Two main approaches : a) Observational (field data) b) Experimental

a) **Observational:** recruitment time method - definition - generation time method - definition - growth increment method – definition - using identifiable life stages – copepods

1. Growth increment method

B = N x w, where **B** - biomass, **N** - number of individuals in a population, **w** - mean weight of an individual. Production (P_t) during a time interval t_1 to t_2 ,

$P_t = (N_1 - N_2) \frac{w_1 + w_2}{2} + B_2 - B_1$, $B_2 - B_1$ - increase in biomass

during the time interval, $t_1 - t_2$ and the subscripts **1, 2** pertain to t_1 (initial) & t_2 (final) - concept of production of zooplankton population - definition.

P_t (annual production) - $P_t = P_{t1} + P_{t2} + P_{t3} ------ P_{ti}$

Crustaceans – determinate growth pattern - each stage limited by size of exoskeleton

2. Using primary production, predict secondary production & yields of fish

E, Ecological Efficiency (Definition) – Approximated from - **Transfer Efficiency (E_T)**

$E_T = \frac{P_t}{P_{t-1}}$ Annual production at trophic level **t**

P_{t-1} Annual production in the preceding trophic level $_{t-1}$

$P = BE^n$, where, **B** - annual primary production, **E** - the ecological efficiency and **n** - the number of trophic levels

Prediction – Wet wt of fish & dry wt of planktivorous fish – method

3.Production to Biomass (P/B) ratio :

b) experimental :
(i) Laboratory-scale experiments
(ii) Enclosed ecosystem experiments
(iii) Computer model simulations

Assessment of Secondary production (Part II)

Theoretical concepts and applications - Secondary production – regularity & irregularity in the production cycles - Higher latitudes - Mid latitudes

Tropics - principal pathways - open ocean **a)** Microbial loop – DOM - bacteroplankton (0.2 – 2.0µm) – heterotrophic protists-metazoal zooplankton – fish **b)** Picoplankton (prokaryotic & eukaryotic cells, 0.5-2.0 µm) –bacteroplankton - metazoal zooplankton - fish **c)**Traditional food chain – phytoplankton – zooplankton – fish - In estuaries – In coral reefs - In atolls –In mangroves

Volume of water in m^3 filtered by the zooplankton net fitted with a digital flow meter

$V = \frac{A \times R}{K}$ Where, **A** - the area of the mouth of net ring in m^2 (Πr^2)
R - revolutions of flowmeter during operation of the net.

$K = \frac{R}{L}$ $\frac{\text{(Revolutions)}}{\text{(Length of tow)}}$

Calibration factor of flowmeter - **(m/rev)**

Average displacement volume of the zooplankton in ml/m^3 converted to ml/m^2 for a particular depth using the formula, $N \times \frac{D}{V}$ where

N = Nos. or Dis.Vol. of zooplankton

D = Depth in m

V = Volume of water in m^3

Assuming zooplankton standing stock in steady state - secondary production estimated as 1 ml = 0.025 g cm^{-2} - modified method - The annual secondary production - the average generation time of tropical copepods (18 days) - multiplying with 365/n, where n - the generation time of copepods.

Ichthyoplankton of inshore waters (Part - I)

Introduction - Ichthyofauna spawning ground – spawning season Ichthyoplankton survey - Methods used in identification of fish eggs and larvae - series method - hatching method.

Sampling - Sampling design - quantitative – qualitative - standard sampling. Sampling methods – tows - sampling with plankton nets – Bongo net – gauze – cod end bucket – filtration efficiency – flow meter - closing net – tripping mechanism – messenger

Quantitative analyses - Zooplankton volume determination - fractioning sample – Folsom splitter.

Qualitative analyses - Sorting fish eggs and larvae - counting – counting chamber

$$\text{Standardised number of spawn products (No. / } m^3) = \frac{N \times D}{m^3}$$

Where, N = Number of eggs/larvae

D = Depth of collection (in m)

m^3 = Volume of water filtered

Ichthyoplankton of inshore waters of the sea (Part II)

Structure of fish egg and larva – terminologies - definitions

Guidelines - identification - **fish eggs-** Egg size – shape - extent of perivitelline space - nature of egg membranes – Yolk - oil globule – number-size & position - embryonic characters

Guidelines - identification **- fish larvae -** Morphometrics - measurement of body parts - fin positions - Meristics - number of myotomes / vertebrae – spines / rays - Pigment pattern - type – nature – position - changes during development - Specialised characters peculiar shape of body / eye - elongation of spines / rays

Common coastal **Ichthyoplankton** families – salient **diagnostic** characters -

Order Anguilliformes – Family Ophichthidae (snake eels)

Order Clupeiformes – Family Clupeidae (sardines) - *Sardinella longiceps* myotome 48 - Family Engraulidae (anchovies) - *Stolephorus punctifer* myotome 42.

Order Cyprinodontiformes – Family Hemiramphidae (half beaks) - Family Belonidae (needle fishes) - Family Oryzidae (rice fishes)

Order Myctophiformes – Family synodontidae (lizard fishes)

Order Scorpaeniformes – Family Platycephalidae (flat heads)

Order Perciformes – Family Ambassidae (glass fishes) - Family Carangidae (trevally/scad) - Family Leiognathidae (silver bellies) - Family Lutjanidae (snappers) - Family Sciaenidae (croakers) - Family Scombridae (mackerel, tuna) mackerel 31, tuna 39-42.

Order Mugiloidei - Family Mugilidae (mullets)

Order Gobioidei – Family Gobidae (Gobies)

Order Pleuronectiformes – Family Bothidae (left-eye flounders) - Family Pleuronectidae (right-eye flounders) - Family Cynoglossidae (tongue fishes) - Family Soleidae (Soles)

Soil / Sediment – An Overview and Physical properties of soil

Soil – definition – submerged soil – sediment - surface soil – subsoil - soil profile –soil horizon –mineral soil - organic soil – Pedology - definition – Edaphology – definition –soil components - soil solids - inorganic – organic – soil water - a dynamic solution – soil air – a changeable constituent – soil as a biological laboratory – factors affecting nutrient availability in soil – soil as a colloid – definition of colloid – clay colloids – silicate clays and hydrous oxide clays – sources of negative charge in clay colloids – amorphous colloids in soil – organic colloids in soil – humus – composition – properties

Physical properties of soil: Soil depth – Soil texture – definition – the USDA classification of soil into textural classes - textural triangle diagram – Particle density of soil – factors affecting - unit of expression – Bulk density – a measure of compactness of soil – unit of expression – Pore space in soil – formula for calculation of pore space – Structure of soil – definition – types of soil structure – aggregation - role of binding agents – Soil consistence – definition – plasticity indices – soil cohesion – factors responsible for cohesion – soil cementation – cementing agents – levels of cementation of soil –swelling and shrinkage of soil – soil colour

Sedimentation process: What is sedimentation - Mechanism of sedimentation - Small scale process - Gravitational process – Entrainment process - Large scale process - Factors influencing sedimentation - Physical – deforestation – tidal / fresh water currents - semidiurnal tides – topography - upwelling currents - density currents - depth of estuary - Chemical - flocculation - chemical interaction - pollutant reactions - Biological - microbial organisms - mangrove roots- benthic algae and invertebrate feeders - uses of sediments - disadvantage of over sedimentation

Chemical properties of soil / sediment

Ion exchange - definition – cation exchange – anion exchange – factors affecting ion exchange – unit of expression – effect on nutrient availability

Soil reaction - definition – pH – active acidity- exchange acidity - reclamation of acidic and alkaline soils – nutrient availability in relation to pH – pH kinetics in aerobic soil and submerged soil – pH of different kinds of sediments

Specific conductance – definition – measurement – properties of salt affected soils - kinetics of specific conductance in aerobic and submerged soil

Oxidation - reduction potential – definition – differentiation in aerobic and submerged soil – measurement – factors affecting Eh – effect on marine environment – sequential reduction in lakes

Organic carbon – origin in soil – effect on soil fertility – decomposition of organic matter – mineralization and immobilization in aerobic and submerged soil – C/N ratio – factors affecting mineralization

Nitrogen – forms of occurrence in sediment – the nitrogen cycle in sediment – aminisation – ammonification – nitrification – nitrogen fixation – denitrification – factors affecting nitrogen availability

Phosphorus – forms present in sediment – factors affecting phosphorus availability – phosphorus fixation by sediment in acidic and alkaline conditions

Potassium – the potassium cycle in sediment – factors affecting potassium availability

Sulfur – forms of sulfur present in sediment – the sulfur cycle – factors affecting sulfur availability

Iron – forms of iron present in sediment – factors affecting iron availability - **Manganese** – forms of manganese present in sediment – factors affecting manganese availability - **Silicon** – forms of silicon present in sediment – factors affecting silicon availability

Sediment - Water Interactions

Dynamics of dissolved oxygen in water and sediment – stratification in lakes – Adsorption of chemical substances by mud and release into the water based on redox potential – changes in the nitrogen economy of bottom muds - Phosphorus sorption by mud and release into water based on change in pH – Sorption and release of heavy metals by bottom mud based on changes in salinity

Minerals and trace elements in aquatic ecosystem: Eutrophication – definition - nutrient load - Primary nutrients – Nitrogen, Phosphorus, Potassium – forms of occurrence – source – functions – favourable range in brackish and marine environments - Secondary nutrients – Calcium, Magnesium, Sulfur and silica - functions – favourable range in brackish and marine environments - Micronutrients – Chlorine – Manganese – Iron – Copper – Zinc - Cobalt - functions – favourable range in brackish and marine environments

Decomposition of organic matter in bottom sediment: Types of decomposition of soil organic matter – aerobic – anaerobic – factors affecting aerobic decomposition - factors affecting anaerobic decomposition – differentiation of end products in aerobic and anaerobic decomposition - influence of microbes – effect of type of carbonaceous material present in the environment - Effect of C/N ratio on decomposition of organic matter – influence of organic matter decomposition on nitrogen cycle - Effect of C/P ratio in organic matter decomposition and phosphorus cycle - Effect of C/S ratio in organic matter decomposition and sulphur cycle - Functions of soil organic matter

Occurrence and distribution of microbes in seawater (Part I)

General Marine environment – importance of marine microbiology- microbial standing crop- microbial elements- bacteria- fungi- yeast- flagellates- ciliates- unicellular/ multicellular microalgae-Factors influencing the distribution of bacteria in the sea - fluctuations in numbers of microorganisms - distance from land - effect of tides - diurnal fluctuations in the bacterial population - vertical distribution of marine bacteria - effect of solar radiations - temperature as an ecological factor - seasonal distribution of marine bacteria - effect of other organisms - the antagonistic effects of microorganisms - bacteriophage in seawater - effect of solid surfaces - effect of sedimentation - effect of organic matter;

Physico-chemical factors influencing bacterial distribution – light - turbidity – pH - redox potential – salinity - inorganic and organic substances - dissolved gases - Biological factors influencing bacterial distribution - competition for nutrients - bacteria and fungi as food for other organisms – photosynthetic bacteria- bacteria and fungi parasitized by other microorganisms.

Habitats for microorganisms – Neuston / pleuston – Nekton - Epibiotic habitat - Endobiotic habitat; Water borne microbial habitats in sea – Epipelagic – Mesopelagic –Bathypelagic – Abyssopelagic - Benthic habitats.

Occurrence and distribution of microbes in seawater (Part II)

Marine sediment- redox potential- bottom rich in organic compounds- negative Eh in clayey sediment- reducing bacteria increase – Eh decrease and depth- coarse sediment – less reducing- pH- increase and depth- negative Eh correlates with hydrogen sulphide *(Desulphovibrio)*- heterotrophic count reduce with depth- bacterial population in different types of sediment- sand- silt- clay- colloid- microbial population of sediments – their functions- total aerobes- total anaerobes- ammonification- urea fermentation- gelatin liquefaction- denitrification (to nitrogen)- nitrate reduction (to nitrite)- starch hydrolysis- glucose fermentation- xylose fermentation- cellulose decomposition- fat hydrolysis- chitin digestion- red clays in bottom - vertical distribution of bacteria in mud - factors influencing abundance of bacteria in mud - microbial oozes- siliceous and calcareous oozes- calcium carbonate precipitation- zooxanthellae- coral reef formation- microbes in estuarine sediments- organic- high sulphide- organic matter- purple bacteria- bloom of cyanobacteria- later diatom bloom- bacteria are heterotrophic- more chitin and lignin degrading microbes (*Actinomycetes*)- proteolytic bacteria maximum- chitin digestion- gram negative rods dominate surface -Culture Systems - Microbial habitats - Water- Sediment - Cultured organisms- autotrophs- chemoautotrophs- heterotrophs- Sampling methods - surface sampling systems - water column samplers - net samplers - water samplers - bottom sampling systems - grab samplers;

Lecture 34

Prepared by Dr.Imelda Joseph

Methods for estimation of bacterial population

Determination of biomass - direct methods –sample preparation -Microscopic examination – fresh samples / preserved samples - direct counts- aliquot sample on slide-haemocytometer- count organisms in the field of microscope- epifluorescence microscopy - phase contrast and light microscopy - Direct counting- slide count- viable counts- absolute concentration- viable organisms- principle- microbial population – diluted- sample preparation – homogenized sample- dilution procedure- serial dilution- 1 ml to 10 ml- choice of dilution- pour plate method- solid media- liquid culture- 200 to 300 viable colonies ideal- less error; Isolation and purification of major groups of microbes from culture systems – classification prokaryotes- bacteria- cyanobacteria- archaeobacteria- classification of bacteria- autotrophs- anaerobic- sulphur bacteria- *Chlorobium; Chromatium, Rhodospirillum*- Heterotrophs- aerobic; *Vibrio* –32% total bacterial population- Pseudomonas- Alcaligenes- flavobacterium- *Bacillus, Micrococcus- Cytophagae- Enterobacteriaceae*- contaminants- common shapes of bacteria- spherical coccus- rod shaped bacilli/ mostly single cell- spiral spirillum/ mostly single cell- common arrangement of bacterial cells- pairs/ diplo; parallel chains/strepto; irregular clusters/ staphylo; regular packets-perpendicular 4 cells each/tetrad/ 8 cells each Sarcinae- basic techniques - sterilization of media and equipments - culture vessels - enrichment cultures - enrichment by direct plating - membrane filtration-characteristics of membrane filters- cellulose esters- pore size- application in microbiology- Isolation (Pure cultures) - streak plate method - pour plating - dilution in a liquid medium - preservation of cultures – Methods- Identification - diagnostic tables.

Faecal pollution through sewage

Survival of indigenous and non-indigenous organisms in the aquatic environment - Microflora and sewage – domestic- waste water- remains of food- Faecal contaminants –process- removing pollutants continuously- physical- sedimentation- chemical- oxidation- biological- fish- microbes- decisive role- bacteria- fungi- organic compound breakdown- solids and liquids to carbon dioxide- water- inorganic salts- remineralization- change in microbial population- domestic sewage- proteolytic to cellulose degrading- human pathogens in sea water – *Salmonella* – *Shigella* – *Leptospira* - *E.coli* -*Vibrio cholerae* - *Mycobacterium tuberculosis*.

The role of microorganisms in the self-purification of waters - Pollution by refuse and sewage - natural self-purification of polluted systems – putrefying bacteria- groups breaking down sugar- starch- fat- urea- cellulose- coliform bacteria- indicator- faecal matter- *Escherichia coli*- *Streptococcus faecalis*- bacteriophages- anoxic conditions- H2S production- sulphur oxidizing bacteria- denitrifiers- iron bacteria- methane producers- how and extent of self-purification - factors affecting self-purification - change in population of micro organisms during different stages of self-purification – bioremediation in culture systems of pollutants;

Hydrogen sulphide production in mariculture systems

Suphur- occurs in different forms- marine environment- hydrogen sulphide gas- sewage/ rotten egg smell- detection level- 0.002 mg/l- human beings- Heterotrophs precipitating metals as sulphides - hydrogen sulphide formation - during the decomposition of proteins - from reduction of sulphates - fixation in sediments as metallic sulphides – escape into the overlying water - depletion of oxygen – role of anaerobic conditions - Sources of hydrogen sulphide prduction – Causes for production of hydrogen sulphide - Microbes involved in hydrogen sulphide production – microbes involved in oxidation of sulphide - role of oxygen – role of environmental conditions- aerobic decomposition- organic matter- anaerobic decomposition- reducing bacteria-

Microbial Sulphur cycle - liberation of sulphur from organic compounds - sulphate reduction - bacteria involved in the process - oxidation of sulphur compounds – role of achromic sulphur bacteria – role of purple sulphur bacteria.

Role of microbes on the regeneration of nutrients

Production of organic matter - chemo-autotrophic bacteria occurring in the aquatic habitat - breakdown of organic matter – proteolysis – lipoclastic / lipolytic bacteria - decomposition of carbohydrates - lignin decomposition - chitin decomposition - bacterial oxidation of hydrocarbons - methane fermentation by methanogens - marine humus – formation

Nutrient cycles in marine and estuarine systems – CHNOPS- occur in different forms- change in chemical form- aerobic- anaerobic- activities- soil microbes- cycling of carbon- nitrogen- sulphur- material interconversion- carbon cycle- carbon dioxide fixation- photosynthesis- chemosynthesis- forms of carbon- plant derived compounds- aerobic- anaerobic cycling- fermentation- respiration;

Nitrogen cycle - ammonia production - bacterial oxidation of ammonia - autotrophic bacteria involved in oxidation of ammonia - oxidation of nitrite to nitrate – bacterial genera involved in the process - reduction of nitrate to nitrite - bacterial genera involved in the process - nitrogen fixation - bacteria involved in the process.

Phosphorus cycle - assimilation of phosphate by microorganisms - regeneration of phosphate from phospholipids and nucleioproteins – microorganisms involved in the process - effect of bacteria on solubility of phosphate.

Lecture 38

Prepared by Dr.Reeta Jayasankar

Role of aquatic weeds in estuarine culture system and weed control

Classification of aquatic weed

Floating type : *Lemna minor, Nymphaea alba,Eichhornia, Salvinia, Pistia* - Submerged type : *Elodea, Myriophyllum, Ceratophyllum* - Emerged type : *Phragmites, Sagittaria, Typha, Nymphaea, Nelumbo* - Algae: *Enteromorpha*

Control of Aquatic weed

Mechanical control - Manual method: - Emergent weed: cutting with suitable tools - Free floating weed:Floating bamboo rafts, nets to encircle the weed and pulling ashore - Submerged weed: Pulled by hand at regular interval - Power operated machines - Motorised hand tool - - Non motorized method for free floating type - Fully powered weed cutter - General consideration - Involvement of local people and resource - Pilling these weeds and burning - Choosing best time for harvest eg. Typha at flowering and post flowering stage delays re growth - Chemical method - Using herbicides - Free floating - Water hyacinth and Eichhornia : 2,4 D, 2,4D sodium salt, 2,4D urea - Salvinia:Paraquat - Pistia straitiota:2,4D ester and 24D butunyl ethanol - Floating rooted - Nymphaea : 2,4 D BEE - Nelumbo : 2,4D salt - Rooted submerged - Phargmites, Typha: Delapan - Ipomea, Typha, Cyperaceae:Amitrole - Biological control - Use of competitive organism: Use of Flea beetle (*Agasicles hygrophila*) in south eastern U.S to suppress alligator weed *Alternanthera philoxeroids*

Prepared by Dr. Geetha Antony

Potential Live Feeds of Coastal Waters

Introduction - Importance of live food organisms in culture of fin / shell fishes - Live feed and target organisms – size - mobility - nutritional value

Live feed organisms - **Infusoria** - Taxonomic position – Morphology - Food and feeding habits - nutritional requirements – Reproduction - Evaluation and improvement of nutritional value - probiotics – **Rotifers** - Taxonomic position – Morphology - Food and feeding habits - nutritional requirements – Reproduction - Evaluation and improvement of nutritional value - probiotics – **Cladocerans** - Taxonomic position – Morphology - Food and feeding habits - nutritional requirements – Reproduction - Evaluation and improvement of nutritional value - probiotics – **Artemia** - Taxonomic position – Morphology - Food and feeding habits - nutritional requirements – Reproduction - Evaluation and improvement of nutritional value - probiotics – **Copepods** - Taxonomic position – Morphology - Food and feeding habits - nutritional requirements – Reproduction - Evaluation and improvement of nutritional value - probiotics – **Mysids** - Taxonomic position – Morphology - Food and feeding habits - nutritional requirements – Reproduction - Evaluation and improvement of nutritional value - probiotics

Lecture 40 Prepared by Dr. Geetha Antony

Water Quality Issues in the Maintenance of Live feeds in Laboratories

Introduction – Isolation - pure culture - stock culture - mass culture

Culture of live feeds - Infusoria – Culture Methods - Rotifers – Culture Methods - Cladocerans – Culture Methods - Artemia - Culture Methods – Copepod - Culture Methods

Maintenance of live feed in laboratory – factors affecting live feed culture - Physical - Light - Temperature – Chemical - Dissolved oxygen - Salinity - pH - Ammonia - Nitrite - Biological - Feeding strategies - Bloom / swarm - Infestation - Effect of factors on - Survival - growth - reproduction - production

Lecture 41 Prepared by Dr. D. Prema

Toxicities and Optimum ecological conditions in ponds

CO_2 toxicity – effect of CO_2 toxicity on fish – conditions leading to CO_2 toxicity - effect of normal levels of CO_2 in pond environment - Toxic forms of nitrogen – ammonia and nitrite toxicity - Source of ammonia – factors affecting ammonia toxicity – effect of ammonia on fish – lethal concentration and sublethal effects on fish - Nitrite toxicity – effect on fish - methaemoglobinemia – sublethal effects - source of nitrite – factors affecting nitrite toxicity - effect of chloride on nitrite toxicity - H_2S toxicity – formation – factors affecting H_2S toxicity – effect of H_2S toxicity on fish - Correction of different toxicities - methods

Optimum and adverse levels of various water quality parameters and their effect on fish - DO – pH - CO_2 - BOD - COD - ammonia N - nitrite N - nitrate N - H_2S - CH_4 - chlorine - heavy metals - pesticides - Favourable range of soil parameters for mariculture - soil nature - soil colour – pH - water retention capacity - sand - silt - clay – nitrogen – phosphorus - potassium - organic carbon - electrical conductivity - Classification of muds based on their fish / shrimp production potential with respect to different soil parameters

Lecture 42 Prepared by Smt. Molly Varghese

Water Quality Management in Culture and Hatchery Systems

Introduction - Water quality problems – causes - natural quality of water - concerns with events develop as a result of culture activities - concerns with pollutants which may enter from surroundings

Improvement of water quality – methods - Liming – when needed - advantages - liming material - liming rate - method of application Fertilization – when required – advantages - chemical fertilizers - organic fertilizers or manures – rate, frequency and method of application – Aeration - Circulation - Water exchange - Biofilters in marine hatchery - advantages

Phytoplankton control – use of algicides use of plankton feeding fish – use of macrophytes - water change - nutrient manipulation - Other treatments - application of $KMnO_4$ - treatment with chlorine – application of piscicides - application of ammonia – application of mahua oil cake – application of chlorinated hydrocarbon – application of insecticides – application of tea seed cake - turbidity and sedimentation – treatment with alum

Biological factors affecting water quality – Phytoplankton - other aquatic plants - zooplankton