Ph.D. (Aquaculture)

Course Structure – At a Glance

A	**MAJOR COURSES**			**17 Credits**
1.	AQC 601	Recent advances in Aquaculture Production Systems	2+0	
2.	AQC 602	Recent Advances in Seed Production And Hatchery Management	2+1	
3.	AQC 603	Aquaculture System Management	1+1	
4.	AQC 604	Engineering of water management for aquaculture	1+1	
6.	AQC 605	Fish and Shellfish Physiology and Endocrinology	1+1	
7.	AQC 606	Intensive Farming Systems	1+1	
8.	AQC 607	Enhanced fisheries in open waters	1+1	
9.	AQC 608	Breeding & culture of ornamental fishes	1+1	
B	**MINOR COURSES** (Courses outside major discipline / from other relevant disciplines)			**6 Credits**
C	**SUPPORTING COURSES** (Compulsory)			**5 Credits**
1.	FST 601	Advanced Statistical Methods	2+1	
2.	FST 602	Software for Fisheries Data Analysis and Management	0+2	
		Total Course Work Credits		**28 Credits**
D	**DOCTORAL SEMINAR**			**2 Credits**
1.	AQC 691	Doctoral Seminar I	0+1	
2.	AQC 692	Doctoral Seminar II	0+1	
E	**DOCTORAL RESEARCH**			**45 Credits**
	AQC 699	Doctoral Research (Semester III)	0+11	
	AQC 699	Doctoral Research (Semester IV)	0+11	
	AQC 699	Doctoral Research (Semester V)	0+11	
	AQC 699	Doctoral Research (Semester VI)	0+12	
		Total Ph.D. Program Credit Hours		**75 Credits**

AQUACULTURE
Course Contents

AQC 601 RECENT ADVANCES IN AQUACULTURE PRODUCTION SYSTEMS (2+0)

Objective

To impart knowledge and skill regarding advanced technologies of different aquaculture production systems.

Theory

Unit I

An overview of aquaculture production systems: Present status, constraints and future perspectives of aquaculture production systems in India and the world.

Unit II

Advances in design and construction: hatcheries, earthen ponds, concrete tanks, pens and cages, rafts and racks.

Unit III

Aquatic plant production systems: Ornamental aquatic plants, microalgae and seaweeds.

Unit IV

Aquaculture production management: Monitoring of water quality, feeding, sampling and harvesting of fin fishes and shellfishes.

Unit V

Advances in farming systems: Enhancing carrying capacity, integrated farming systems, semi-intensive and intensive culture systems, recirculatory system, flow-through system.

Unit VI

Code of conduct for responsible and sustainable aquaculture. Cluster farming, organic farming, satellite farming and co-operative farming.

Suggested readings

1. Midlen& Redding TA. 1998. *Environmental Management for Aquaculture*. Chapman & Hall.
2. ICAR. 2006. *Hand Book of Fisheries and Aquaculture*. ICAR.
3. Jhingran VG &Pullin RSV. 1985. *Hatchery Manual for the Common, Chinese and Indian Major Carps*. ICLARM, Philippines.
4. Pillay TVR &Kutty MN. 2005. *Aquaculture- Principles and Practices*.Blackwell.

5. Rath RK. 2000. *Freshwater Aquaculture*. Scientific Publ.
6. Selvamani BR &Mahadevan RK. 2008. *Aquaculture, Trends and Issues*. Campus Books
7. Agarwal SC. 2008. *A Handbook of Fish Farming*. 2nd Ed. Narendra Publ. House.
8. Beveridge MCM & Mc Andrew BJ. 2000. *Tilapias: Biology and Exploitations*. Kluwer.
9. FAO. 2007. *Manual on Freshwater Prawn Farming*.
10. Goswami UC and Dilip Kumar 2009. Aquaculture management.

AQC 602: RECENT ADVANCES IN SEED PRODUCTION AND HATCHERY MANAGEMENT (2+1)

Objective:

To impart knowledge about the requirements for seed production of commercially important finfish and shellfish.

Theory

Unit I

Reproductive biology of important fishes, crustaceans and mollusks.Reproductive behavior of fishes, sex determination, anatomy and morphology of reproductive organs.

Unit II

Brood stock management: Factors affecting the maturation and spawning of fin fishes and shell fishes, nutritional and environmental requirement for broodstock and its manipulation for early maturation, criteria for the selection of brood stock, selective breeding strategies, tagging, transportation of brood stock, natural and synthetic anesthetics for transport, vaccines and therapeutics for health management of broodstock.

Unit III

Induced Spawning: Comparative evaluation of commercially available inducing agents, artificial insemination in crustaceans and mollusks; cryopreservation of gametes and embryos in fin fishes and shellfishes.

Unit IV

Hatchery management: Water quality management in hatcheries–physico-chemical and biological approaches, nutritional requirement of larvae and post larvae, live feed culture, nutritional enrichment of live feed, formulation of artificial diets, strategies to control diseases in hatcheries, diagnosis, quarantine and seed certification, use of probiotics and immunostimulants in hatcheries, SPF and SPR, effluent treatment in hatcheries, seed transportation methods.

Unit V

Seed production and hatchery technology: Advances in seed production of commercially important fin fishes and shellfishes, artificial propagation of seaweeds.

Practical:

Insemination Cryopreservation of fish and shellfish gametes; Project preparation for constructing hatchery ; Quantitative and qualitative determination of fish gametes like sperm motility, viability, counts; Digital equipment in brood stock management ; Methods to identity quality, seeds –stress test, microscopic exanimation. Water quality'smanagement in aqua-hatcheries. Visit of hatcheries.

Suggested Readings

1. Bardach EJ, Rhyther JH & Mc Larney WO. 1972. *Aquaculture. The Farming and Husbandry of Freshwater and Marine Organisms*.John Wiley & Sons.
2. Chakraborty C & Sadhu AK. 2000. *Biology Hatchery and CultureTechnology of Tiger Prawn and Giant Freshwater Prawn*. Daya Publ. House.
3. Diwan AD, Joseph S &Ayyappan S. 2008. *Physiology of Reproduction, Breeding and Culture of Tiger Shrimp*. Narendra Publ. House.
4. Gilbert B. 1990. *Aquaculture*. Vol. II. Ellis Harwood.
5. Jhingran VG &Pullin RSV. 1985. *Hatchery Manual for the Common, Chinese and Indian Major Carps*. ICLARM, Philippines.
6. Thomas PC, Rath SC &Mohapatra KD. 2003. *Breeding and Seed*
7. *Production of Finfish and Shellfish*. Daya Publ. House.

AQC 603 AQUACULTURE SYSTEM MANAGEMENT (2+1)

Objective

To impart knowledge on interactions between aquaculture and the environment.

Theory

Unit I

Aquaculture and ecosystem relationship: Ecosystems and productivity, biotic interaction within ecosystems and ecological homeostasis. Climate: Weather elements of concern in aquaculture, greenhouse gases, global warming and their impact.

Unit II

Impact of environment on aquaculture: Raw water source, physical and chemical characteristics, contaminants and pollutants (algae, pathogens, heavy metals, pesticides) and their effect on productivity.

Unit III

Impact of aquaculture on environment: Waste water discharge, its quality and quantity, impacts of effluents on ecosystems, chemical degradation of soil and water.

Unit IV

Environment monitoring: Problems and preventive measures of antibiotic and drug residues, salination of soil and water, eutrophication, environment impact assessment and environmental audit.

Unit V

Biosensors in aquatic environment, toxicity assessment, eco-labeling and traceability, environment management.

Unit VI

Introduction of exotics and escape of farmed fish, pathogens in aquatic environment, safety of aquaculture products, role of microbes in aquatic environment, assessment of probiotic impact in aquaculture.

Practical

Waste water analysis, toxicity assessment studies; eco-labeling and traceability, isolation, nutrients budgeting, quantification and administration of solid and liquid doses, physical and chemical characteristics of soil, design and construction of effluent treatment plant.

Suggested Readings

1. Holmer M, Black K, Duarte CM, Marba N &Karakassis I. (Eds.). 2008. *Aquaculture in the Ecosystem*. Daya Publ. House.

2. Lagler KP, Bardach JE, Miller RR &Passino MDR. 1977. *Ichthyology*.
3. John Wiley & Sons. Midlen& Redding TA. 1998. *Environmental Management for Aquaculture*. Chapman & Hall.
4. Nikolsky GV. 2008. *The Ecology of Fishes*. Academic Press.
5. Upadhyay AR. 2004. *Aquatic Plants for the Wastewater Treatment*. Daya Publ. House.

AQC: 604. ENGINEERING PRINCIPLES OF WATER MANAGEMENT FOR AQUACULTURE (1+1)

Objective:

To acquaint the students with judicious utilization of water for various aqua-farming systems, re-use of water; to acquire knowledge of recirculating aquaculture system (RAS), use of biofilter for designing of RAS based aquafarms/ hatcheries; to get knowledge of modern integrated systems using aquaponics, design of pumping systems, cages and pens.

Unit I

Water resources, precipitation, seepage, infiltration, evaporation, transportation, runoff, water cycle, aquifers, hydraulic conductivity, wells, water quality management, project layout, types of ponds, flow scheme for water supply and drainage, water flow channel, inlet and outlet.

Unit II

Pumps: centrifugal, reciprocating turbine, propeller, air-lift pumps, selection and application in aquaculture farms. Aeration: air-blowers and air-compressors, types, design of aeration grid and uses.

Unit III

Water budgeting: estimation, design factors, estimation of requirement of water for hatchery, nursery, rearing and culture ponds.

Unit IV

Introduction to recirculating aquaculture system (RAS), concept of water reuse and recirculation, principle, advantages and disadvantages, components of RAS- solid removal, biological filtration, aeration and oxygenation, disinfection and sterilization, water quality management, species selection.

Unit V

Biofilters: Waste water treatment, zero discharge level, bio-ponds, physical, chemical and biological treatments, types of bio-filters, water quality maintenance and design of intensive aqua culture systems.

Unit- VI

Aquaponics: Introduction, principle and design, components of aquaponics system, system design- types of system, component ratio, fish, plants, water quality and system maintenance.

Unit-VII

Cages and Pens: Introduction, site selection, advantages and disadvantages, design and construction, types of cages, species selection.

Practical

Visit to aqua farms, estimation of hydraulic conductivity, design of subsurface drainage system, design of biofilters, design of recirculating aquaculture system, design of pen and cages, estimation of water requirement for hatchery, nursery, rearing and culture, estimation of pumps capacity.

Suggested Readings

1. Thomas L., 1995. Fundamentals of Aquacultural Engineering. Chapman & Hall.
2. Wheaton F.W., 1977. Aquacultural Engineering. John Wiley & Sons.
3. Ivar L.O., 2007. Aquaculture Engineering. Daya Publ. House.
4. Bimal Chandra Mal, 1995. Soil and Water Conservation Engineering. Kalyani Publishers.
5. Sylvia Bernstein, 2011. Aquaponic Gardening- A step-by-step guide to raising.

AQC 605 FISH AND SHELLFISH PHYSIOLOGY AND ENDOCRINOLOGY (1+1)

Objective

To impart knowledge on functional physiology of finfish and shellfish.

Theory

Unit I

Structure and function of neuro-endocrine system in finfish and shellfish.

Unit II

Chemical nature of hormones, synthesis storage, release and control of hormones, homeostasis, endocrine control of growth.

Unit III

Eco-physiology, adaptive mechanisms - reversible & irreversible changes, physiology of migration and behavior.

Unit IV

Neurophysiology: Neurosecretory system in fishes, crustaceans and mollusks, neurotransmitters, physiology of ecdysis.

Unit V

Reproductive physiology: Endocrine control of maturation, spermatogenesis, oogenesis, spawning vitellogenesis.

Unit VI

Respiratory physiology, gas exchange concept, excretion and osmoregulation.

Practical

Hormone assay – ELISA, dissection of finfish and shellfish to study endocrine glands, histological techniques to study reproductive and endocrine glands, identification of moult stages, application of respirometer and osmometer.

Suggested Readings

1. Adiyodi KG &Adiyodi RG. 1971. *Endocrine Control of Reproduction in Decapod Crustacea*. Biology Reviews.
2. Agarwal NK. 2008. *Fish Reproduction*. APH Publ.
3. Bell TA & Lightner TA. 1988. *A Handbook of Normal Penaeid Shrimp Histology*. World Aquaculture Society.
4. Ghosh R. 2007. *Fish Genetics and Endocrinology*. Swastik Publ. & Distr.
5. Hoar WS, Randall DJ & Donaldson EM. 1983. *Fish Physiology*. Vol. IX. Academic Press.
6. Maria RJ, Augustine A & Kapoor BG. 2008. *Fish Reproduction*. Science Publ.

7. Matty AJ. 1985. *Fish Endocrinology*. Croom Helm.
8. Mente E. 2003. *Nutrition, Physiology and Metabolism in Crustaceans*. Science Publ.
9. Nikolsky GV. 2008. *The Ecology of Fishes*. Academic Press.
10. Thomas PC, Rath SC &Mohapatra KD. 2003. *Breeding and Seed Production of Finfish and Shellfish*. Daya Publ. House.

AQC 606 INTENSIVE FARMING SYSTEMS (1+1)

Objective

To impart knowledge and techniques in intensive farming.

Theory

Unit I

Global status and prospects in India, development of intensive farming and needs for intensification.

Unit II

Different culture systems, means of intensification, monoculture and polyculture, constraints in intensive farming of carps, catfishes (channel catfish) and tilapia, health management, recirculatory and high-tech aquaculture system.

Unit III

Water quality management, food and feeding in intensive farming, automatic feeding, floating pellets.

Unit IV

Economics of intensive culture.

Practical

Study of aeration devices- aerators, blowers and biofilters in recirculatory systems.Formulation of feeds and floating pellets.Stocking density manipulation and fish production.Economics of different intensive farming systems with case studies.

Suggested Readings

1. Bardach E J, Rhyther JH & Mc. Larney WO. 1972. *Aquaculture The Farming and Husbandry of Freshwater and Marine Organisms*.John Wiley & Sons.
2. Beveridge MCM & Mc Andrew BJ. 2000. *Tilapias: Biology and*
3. *Exploitations*. Kluwer.
4. Gilbert B. 1990. *Aquaculture*. Vol II. Ellis Harwood.
5. Jayaram KC. 2006. *Catfishes of India*. Narendra Publ. House.
6. Pillay TVR. 1990. *Aquaculture, Principles and Practices*. Fishing News Books.
7. Rath PK. 2000. *Freshwater Aquaculture*. Scientific Publ.

AQC 607 ENHANCED FISHERIES IN OPEN WATERS (2+1)

Objective

To impart knowledge about different types of open water bodies and techniques to enhance their productivity in sustainable way.

Theory

Unit I

Capture cum culture fisheries: World review of aquaculture in open waters, *e.g*., pen culture , cage culture, integrated fish farming in open water bodies like lakes, reservoirs, oxbow lakes, beels, mans, chaurs, tanks, rivers, sea, wetlands and brackish water etc.

Unit II

Enhancement of production in open water bodies: Species selection techniques (size and quantity), introduction of new species, stocking, fertilization, eradication of unwanted fishes, ranching of open waters, aggregating devices.

Unit III

Techniques of cage and pen culture – cages for sea, reservoirs, lakes, and canals, different construction materials, construction of cages and pens. Consideration of species for rearing fingerlings and table size fishes in cages and pens. Fish feeds, feeding methods,

Unit IV

Monitoring of stock in open water, EIA, maintenance of cages, economics of cage and pen farming.

Unit V

Aquaculture in running water systems. Health assessment of stock: prophylaxis and treatment of diseases in fin and shell fish in open water system.

Practical

Different types of cage materials. Fabrication of cages, frames. Fabrication of pens.Working out economics of different farming system, water and soil quality monitoring.

Suggested Readings:

1. Cage Culture in Reservoirs in India. Technical manual prepared for the Project: Improved fisheries productivity and management in tropical reservoirs,
2. CP-PN34: Challenge Program on Water and Food
3. Cage culture - Regional review and global overview - FAO.org
4. Diseases and Disorders of Finfish in Cage Culture P. T. K. Woo, D. W. Bruno, L. H. Susan Lim
5. Pen culture (Enclosure culture) as an aquaculture system. FAO

6. Review on cage and pen culture - CMFRI
7. Introduction to intensive cage culture of warm water fish. www.ag.auburn.edu
8. A review of stock enhancement practices in the inland water. www.fao.org/
9. Inland Fisheries Resource Enhancement and Conservationwww.enaca.org/
10. Cage aquaculture in open waters. CIFE
11. Cage Aquaculture. Malcolm Beveridge
12. Enhancement in open water bodies - Welcome
13. Reservoir fisheries of India - Food and Agriculture .www.fao.org by V.V. Sugunan central Inland Capture Fisheries Research Institute Barrackpore,

AQC 608ADVANCES IN BREEDING AND CULTURE OF ORNAMENTAL FISHES (1+1)

Objective:

To impart knowledge about different ornamental species, their culture and breeding techniques, present status of culture and trade, conservation approaches, value addition.

Theory

Unit I

Global status of ornamental fish trade, present status and prospects of ornamental fish farming and trade in India, Indian ornamental fish diversity and its status.

Unit II

Case studies of successful ornamental fish farming agencies and NGOs in various states of India. Satellite and cluster approach for developing ornamental fish village, in marketing of ornamental fishes.

Unit III

Concept of aquaponics in ornamental fish rearing. Artificially pigmented or painted fish.

Unit IV

Aquariscaping

Practical

Identification and preparation of herbarium of ornamental aquatic plants.

Suggested Readings

1. Axelrod HR &Vorderwinkler W. 1978. *Encyclopaedia of Tropical Fishes*. TFH Publ.
2. Axelrod HR &Sweenen ME. 1992. *The Fascination of Breeding Aquarium Fishes*. TFH.
3. *Handbook of Fisheries and Aquaculture*. 2006. ICAR.
4. Mills D. 1981. *Aquarium Fishes*. Kingfisher Books.
5. Sanford G & Crow R. 1991. *The Manual of Tank Busters*. Salamander Books.
6. Spotte S. 1979. *Fish and Invertebrate Culture*. John Wiley & Sons.
7. Thabrow De WV. 1981. *Popular Aquarium Plants*. Thornbill Press.