

**Course Syllabus for M.F.Sc. (Aquaculture), P.G. Department of Aquaculture,  
College of Fisheries (OUAT) as per the New & Restructured Post Graduate  
Curricula & Syllabi of BSMA (2020), ICAR, New Delhi**

**COURSE SYLLABUS  
FOR  
M.F.Sc. (AQUACULTURE)**



**ODISHA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY  
BHUBANESWAR – 751 003**

## CONTENTS

Sl. No.	Course No.	Course title	Credit Hours	Page No.
<b>Organization of Course Contents &amp; Credit Requirements</b>				1
<b>A.</b>	<b>MAJOR COURSES (Maximum 20 Credits to be taken)</b>			
1	AQC 501	Freshwater Aquaculture Production Systems	2+1	
2	AQC 502	Coastal Aquaculture & Mariculture Farming Systems	2+1	
3	AQC 503	Hatchery Technology for Finfishes and Shellfishes	2+1	
4	AQC 504	Aquaculture Policy and Planning	1+1	
5	AQC 505	Fish Nutrition and Feed Technology	2+1	
6	AQC 506	Soil and Water Quality Management in Aquaculture	2+1	
7	AQC 507	Therapeutics and Health Management in Aquaculture	2+1	
<b>B</b>	<b>MINOR COURSES (Maximum 8 Credits to be taken)</b>			
1	AQC 508	Larval Nutrition and Live Feed Production	1+1	
2	AQC 509	Aquaculture Engineering	1+1	
3	AQC 510	Open Water Aquaculture	1+1	
4	AQC 511	Commercial Ornamental Fish Breeding and Culture	1+1	
5	AQC 512	Computer Application in Aquaculture Data Processing	0+1	
6	AQC 513	Inland Saline Aquaculture	1+1	
7	AQC 514	Multilevel Integrated Aquaculture Systems	1+1	
8	AQC 515	Coldwater Aquaculture and Recreational Fisheries	1+1	
9	AQC 516	Recirculating Aquaculture Systems	1+1	
<b>C</b>	<b>SUPPORTING COURSES (Maximum 6 Credits to be taken)</b>			
1	STAT 502	Statistical Methods for Applied Sciences	2+1	
2	STAT 511	Experimental Designs	2+1	
<b>D</b>	<b>COMMON COURSES (Maximum 5 Credits to be taken)</b>			
1	PGS 501	Library and Information Services	0+1	
2	PGS 502	Technical Writing and Communication Skills	0+1	
3	PGS 503	Intellectual Property and its management in Agriculture	1+0	
4	PGS 504	Basic concepts in Laboratory Techniques	0+1	
5	PGS 505	Agricultural Research, Research ethics and Rural Development Programmes	1+0	
		<b>Total Course Work Credits</b>	<b>39</b>	
<b>E</b>	<b>MASTERS' SEMINAR</b>			
1.	AQC 591	Masters' Seminar	0+1	
<b>F</b>	<b>MASTERS' THESIS RESEARCH</b> 2			
1.	AQC 599	Masters' Research (Semester III)	0+15	

2.	AQC 599	Masters' Research (Semester IV)	0+15	
		<b>Total M.F.Sc Program Credit Hours</b>	<b>70</b>	

- a: From the subjects closely related to a student's major subject
- b: The subject not related to the major subject. It could be any subject considered relevant for student's research work (such as Statistical Methods, Design of Experiments etc.) or necessary for building his/her overall competence
- c: Some of these courses are already in the form of e- courses/MOOCs. The students may be allowed to register these courses/similar courses on these aspects, if available online on SWAYAM or any other platforms. If a student has already completed any of these courses during UG, he/she may be permitted to register for other related courses with the prior approval of the HoD/BoS).

**ORGNISITION OF COURSE CONTENTS  
&  
CREDIT REQUIREMENT**

**Course number**

- All courses are divided in two series: 501- series courses pertain to Master's level, and 601- series to Doctoral level. A Ph.D. student must take a minimum of two 601 series courses, but may also take 501- series courses if not studied during Master's programme.
- Credit seminar of Master's level is designed by code number no.591, and the two seminars for Doctoral level are coded as 691 and 692 receptively.
- Similarly, 599 and 699 codes have been given for Master's Research and Doctoral research receptively.

**Course contents**

The contents of each course have been organized into:

- Objective- to elucidate the basic purpose.
- Theory units- to facilitate uniform coverage of syllabus for paper setting.
- Suggested Reading- to recommend some standard books are reference material. This does not unequivocally exclude other such reference material that may be recommended according to advancement and local requirement.
- A list of journals pertaining to the discipline is provided at the end which may be useful as study material for 601 -series courses as well as research topics.
- Compulsory courses- for quick's update on specific topics/events pertaining to the subjects.
- Broad research topic provide at the end would facilitate the advisors for appropriate research directions to the PG students.

**Minimum Credits Requirement**

Course Work	Master's programme	Doctoral programme
Major Course	20	12
Minor Course	08	06
Supporting Course	06	05
Common Courses	05	-
Seminar	01	02
Thesis Research	30	75
<b>Total credits</b>	<b>70</b>	<b>100</b>

**Major subject:** The subject (department) in which the students takes admission

**Minor Subject:** The subject closely related to student major subject (e.g., if the major subject is Entomology, the appropriate minor subject should be plant pathology and Nematology).

**Supporting subject:** The subject not related to major subject. It could be any subject considered relevant for students research work.

**Common courses:** Please see the relevant section for details. Five courses (PGS 501- PGS 805) are the general nature and are compulsory for Master's programme. Ph.D. students may be exempted from these 4 courses, if already studied during Master degree.

**M.F.Sc Syllabus (Revised) as per BSMA (2020)**  
**SEMESTER WISE COURSE DISTRIBUTION**

Sem.	Course No. proposed by OUAT	Course Title	Major/ Core Course Credit Hour	Minor Course Credit Hour	Supporting Course Credit hour	Common Course	Seminar	Research
<b>I</b>	AQC-501	Fresh water Aquaculture Production	2+1	-	-	-	-	-
	AQC-502	Coastal Aquaculture and Mariculture Farming	2+1	-	-	-	-	-
	AQC-503	Hatchery Technology for Fin fishes and Shell fishes	2+1	-	-	-	-	-
	AQC-504	Aquaculture Policy and Planning	1+1	-	-	-	-	-
	AQC-508	Larval Nutrition and Live-Feed Production	-	1+1	-	-	-	-
	AQC-509	Aquaculture Engineering	-	1+1	-	-	-	-
	STM-501	Statistical Methods for Applied Sciences	-	-	2+1	-	-	-
	PGS-501	Library and Information Services	-	-	-	0+1	-	-
	PGS-502	Technical Writing and Communication Skills	-	-	-	0+1	-	-
	<b>TOTAL</b>			<b>11</b>	<b>4</b>	<b>3</b>	<b>2</b>	<b>Nil</b>
<b>Major-11; Minor-04; Supporting-03; Common : 02:</b>							<b>Total: 20</b>	

Sem.	Course No.	Course Title	Major/ Core Course Credit Hour	Minor Course Credit Hour	Supporting Course Credit hour	Common Course	Seminar	Research
II	AQC-505	Fish Nutrition and Feed Technology	2+1	-	-	-	-	-
	AQC-506	Soil and Water Quality Management in Aquaculture	2+1	-	-	-	-	-
	AQC-507	Therapeutics and Health Management in Aquaculture	2+1	-	-	-	-	-
	AQC-510	Open water Aquaculture	-	1+1	-	-	-	-
	AQC-511	Commercial Ornamental Fish Breeding and Culture	-	1+1	-	-	-	-
	STAT-511	Experimental Designs	-	-	2+1	-	-	-
	PGS-503	Intellectual property and its management in Agriculture	-	-	-	1+0	-	-
	PGS-504	Basic concepts in Laboratory Techniques	-	-	-	0+1	-	-
	PGS-505	Agricultural/ Fisheries Research, Research Ethics and Rural Development programme	-	-	-	1+0	-	-
	<b>TOTAL</b>			<b>09</b>	<b>04</b>	<b>03</b>	<b>03</b>	-
<b>Major-09; Minor-04; Supporting-03; Common Course : 03 ; Total: 19</b>								

Sem.	Course No.	Course Title	Major/ Core Course Credit Hour	Minor Course Credit Hour	Supporting Course Credit hour	Common Course	Seminar	Research
III	AQC-591	Masters Seminar	0+1	-	-	-	0+1	
	AQC-599	Masters Research	0+15	-	-	-	-	0+15
	TOTAL		0+16	-	-	-	0+1	0+15
<b>Major-00; Minor-00; Supporting-00; Seminar: 01 ; Research-15;</b>								<b>Total: 16</b>

Sem.	Course No.	Course Title	Major/ Core Course Credit Hour	Minor Course Credit Hour	Supporting Course Credit hour	Common Course	Seminar	Research
IV	AQC-599	Masters Research	-	-	-	-	-	0+15
	TOTAL		-	-	-	-	-	0+15
<b>Major-00; Minor-00; Supporting-00; Seminar-00; Research-15</b>								<b>Total: 13</b>

**GRAND TOTAL:**

Major	Minor	Supporting Courses	Common Courses	Total Course Credit	Seminar	Master's Research	Total Credit hours
20	08	06	05	39	01	30	70

**A) MAJOR COURSES**

**M.F.Sc. Aquaculture**

**Course Content**

<b>AQC 501</b>	<b>FRESHWATER AQUACULTURE PRODUCTION SYSTEMS</b>	<b>2+1</b>
<b>Objective</b>	To gain knowledge and understand the recent advances in freshwaterfish and prawn farming under different culture systems.	
<b>Theory</b>		
Unit I	<b>Introduction:</b> Present status, hindrances / problems / constraints and prospects for fish and prawn farming in global and Indian perspective. Development process, different supports and driving factors for production enhancement.	
Unit II	<b>Aquaculture systems:</b> Extensive, semi-intensive and intensive culture of fish and prawn. Partitioned aquaculture systems: raceways, tanks, flow-through systems, polyculture, and composite fish culture. Cages and enclosure. Peri-urban aquaculture systems: aquaponics, RAS, flow- through systems, bio-floc technology and land based aquaculture systems.	
Unit III	<b>Aquaculture practices for cultivable species:</b> carps, catfish, snakeheads, feather backs, tilapia, mahseer, trouts and freshwater prawn. Grow out practices: pre stocking, post stocking management, harvesting and BMP. Other alternative species for high production. Species selection and crop planning. Economics of different fish farming Systems	
Unit IV	<b>Freshwater prawn farming:</b> Monoculture practice of prawn in ponds, all-male culture and its advantages, polyculture with carps, prawn farming in inland saline soils. Nursery rearing, sex segregation, pond preparation, stocking, feeding and water quality management, disease prevention and treatment; harvesting methods, handling and BMP.	
Unit V	<b>Integrated farming systems:</b> Design, farming practices, constraints and economics of IFS of fish with vegetables, fodder, paddy, cattle, pig, poultry, duck, rabbit and quail. IMTA, Freshwater pearl culture, multi- level integrated system. Resource utilization and conversion of waste to wealth.	
Unit VI	<b>Wastewater-fed aquaculture:</b> Water treatment methods, species selection, culture practices, harvesting and depuration process. Merits and demerits of wastewater fed aquaculture systems. Pre-requisites and precautions to be taken in the technology adoption.	



<b>Practical</b>	<p>Identification of commercially important cultivable finfish and shellfish species; Assessment of seed quality- stress test; pre-stocking factors evaluation and observation; Calculating carrying capacity of pond and stocking density; Check tray assessment and feed ration calculation; Sampling process and species wise growth estimation; Farm feed production and feeding; Lime and fertilizer requirement calculations; Farm visits and observation; Records keeping and data analysis;</p> <p>Modelling of different culture systems.</p>
<b>Suggested Readings</b>	<p>1. AAHRI. 1998. <i>Health Management in Shrimp Ponds</i>. Aquatic Animal Health Research Institute (AAHRI), Department of Fisheries, Thailand.</p>
	<p>2. Agarwal SC. 2008. <i>A Handbook of Fish Farming</i>. 2nd Ed. Narendra Publ. House.</p> <p>3. Beveridge MCM &amp; Mc Andrew BJ. 2000. <i>Tilapias: Biology and Exploitations</i>. Kluwer.</p> <p>4. De Silva SS. (Ed.). 2001. <i>Reservoir and Culture Based Fisheries: Biology and Management</i>. ACAIR Proceedings.</p> <p>5. FAO. 2007. <i>Manual on Freshwater Prawn Farming</i>.</p> <p>6. Midlen&amp; Redding TA. 1998. <i>Environmental Management for Aquaculture</i>.Kluwer.</p> <p>7. New MB. 2000. <i>Freshwater Prawn Farming</i>. CRC Publ.</p> <p>8. Pillay TVR. 1990. <i>Aquaculture: Principles and Practices</i>. FishingNews Books, Cambrige University Press, Cambridge.</p> <p>9. Venugopal S. 2005. <i>Aquaculture</i>. Pointer Publ.</p> <p>10. Welcomme RL. 2001. <i>Inland Fisheries: Ecology and Management</i>. Fishing News Books.</p>

<b>AQC 502</b>	<b>COASTAL AQUACULTURE &amp; MARICULTURE FARMING SYSTEMS</b>	<b>2+1</b>
<b>Objectives</b>	To gain knowledge in establishing and managing different fish/shellfish farming systems in coastal zone and marine waters.	
<b>Theory</b>		
Unit I	<b>Introduction:</b> Overview of coastal aquaculture and open sea mariculture; Present trend and future prospects in India. Practices in tropical countries, production levels and adoption of technology. Major bottlenecks in the practices	
Unit II	<b>Different farming systems:</b> Cage and pen culture – types, site selection, construction, specifications for different species; Raft and rack culture – Principles, site selection, design and construction; operations & troubles shooting, threats and environmental issues; Land based aquaculture-. Principle, design, construction and operations, rules and legislations	
Unit III	<b>Aquaculture of finfishes:</b> Distribution, biology, seed collection, nursery rearing, weaning on artificial feed, culture techniques, feeding strategies, constraints and scope (Seabass, milkfish, mullets, pearlspot, sea breams, grouper, snapper, cobia, pompano).	
Unit IV	<b>Shrimp farming (<i>Penaeus monodon</i>, <i>P. indicus</i>, <i>P. semisulcatus</i>, and <i>Litopenaeusvannamei</i>):</b> Systems of farming – extensive, semi- intensive, intensive and super intensive (Biofloc, RAS, etc.); site selection, design and construction of culture systems, pond preparation, stocking, feed and water quality management, disease prevention and treatment; use of probiotics and prebiotics: harvesting and handling; continuous stocking and harvesting, staggered harvest, management of differential growth; shrimp farming in undrainable ponds. Mud crab fattening, production of soft-shell crabs and Lobster culture.	
Unit V	<b>Culture practices for marine molluscs and echinoderms:</b> Presentstatus and future prospects in India, Species cultured (mussels, oysters, pearl oysters, clams, abalone, sea cucumber) distribution, biology, practices followed in India and other Asian countries, farming methods –different types and culture methods; Problems andprospects.	
Unit VI	<b>Seaweed farming:</b> Major seaweed species of commercial importance; tissue culture of seaweeds, methods of culture; farming of agar, algin and carragenan yielding species; emerging trends in their farming in open seas; Integration with other coastal and marine farming systems.	

<p><b>Practical</b></p>	<p>Identification of commercially important cultivable finfish and shellfish species; Assessment of seed quality, rearing techniques; Feeds for nursery rearing, preparation and evaluation; pre-stocking factors in different systems, valuation and observation; Calculating carrying capacity of pond and stocking density; Cage construction, pen construction and identification of bottlenecks; Sampling process and species wise growth estimation; Construction of rafts and mollusc culture; Seaweed collection and identification; Farm feed production and feeding; Disease identification and management; Visits to cage sites and observation; Records keeping and data analysis; Modelling of different culture systems.</p>
<p><b>Suggested Readings</b></p>	<ol style="list-style-type: none"> <li>1. Bardach EJ, Rhyther JH &amp; Mc Larney WO. 1972. <i>Aquaculture the Farming and Husbandry of Freshwater and Marine Organisms</i>. John Wiley &amp; Sons.</li> <li>2. FAO. 2001. <i>Planning and Management for Sustainable Coastal Aquaculture Development</i>.</li> <li>3. FAO Publ. Gilbert B. 1990. <i>Aquaculture</i>. Vol. II. Ellis Horwood.</li> <li>4. ICAR. 2006. <i>Handbook of Fisheries and Aquaculture</i>. ICAR.</li> <li>5. Pillay TVR. 1990. <i>Aquaculture, Principles and Practices</i>. Fishing News Books.</li> <li>6. Pillay TVR &amp; Kutty MN. 2005. <i>Aquaculture: Principles and Practices</i>. 2<sup>nd</sup> Ed. Blackwell.</li> <li>7. Shepherd J &amp; Bromage N. 1990. <i>Intensive Fish Farming</i>. B.S.P. Professional Books.</li> <li>8. Ghosh, P.K., 2010. <i>Brackishwater Aquaculture</i>. Agrobios (India)</li> <li>9. Appukuttan KK, Asokan PK, Mohamed KS, Subramaniam S &amp; Geroge Joseph K. 2003. <i>Manual on mussel farming</i>. CMFRI Technical Bulletin 3.</li> <li>10. James PM. 1983. <i>Handbook of Mariculture</i>. Vol. I. <i>Crustacean Aquaculture</i>. CRC Press.</li> <li>11. NFDB, 2018. <i>Guidelines for sea cage farming in India</i>.</li> <li>12. Ottolenghi F, Silvestri C, Giordano P, Lovatelli A &amp; New MB. 2004. <i>Capture-based aquaculture: the fattening of eels, groupers, tunas and yellowtails</i>. FAO Publ.</li> <li>13. Sekar M, Ranjan R, Xavier B &amp; Ghosh S. 2016. <i>Training manual on cage culture of marine finfish</i>. CMFRI Publ.</li> <li>14. Syda Rao G, Imelda-Joseph, Philipose KK &amp; Suresh Kumar M, 2013. <i>Cage aquaculture in India</i>. CMFRI Publ.</li> <li>15. Shepherd J &amp; Bromage N. 1990. <i>Intensive Fish Farming</i>. B.S.P. Professional Books.</li> </ol>

<b>AQC 503</b>	<b>HATCHERY TECHNOLOGY FOR FIN FISHES AND SHELL FISHES</b>	<b>2+1</b>
<b>Objective</b>	To learn research outlines and recent advances in seed production and hatchery management of commercially important cultivable finfishes and shellfishes.	
<b>Theory</b>		
Unit I	<b>Introduction:</b> Current status; problems and prospects of seed of different shellfish species – freshwater and marine. Site selection and techniques of collection; identification and segregation of finfish & shellfish seed, handling, packing and transportation. Natural collection processes and their merits and demerits.	
Unit II	<b>Reproductive biology:</b> Morphology and reproductive physiology; gonad anatomy; histology of gonad; Hormonal pathways and mode of control; Spermatogenesis and oogenesis; gametology (evaluation of milt and egg); Overview of current developments in reproductive biology of commercially important finfishes and shellfishes.	
Unit III	<b>Environmental and nutritional control of reproduction:</b> Reproductive cycles, factors influencing reproduction (Photoperiod, change in water quality and quantity, temperature, lunar cycle, etc.), simulated environment and exogenous hormonal stimuli. Nutritional factors (types of feed - live and prepared feeds, nutritional quality, quantity, feeding management, feed utilisation, etc.) affecting maturation, spawning and nursery rearing.	
Unit IV	<b>Induced spawning:</b> , Brooder development, quality and its health management, transportation of brooders, hormonal and environmental stimulation, use of different natural, synthetic hormones and analogues and their application; GnRH and LINPE models, PIT tagging, Canulation and volitional spawning, Estimation of spawning efficiency, cryopreservation of gametes.	
Unit V	<b>Hatchery management:</b> Indian major and minor carps, exotic carps, catfishes, tilapia, mahseer, murrels, Trout, Seabass, milkfish, mullets, grouper, snapper, breams, pompano, and cobia. Seed production of commercially important prawns ( <i>Macrobrachium rosenbergii</i> ), shrimps ( <i>Penaeus monodon</i> , <i>P. indicus</i> , <i>P. semisulcatus</i> , and <i>Litopenaeus vannamei</i> ), crabs ( <i>Scylla serrata</i> , <i>Portunus pelagicus</i> ), spiny lobsters ( <i>Panulirus</i> spp), mussels, edible oysters, pearl oyster and clams. Hatchery protocols, water quality management, larval rearing, estimations, troubleshooting in hatcheries, record keeping, packing and transport of seed, anaesthetics in fish seed transport. Quarantine and Hatchery protocols and biosecurity principles; sanitary and phytosanitary (SPS) measures; Better Management Practices (BMPs); packaging and transport of seed. SPF broodstock development.	
Unit VI	<b>Seed quality:</b> Hatchery protocols, water quality management, larval rearing, estimations, troubleshooting in hatcheries, record keeping, packing and transport of seed, anaesthetics in fish seed transport.	

	Quarantine and Hatchery protocols and biosecurity principles; sanitary and phytosanitary (SPS) measures; Better Management Practices (BMPs); packaging and transport of seed. SPF broodstock development. Economics of seed production of different species
<b>Practical</b>	Study of primary and secondary sexual characters; Brooder handling and morphological features recording; Gonadal development observation in carps and other cultivable finfishes; Histological observation of gonads and eggs; Estimation of GSI, fecundity, Absolute fecundity, egg parameters, ovarian features; Collection and identification of cultivable finfish seed; Seed quality character identification; Observation and analysis of inducing agents; Induced breeding of fishes through various inducing agents; Evaluation of carp milt and egg; Cryopreservation of gametes; Preparation of brood and larval feed for different cultivable finfish; Packing and transportation of cultivable finfish seed; Visit to different finfish hatcheries.
<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Chattopadhyay NR. 2016. <i>Induced fish breeding: a practical guide for hatcheries</i>. Elsevier Academic Press.</li> <li>2. FAO. 1992. <i>Manual of Seed Production of Carps</i>. FAO Publ.</li> <li>3. Gupta SD, Mohapatra PC, Routray P, Sahoo SK, Verma DK, Sarangi N. 2008. <i>Textbook of breeding and management of carps</i>. Narendra Publ. House</li> <li>4. ICAR. 2006. <i>Hand Book of Fisheries and Aquaculture</i>. ICAR.</li> <li>5. Jhingran VG &amp; Pullin RSV. 1985. <i>Hatchery Manual for the Common, Chinese and Indian Major Carps</i>. ICLARM, Philippines.</li> <li>6. Jhingran VG. 1991. <i>Fish and Fisheries of India</i>. Hindustan Publ.</li> <li>7. Landau M. 1992. <i>Introduction to Aquaculture</i>. John Wiley &amp; Sons.</li> <li>8. Mcvey JP. 1983. <i>Handbook of Mariculture</i>. CRC Press.</li> <li>9. Pillay TVR &amp; Kutty MN. 2005. <i>Aquaculture- Principles and Practices</i>. Blackwell.</li> <li>10. Rath RK. 2000. <i>Freshwater Aquaculture</i>. Scientific Publ.</li> <li>11. Thomas PC, Rath SC &amp; Mohapatra KD. 2003. <i>Breeding and Seed Production of Finfish and Shellfish</i>. Daya Publ.</li> <li>12. Betsy, C.J. &amp; Kumar, J.S.S., 2017. Cryopreservation and spermatology in fishes. Narendra Publishing House</li> <li>13. ICAR. 2006. <i>Handbook of Fisheries and Aquaculture</i>. ICAR.</li> <li>14. Jhingran VG. 1991. <i>Fish and Fisheries of India</i>. Hindustan Publ. Corp.</li> <li>15. Landau M. 1992. <i>Introduction to Aquaculture</i>. John Wiley &amp; Sons.</li> <li>16. Mcvey JP. 1983. <i>Handbook of Mariculture</i>. CRC Press.</li> <li>17. Pillay TVR &amp; Kutty MN. 2005. <i>Aquaculture - Principles and Practices</i>. Blackwell.</li> <li>18. Thomas PC, Rath SC &amp; Mohapatra KD. 2003. <i>Breeding and Seed Production of Finfish and Shellfish</i>. Daya Publ. House.</li> </ol>

AQC 504	AQUACULTURE POLICY AND PLANNING		1+1
<b>Objective</b>	To gain in depth knowledge to develop aquaculture policies for the sustainable aquaculture practices.		
<b>Theory</b>			
<b>Unit I</b>	<b>Sustainability issues:</b> Environmental & Socio-economic issues; Exotic species introduction; escapement; contamination of indigenous gene pool; salinization of soil and water; environmental impact; over exploitation of wild stocks; mangrove deforestation. EIA, eco-system approach to aquaculture. Conflicts over water and land use; conflicts of interest between aqua farmers and fishermen, aquaculture and other enterprises; social issues; anti-dumping duties.		
<b>Unit II</b>	<b>Climate Change Impact:</b> Weather elements of concern in aquaculture, Green house gases, global warming and their impact, Carbon sequestration in aquaculture, Microplastics in Aquaculture, measures and tools to reduce energy use and greenhouse gas emission in aquaculture		
<b>Unit III</b>	<b>Strategies for sustainability:</b> Sustainability concept; food security; biosecurity; organic farming; responsible aquaculture; rotational aquaculture; bioremediation; role of biotechnology, traceability. Energy conservation. Application of renewable energy in aquaculture - solar energy, wind, and tidal energy, Seed certification, Sustainable use of antibiotics, minimal water exchange system, natural productivity, preservation of natural resources		
<b>Unit IV</b>	<b>Guiding principles for sustainable aquaculture:</b> Coastal Aquaculture Guidelines Source Book, FAO Code of Conduct for Responsible Fisheries; Holmenskollen Guidelines for Sustainable Aquaculture. BMP, CRZ implications, CAA and it's role, ecolabelling, organic certification. PCB and State water bodies protection guidelines.		
<b>Practical</b>	Visit to conventional aqua farm to see the management of used water; Survey on environmental impact on nearby aquaculture farms; Applications of remote sensing and GIS (geographical information system); Economic evaluation of aquaculture practices. Case studies on environmental issues of different types of farms.		
<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Bardach JE. 1997. <i>Sustainable Aquaculture</i>. John Willey &amp; Sons.</li> <li>2. Bardach JE, Rhyther JH &amp; Mc. Larney WO. 1972. <i>Aquaculture Farming and Husbandry of Freshwater and Marine Organisms</i>. John Wiley &amp; Sons.</li> <li>3. Beets WC. 1990. <i>Raising and Sustaining Productivity of Small- Holder Farming Systems in the Tropics</i>. Agbe Publ.</li> <li>4. Edwards P, Little DC &amp; Demaine H. (Eds.). 2002. <i>Rural Aquaculture</i>. CABI.</li> <li>5. FAO 2001. <i>Planning and Management for Sustainable Coastal Aquaculture Development</i>. FAO.</li> <li>6. Imai T. 1978. <i>Aquaculture in Shallow Seas. Progress in Shallow Sea Culture</i>. Amerind Publ.</li> <li>7. James PM. 1983. <i>Handbook of Mariculture. Vol. I. Crustacean Aquaculture</i>. CRC Press.</li> <li>8. Leung P, Lee CS &amp; O'Bryen JP. (Eds.). 2007. <i>Species and System Selection for Sustainable Aquaculture</i>. Blackwell Publ.</li> <li>9. Midlen &amp; Redding TA. 1998. <i>Environmental Management for Aquaculture</i>. Chapman &amp; Hall.</li> </ol>		

	10. Selvamani BR &Mahadevan RK. 2008. Aquaculture, Trends and Issues. Campus Books International. FAO, 2011. Code of conductfor responsible fisheries. FAO special edition.
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AQC 505	FISH NUTRITION AND FEED TECHNOLOGY	2+1
<b>Objective</b>	To learn the nutritional requirements and feed equipment's of major cultivable to develop new and novel feeds for the commercial aquaculture	
<b>Theory</b>		
Unit I	<b>Introduction:</b> Need for studying the nutritional requirements of cultivable fishes, feed formulation, methods to study the nutritional requirements, and its need.	
Unit II	<b>Feed ingredients &amp; Feed preparation:</b> Commonly used feed ingredients in aqua feeds, novel feed ingredients, estimation of quality of feed ingredients, qualities of feed ingredients that determine feed quality, selection of ingredients, formulation of feeds, feed processing and making. Different feed preparation methods.	
Unit III	<b>Types of feeds:</b> Floating, semi-floating, sinking and stable feeds for aquaculture. Feed making methods for different feeds, Nutrient leeching in feeds, feed quality determination and feed making, Evaluation of feeds, Simulated system evaluation, lab analysis.	
Unit IV	<b>Advanced feeds:</b> high energy feeds, alternative protein sources for feeds, maturation diets to enhance breeding efficiency, larval feeds, bioavailability in feeds, high FCE and economic benefits of feeding in the farming. Live feed enrichment, bio-routing of nutrients, chemo-therapeutants, other growth promoting agents through live feeds. Evaluation of bio-accumulation and bio-utilisation.	
Unit V	<b>Feed processing technology:</b> Common processes in feed manufacture; Grinding, Dosing, Homogenization; Extrusion cooking; Complimentary processes; Drying, crumbling, coating; Use of binders; Feed manufacture productions with high energy diets vacuum coating with lipid. Equipments used in feed manufacture; Pulverizer, grinder, mixer, pelletizer, crumbler, drier, Extruder / Expander, Vacuum coater, fat sprayer	
Unit VI	<b>Quality control in fish feed manufacturing;</b> Quality control procedures, raw materials, finished products; Geometrical, and physical feature; mechanical characteristics in air, Behavioral characteristics in water. Feed economics and evaluation criteria: FCR, AFCR, SGR, PRE, ERE, PER, NPU.	
<b>Practical</b>	Nutritional requirements determination for different species; Collection and analysis of different feed ingredients; Feed formulation with different feed ingredients; Feed quality analysis; Evaluation process in farms and labs; Visit to feed mills and feed making process; Economic analysis of feeding and non feeding systems; Identification of different feed additives; Observation of novel feeds and their utilization	
<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Nates, S.F., 2016. Aquafeed formulation. Academic Press</li> <li>2. ADCP (Aquaculture Development and Co-ordination Programme), 1980. <i>Fish Feed Technology</i>. ADCP/REP/80/11. FAO.</li> <li>3. Cyrino EP &amp; Bureau D &amp; Kapoor BG. 2008. <i>Feeding and Digestive Functions in Fishes</i>. Science Publ.</li> <li>4. D' Abramo LR, Conklin DE &amp; Akiyama DM. 1977. <i>Crustacean Nutrition: Advances in Aquaculture</i>. Vol. VI. World Aquaculture Society, Baton Rouge.</li> </ol>	



	<p>5. De Silva SS &amp; Anderson TA. 1995. <i>Fish Nutrition in Aquaculture</i>. Chapman &amp; Hall Aquaculture Series.</p> <p>6. Elena M. 2003. <i>Nutrition, Physiology and Metabolism in Crustaceans</i>. Science Publishers.</p> <p>7. Guillame J, Kaushik S, Bergot P &amp; Metallier R. 2001. <i>Nutrition and Feeding of Fish and Crustaceans</i>. Springer Praxis Publ.</p> <p>8. Halver J &amp; Hardy RW. 2002. <i>Fish Nutrition</i>. Academic Press.</p> <p>9. Halver JE &amp; Tiews KT. 1979. <i>Finfish Nutrition and Fish feed Technology</i>. Vols. I, II Heenemann, Berlin.</p> <p>10. Hertrampf JW &amp; Pascual FP. 2000. <i>Handbook on Ingredients for Aquaculture Feeds</i>. Kluwer.</p> <p>11. Houlihan D, Boujard T &amp; Jobling M. 2001. <i>Food Intake in Fish</i>. Blackwell.</p> <p>12. Lavens P &amp; Sorgeloos P. 1996. <i>Manual on the Production and Use of Live Food for Aquaculture</i>. FAO Fisheries Tech. Paper 361, FAO.</p> <p>13. Lovell RT. 1998. <i>Nutrition and Feeding of Fishes</i>. Chapman &amp; Hall.</p> <p>14. New MB. 1987. <i>Feed and Feeding of Fish and Shrimp. A Manual on the Preparation and Preservation of Compound Feeds for Shrimp and Fish in Aquaculture</i>. FAO – ADCP/REP/87/26.</p> <p>15. Ali SA. 2018. <i>Nutritional feeding of fish and shrimps in India</i>. MJP Publ.</p> <p>16. Ganguly S. 2014. <i>Potential and recommended feed additives for sustainable aquaculture, livestock and poultry farming practices</i>. Narendra Publ.</p> <p>17. Guillame J, Kaushik S, Bergot P &amp; Metallier R. 2001. <i>Nutrition and Feeding of Fish and Crustaceans</i>. Springer Praxis.</p> <p>18. Hertrampf JW, Piedad-Pascual F, 2000. <i>Handbook on ingredients for aquaculture feeds</i>. Springer Publ.</p> <p>19. Lovell T. 2014. <i>Nutrition and feeding of fish</i>. Springer Publ.</p> <p>20. Merrifield D &amp; Ringo E. 2014. <i>Aquaculture Nutrition: gut health probiotics and prebiotics</i>.</p> <p>21. Wiley Blackwell. Ninawe AS &amp; Khedkar GD. 2009. <i>Nutrition in aquaculture</i>. Narendra Publ.</p> <p>22. Strasbourg LK. 2013. <i>Fish feeding in integrated fish farming</i>. Random Exports.</p>
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<b>AQC 506</b>	<b>SOIL AND WATER QUALITY MANAGEMENT IN AQUACULTURE</b>	<b>2+1</b>
<b>Objective</b>	To learn effective soil and water quality management practices for Aquaculture	
<b>Theory</b>		
Unit I	<b>Soil and water interaction:</b> Physical and chemical properties of soil and water, Productivity vs. nutrient quality and quantity of soil and water; aquatic microorganisms and their role in carbon, nitrogen, phosphorus and sulphur cycles and impact on aquatic habitats and species.	
Unit II	<b>Soil and water quality monitoring:</b> soil and water quality standards; equipment used for soil and water quality estimations, automated systems for monitoring, quality checks and management, aeration system for water quality management.	
Unit III	<b>Fertilizers and manures:</b> Different kinds of fertilizers and manures, fertilizer grade, source, rate and frequency of application, Biofertilizers. Use of treated sewage for pond fertilization, Ecological changes taking place after fertilizing, primary production, degradation of molecules in aquatic environment, Utilization of bioactive compounds by microorganisms.	
Unit IV	<b>Soil and water conditioners:</b> Biological indicators, chemical and physical method of conditioning, prebiotics, probiotics, minerals, micro-nutrients and additives.	
Unit V	<b>Development of suitable soil and water quality:</b> Cat clay/pyrite soil, seepage, water treatment, water filtration devices, aeration, chlorination, ozonation and UV radiation, Algal bloom control, eutrophication, Aquatic weed management, Water quality management in hatcheries.	
Unit VI	<b>Waste water treatment practices:</b> Waste discharge standards, Role of microorganisms in fish production, fish health and fish safety; Microbial load and algal blooms.	
<b>Practical</b>	Preparation of water quality charts and maintenance; Equipment used in soil and water analysis; Soil sampling, determination of soil moisture and bulk density; pond filling, Analyses of mud acidity and soil texture; Measurements of temperature, pH, conductivity, salinity, transparency, turbidity and solids; Analyses of dissolved oxygen, alkalinity and hardness, phosphorus, nitrogen; Estimation of primary productivity and chlorophyll; Application of fertilizers and pond liming; Analysis of toxic elements, microbial techniques, Visit to effluent treatment plant.	
<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Adhikari S &amp; Chatterjee DK. 2008. <i>Management of Tropical Freshwater Ponds</i>. Daya Publ. APHA, AWWA, WPCF. 1998. Standard Methods for the Examination of Water and Wastewater, 20th Ed. American Public Health Association, American Water Works Association, and Water Pollution Control Federation, Washington, D. C.</li> <li>2. Boyd, C. E. and Tucker, C. S. 1992. <i>Water Quality and Pond Soil Analysis for Aquaculture</i>, Alabama Agricultural Experimental Station, Auburn University.</li> <li>3. Boyd CE. 1979. <i>Water Quality in Warm Water Fish Ponds</i>. Auburn University.</li> <li>4. ICAR. 2006. <i>Handbook of Fisheries and Aquaculture</i>. ICAR.</li> </ol>	

	<ol style="list-style-type: none"><li>5. Mcvey JP. 1983. Handbook of Mariculture. CRC Press.</li><li>6. Parsons TR, Maita Y &amp; Lalli CM. 1984. A Manual of Chemical and Biological Methods for Seawater Analysis. Pergamon Press.</li><li>7. Rajagopalsamy CBT &amp; Ramadhas V. 2002. Nutrient Dynamics in Freshwater Fish Culture System. Daya Publ.</li><li>8. Sharma LL, Sharma SK, Saini VP &amp; Sharma BK. (Eds.). 2008. Management of Freshwater Ecosystems. Agro-tech Publ. Academy.</li></ol>
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<b>AQC 507</b>	<b>THERAPEUTICS AND HEALTH MANAGEMENT IN AQUACULTURE</b>	<b>2+1</b>
<b>Objective</b>	To gain knowledge on health management in aquaculture systems through diagnosis, treatment and preventing the disease outbreaks to protect aquaculture production.	
<b>Theory</b>		
Unit I	<b>Diseases of fishes:</b> Bacterial, fungal, viral diseases of fishes and shell fishes in farm ponds, natural waters, and incidental outbreaks, Nutritional disorders and environmental diseases, situations for disease outbreaks, natural immunity and disease control.	
Unit II	<b>Prophylaxis in aquaculture systems:</b> Preventive measures for fish and shellfish diseases, disinfection for environmental improvement, improved nutritional support methods, immune modulations, use of immunostimulants and vaccines, bioremediation in aquaculture systems. Prevention of fish and shellfish diseases in various aquaculture systems, their limitations and benefits.	
Unit III	<b>Therapeutics in aquaculture systems::</b> Concept of therapeutics in aquaculture, effectiveness of medication, drugs in aquaculture, herbal therapeutants, use of and disuse chemicals and antibiotics in fish and shellfish farming, permissible and banned drugs in finfish and shellfish culture, therapies for ornamental fishes, Mode of action of antibiotics, Antibiotic resistance, legislation and jurisprudence in therapeutics for aquaculture organisms, Residual drugs and bio traceability of antibiotics use in aquaculture.	
Unit IV	<b>Health management strategies:</b> Special features of hatcheries and health management of brooders, larvae, fry and young ones for finfish and shellfishes. Disease impacts on hatchery production, disinfection protocol, live feed crash due to diseases, communicable diseases and their mechanism of spreading, controlling outbreak of viral infections in all types of finfish and shellfish hatcheries. Economic benefits of investment in disease management.	
Unit V	<b>Modern treatment methods for fishes and shellfishes:</b> Treatment methods currently in practice, isolation, hospital tanks, disinfection, oral drug administration, immersion, brooder treatment for immunity enhancement, mass treatment protocol, vaccination and immunostimulation protocol, use of pre-biotics and pro-biotics, advantages and disadvantages.	
Unit VI	<b>Other health management aspects:</b> One health concept including aquatic system, aquatic animals and human beings, Development of SPF, SPR and SPT seeds and brooders, Control of vertical and horizontal transmission of diseases in aquaculture, Health improvement through fortified feeds, medicated feeds, Use of nanotechnology in health management..	
<b>Practical</b>	Identification of disease conditions, Observation of pathological features in cultivable fishes and shellfishes; Collection of diseased specimens and their identification; Development of treatment protocols for fishes and shellfishes; Analysis of environmental situation favouring disease outbreaks; Study of epidemic conditions in farms identification; Preparation of medicated feeds, validation and observation; Experiments in treatment tanks and management; Trials of probiotics and prebiotics and determination of their effects; Monitoring of fish and shellfish health in quarantine tanks, Visit to hatcheries and farms of finfish and shellfish to collect the specimens for disease diagnosis; Formulation of drugs, chemicals and antibiotics for therapeutics. Economic evaluation of different treatment methods.	

<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Treves-Brown KM. 2013. Applied fish pharmacology (Vol. 3). Springer Science &amp; Business Media.</li> <li>2. Brunton LL. (Ed). 2005. Goodman and Gilman's The Pharmacological Basis of Therapeutics. 11th Ed. McGraw-Hill.</li> <li>3. Riviere JE &amp; Papich MG. (Eds.). 2013. Veterinary pharmacology and therapeutics 9th ed. John Wiley &amp; Sons.</li> <li>4. Sandhu HS &amp; Rampal S. 2006. Essentials of Veterinary Pharmacology and Therapeutics. 1st Ed. Kalyani Publishers.</li> <li>5. Andrews C, Excell A &amp; Carrington N. 1988. The Manual of Fish Health. Salamander Books.</li> <li>6. Sindermann CJ. 1990. Principal Diseases of Marine Fish and Shellfish. Vols. I, II. 2nd Ed. Academic Press.</li> <li>7. Jorge E, Helmut S, Thomas W &amp; Kapoor BG. 2008. Fish Diseases. Science Publ.</li> <li>8. Felix S, Riji John K, Prince Jeyaseelan MJ &amp; Sundararaj V. 2001. Fish Disease Diagnosis and Health Management. Fisheries College and Research, Institute, T. N. Veterinary and Animal Sciences University. Thoothukkudi.</li> <li>9. Humphrey J, Arthur JR, Subasinghe RP &amp; Phillips MJ. 2005. Aquatic Animal Quarantine and Health Certification in Asia. FAO Publ.</li> </ol>
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<b>AQC 508</b>	<b>LARVAL NUTRITION AND LIVE FEED PRODUCTION</b>	<b>1+1</b>
<b>Objective</b>	To learn the nutritional requirements of fish/shellfish larvae and techniques on mass culture and bio-enrichment of live food organisms.	
<b>Theory</b>		
<b>Unit I</b>	<b>Larval nutrition:</b> Nutritional requirements of finfish and shellfish larvae. Nutritional quality of commonly used live feed. Comparison of live feeds against the prepared feeds. Nutritional disorders in larvae. Larval feeds utilization and advantages.	
<b>Unit II</b>	<b>Formulation and preparation of artificial feeds:</b> For larval rearing, micro particulate diets, particulate and microencapsulated diets. High energy feeds, energy sparing nutrients in larval feeds.	
<b>Unit III</b>	<b>Biology of live feeds:</b> Important live feeds and their biological features, identification of new live feeds, live feed use in different forms, advantages and disadvantages. Important microalgae, rotifers, artemia, infusoria, cladocerans, copepods, oligochaetes, nematode and insect larvae. Bio-enrichment of live feed. Biofilm/periphyton and its use, culture of single cell proteins and their nutritional quality.	
<b>Unit IV</b>	Live feeds research in India, around the world, New techniques developed in live feed use. Quality determination and cost benefit analysis, production methods for different micro feeds, lab analysis of quality.	
<b>Practical</b>	Collection, identification and isolation of live feed using various techniques, Preparation of various culture media, Preparation and maintenance of stock microalgal culture; Preparation of formulated feeds for rearing finfish and shellfish larvae; Mass culture of microalgae, cladocerans, copepods and rotifers; Hatching of artemia and enrichment; Culture of infusoria, earthworms and chironomid larvae; Evaluation of different prepared feeds.	
<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. CIFE. 1993. <i>Training Manual on Culture of Live Food Organisms for AQUA Hatcheries</i>. Central Institute of Fisheries Education, Versova, Mumbai.</li> <li>2. Finn RN &amp; Kapoor BG. 2008. <i>Fish Larval Physiology</i>. Science Publ.</li> <li>3. Hagiwara A, Snell TW, Lubzens E &amp; Tamaru CS. 1997. <i>Live Food in Aquaculture</i>. Proceedings of the Live Food and Marine Larviculture Symposium. Kluwer.</li> <li>4. MPEDA. 1993. <i>Handbook on Aqua Farming - Live Feed. Micro Algal Culture</i>. MPEDA Publication.</li> <li>5. Muthu MS. 1983. <i>Culture of Live Feed Organisms</i>. Tech. Paper 14. Summer Institute in Hatchery Production of Prawns Seeds. CMFRI, Cochin.</li> <li>6. Ojha JS. 2005. <i>Aquaculture Nutrition and Biochemistry</i>. Daya Publ.</li> <li>7. Santhanam R, Ramnathan M &amp; Venkataramanjum. 1997. <i>A Manual of Methods in Plankton</i>. Fisheries College and Research Institute, Tamil Nadu Veterinary and Animal Sciences University, Tuticorin.</li> <li>8. Sorgeloos P &amp; Pandian KS. 1984. <i>Culture of Live Food Organisms with Special Reference to Artemia Culture</i>. CMFRI Spl. Publ. No. 15.</li> <li>9. Tonapi GT. 1980. <i>Freshwater Animals of India</i>. Oxford &amp; IBH.</li> </ol>	

	<p>10. Lee, C.S., O'Bryen, P.J., Marcus, N.H., 2005. Copepods in aquaculture. Blackwell Publishing.</p> <p>11. Gopinathan CP. 1993. <i>Handbook on Aqua Farming - Live Feed</i>. MPEDA Publication</p> <p>12. Joan Holt, G., 2011. <i>Larval fish nutrition</i>. Wiley Blackwell Publ.</p>
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<b>AQC 509</b>	<b>AQUACULTURE ENGINEERING</b>	<b>1+1</b>
<b>Objective</b>	To learn basic aspects of different aquaculture farm designing for effective management and optimum yield.	
<b>Theory</b>		
Unit I	<b>Site selection:</b> Criteria for site selection, correction factors, survey methods, earth work calculations and cost estimation; water resources and their suitability, suitability of soil from stability and productivity point of view; land conversion effects and Environmental Impact Assessment (EIA).	
Unit II	<b>Estimation in farm construction:</b> Area and volume calculations for an aquafarm and water bodies, surveying and leveling (chain, compass and plain table survey, dumpy level and the odolite).	

Unit III	<b>Design, layout planning and construction of different types of production systems:</b> Types of ponds, shape, size and orientation, design of embankments, ponds and tanks, water distribution, canals and exchange structures (inlets, outlets, sluice gates, and monks); design of feeder channels and drainage systems. Pens, cages (fixed, floating, semi-submerged and tray cages) raceways, flow-through systems and re-circulatory aquaculture systems (RAS), aquaponics, feed dispensers, demand feeders and effluent treatment systems (ETS), automation in aquaculture.	
Unit IV	<b>Design and construction of hatcheries:</b> (carp, freshwater prawn, shrimp and trout). Selection of aquaculture equipment and implement: Selection criteria and maintenance of water pumps, water filtration systems, principles of aeration, aerators, oxygen budgeting, aeration grid, automatic and demand feeders, soil and water samplers. Aquifers, soil permeability, hydraulic conductivity, water budgeting, water harvesting, multiple uses of water. Economic impact of modernization in aquafarms	
<b>Practical</b>	Estimation in construction, model development, Visit to aqua farms and hatcheries. Survey - contour survey and mapping, chain and compass survey, dumpy leveling. Evaluation of performance of seepage control measures, Layout planning and design of hatcheries (carp, freshwater prawn, shrimp and trout) and farms including their costing and evaluation, Estimation of pump capacity, Estimation of construction cost of ponds, hatchery shed, aeration devices and Evaluation of their capacity.	
<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Thomas L. 1995. <i>Fundamentals of Aquacultural Engineerin</i>. Chapman &amp; Hall.</li> <li>2. Wheaton FW. 1977. <i>Aquacultural Engineering</i>. John Wiley &amp; Sons.</li> <li>3. Creed R. 2017. <i>Aquaculture and fish farming</i>. Syrawood Publ.</li> <li>4. Bose AN. 1991. <i>Coastal Aquaculture Engineering</i>. Oxford and IBH Publ.</li> <li>5. Ivar LO. 2007. <i>Aquaculture Engineering</i>. Daya Publ. House.</li> <li>6. Lekang OI. 2013. <i>Aquaculture Engineering</i>. Wiley-Blackwell Publ.</li> <li>7. Pillay TVR &amp; Kutty MN 2005 <i>Aquaculture-Principles and Practices</i>. Blackwell.</li> </ol>	
<b>AQC 510</b>	<b>OPEN WATER AQUACULTURE</b>	<b>1+1</b>
<b>Objective</b>	To learn about the open water aquaculture for production enhancement	
<b>Theory</b>		
Unit I	<b>Introduction:</b> Overview of global scenario of aquaculture in open waters, open water resources in India, present status, utilization, prospects of production augmentation. Utilization of open water bodies for aquaculture to enhance production	



Unit II	<b>Different culture systems:</b> Cages, pens and enclosures in open waters, seed stocking, quality and quantity. Cages for sea, estuaries, reservoirs, lakes and canals. Pen culture. Selection of site for sea farming. Different designs of open sea farming structures-construction of cages-bioengineering problems and solutions. Species selection for open water aquaculture. Rearing of fingerlings, advanced fingerlings and table size fish in open water bodies.
Unit III	<b>Practices:</b> Ranching in open waters, species quality and quantity, natural feed enhancement, supplementary feeding in cages. Stock assessment, harvesting and conflicts with irrigation, drinking water and hydroelectric projects on open water farming.
Unit IV	<b>Environmental impact of Open water Aquaculture</b> - Salinity intrusion, effluent, discharge, eutrophication, chemical residues including antibiotics and hormones, destruction of natural habitat including paddy field and mangroves. Social issues and conflicts with other users on resources
<b>Practical</b>	Different types of cage materials, fabrication of cages and pens and their installation. Determination of stocking density in cages and pens, Feeding in cages and pens, Stock assessment in cages and pens; Environmental impact of cages and pens. Visit to cages and pen sites.
<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Tidwell, J.H. (Ed.), 2012. Aquaculture Production Systems. Wiley-Blackwell.</li> <li>2. Beveridge, M.C.M.(Ed.), 2004. Cage Aquaculture, 3<sup>rd</sup> Edition. Blackwell Publishing.</li> <li>3. Burnell, G., Allan, G., 2009. New technologies in Aquaculture. 1<sup>st</sup> Edition. Woodhead Publishing House.</li> <li>4. Beveridge M. 2008. <i>Cage aquaculture</i>. Oxford Publ.</li> <li>5. Chiu Liao I, Kwei Lin C, 2000. <i>Cage aquaculture in Asia: Proceedings of the First International Symposium on Cage Aquaculture in Asia</i>, AFS and WAS Publ.</li> <li>6. NFDB, 2018. <i>Guidelines for sea cage farming in India</i>.</li> <li>7. FAO, 2018. <i>The State of World Fisheries and Aquaculture - Meeting the sustainable development goals</i>. Rome.</li> <li>8. Syda Rao G, Imelda-Joseph, Philipose KK &amp; Suresh Kumar M, 2013. <i>Cage aquaculture in India</i>. CMFRI Publ.</li> </ol>

<b>AQC 511</b>	<b>COMMERCIAL ORNAMENTAL FISH BREEDING AND CULTURE</b>	<b>1+1</b>
<b>Objective</b>	To gain knowledge on advanced ornamental fish production technologies and aquatic ornamental plant propagation.	
<b>Theory</b>		
<b>Unit I</b>	<b>Introduction:</b> 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. Prospects of production of new strains / varieties. Ornamental fish breeding techniques towards strain development.	
<b>Unit II</b>	<b>Design &amp; construction:</b> Self-maintained aquarium, species compatibility, high value species, aquarium maintenance and care. Common aquarium plants and their identification. Gadgets used in freshwater and marine aquarium, aerators, filters (UV, trickling and biofiltration), protein skimmers, ozonizer, thermostatic heater, chiller, lighting, water conditioners, etc.	
<b>Unit III</b>	<b>Captive Breeding techniques:</b> Mass production of commercially important freshwater and marine ornamental fishes. Nursery and grow out culture of commercially important ornamental fish species in Raceways, RAS etc. Hybrids development. Feed and feeding, Color enhancement through pigmented feed, novel feeds. Common diseases, and control. Water quality management.	
<b>Unit IV</b>	<b>Transportation &amp; Trading of Ornamental Fishes:</b> Medicines and chemicals used in the ornamental fish industry. Anaesthetics, packing, transportation and marketing strategies. Culture unit for entrepreneurship development. Socio-economic upliftment through backyard ornamental fish farming. Micro-traders in ornamental fish marketing.	
<b>Practical</b>	Identification of common ornamental fishes; Plants and gadgets used in aquariums; Breeding of commercially important ornamental fishes. Visit to ornamental fish units. Aquarium fabrication, Setting and maintenance. Application and use of medicines/chemicals.	
<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Axelrod HR &amp; Vorderwinkler W. 1978. <i>Encyclopaedia of Tropical Fishes</i>. TFH Publ.</li> <li>2. Axelrod HR &amp; Sweenen ME. 1992. <i>The Fascination of Breeding Aquarium Fishes</i>. TFH Publ.</li> <li>3. Axelrod HR. 1967. <i>Breeding Aquarium Fishes</i>. TFH Publ.</li> <li>4. Mills D. 1981. <i>Aquarium Fishes</i>. Kingfisher Books.</li> <li>5. Sanford G &amp; Crow R. 1991. <i>The Manual of Tank Busters</i>. Salamander Books.</li> <li>6. Saxena A. (Ed.). 2003. <i>Aquarium Management</i>. Daya Publ.</li> <li>7. Spotte S. 1979. <i>Fish and Invertebrate Culture</i>. John Wiley &amp; Sons.</li> <li>8. Thabrow De WV. 1981. <i>Popular Aquarium Plants</i>. Thornbill Press.</li> <li>9. Ahilan, B., Felix, N., Santhanam, R., 2008. Textbook of Aquaculture. Daya Publishing House, Delhi.</li> </ol>	

<b>AQC 512</b>	<b>COMPUTER APPLICATION IN AQUACULTURE DATA PROCESSING</b>	<b>0+1</b>
<b>Objective</b>	To understand the scope on the computer application in the aquaculture process flow and systems	
<b>Practical</b>	Computer application basics; different common software installation and application; Identification of farm based software; installation and application; Application of SPSS, SAS, SYSTAT and STATISTICA for analysis and presentation of fisheries data; Basic concepts of database management systems: Introduction to MS-ACCESS, ORACLE (RDBMS); Exercise on analysis of data using MS-EXCEL, SPSS, SAS, FISAT, SYSTAT and STATISTICA; Creation of Database using MS-ACCESS, ORACLE. Linear modelling of Feed formulation, software installation and use.	
<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Cody RP &amp; Smith JF. 1997. <i>Applied Statistics and SAS Programming Language</i>. Elsevier.</li> <li>2. FAO, 2018. <i>The State of World Fisheries and Aquaculture - Meeting the sustainable development goals</i>. Rome.</li> <li>3. Landou S &amp; Everitt BS. 2004. <i>A handbook of statistical analyses using SPSS</i>. Chapman &amp; Hall/CRC.</li> <li>4. Paulraj R. 1997. <i>Aquaculture feed: handbook on aquafarming</i>. MPEDA Publ.</li> <li>5. Gempesaw II, C. M., F.F. Wirth, J.R. Bacon, and L. Munasinghe (1993).</li> <li>6. Economics of vertical integration in hybrid striped bass aquaculture, in <i>Aquaculture: Models and Economics</i> (Ed.) U. Hatch and H. Kinnucan, Boulder: Westview Press, pp. 91-105.</li> <li>7. Griffin, W.L., J.S. Hanson, R.W. Brick and M.A. Johns (1981). Bioeconomic modelling with stochastic elements in shrimp culture. <i>J. World Maric. Soc.</i> 12:94-103.</li> <li>8. Griffin, W.L., L.A. Jensen and C.M. Adams (1983). A generalized budget simulation model for aquaculture. TAMU-SG-83-202, Texas A&amp;M University, 131 pp.</li> <li>9. Haakanson, L. and M. Wallin (1991). Use of econometric analysis to establish load diagrams for nutrients in coastal areas, in <i>Marine Aquaculture and the Environment</i> (Ed.) T. Maekinen, pp. 9-23.</li> <li>10. Johnson, F.C. (1974). Hatch--a model for fish hatchery analysis U.S. National Bureau of Standards, Washington, D.C. Report NBSIR 74-521, 51 pp.</li> <li>11. Lester, L.J., S. Perkins and B.T. Wong (1987). Microcomputer use in aquaculture genetics.</li> <li>12. Lee, P.G. (1993). Computer automation for recirculating aquaculture systems, in <i>Techniques for Modern Aquaculture</i> (Ed.) J. K. Wang, St. Joseph, Minnesota: American Society of Agricultural Engineers, pp. 61-70.</li> </ol>	

<b>AQC 513</b>	<b>INLAND SALINE AQUACULTURE</b>	<b>1+1</b>
<b>Objective</b>	To understand the scope for expanding aquaculture in inland saline waters for effective use	
<b>Theory</b>		
Unit I	<b>Introduction:</b> Inland saline waters, surface and ground water. Quality parameters of inland saline water in India. Global and national status of inland saline soils and underground saline water. Causes and process of salinization, geo-morphological changes. Problems of salinization, potential for aquaculture.	
Unit II	<b>Soil and water characteristics:</b> Comparison with coastal waters, ionic amendment, water conditioning. Technological and engineering interventions for water quality improvement. Nutrient sparing and chelation in inland saline water.	
Unit III	<b>Potential candidate species:</b> Seabass, pearlspot, milkfish, mullet, shrimps, freshwater prawn, tilapia, cobia, pompano and selective carps for culture, constraints and solutions, alternate species with breeding possibilities. Metabolic interactions and growth promotion in altered water systems. Different farming systems	
Unit IV	<b>Socio-economic Importance of Inland Saline Aquaculture;</b> Nutritional intervention in inland shrimp farming; Economics of various finfish & shellfish culture in inland saline arenas; Integrated inland saline aquaculture systems; Recommendations for an action Plan	
<b>Practical</b>	Inland saline soil and water sample collection, analysis and ionic amendments. Visit to inland saline water farms. Case studies of inland saline farms. Evaluation of different systems with regard to species cultured. Trials with different species in known inland saline water bodies.	
<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Tidwell, J.H. (Ed.), 2012. Aquaculture Production Systems. Wiley-Blackwell.</li> <li>2. Pillay TVR &amp; Kutty MN. 2005. <i>Aquaculture - Principles and Practices</i>. Blackwell.</li> <li>3. Boyd CE. 2000. <i>Water quality: an introduction</i>. Kluwer Academic.</li> <li>4. Burnell G &amp; Allan G. 2009. <i>New technologies in aquaculture improving production efficiency, quality and environment management</i>. Woodhead Publ.</li> <li>5. CIFE 2014. <i>Training manual on inland saline water aquaculture management practices</i>.</li> <li>6. Garg SK &amp; Arasu ART. 2003. <i>Proceedings of 3<sup>rd</sup> Interaction workshop, fish production using brackish water in arid ecosystem</i>.</li> </ol>	

<b>AQC 514</b>	<b>MULTILEVEL INTEGRATED AQUACULTURE SYSTEMS</b>	<b>1+1</b>
<b>Objective</b>	To gain knowledge on advanced integration practices along with aquaculture for enhancing aquaculture production.	
<b>Theory</b>		
Unit I	<b>Integrated fish farming:</b> Global status, integration with agricultural (paddy), horticultural crops (vegetable & fruits) and livestock (cattle, poultry, ducks, pigs and other terrestrial animals). Effective recycling of wastes, nutrient budgeting in different integrated farming systems. Production levels and economics.	
Unit II	<b>Bioprocessed manures in integration</b> – Vermicompost, farmyard manure/ compost, biogas slurry <i>etc.</i> Advantages of biomanures, control of microbial interactions, fermentation of manures.	
Unit III	<b>Concepts:</b> Integrated multitrophic aquaculture systems and design of an IMTA unit. Aqua tourism. Aquaponics: concept, principles, types and operation. Multilateral interaction and resource management	
Unit IV	<b>Bio-resource flow in integrated aquaculture system:</b> Discharge of nutrient wastes from integrated aquafarms: environmental effects, and potential for integrated multi-trophic aquaculture. An economic analysis of different integrated culture systems;	
<b>Practical</b>	Preparation of vermicompost; Analysis of nutrient value of different manures; Design of various integrated farming models; Different models of aquaponics; Nutrient analysis and management in aquaponics; Visit to integrated farms; Economics of different integrated systems with case studies	
<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Tidwell, J.H. (Ed.), 2012. Aquaculture Production Systems. Wiley-Blackwell.</li> <li>2. Ahilan, B., Ravaneshwaran, K., Kumaravel, P., 2011. Integrated Aquaculture. Daya Publishing House.</li> <li>3. Little D, Edwards P. 2003. <i>Integrated livestock-fish farming systems</i>. FAO Publ.</li> <li>4. Mathias JA, Charles AT &amp; Baotong H. 1994. <i>Integrated Fish Farming</i>. CRC Press</li> <li>5. Pandey N &amp; Davendra SM. 2008. <i>Integrated Fish Farming</i>. Daya Publ. House</li> <li>6. Sherman RL, Arancon NQ &amp; Edwards CA. 2010. <i>Vermiculture technology: earthworms, organic wastes, and environmental management</i>. CRC Press.</li> <li>7. Soto D. 2009. Integrated mariculture a global review. FAO Publ.</li> </ol>	

<b>AQC 515</b>	<b>COLD WATER AQUACULTURE AND RECREATIONAL FISHERIES</b>	<b>1+1</b>
<b>Objective</b>	To learn about the breeding and culture of different coldwater fishes and their importance as sport fishes	
<b>Theory</b>		
Unit I	<b>Introduction:</b> Status of coldwater fisheries in World with special reference to India. Biology, breeding and culture of trouts ( <i>Oncorhynchus mykiss</i> , <i>Salmo truttafario</i> , <i>Schizothorachthysesocinus</i> , <i>S. longipinnis</i> , <i>S. niger</i> , <i>Schizothoraxrichadsonii</i> ), Mahseer ( <i>Tor putitora</i> , <i>Tor tor</i> , <i>Tor khudree</i> ), Common carp ( <i>Cyprinus carpio cummuinis</i> , <i>Cyprinus carpio specularis</i> ). Specific environmental parameters pertaining to coldwater fish culture and metabolic interaction. Feeds suitable for coldwater aquaculture.	
Unit II	<b>Culture of coldwater fishes:</b> construction and management of coldwater fish farms. Effect of exotic fish introduction on indigenous fish fauna. Polyculture of exotic carps in mid hill region based on three Chinese carps, post-harvest and harvest issues in trouts with regard to cold water species. Special factors for consideration in coldwater fish seed production and nursery rearing.	
Unit III	<b>Introduction to sport fisheries:</b> Sports fishes and their life history. Equipments for sports fishing, fishing methods, area suitable for sports fishing etc. Management and conservation of sports fisheries through aquaculture. Sports fisheries and tourism, recreational aquaculture.	
Unit IV	<b>Issues and Desired Interventions</b> – Potential and Innovative Strategies for the Development of Coldwater Aquaculture in India- problems encountered in fisheries development of rivers supporting cold water fisheries.	
<b>Practical</b>	Identification of cold water fish species; Primary and secondary sexual characters in coldwater fishes; Different breeding methods for coldwater fishes; Identification of larval stages of trout and mahseer; Preparation of hatchery layout for coldwater fishes; Studies on different types of sports fishing equipment; Visit to cold water fish hatchery.	
<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Thomas PC, Rath SC &amp; Mohapatra KD. 2003. <i>Breeding and Seed Production of Finfish and Shellfish</i>. Daya Publ.</li> <li>2. Singh, H.R. &amp; Lakra, W.S., 2008. <i>Coldwater aquaculture &amp; fisheries</i>. Narendra Publishing House.</li> <li>3. Mahanta, P.C., Sarma, D., 2010. <i>Coldwater Fisheries Management</i>. ICAR</li> <li>4. Boghen, A.D., 1989. <i>Cold-water aquaculture in Atlantic Canada</i>. Institut Canadien de recherche sur le developpement regional, Atlantic Coast, Canada</li> <li>5. Jhingran VG &amp; Sehgal KL. 1978. <i>Cold Water Fisheries of India</i>. J. Inland Fish. Soc. India. Sp. Publ.</li> <li>6. Jhingran VG. 1991. <i>Fish and Fisheries of India</i>. 3rd Ed. Hindustan Publ.</li> <li>7. Singh AK, Sarma D, Akhtar, MS &amp; Baruah D. 2017. <i>Souvenir – National seminar on strategies, innovations and sustainable management for enhancing coldwater fisheries and aquaculture</i>. ICAR-DCFR, Bhimtal.</li> <li>8. ICAR. 2006. <i>Handbook of Fisheries and Aquaculture</i>.</li> </ol>	

<b>AQC 516</b>	<b>RECIRCULATING AQUACULTURE SYSTEMS</b>	<b>1+1</b>
<b>Objective</b>	To gain complete knowledge about the recirculating aquaculture systems and its recent developments	
<b>Theory</b>		
Unit I	<b>Introduction:</b> Evolution of intensive culture technologies, Need for intensification in aquaculture, land and water constraints, Conflicts between enterprises for water use, need for RAS, Current status and prospects of RAS in world with special reference to Asian countries.	
Unit II	<b>System engineering:</b> Basic needs for the construction of RAS, Design of RAS, water re-use methods, water budgeting, culture tanks, shape and size, special features, waste solids removal, Cornell dual-drain system, settling basins and tanks- design, fabrication and construction. Water collection and sludge removal	
Unit III	<b>Filters:</b> Mechanical filters, biofilters- trickling towers, floating bead filters, fluidized sand beds, down flow micro-bead biofilter, moving bed bioreactors; aerators.	
Unit IV	<b>Management of RAS:</b> Waste management, feeding management. Animal health management in RAS. Economic viability of RAS for various commercially important finfishes. Challenges in uplifting RAS practices.	
<b>Practical</b>	Species for RAS; Calculating stocking density of fishes in RAS; Determining the controlling flow rate; Calculating required design flow rate for DO; Calculating tank sizes; Feeding management in RAS; Waste water management in RAS; Visit to RAS units	
<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Kaul, S.N., Juwarkar, A.S., et al., 2002. <i>Utilization of wastewater in agriculture &amp; aquaculture</i>. Scientific Publishers.</li> <li>2. Tidwell, J.H. (Ed.), 2012. <i>Aquaculture Production Systems</i>. Wiley-Blackwell.</li> <li>3. Burnell, G., Allan, G., 2009. <i>New technologies in Aquaculture</i>. 1<sup>st</sup> Edition. Woodhead Publishing House.</li> <li>4. Bregnballe J. 2015. <i>A guide to recirculation aquaculture</i>. FAO Publ.</li> <li>5. Christenson K. 2014. <i>Aquaponics: Aquaculture – An introduction to aquaculture for small farmers</i>.</li> <li>6. Davion, A., 2018. <i>Recirculating aquaculture systems: a guide to farm design and operations</i>.</li> <li>7. Hendry lau, 2015. <i>Aquaculture Production system</i></li> <li>8. Hughston, M., 2015. <i>Hydroponics: hydroponic gardening and growing vegetables without soil</i>.</li> <li>9. Timmons MB, Guerdat, T, Vinci, BJ. 2019. <i>Recirculating aquaculture</i>. Ithaca Publishing Comp.</li> <li>10. Yoram, A., 2015. <i>Biofloc technology: a practical guidebook</i>. WAS Publ.</li> </ol>	

### C. SUPPORTING COURSES

#### Course Content

STAT 502	Statistical Methods for Applied Sciences	2+1
<b>Objective</b>	This course is meant for students who do not have sufficient background of Statistical Methods. The students would be exposed to concepts of statistical methods and statistical inference that would help them in understanding the importance of statistics. It would also help them in understanding the concepts involved in data presentation, analysis and interpretation. The students would get an exposure to presentation of data, probability distributions, parameter estimation, tests of significance, regression and multivariate analytical techniques.	
<b>Theory</b>		
Unit I	Box-plot, Descriptive statistics, Exploratory data analysis, Theory of probability, Random variable and mathematical expectation.	
Unit II	Discrete and continuous probability distributions, Binomial, Poisson, Negative Binomial, Normal distribution, Beta and Gamma distributions and their applications. Concept of sampling distribution: chi-square, t and F distributions. Tests of significance based on Normal, chi-square, t and F distributions.	
Unit III	Introduction to theory of estimation and confidence-intervals, Simple and multiple correlation coefficient, partial correlation, rank correlation, Simple and multiple linear regression model, test of significance of correlation coefficient and regression coefficients, Coefficient of determination, Fitting of quadratic models.	
Unit IV	Non-parametric tests – sign, Wilcoxon, Mann-Whitney U-test, Run test for the randomness of a sequence. Median test.	
Unit V	Introduction to ANOVA: One way and Two Way, Introduction to Sampling Techniques, Introduction to Multivariate Analysis, Transformation of Data.	
Practical	<ul style="list-style-type: none"> <li>• Exploratory data analysis, fitting of distributions ~ Binomial, Poisson, Negative Binomial, Normal.</li> <li>• Large sample tests, testing of hypothesis based on exact sampling distributions ~ chi square, t and F.</li> <li>• Confidence interval estimation and Correlation and regression analysis, fitting of Linear and Quadratic Model.</li> <li>• Non-parametric tests. ANOVA: One way, Two Way, SRS.</li> </ul>	
Suggested Readings	<p>Goon A.M, Gupta M.K and Dasgupta B. 1977. An Outline of Statistical Theory. Vol. I. The World Press.</p> <ul style="list-style-type: none"> <li>• Goon A.M, Gupta M.K. and Dasgupta B. 1983. Fundamentals of Statistics. Vol. I. The World Press.</li> <li>• Hoel P.G. 1971. Introduction to Mathematical Statistics. John Wiley.</li> <li>• Hogg R.V and Craig T.T. 1978. Introduction to Mathematical Statistics. Macmillan.</li> <li>• Morrison D.F. 1976. Multivariate Statistical Methods. McGraw Hill.</li> <li>• Hogg RV, McKean JW, Craig AT. 2012. Introduction to Mathematical Statistics 7th Edition.</li> <li>• Siegel S, Johan N &amp; Casellan Jr. 1956. Non-parametric Tests for Behavior Sciences. John Wiley.</li> </ul>	



	<ul style="list-style-type: none"> <li>• Anderson TW. 2009. An Introduction to Multivariate Statistical Analysis, 3rd Ed . John Wiley</li> <li>• <a href="http://freestatistics.altervista.org/en/learning.php">http://freestatistics.altervista.org/en/learning.php</a>.</li> <li>• <a href="http://www.statsoft.com/textbook/stathome.html">http://www.statsoft.com/textbook/stathome.html</a>.</li> </ul>
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<b>STAT 511</b>	<b>Experimental Designs</b>	<b>2+1</b>
<b>Objective</b>	This course is meant for students of agricultural and animal sciences other than Agricultural Statistics. Designing an experiment is an integrated component of research in almost all sciences. The students would be exposed to concepts of Design of Experiments so as to enable them to understand the concepts involved in planning, designing their experiments and analysis of experimental data.	
<b>Theory</b>		
Unit I	Need for designing of experiments, characteristics of a good design. Basic principles of designs- randomization, replication and local control.	
Unit II	Uniformity trials, size and shape of plots and blocks, Analysis of variance, Completely randomized design, randomized block design and Latin square design.	
Unit III	Factorial experiments, (symmetrical as well as asymmetrical), orthogonality and partitioning of degrees of freedom. Concept of confounding.	
Unit IV	Split plot and strip plot designs, analysis of covariance and missing plot techniques in randomized block and Latin square designs; Transformations, Balanced Incomplete Block Design, resolvable designs and their applications, Lattice design, alpha design - concepts, randomization procedure, analysis and interpretation of results. Response surfaces. Combined analysis.	
Practical	Uniformity trial data analysis, formation of plots and blocks, Fairfield Smith Law, Analysis of data obtained from CRD, RBD, LSD, Analysis of factorial experiments, <ul style="list-style-type: none"> <li>• Analysis with missing data,</li> <li>• Split plot and strip plot designs.</li> </ul>	
Suggested Readings	<ul style="list-style-type: none"> <li>• Cochran WG and Cox GM. 1957. Experimental Designs. 2nd Ed. John Wiley.</li> <li>• Dean AM and Voss D. 1999. Design and Analysis of Experiments. Springer.</li> <li>• Montgomery DC. 2012. Design and Analysis of Experiments, 8th Ed. John Wiley.</li> <li>• Federer WT. 1985. Experimental Designs. MacMillan.</li> <li>• Fisher RA. 1953. Design and Analysis of Experiments. Oliver &amp; Boyd.</li> <li>• Nigam AK and Gupta VK. 1979. Handbook on Analysis of Agricultural Experiments. IASRI Publ.</li> <li>• Pearce SC. 1983. The Agricultural Field Experiment: A Statistical Examination of Theory and Practice. John Wiley.</li> <li>• <a href="http://www.drs.icar.gov.in">www.drs.icar.gov.in</a>.</li> </ul>	

## D) COMMON COURSES

<b>PGS -501</b>	<b>LIBRARY AND INFORMATION SERVICES</b>	<b>0+1</b>
<b>Objective</b>	To equip the library user with skill to trace information from libraries efficiently, to apprise them of information and knowledge resources, to carry out literature survey, to formulate information search strategies, and to use modern tools (Internet, OPAC, search engines etc.) of information search.	
<b>Practical</b>	Introduction to library and its services; Role of libraries in education, research and technology transfer; Classification system and organization of library; Sources of information – primary Sources, Secondary Sources and Tertiary Sources; Intricacies of abstracting and indexing services (Science Citation Index, Biological Abstracts, Chemical Abstract, CABI Abstract, etc.); Tracing information from reference sources; literature survey; Citation technique/Preparation of bibliography ; Use of CD-ROM Database , Online Public Access Catalogue and other computerized library services; Use of Internet including search engines and its resources ; e-resources access methods.	

<b>PGS -502</b>	<b>TECHNICAL WRITING AND COMMUNIACTION SKILL</b>	<b>0+1</b>
<b>Objective</b>	To equip the student/scholars with skill to write dissertations, research papers, etc. To equip the student/scholars with skill to communicate and articulate in English (verbal as well as writing).	
<b>Practical</b>		
<b>Technical Writing</b>	Various forms of scientific writings- theses, technical papers, reviews, manual, etc. Various parts of thesis and research communication (title page, authorship contents page, preface, introduction, review of literature, martial and methods, experimental result and discussion); Writing of abstract, summaries, précis, citations etc.; commonly used abbreviation in the these and research communication; illustrations, photographs and drawing with suitable caption ; pagination, numbering of table and illustrations ; Writing of a review article .	
<b>Communication Skill- Grammar</b>	Tenses, part of speech, clauses, punctuation marks; Error analysis (common errors); Concord; Collection; Phonetic symbol and transcription; Accentual pattern: Weak forms in connected speech; Participation in group discussion: Facing an interview; presentation of scientific papers.	
<b>Suggested Readings</b>	<ul style="list-style-type: none"> <li>• <i>Chicago manual of style</i> . 14<sup>th</sup> Ed. 1996. prentice Hall of India.</li> <li>• <i>Collins' Cobuild English Dictionary</i>. 1995 . Harper Collins.</li> <li>• Grodon HM &amp; Walter JA. 1970. <i>Technical Writing</i> . 3<sup>rd</sup> Ed. Holt , Rinehart &amp; Winston.</li> </ul>	

	<ul style="list-style-type: none"> <li>• Hornby AS. 2000. <i>Comp. Oxford Advance Learner Dictionary of Current English</i> . 6<sup>th</sup> Ed. Oxford University Press.</li> <li>• James HS. 1994. <i>handbook for Technical Writing</i> .NCT Business books.</li> <li>• Joseph G.2000. <i>MLA Handbook for Writers of Research Papers</i>. 5<sup>th</sup> Addition Affiliated East-West Press.</li> <li>• Mohan K. 2005 <i>Speaking English Effectively</i>. Mac Millan India.</li> <li>• Richard W.S. 1969. <i>Technical Writing</i>. Barnes &amp; Noble.</li> <li>• Robert C.(Ed.).2005. <i>Spoken English: Flourish Your Language</i>. Abhishek.</li> <li>• Sethi J &amp; Dhamija PV. 2004. <i>Course in Phonetics and Spoken English</i>. 2<sup>nd</sup> Ed.Prentice Hall of India.</li> <li>• Wren PC &amp; Martin H. 2006. <i>High School English Grammar and composition</i>. S. Chand &amp; Co.</li> </ul>
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<b>PGS -503</b>	<b>INTELLECTUAL PROPERTY AND ITS MANAGEMENT IN AGRICULTURE</b>	<b>1+0</b>
<b>Objective</b>	The main objective of this course is to equip students and stakeholders with knowledge of intellectual property rights (TRIP) related protection systems, their significance and use of IPR as a toll for wealth and value creation in a knowledge-based economy.	
<b>Theory</b>	Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, geographical indications, designs and layout, trade secrets and traditional knowledge, trademarks, protection of plant varieties and farmers' rights and bio-diversity protection; Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection; National Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, research collaboration Agreement, license Agreement.	
<b>Suggested Readings</b>	<ul style="list-style-type: none"> <li>• Erbisch FH&amp;marelia K.1998.<i>Intellectual Property Right in AgriculturalBiotechnology</i>. CABI.</li> <li>• Ganguli P. 2001. <i>Intellectual Property Rights: Unleashing Knowledge Economy</i>. McGraw-Hill.</li> <li>• <i>Intellectual Property Rights: Key to New Wealth Generation. 2001</i>.NRDC &amp; Aesthetic Technilogies.</li> <li>• Ministry of Agriculture, Government of India. 2004. <i>State of Indian Farmer. Vol. V. Technology Generation and IPR Issues</i>. Academic Foundation.</li> <li>• Rothschild M &amp; Scott N. (Ed.) . 2003. <i>Intellectual Property Rights in Animal Breeding and Genetics</i>. CABI.</li> <li>• Saha R. (ed.). 2006. <i>intellectual Property Rights in NAM and Other Developing Countries: A compendium on Law and Politices</i>. Daya Publ. House.</li> <li>• <i>The Indian Acts – Patents Act, 1970 and amendments; Design Act, 2000;</i></li> <li>• <i>Trademarks Act, 1999; The copyright Act, 1957 and amandments; Layout Design Act, 2000; PPV and FR Act 2001, and Rules 2003; NationalBiological Diversity Act, 2003.</i></li> </ul>	

<b>PGS -504</b>	<b>BASIC CONCEPTS IN LABORATORY TECHNIQUES</b>	<b>0+1</b>
<b>Objective</b>	To acquaint the students on the basics of commonly use techniques in laboratory	
<b>Practical</b>	Safety measures while in Lab; Handling of chemical substances; Use of burettes, pipettes, measuring cylinders, flasks, separatory funnel, condensers, micropipettes and vaccupets; washing, drying and sterilization of glassware; Drying of solvents/chemicals. Weighing and preparation of solution of different strengths and their dilution; Handling techniques of solutions; preparation of different agro-chemical doses in field and pot applications; Preparation of solutions of acids; Neutralization of acid and bases; Preparation of buffers of different strengths and pH values. Use and handling of microscope, laminar flow, vacuum pumps, viscometer, thermometer, magnetic stirrer, micro-ovens, incubators, sand bath, water bath, oil bath; Electric wiring and earthing. Preparation of media and methods of sterilization; Seed viability testing, testing of pollen viability; Tissue culture of crop plants; Description of flowering plants in botanical terms in relation to taxonomy.	
<b>Suggested Readings</b>	<ul style="list-style-type: none"> <li>Furr AK. 2000. <i>CRC Hand Book of Laboratory Safety</i>. CRC Press</li> <li>Gabb MH &amp; Latchem WE. 1068. <i>A handbook of Laboratory Solutions</i>. Chemical Publ. Co.</li> </ul>	

<b>PGS -505</b>	<b>AGRICULTURE RESEARCH, RESEARCH ETHICS AND RURAL DEVELOPMENT PROGRAMMES</b>	<b>1+0</b>
<b>Objective</b>	To enlighten the students about the organization and functioning of agriculture research system at national levels, research ethics, and rural development and policies of government.	
<b>Theory</b>		
<b>UNIT I</b>	<b>History</b> of agriculture in brief ; Global agriculture research system; need, scope, opportunities; Role in promotion food security , reducing poverty and protecting the environmental ; National Agriculture Research System (NARS) AND Regional Agriculture Research institutions ; Consultative Group on international Agriculture Research (CGIAR); International Agriculture Research Centers (IARC) , partnership with NARS, role as a partner in the global agriculture research system, Strengthening capacities at national and regional levels; International fellowship for scientific mobility.	
<b>UNIT II</b>	Research ethics: research integrity , research safety in laboratories, welfare of animals used in research , computers ethics, standards and problems in research ethics.	
<b>UNIT III</b>	Concept and connotations of rural development , rural development policies and strategies , Rural development programmes ; Community development programme, Intensive Agriculture District programme, Special group – Area Specific Programme , intergrated Rural Development Programme (IRDP) Panchayati Raj institutions , Co-operatives , Voluntary Agencies/Non-Governmental Organization . Critical evolution of rural development policies and programme . Constrains in implementations of rural policies and programmes.	
<b>Suggested readings</b>	<ul style="list-style-type: none"> <li>Bhalla Gs &amp; Sing G. 2001. <i>Indian Agriculture – four Decades of Development</i>. Sage Publ.</li> <li>Punia MS. <i>Manual on international Research and Research Ethics</i>. CCS, Haryana Agriculture University , harsar.</li> <li>Rao BSV. 2007. <i>Rural Development Strategies and Role of Institutions – Issues, Innovations and Initiatives</i>. Mittal Publ.</li> </ul>	

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|  | <ul style="list-style-type: none"><li>• Sing K.. 1998. <i>Rural Development – Principal . policies and Management</i> . Sage Publ.</li></ul> |
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Course Syllabus for Ph.D. (Aquaculture), P.G. Department of Aquaculture,  
College of Fisheries (OUAT) as per the New & Restructured Post Graduate  
Curricula & Syllabi of BSMA (2020), ICAR, New Delhi

# **COURSE SYLLABUS FOR Ph.D. (AQUACULTURE)**

*(Approved vide Resolution No. -----, dt. -----of the Academic Council)*



**ODISHA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY  
BHUBANESWAR – 751 003**

**Ph. D. (Aquaculture)**  
**Course Structure and Credit Distribution**

Sl No.	Course No.	Course title	Credit Hours	Page No.
	<b>Organization of Course Contents &amp; Credit Requirements</b>			01
<b>A. MAJOR COURSES (Maximum 12 Credits to be taken)</b>				
1	AQC 601	Hi-tech Aquaculture Production Systems	2+1	
2	AQC 602	Seed Production and Hatchery Management	2+1	
3	AQC 603	Aquaculture Ecosystem Management and Climate Change	2+1	
4	AQC 604	Fish and Shellfish Physiology and Endocrinology	2+1	
<b>B Minor Courses(Maximum 06 Credits to be taken)</b>				
1	AQC 605	Feed Management in Aquaculture	1+1	
2	AQC 606	Applied Biotechnology in Aquaculture	1+1	
3	AQC 607	Automation in Aquaculture Systems	1+1	
4	AQC 608	Aquaculture Medicine	1+1	
<b>C Supporting courses (Maximum 05 Credits to be taken)</b>				
1	STAT 622	Data Analysis Using Statistical Packages	2+1	
2	MCA 612	Information Technology in Agriculture	1+1	
		<b>Total Course Credits</b>		<b>23 Credits</b>
<b>D DOCTORAL SEMINAR</b>				
				<b>02 Credits</b>
1	AQC 691	Doctoral Seminar-I	0+1	
2	AQC 692	Doctoral Seminar-II	0+1	
<b>DOCTORAL RESEARCH</b>				
				<b>75 Credits</b>
1	AQC 699	Doctoral Research (Semester II)	0+5	
2	AQC 699	Doctoral Research (Semester III)	0+15	
3	AQC 699	Doctoral Research (Semester IV)	0+15	
4	AQC 699	Doctoral Research (Semester V)	0+20	
5	AQC 699	Doctoral Research (Semester VI)	0+20	
		Total Ph.D Program Credit Hours		<b>100 Credits</b>



## ORGANISATION OF COURSE CONTENTS & CREDIT REQUIREMENT

### Course number

- All courses are divided in two series: 501- series courses pertain to Master's level, and 601- series to Doctoral level. A Ph.D. student must take a minimum of two 601 series courses, but may also take 501- series courses if not studied during Master's programme.
- Credit seminar of Master's level is designed by code number no.591, and the two seminars for Doctoral level are coded as 691 and 692 respectively.
- Similarly, 599 and 699 codes have been given for Master's Research and Doctoral research respectively.

### Courses contents

The contents of each course have been organized into:

- Objective- to elucidate the basic purpose.
- Theory units- to facilitate uniform coverage of syllabus for paper setting.
- Suggested Reading- to recommend some standard books as reference material. This does not unequivocally exclude other such reference material that may be recommended according to advancement and local requirement.
- A list of journals pertaining to the discipline is provided at the end which may be useful as study material for 601 -series courses as well as research topics.
- Compulsory courses- for quick's update on specific topics/events pertaining to the subjects.
- Broad research topic provide at the end would facilitate the advisors for appropriate research directions to the PG students.

### Minimum Credits Requirement

Course Work	Master's programme	Doctoral programme
Major Course	20	12
Minor Course	08	06
Supporting Course	06	05
Common Courses	05	-
Seminar	01	02
Thesis Research	30	75
<b>Total credits</b>	<b>70</b>	<b>100</b>

**Major subject:** The subject (department) in which the students takes admission

**Minor Subject:** The subject closely related to student major subject (e.g., if the major subject is Entomology, the appropriate minor subject should be plant pathology and Nematology).

**Supporting subject:** The subject not related to major subject. It could be any subject considered relevant for students research work.

**Common courses:** Please see the relevant section for details. Five courses (PGS 501-PGS 805) are the general nature and are compulsory for Master's programme. Ph.D. students may be exempted from these courses, if already studied during Master degree.

**Ph.D Syllabus (Revised) as per BSMA (2020)**  
**SEMESTER WISE COURSE DISTRIBUTION**

Sem.	Course No. proposed by OUAT	Course Title	Major/ Core Course Credit Hour	Minor Course Credit Hour	Supporting Course Credit hour	Common Course	Seminar	Research	
<b>I</b>	AQC 601	Hi-tech Aquaculture Production Systems	2+1	-	-	-	-	-	
	AQC 602	Seed Production and Hatchery Management	2+1	-	-	-	-	-	
	AQC 603	Aquaculture Ecosystem Management and Climate Change	2+1	-	-	-	-	-	
	AQC 605	Feed Management in Aquaculture		1+1	-	-	-	-	
	AQC 606	Applied Biotechnology in Aquaculture		1+1	-	-	-	-	
	STAT 622	Data Analysis Using Statistical Packages			2+1	-	-	-	
	<b>TOTAL</b>			<b>9</b>	<b>4</b>	<b>3</b>	<b>Nil</b>	<b>Nil</b>	<b>Nil</b>
<b>Major: 09; Minor:04</b>			<b>Supporting: 03</b>			<b>Total: 16</b>			
<b>II</b>	AQC 604	Fish and Shellfish Physiology and Endocrinology	2+1	-	-	-	-	-	
	AQC 608	Aquaculture Medicine		1+1	-	-	-	-	
	MCA 612	Information Technology in Agriculture			1+1	-	-	-	
	AQC-699	Doctoral Research				-	-	<b>0+5</b>	
	<b>TOTAL</b>			<b>03</b>	<b>02</b>	<b>02</b>	-	-	<b>05</b>
<b>Major: 03; Minor:02</b>			<b>Supporting: 02</b>			<b>Doctoral Research: 05</b>			<b>Total: 12</b>

Sem.	Course No. proposed by OUAT	Course Title	Major/ Core Course Credit Hour	Minor Course Credit Hour	Supporting Course Credit hour	Common Course	Seminar	Research
III	AQC-699	Doctoral Research	-	-	-	-	-	0+15
	<b>TOTAL</b>		-	-	-	Nil	Nil	0+15
<b>Major: 00 Minor:00</b>			<b>Supporting: 00</b>		<b>Doctoral Research: 15</b>		<b>Total: 15</b>	
IV	AQC-699	Doctoral Research	-	-	-	-	-	0+15
	<b>TOTAL</b>		-	-	-	Nil	Nil	0+15
<b>Major: 00 Minor:00</b>			<b>Supporting: 00</b>		<b>Doctoral Research: 15</b>		<b>Total: 15</b>	
V	AQC-691	Doctoral Seminar	-	-	-	-	0+1	-
	AQC-699	Doctoral Research	-	-	-	-	-	0+20
	<b>TOTAL</b>		-	-	-	-	0+1	0+20
<b>Major: 00 Minor:00</b>			<b>Supporting: 00</b>		<b>Doctoral Seminar: 01</b>		<b>Doctoral Research: 20</b>	
<b>Total: 21</b>								
VI	AQC-691	Doctoral Seminar	-	-	-	-	0+1	-
	AQC-699	Doctoral Research	-	-	-	-	-	0+20
	<b>TOTAL</b>		-	-	-	-	0+1	0+20
<b>Major: 00 Minor:00</b>			<b>Supporting: 00</b>		<b>Doctoral Seminar: 01</b>		<b>Doctoral Research: 20</b>	
<b>Total: 21</b>								

**GRAND TOTAL - 100**

Major	Minor	Supporting Courses	Common Courses	Total Course Credit	Seminar	Master's Research	Total Credit hours
12	06	05	00	23	02	75	100

## Ph.D. AQUACULTURE

### Course Contents

#### A) MAJOR COURSES

<b>AQC 601</b>	<b>HI-TECH AQUACULTURE PRODUCTION SYSTEMS</b>	<b>2+1</b>
<b>Objective</b>	To learn the advanced aquaculture production system research for different species globally	
<b>Theory</b>		
<b>Unit I</b>	<b>Introduction:</b> An overview of global aquaculture production, demand- consumption scenario and emerging trends. Present status, constraints and future prospects in India and the world. Aquaculture practices indifferent parts of the world. Enhancing carrying capacity in culture systems.	
<b>Unit II</b>	<b>Biofloc technology:</b> Principles of biofloc, different carbon sources, design of aeration system and biofloc reactor, carrying capacity, C:N ratio, harvesting of biofloc, biofloc quality and quantity, biofloc as feed ingredient, stocking of fish and shellfish species. Bioremediation in wastewater aquaculture.	
<b>Unit III</b>	<b>Minimal water exchange aquaculture systems:</b> Principles of closed system farming, RAS, components, design of mechanical and biological filters for the water reuse system, sludge removal, disposal of wastes and control of pollution to the environment, design of RAS, biofiltration and nitrifiers, suitable cultivable species for indoor culture systems, polyhouses.	
<b>Unit IV</b>	<b>Aquaponics:</b> Principles, components and design of different aquaponics systems. Components in aquaponics, ratio of fish and plants, water quality and system maintenance. Resource utilization, nutrient recycling and zero discharge of nutrients	
<b>Unit V</b>	<b>Running water systems:</b> Flow-through system, Raceways (IPR), IMTA, Partitioned Aquaculture Systems (PAS), Aqua-mimicry systems.	
<b>Unit VI</b>	<b>Other farming methods:</b> Cluster farming, organic farming, satellite farming, co-operative farming and conservation aquaculture. Network of production and marketing aspects. Economics of super intensive farming systems, advantages and disadvantages.	
<b>Practical</b>	Design, fabrication and performance evaluation of biofloc systems; Different equipment in closed grow-out system; Aerators, biofilters, RAS, Raceways, IMTA, PAS and aquaponics systems; Plankton and microbial analysis of biofloc. Studies on different C:N ratio; Nutrient analysis in aquaponics; Visit to hatcheries with super-intensive models. Identification and understanding the network of the systems; Market analysis for the produces; Analysis of economic advantages, case studies	

<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Felix, S., 2008. Biosecured Aquaculture- Principle &amp; Prototype. Agrobios (India)</li> <li>2. Avnimelech, Y., 2015. Biofloc Technology- a practical guidebook. 3rd edition. World Aquaculture Society</li> <li>3. Soderberg, R.W., 1995. Flowing water fish culture. Lewis Publishers.</li> <li>4. Tidwell, J.H. (Ed.), 2012. Aquaculture Production Systems. Wiley-Blackwell.</li> </ol>
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	5. Chakrabarti, N.M., 2014. Biology, culture and production of Indian major carps.
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<b>AQC 602</b>	<b>SEED PRODUCTION AND HATCHERY MANAGEMENT</b>	<b>2+1</b>
<b>Objectives</b>	To gain knowledge in the latest research in seed production methods for finfishes and shellfishes along with hatchery management technology.	
<b>Theory</b>		
<b>Unit I</b>	<b>Reproductive biology:</b> High value cultivable fishes, crustaceans and molluscs. Reproductive behaviour of fishes, sex determination, anatomy and morphology of reproductive organs. Gametology and factors influencing the gamete quality.	
<b>Unit II</b>	<b>Broodstock management:</b> Factors affecting the maturation and spawning of cultivable finfishes and shellfishes, nutritional and environmental requirement for brood stock and their manipulation for early maturation, criteria for the selection of brood stock, selective breeding strategies, tagging, transportation of broodstock, natural and synthetic anaesthetics for transport, vaccines and therapeutics for health management of brood stock. Brood stock quality determination and hormonal dynamics	
<b>Unit III</b>	<b>Induced Spawning:</b> Inducing agents, factors behind the development of inducing agents, Analogues development, comparative evaluation of commercially available inducing agents, artificial insemination in crustaceans and molluscs; cryopreservation of gametes and embryos in finfishes and shellfishes. Artificial fertilization protocols.	
<b>Unit IV</b>	<b>Larval Nutrition:</b> nutritional requirement of larvae and post larvae, live food culture, nutritional enrichment of live food organisms, different live feed products like powdered algae, algal paste, micronized algae, vitamin fortified algal products, formulation of artificial diets.	
<b>Unit V</b>	<b>Hatchery management:</b> Water quality management in hatcheries; physico-chemical and biological approaches; Strategies to control diseases in hatcheries, diagnosis, quarantine procedure, prebiotics, probiotics use in hatcheries, seed quality testing methods and seed certification, use of immunostimulants and immune modulators in hatcheries, SPF and SPR, effluent treatment in hatcheries, seed transportation methods.	
<b>Unit VI</b>	<b>Seed production and hatchery technology:</b> Advances in seed production of commercially important finfishes and shellfishes, artificial propagation of seaweeds (tissue culture), recent technologies for enhancing survival and growth in nurseries, nursery technology for different finfishes and shellfishes, legal issues in seed quality and marketing.	

<b>Practical</b>	Determination of brood stock quality; Quantitative and qualitative determination of fish gametes like sperm motility, viability, counts; Cryopreservation of fish and shellfish gametes;Artificial fertilization in fishes;Project preparation for constructing hatchery (freshwater fish, marine fish, shrimp, molluscs);Broodstock quarantine in hatcheries; Live feed culture; Methods to identify quality of seeds (stress test, microscopic examination);Water quality management in hatcheries; Disease identification and treatment in hatcheries;Visit to hatcheries.
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<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. FAO. 1992. <i>Manual of Seed Production of Carps</i>. FAO Publ.</li> <li>2. ICAR. 2006. <i>Hand Book of Fisheries and Aquaculture</i>. ICAR.</li> <li>3. Jhingran VG &amp; Pullin RSV. 1985. <i>Hatchery Manual for the Common, Chinese and Indian Major Carps</i>. ICLARM, Philippines.</li> <li>4. Thomas PC, Rath SC &amp; Mohapatra KD. 2003. <i>Breeding and Seed Production of Finfish and Shellfish</i>. Daya Publ.</li> <li>5. Betsy, C.J. &amp; Kumar, J.S.S., 2017. Cryopreservation and spermatology in fishes. Narendra Publishing House.</li> <li>6. Betsy, C.J. &amp; Kumar, J.S.S., 2017. Biotechnological applications in fish seed production. Narendra Publishing House.</li> <li>7. Gjedrem, T. &amp; Baranski, M., 2009. <i>Selective Breeding in Aquaculture: an Introduction</i>. Springer.</li> <li>8. Gjedrem, T. (Ed.), 2005. <i>Selection &amp; Breeding Programs in Aquaculture</i>. Springer.</li> <li>9. Hagiwara A, Snell TW, Lubzens E &amp; Tamaru CS. 1997. <i>Live Food in Aquaculture</i>. Proceedings of the Live Food and Marine Larviculture Symposium. Kluwer.</li> <li>10. Muthu MS. 1983. <i>Culture of Live Feed Organisms</i>. Tech. Paper 14. Summer Institute in Hatchery Production of Prawns Seeds. CMFRI, Cochin.</li> <li>11. Allan, G. &amp; Burnell, G., 2013. <i>Advances in aquaculture hatchery technology</i>. Woodhead Publishing Limited.</li> <li>12. Diwan, A.D., 2018. <i>Biotechnology of penaeid shrimps</i>. Narendra Publ.</li> <li>13. Gupta SD, Mohapatra PC, Routray P, Sahoo SK, Verma DK, Sarangi N. 2008. <i>Textbook of breeding and management o carps</i>. Narendra Publ. House</li> <li>14. Elsa Cabrita, Vanesa Robles, Paz Herraiez, 2015. <i>Methods in Reproductive Aquaculture</i>.</li> </ol>
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<b>AQC 603</b>	<b>AQUACULTURE ECOSYSTEM MANAGEMENT AND CLIMATE CHANGE</b>	<b>2+1</b>
<b>Objective</b>	To learn the impact of aquaculture on ecosystem management and climate change effects.	
<b>Theory</b>		
<b>Unit I</b>	<b>Aquaculture and ecosystem relationship:</b> Ecosystems and productivity, biotic interaction within ecosystems and ecological homeostasis. Climate: Weather elements of concern in aquaculture, greenhouse gases, global warming and their impact.	
<b>Unit II</b>	<b>Impact of environment on aquaculture:</b> Raw water source, physical and chemical characteristics, contaminants and pollutants (algae, pathogens, heavy metals, pesticides) and their effect on productivity.	
<b>Unit III</b>	<b>Impact of aquaculture on environment:</b> Waste water discharge, its quality and quantity, impacts of effluents on ecosystems, chemical degradation of soil and water.	
<b>Unit IV</b>	<b>Environment monitoring:</b> Problems and preventive measures of antibiotic and drug residues, salinization of soil and water, eutrophication, environment impact assessment and environmental audit.	
<b>Unit V</b>	<b>Sensor based monitoring:</b> Biosensors in aquatic environment, toxicity assessment, eco-labeling and traceability, environment management.	

<b>Unit VI</b>	<b>Environment threats:</b> 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.
<b>Practical</b>	Waste water analysis, toxicity assessment studies; Eco-labelling 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. Carbon credit/ budgeting.
<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Black, K.D., 2001. Environmental Impacts of Aquaculture. CRC Press.</li> <li>2. Phillips, B.F., Ramirez, M.P. (Eds.), 2018. Climate Change Impacts on Fisheries &amp; Aquaculture- a Global Analysis. Vol. I. Wiley Blackwell.</li> <li>3. Midlen, A. &amp; Redding, T., 1998. Environmental Management for Aquaculture. Chapman &amp; Hall.</li> <li>4. Mustafa, S. &amp; Shapawi, R. (Eds.), 2015. Aquaculture Ecosystems- Adaptability &amp; Sustainability. Wiley Blackwell.</li> <li>5. Holmer M, Black K, Duarte CM, Marba N &amp; Karakassis I. (Eds.). 2008. <i>Aquaculture in the Ecosystem</i>. Daya Publ. House.</li> <li>6. Mischke, C.C., 2014. Aquaculture Pond Fertilization - Impacts of Nutrients Input on Production.</li> <li>7. Rajagopalsamy CBT &amp; Ramadhas V. 2002. <i>Nutrient Dynamics in Freshwater Fish Culture System</i>. Daya Publ.</li> <li>8. Saha, R.K., 2013. Soil and Water Quality Management for Sustainable Aquaculture.</li> <li>9. Sharma LL, Sharma SK, Saini VP &amp; Sharma BK. (Eds.). 2008. <i>Management of Freshwater Ecosystems</i>. Agrotech Publ. Academy.</li> </ol>

<b>AQC 604</b>	<b>FISH AND SHELL FISH PHYSIOLOGY AND ENDOCRINOLOGY</b>	<b>2+1</b>
<b>Objective</b>	To gain knowledge and physiological aspects on finfish and shellfish endocrinology	
<b>Theory</b>		
<b>Unit I</b>	<b>Endocrine system:</b> Endocrine glands in fishes, hormones and their kinetics. Structure and function of neuro-endocrine system in finfish and shellfish. Hormonal control of physiology.	
<b>Unit II</b>	<b>Hormones:</b> Chemical nature of hormones, synthesis, storage, release and control of hormones, homeostasis, endocrine control of growth and metabolism in fishes, exogenous hormone administration, implication, impact on the general health and wellbeing of fishes.	
<b>Unit III</b>	<b>Influence of hormones:</b> Eco-physiology, adaptive mechanisms –reversible & irreversible changes, physiology of migration and behaviour.	
<b>Unit IV</b>	<b>Neurophysiology:</b> Neurosecretory system in fishes, crustaceans and molluscs, neurotransmitters, physiology of ecdysis.	
<b>Unit V</b>	<b>Reproductive physiology:</b> Endocrine control of maturation, spermatogenesis, oogenesis, spawning vitellogenesis.	
<b>Unit VI</b>	<b>Respiratory physiology:</b> gas exchange concept, excretion and	



	osmoregulation.
<b>Practical</b>	Dissection of finfish and shellfish to study endocrine glands, Hormone assay – ELISA, Histological techniques to study reproductive and endocrine glands, Identification of moult stages, Application of respirometer and osmometer.

<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Hoar, W.S. &amp; Randall, D.J., 2014. Fish Physiology Vol. 2 The Endocrine System. Academic Press</li> <li>2. Hoar, W.S., Randall, D.J. &amp; Donaldson, E.M., 2014. Fish Physiology Vol. 9A Reproduction: Endocrine Tissues &amp; Hormones. Academic Press</li> <li>3. Hoar, W.S., 2014. Fish Physiology Vol. 9B. Academic Press</li> <li>4. Hoar, W.S. &amp; Randall, D.J., 2014. Fish Physiology Vol. 4 The Nervous System, Circulation &amp; Respiration. Academic Press</li> <li>5. Sherwood, N.M. &amp; Hew, C.L., 2014. Fish Physiology Vol. 13. Molecular Endocrinology of fish. Academic Press</li> <li>6. Norris, D.O. &amp; Lopez, K.H., 2011. Hormones &amp; Reproduction of Vertebrates. Vol. I Fishes. Academic Press.</li> <li>7. Babin PJ, Lubzens E. 2007. The fish oocyte: from basic studies to biotechnological applications. Springer Publ.</li> <li>8. Bernier NJ, Van Der Kraak G, Farrell AP, Brauner CJ. 2014. Fish neuroendocrinology. Fish physiology series Vol. 2, Elsevier Publ.</li> <li>9. Diwan AD. 2018. Biotechnology of penaeid shrimps. Narendra Publ.</li> <li>10. Farrell AP 2011. Encyclopedia of fish physiology Vol. I-III. Academic Press.</li> <li>11. Hara TJ &amp; Zielinski BS. 2014. Sensory systems neuroscience. Fish physiology series Vol. 25, Elsevier Publ.</li> <li>12. Modayil MJ &amp; Diwan AD. 2007. Physiology of marine white shrimp <i>Litopenaeus setiferus</i>. Fenneropenaeus indicus.</li> <li>13. Perry SF, Tufts BL. 2014. Fish respiration, Fish physiology series, Vol. 17. Elsevier Publ.</li> <li>14. Reinecke, M., Giacomo, S., Kapoor, B.G., 2006. Fish Endocrinology. CRC Press.</li> <li>15. Samantaray, K., 2015. Physiology of finfish and shellfish. New India Publ. Agency</li> <li>16. Shashikala K.B., Sahoo A.K., 2018. Histology of Indian Major Carps - A Colour Atlas.</li> </ol>
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## B) MINOR COURSES

<b>AQC 605</b>	<b>FEED MANAGEMENT IN AQUACULTURE</b>	<b>1+1</b>
<b>Objective</b>	To learn the latest research in the lines of Understanding the influence of environment on nutrient utilization	
<b>Theory</b>		
<b>Unit I</b>	<b>Nutrient dynamics:</b> Influence of nutrient cycles on web/chain. Influence of detrital food web on nutrient distribution. Nutrient loading through feed and fertilizer. Natural feed augmentation for increasing fish production, Different food chains in aquatic ecosystem, Feeding behavior and feeding niche, Effect of environmental parameters on appetite of fish.	
<b>Unit II</b>	<b>Eco-friendly feed:</b> Use of exogenous phytase and acidifiers, high energy diets, methods of enhancing feed digestibility, biofloc and probiotics influences.	
<b>Unit III</b>	<b>Nutritional pathology:</b> Deficiency and imbalance diseases: essential amino acids, essential n-3 and n-6 fatty acids deficiencies. Micronutrients: fat-soluble vitamins, water-soluble vitamins; macro- elements, trace-elements and mineral toxicity. influence of stress on feed intake, digestion and absorption. Stress indicators and nutritional strategies for mitigate stress.	
<b>Unit IV</b>	<b>Feed Management:</b> Impact of feed and nutrition on environment, Nutrients affecting the water quality. Nutritional strategies to reduce the nutrient flow in aquaculture system, Contribution of feed waste to organic load of aquaculture production systems. Role of additives in reducing environmental pollution.	
<b>Practical</b>	Practical Study of influence of thermal stress, hypoxia, salinity and pH. Stress enzyme. (LDH, catalase, SOD, glutathione peroxidase), stress hormone (cortisol) and sex steroid hormone.	
<b>Suggested readings</b>	<ol style="list-style-type: none"> <li>1. ADCP (Aquaculture Development and Co-ordination Programme). 1980. Fish Feed Technology. ADCP/REP/80/11.F.A.O., Rome.</li> <li>2. De Silva, S. S. and Anderson, T. A. 1995. Fish Nutrition in Aquaculture Chapman and Hall Aquaculture Series, London.</li> <li>3. Guillame, J., Kaushik, S., Berqot, P. and Metallier, R. 2001. Nutrition and Feeding of Fish and Crustaceans. Springer Praxis Publishing, Chichester, U. K.</li> <li>4. Halver, J. E. 1989. Fish Nutrition, Academic Press, San Diego, California.</li> <li>5. Halver, J. E and Tiews, K. T. 1979. Finfish Nutrition and Fishfeed Technology Vol. I and II. Heenemann, Berlin.</li> <li>6. Halver, J. E. and Hardy, R. W. 2002. Fish Nutrition. Academic Press, London.</li> <li>7. Hopher, B. 1988. Nutrition of Pond Fishes. Cambridge University Press, Cambridge.</li> <li>8. Lovell, R. T. 1998. Nutrition and Feeding of Fishes. Kluwer Academic Publishers.</li> </ol>	

<b>AQC 606</b>	<b>APPLIED BIOTECHNOLOGY IN AQUACULTURE</b>	<b>1+1</b>
<b>Objective</b>	To learn about applied biotechnology aspects in aquaculture.	
<b>Theory</b>		
<b>Unit I</b>	<b>Introduction:</b> Scope of biotechnology in fisheries and aquaculture research. Vaccination in fishes- DNA vaccines, sub UNIT vaccines and Biofilm Vaccines.	
<b>Unit II</b>	<b>Feed biotechnology:</b> Probiotics, single cell proteins, Nutraceuticals, Gnotobiotics. Recombinant proteins of commercial importance: enzymes, hormones, bioactive compounds, therapeutic proteins. Anti-microbial Peptides and their applications.	
<b>Unit III</b>	<b>Environmental Biotechnology:</b> Bioremediation, biosensors, biofouling, treatment of waste water. Applications of biotechnological tools: Transgenic technology, Recombinant DNA, Monoclonal antibodies, Cell lines and stem cell culture, DNA markers and MAS. Biotechnological instrumentation in Aquaculture.	
<b>Unit IV</b>	<b>Constraints and Limitations:</b> Biochemical and Molecular Markers; Commercial applications of Fish Biotechnology; Government regulation of Transgenic fish & Biotechnology products.	
<b>Practical</b>	Cell culture and cell lines; Development of hybridoma and production of monoclonal antibodies; Preparation of chromosomes from embryos and young fish. Ploidy determination by RBC measurement and chromosome numbers; DNA markers; Gene transfer experiments; Northern blotting and southern blotting for integration and expression of transgenes.	
<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Fletcher, G.L., Rise, M.L., 2012. Aquaculture Biotechnology. Wiley Blackwell.</li> <li>2. Felix, S. &amp; Ninawe, A.S., 2014. Aquaculture Biotechnology. Daya Publishing House.</li> <li>3. Betsy, C.J. &amp; Kumar, J.S.S., 2017. Biotechnological applications in fish seed production. Narendra Publishing House.</li> <li>4. Montet, D. &amp; Ray, R.C., 2009. Aquaculture Microbiology &amp; Biotechnology. Vol. 1. Science Publishers.</li> <li>5. Gautam, N.C., 2007. Comprehensive Biotechnology- Vol. 4 Aquaculture Biotechnology. Shree Publishers &amp; Distributors</li> <li>6. Sunita, R., 2015. Fish Biotechnology. Random Publications.</li> <li>7. Diwan AD. 2018. <i>Biotechnology of penaeid shrimps</i>. Narendra Publ.</li> <li>8. Greglutz C. 2001. <i>Practical genetics for aquaculture</i>. Wiley Blackwell Publ.</li> <li>9. Lakra WS, Abidi, SAH, Mukherjee, SC, Ayyappan S. 2014. <i>Fisheries biotechnology</i>.</li> <li>10. Preethi Kartan, 2017. <i>Aquaculture Biotechnology</i></li> <li>11. Richard Reece, 2017. <i>Analysis of genes and genomes</i>.</li> <li>12. Se-Kwon Kim, 2017. <i>Springer handbook of marine biotechnology</i>.</li> </ol>	

<b>QC 608</b>	<b>AQUACULTURE MEDICINE</b>	<b>1+1</b>
<b>Objective</b>	To know about the medicines used for finfish and shell fish, pharmacology and toxicology aspects and common health management strategies in aquaculture	
<b>Theory</b>		
<b>Unit I</b>	<b>Principles of disease management in aquaculture:</b> Case studies, sign and symptoms, diagnosis, pathogenesis, epidemiology, health management strategies	
<b>Unit-II</b>	<b>Prevention and control of diseases in aquaculture:</b> Vaccination, immunostimulation, bioremediation, disinfection, chemotherapy, immunotherapy	
<b>Unit III</b>	<b>Pharmacology and toxicology in aquaculture:</b> Pharmacokinetics, pharmacodynamics, mode of action of different classes of antibiotics, bioavailability, antibiotic resistance, adverse drug effect, fundamentals of toxicology, toxins and pesticides in aquaculture, adverse effects of toxicities, Bioaccumulation of toxicities.	
<b>Unit IV</b>	<b>Medicines in aquaculture:</b> Anaesthetics, Hormones, feed additives, growth promoters, immunomodulators, probiotics, disinfectants, chemicals, antibiotics, antifungals, antiparasitic, antiviral agents used in aquaculture, their methods of use and dose calculations, permissibility, regulatory authorities for aquaculture medicines.	
<b>Practical</b>	Level II and level III diagnosis, Estimation of dose of chemicals and antibiotics, Antibiotic sensitivity test, Estimation of antibiotic residues, Detection of gut colonization by probiotic bacteria, Estimation of residual toxicity, Visit to pharmaceutical industries	
<b>Suggested Readings</b>	<ol style="list-style-type: none"> <li>1. Treves-Brown KM. 2013. Applied fish pharmacology (Vol. 3).Springer Science &amp; Business Media.</li> <li>2. Brunton LL. (Ed). 2005. Goodman and Gilman's The Pharmacological Basis of Therapeutics.11th Ed. McGraw-Hill.</li> <li>3. Riviere JE &amp;Papich MG. (Eds.). 2013. Veterinary pharmacologyand therapeutics 9th ed. John Wiley &amp; Sons.</li> <li>4. Sandhu HS &amp;Rampal S. 2006. Essentials of Veterinary Pharmacology and Therapeutics. 1st Ed. KalyaniPublishers.</li> <li>5. Andrews C, Excell A &amp; Carrington N. 1988. The Manual ofFish Health. Salamander Books.</li> </ol>	

### C) SUPPORTING COURSES

<b>STAT 622</b>	<b>Data Analysis Using Statistical Packages</b>	<b>2+1</b>
<b>Objective</b>	This course is meant for exposing the students in the usage of various statistical packages for analysis of data. It would provide the students a hands on experience in the analysis of their research data. This course is useful to all disciplines.	
<b>Theory</b>		
Unit I	Introduction to various statistical packages: Excel, R, SAS, SPSS. Data Preparation; Descriptive statistics; Graphical representation of data, Exploratory data analysis.	
Unit II	Test for normality; Testing of hypothesis using chi-square, t and F statistics and Z-test.	
Unit III	Data preparation for ANOVA and ANCOVA, Factorial Experiments, contrast analysis, multiple comparisons, Analyzing crossed and nested classified designs.	
Unit IV	Analysis of mixed models; Estimation of variance components; Correlation and regression analysis, Probit, Logit and Tobit Models.	
Unit V	Discriminant function; Factor analysis; Principal component analysis; Analysis of time series data, Fitting of non-linear models; Neural networks.	
Unit VI	<ul style="list-style-type: none"> <li>• Use of software packages for summarization and tabulation of data, obtaining descriptive statistics, graphical representation of data;</li> <li>• Testing the hypothesis for one sample t-test, two sample t-test, paired t-test, test for large samples - Chi-squares test, F test, one-way analysis of variance;</li> <li>• Designs for Factorial Experiments, fixed effect models, random effect models, mixed effect models, estimation of variance components;</li> <li>• Linear regression, Multiple regression, Regression plots;</li> <li>• Discriminant analysis - fitting of discriminant functions, identification of important variables;</li> <li>• Factor analysis. Principal component analysis - obtaining principal component.</li> </ul>	
Practical	<ul style="list-style-type: none"> <li>• Use of software packages for summarization and tabulation of data, obtaining descriptive statistics, graphical representation of data;</li> <li>• Testing the hypothesis for one sample t-test, two sample t-test, paired t-test, test for large samples - Chi-squares test, F test, one-way analysis of variance;</li> <li>• Designs for Factorial Experiments, fixed effect models, random effect models, mixed effect models, estimation of variance components;</li> <li>• Linear regression, Multiple regression, Regression plots;</li> <li>• Discriminant analysis - fitting of discriminant functions, identification of important variables;</li> <li>• Factor analysis. Principal component analysis - obtaining principal component.</li> </ul>	

Suggested Readings	<ul style="list-style-type: none"> <li>• Anderson C.W. and Loynes R.M. 1987. The Teaching of Practical Statistics. John Wiley.</li> <li>• Atkinson A.C. 1985. Plots Transformations and Regression. Oxford University Press.</li> <li>• Chambers J.M., Cleveland W.S., Kleiner B and Tukey P.A. 1983. Graphical Methods for Data Analysis. Wadsworth, Belmont, California.</li> <li>• Chatfield C. 1983. Statistics for Technology. 3rd Ed. Chapman &amp; Hall. Chatfield C. 1995. Problem Solving: A Statistician's Guide. Chapman &amp; Hall.</li> <li>• Cleveland W.S. 1985. The Elements of Graphing Data. Wadsworth, Belmont, California.</li> <li>• Ehrenberg ASC. 1982. A Primer in Data Reduction. John Wiley.</li> <li>• Erickson B.H. and Nosanchuk T.A. 1992. Understanding Data. 2nd Ed. Open University Press, Milton Keynes.</li> <li>• Snell E.J. and Simpson HR. 1991. Applied Statistics: A Handbook of GENSTAT Analyses. Chapman and Hall.</li> <li>• Sprent P. 1993. Applied Non-parametric Statistical Methods. 2nd Ed. Chapman &amp; Hall.</li> <li>• Tufte ER. 1983. The Visual Display of Quantitative Information. Graphics Press, Cheshire, Conn.</li> <li>• Velleman PF and Hoaglin DC. 1981. Application, Basics and Computing of Exploratory Data Analysis. Duxbury Press.</li> <li>• Weisberg S. 1985. Applied Linear Regression. John Wiley.</li> <li>• Wetherill GB. 1982. Elementary Statistical Methods. Chapman &amp; Hall.</li> <li>• Wetherill GB. 1986. Regression Analysis with Applications. Chapman &amp; Hall.</li> <li>• Cleveland WS. 1994. The Elements of Graphing Data, 2nd Ed., Chapman &amp; Hall</li> <li>• <a href="http://freestatistics.altervista.org/en/learning.php">http://freestatistics.altervista.org/en/learning.php</a>.</li> <li>• <a href="http://freestatistics.altervista.org/en/stat.php">http://freestatistics.altervista.org/en/stat.php</a>.</li> <li>• <a href="http://www.cas.lancs.ac.uk/glossary_v1.1/main.html">http://www.cas.lancs.ac.uk/glossary_v1.1/main.html</a>.</li> <li>• <a href="http://www.stat.sc.edu/~grego/courses/stat706/">http://www.stat.sc.edu/~grego/courses/stat706/</a>.</li> <li>• <a href="http://www.drs.icar.gov.in">www.drs.icar.gov.in</a></li> </ul>
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<b>MCA 612</b>	<b>Information Technology in Agriculture</b>	<b>1+1</b>
<b>Objective</b>	This is a course on Introduction to Networking and Internet Applications that aims at exposing the students to understand analogy of computer, basic knowledge of MS Office. Also to understand Internet and WWW, use of IT application and different IT tools in Agriculture	
<b>Theory</b>		
Unit I	Introduction to Computers, Anatomy of computer, Operating Systems, definition and types, Applications of MS Office for document creation &	

	Editing, Data presentation, interpretation and graph creation, statistical analysis, mathematical expressions,
Unit II	Database, concepts and types, uses of DBMS in Agriculture, World Wide Web (WWW): Concepts and components, Introduction to computer programming languages, concepts and standard input/output operations. e-Agriculture, concepts and applications.
Unit III	Use of ICT in Agriculture, Computer Models for understanding plant processes. IT application for computation of water and nutrient requirement of crops, Computer controlled devices (automated systems) for Agri-input management, Smartphone Apps in Agriculture for farm advises, market price, postharvest management etc.
Unit IV	Geospatial technology for generating valuable agri-information. Decision support systems, concepts, components and applications in Agriculture, Agriculture Expert System, Soil Information Systems etc. for supporting Farm decisions, Preparation of contingent crop-planning using IT tools.
Suggested Readings	<ul style="list-style-type: none"> <li>• Vanitha G. 2011. Agro-informatics</li> <li>• <a href="http://www.agrimoon.com">http://www.agrimoon.com</a></li> <li>• <a href="http://www.agriinfo.in">http://www.agriinfo.in</a></li> <li>• <a href="http://www.eagri.org">http://www.eagri.org</a></li> <li>• <a href="http://www.agriglance.com">http://www.agriglance.com</a></li> <li>• <a href="http://agritech.tnau.ac.in">http://agritech.tnau.ac.in</a></li> </ul>

### **List of suggested Journals**

- Aquaculture
- Aquacultural Engineering
- Aquaculture International
- Aquaculture Nutrition
- Aquaculture Research
- Reviews in Aquaculture
- Aquaculture Economics and Management
- Journal of the World Aquaculture Society
- Journal of Fish Diseases
- Fisheries Science
- Fisheries Research
- Fish and Fisheries
- Fish and Shellfish Immunology
- Fisheries Management and Ecology
- FEMS Microbiology Ecology
- FEMS Microbiology Letters
- Current Science
- Canadian Journal of Fisheries and Aquatic Sciences
- British Journal of Environment and Climate Change
- Biotechnology Letters
- Asian Fisheries Science
- Asian Journal of Animal Sciences
- Aquatic Sciences
- Aquatic Toxicology
- African Journal of Aquatic Science
- Turkish Journal of Fisheries and Aquatic Sciences
- Indian Journal of Animal Nutrition
- Journal of Fish Physiology and Biochemistry
- Journal of Applied Ichthyology
- Journal of Aquaculture in Tropics
- Journal of Aquatic Living Resources
- Journal of Biotechnology
- Journal of Fish Physiology and Biochemistry
- Annual Review of Nutrition
- Annual Review of Physiology
- Journal of Plankton Research
- Water Research
- World Journal of Microbiology and Biotechnology
- Ecotoxicology and Environmental Safety
- Environment and Ecology
- Environmental Pollution
- Environmental Science



- Environmental Studies
- Environmental Technology
- Environmental Toxicology
- Indian Journal of Agricultural Statistics
- Indian Journal of Cytology and Genetics
- Indian Journal of Genetics and Plant Breeding
- Indian Journal of Statistics
- Journal of Animal Breed and Genetics
- Journal of Animal Science
- Journal of Applied Statistics
- Indian Journal of Fisheries
- Indian Journal of Experimental Biology
- Indian Journal of Entomology
- Indian Journal of Animal Research
- Indian Journal of Animal Sciences
- Journal of Statistical Software
- Statistics Education
- Indian Journal of Agricultural Economics
- Indian Journal of Agricultural Marketing
- Indian Journal of Pharmacology
- International Journal for Parasitology
- Journal of Applied Microbiology
- Journal of Aquatic Animal Health

### **List of suggested e-Resources**

- <https://www.icar.org.in/>
- <http://www.fao.org/home/en/>
- <https://www.worldfishcenter.org/>
- <http://epubs.icar.org.in/ejournal/>
- [https://lib.icar.gov.in/full\\_text\\_ebooks.html](https://lib.icar.gov.in/full_text_ebooks.html)
- [https://lib.icar.gov.in/Open\\_Access\\_Journal.html](https://lib.icar.gov.in/Open_Access_Journal.html)
- <https://www.aquaculturealliance.org/>
- <https://www.sciencedirect.com/>
- <http://www.ciba.res.in/>
- <http://www.cmfri.org.in/>
- <http://www.cife.edu.in/>
- <http://cifa.nic.in/>
  
- <http://www.nbfgr.res.in/> <http://www.dcfrr.res.in/>
- <http://www.cift.res.in/>
- <http://www.tnifu.ac.in/>
- <https://www.was.org/>

- <https://www.asianfisheriessociety.org/>
- <https://www.aquaeas.eu/>
- <https://www.curtin.edu.au/>
- <https://www.tp.edu.sg/>
- <https://www.arizona.edu/>
- <https://mpeda.gov.in/MPEDA/>
- <http://dof.gov.in/>
- <http://www.caa.gov.in/>
- <http://www.fao.org/fishery/statistics/en>
- <http://kufos.ac.in/>
- <http://www.auburn.edu/>
- <https://www.ugent.be/en>

### **Broad Areas for Master's and Doctoral Research**

- Recirculating aquaculture systems (RAS)
- Development of genetically improved broodstock
- Cryopreservation of gametes and embryos
- Development of vaccines for larvae
- Renewable energy in aquaculture
- Replacement of fish meal ingredient in shrimp and fish feed
- Development of novel feed ingredients
- Ontogeny of digestive system in fish larvae
- Cell lines and stem cell culture
- Inland saline aquaculture
- Dessert Aquaculture
- Arid land aquaculture
- Defense mechanisms and immunity
- Cage and pen culture of marine finfishes
- Study of nutrient dynamics in ponds
- Nutraceuticals for aquaculture feed
- Impact of climate change in aquaculture
- Statistical tools in Aquaculture
- Microbiomes in host environment interactions
- Status of seafood consumption and promotion
- Climate resilient aquaculture
- Carrying capacity and environmental impact in aquaculture
- Development of high resistant materials in the fabrication of cages
- Designing the cost effective probes for the water management
- Automation in aquaculture
- Development or restructuring of the aquaculture systems
- Integration of ANNAMOX nitrogen removal
- Nitrogen removal using Heterotrophic bacteria
- Algal culture and its impact in aquaculture systems

- Development of innovative and advanced filters and sludge units
- Open Ocean Aquaculture
- Aquaponics
- Open water IMTA and land-based IMTA
- Breeding and seed production of new candidate species
- Natural history of the cultured animal throughout its life stages.
  - Biology of the cultured animal in terms of an aquaculture perspective
  - The management of microbiome in the gut of the fish
  - Novel and rapid diagnostic methods for the emerging diseases of commercial importance in Aquaculture
  - Hi-Tech Aquaculture systems
  - control in feed and feed supplements
  - Nutritional requirement of commercially important fishes
  - Precision farming in Aquaculture
  - Development of Phyto-genic compounds to combat the diseases
  - Electron-beam irradiation for the major deactivation of anti-nutritional factors.
  - Supplementation of Exogenous enzymes to remove anti-nutritional factors
  - Supplementation of nutraceuticals in mitigating multiple stressors
  - The stress management strategies of super intensive culture
  - The Nutrigenomic studies involving transcriptomics, proteomics and metabolomics
  - Evaluating flesh quality using different feed supplements.
  - Altering the dietary protein/energy ratio to increase the product shelflife.
  - Integration of proteomic approaches with genomics and transcriptomics is the need of the hour.
  - Bioinformatic capabilities to integrate omics technologies with aquaculture.
  - Germplasm study and the analysis of the genetic diversities
  - Larval fish nutrition
  - Impact of aquaculture amendments
  - Organic aquaculture
  - Impact of Algal driven aquaculture
  - Soil and water quality management
  - Functional feed ingredient supplements in aquaculture
  - Physiology of the major organs in finfishes and shellfishes
  - Gene expression on growth stimulating factors in fishes
  - Induce breeding and sex reversal
  - Bioremediation and waste management
  - Importance of fermentation and fermented products in aquaculture

- Micro and trace minerals requirements for the commercial candidate species
- Development of phyto sanitary measures and Standard operating procedures
- Disease surveillance, forecasting and development of field level diagnostic kits.
- Pigment enhancement studies in Ornamental aquaculture
- Hybridization of cultivable species
- Participatory aquaculture development models
- Control of cyanobacteria in aquaculture systems
- Bio-enrichment of live feed
- Microscopic studies on the microbial community
- Pharmacodynamics of drugs in fish, drug delivery systems, excretion of drugs, residual assays, herbal compounds as therapeutic drugs
- Characterization of parasites infecting fish and shellfish
- Host-parasite relation of various parasites and their biology
- Therapeutic approaches for control of infections
- Histopathological investigations of specific disease conditions
- Economic analysis of aquaculture practices
- Development of tissue specific cell expression systems
- Genetically engineered microorganisms for recombinant protein production
- Design of viral vectors for efficient gene delivery
- Digestibility due to plant to animal ingredient ratio
- Enhancement of digestibility of plant feed ingredients