OUTCOME BASED EDUCATION (OBE)

CURRICULUM BASED SYLLABUS IN M.Sc.

MARINE BIOLOGY PROGRAMME

Department of Marine Biology, Microbiology and Biochemistry

School of Marine Sciences

Cochin University of Science and Technology,

Fine Arts Avenue, Kochi-682016, Kerala, India

2024

INDEX

ELECTIVE COURSES			
Elective courses offered by Dept. of Marine Biology, Microbiologyand Biochemistry	24-315-0106	Planktonology	40
	24-315-0107	Coral Reef Ecology	42
	24-315-0108	Ornamental Fish Culture	44
	24-315-0109	Biological Oceanography	46
	24-315-0110	Applied Molecular Biology	48
	24-315-0207	Aquarium Plants and Cultureof Fish Food Organisms	50
	24-315-0208	Marine ConservationBiology	52
	24-315-0209	Ornamental Fish Culture and Live Feed Organisms -Practical	53
	24-315-0210	Discovery of Marine drugs and Nutraceuticals	54
	24-315-0211	Marine Genomics	57
	24-315-0307	Seafood Microbiology andQuality Control	58
	24-315-0308	Marine Botany	60
	24-315-0309	Health management in aquaculture	63
	24-315-0310	Advanced Taxonomy and Phylogenetics of Marine Organisms	65
Elective course offered by SWAYAM	24-315-0402	MOOC	
Elective courses offered by other Departments		General Oceanography	
		Marine Geology	
		Chemical Oceanography	
		General Chemical Oceanography-Practical	
		Statistics-Practical	

OUTCOME BASED EDUCATION (OBE), CURRICULUM BASED SYLLABUS FOR M.Sc. MARINE BIOLOGY PROGRAMME

BACKGROUND

OUTCOME

UGC has made it mandatory to follow the system of Choice Based Course (CBC) and Outcome Based Education (OBE), as our UG courses with fairly well updated contents have been under choice based credit and semester system. Although their overall standard is quite good, their structure, composition, procedures and credit administration are to be further fine tuned to incorporate the features of OBE. Courses are well designed instruction packages in specific knowledge fields, with preconceived results that go into the making of the outcome of the Academic Programme. They are scientifically structured with insights of continuity, sequence, and integration, appropriate for effective learning. Workshops are organized in different universities in the state in this direction for the Board of Studies for redesigning the courses at the UG/PG level.

A high priority task in the context of future education development agenda in India is fostering quality higher education. Further improvement of quality of higher education is considered critical for enabling effective participation of young people in knowledge production and participation in the knowledge economy, improving national competitiveness in a globalized world and for equipping young people with skills relevant for global and national standards and enhancing the opportunities or social mobility. Sustained initiatives are required for institutionalizing an outcome- oriented higher education system and enhancing employability of graduates through curriculum reform based on a learning outcomes-based curriculum framework, improving/upgrading academic resources and learning environment, raising the quality of teaching and research across all higher education institutions; technology use and integration to improve teaching-learning processes and reach a larger body of students through alternative learning modes such as open and distance learning modes and use of MOOCs (massive open online courses). Other priority areas of action for fostering quality higher education include translation of academic research into innovations for practical use in society and economy, promoting efficient and transparent governance and management of higher education system, enhancing the capacity of the higher education system to govern itself through coordinated regulatory reform and increasing both public and private sector investment in higher education, with special emphasis on targeted and effective equity-related initiatives (https://www.ugc.ac.in/.)

India's National MOOC platform 'SWAYAM' (Study Webs of Active–Learning for Young Aspiring Minds) was launched in July 2017. The objective of the programme is to make available the best teaching learning resources of an Institution to all, including the most disadvantaged. As per the UGC (Credit Framework for online learning courses through SWAYAM) Regulation 2016, Universities can identify courses where credits can be transferred on to the academic record of the students for courses done on SWAYAM. Up to 20% of the total credit in each semester can be based on online courses offered through

SWAYAM Platform (www.swayam.gov.in). Courses delivered through SWAYAM are available free of cost to the learners, and students are advised to register for the final proctored exams, some of which come at a fee and attend in person at designated centres on specific dates, so as to get SWAYAM certificate. Universities/colleges approving credit transfer for these courses can use the marks/certificate obtained in these courses for the same. With this prelude, the curriculum based syllabus MSc Marine Biology course is amended based on the Outcome Based Education.

Program Outcomes (PO)

PO 1	Bridging the knowledge of basic sciences and technologies to understand marine ecosystem
PO 2	Problem analysis: Identify, formulate, research and analyze
PO 3	Develop analytical and computational skills to address challenges in environmental issues

Program Specific Outcomes (PSO)

PSO 1	Develop knowledge on the operation of analytical equipments and onboard equipments for collection of water, sediment and biological samples
PSO 2	Create skills on the characterization of various microbes, phytoplankton, zooplankton, benthos, fish and shellfish
PSO 3	Apply skills to identify and culture microalgae for hatchery rearing of fish and shellfish larvae
PSO 4	Create knowledge and skills in aquaculture as well as the diseases in culture system so as to become employed in the aquaculture and seafood industry
PSO 5	Develop skills in biochemistry, cytology, genomics, microbiology and molecular biology
PSO 6	Apply the knowledge and skills developed on marine biodiversity and pollution to conserve the marine environment and biota
PSO 7	Prepare students in undertaking research in all areas of Marine Biology

Mapping of Programme Outcomes (POs) and Programme Specific Outcomes (PSOs)

Programme Outcomes (POs)	**Programme Specific Outcomes (PSOs)**						
	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
PO1	2	3	1	1	3	2	3
PO2	3	1	2	2	2	2	3
PO3	1	2	3	3	2	3	2

Note: Correlations Levels: 1 = Low, 2 = Medium, 3 = High

Faculty of Marine Sciences

Dept. of Marine Biology, Microbiology and BiochemistryCochin University of Science and Technology

Scheme & Syllabus applicable from 2020 admission

Semester I

CourseCode	Course	C/E	Credits	Internal Marks	External Marks	Total
24-315-0101	Marine Biology	C	3	50	50	100
24-315-0102	Cytology and Fish Genetics	C	3	50	50	100
24-315-0103	Biochemistry	C	3	50	50	100
24-315-0104	Marine Biology Practical	C	2	100	-	100
24-315-0105	Biochemistry and Instrumentation-Practical	C	2	100	-	100
24-315-0106	Planktonology	E	2	50	50	100
24-315-0107	Coral Reef Ecology	E	2	50	50	100
24-315-0108	Ornamental Fish culture	E	2	50	50	100
24-315-0109	Biological Oceanography	E	2	50	50	100
24-315-0110	Applied Molecular Biology	E	2	50	50	100

Semester 2

Course Code	Course	C/E	Credits	Internal Marks	External Marks	Total
24-315-0201	Marine Microbiology	C	3	50	50	100
24-315-0202	Fish and Fisheries	C	3	50	50	100
24-315-0203	Marine Pollution	C	3	50	50	100
24-315-0204	Marine Biotechnology	C	3	50	50	100
24-315-0205	Marine	C	2	100	-	100

	Microbiology and Biotechnology – Practical					
24-315-0206	Fish and Fisheries – Practical	C	2	100	-	100
24-315-0207	Aquarium plants and culture of live feed organisms	E	2	50	50	100
24-315-0208	Marine Conservation Biology	E	2	50	50	100
24-315-0209	Ornamental fish culture and live food organisms- Practical	E	2	100	-	100
24-315-0210	Discovery of Marine drugs and Nutraceuticals	E	2	50	50	100
24-315-0211	Marine Genomics	E	2	50	50	100

Semester 3

Course Code	Course	C/E	Credits	Internal Marks	External Marks	Total
24-315-0301	Fish Pathology	C	3	50	50	100
24-315-0302	Aquaculture	C	3	50	50	100
24-315-0303	General Animal Physiology	C	3	50	50	100
24-315-0304	Marine Ecology	C	3	50	50	100
24-315-0305	Marine Ecologyand Aquaculture – Practical	C	2	100	-	100
24-315-0306	Fish Physiologyand Pathology – Practical	C	1	100	-	100
24-315-0307	Seafood Microbiologyand Quality Control	E	2	50	50	100
24-315-0308	Marine Botany	E	2	50	50	100

24-315-0309	Health Management in Aquaculture	E	2	50	50	100
24-315-0310	Advanced Taxonomy and Phylogenetics of Marine Organisms	E	2	50	50	100

Semester 4

CourseCode	Course	C/E	Credits	Internal Marks	External Marks	Total
24-315-0401	Project work and Dissertation	C	16	50	50	100
24-315-0402	MOOC	E	2	-	100	100

Credit Distribution of M.Sc. Marine Biology

Sl. No.	Courses	CC/EC	No. of Courses	Credit Per Course	Total Credit
1	Core Courses (other than Project and Dissertation)	CC	11	3	33
2	Core Courses (Lab)	CC	7	2	14
3	Elective Courses (including MOOC course)	EC	4	2	8
4	Elective Courses (interdepartmental)	EC	3	3	9
5	Project work and Dissertation	CC	1	16	16
	Total Courses	-	26	-	80

Note: CC – Core courses and EC – Elective Courses

There are 18 core subjects and 20 electives, which are interdisciplinary in nature. A student shall register for a minimum of 56 credits in the first three semesters before he/she registers for the fourth semester. Accumulated minimum credit required for successful completion of the programme is 72 credits.

***** The student has to devote the fourth semester on dissertation work related to a relevant area of specialization either in the Department or in an industrial/ research/ academic institution outside the University. All the students have to submit a project dissertation at the end of the fourth semester.

******In addition, it is mandatory for the students to register for a suitable MOOC (as recommended by the faculty members of the department from time to time), available in the SWAYAM platform (www.swayam.gov.in)The students can avail the courses at any time

during the first three semesters, based on the availability of suitable courses at www.swayam.gov.in and should procure the required credits for MOOC before completion of the fourth semester. Grading of MOOC will be decided by the Department council and University based on the results obtained from www.swayam.gov.in

The award of a maximum 100 marks for the project dissertation to a student is based on:

A) *Continuous assessment by his/her guide based on his/her performance and progress during the dissertation work will carry a maximum of 50 marks.*

B) *The Project dissertation submitted by the student at the end of the semester will be evaluated internally for a maximum of 50 marks.*

Equal weightage shall be given for the continuous assessment and the end semester components.

Grading Scale

Range of Marks	Grade	Weightage
Below 50%	F (FAILED)	0
50 – 59	D (SATISFACTORY)	6
60 - 69	C (GOOD)	7
70 - 79	B (VERY GOOD)	8
80 – 89	A (EXCELLENT)	9
90 and above	S (OUTSTANDING)	10

CLASSIFICATION SCALE

Classification	CGPA
First Class with Distinction	8 & above
First Class	7 & above
Second Class	6 & above

$$GPA = \frac{G_1C_1 + G_2C_2 + GnCn}{C_1 + C_2 + \_ \; Cn}$$

G = Grade Weightage C = Credit Value

$$GPA = \frac{A_1T_1 + A_2T_2 + AnTn}{T_1 + T_2 + \_ \; Tn}$$

A = GPA

T = Total Credit Value for a Semester

Percentage of Marks = [55 + 10 (CGPA – 6)] Approximately

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COMPREHENSIVE SYLLABUS

I SEMESTER

24-315-0101

Marine Biology (Core) Credit: 3

Course Outcome (CO): After completing the course, students will be able to

CO1: *Describe the salient features and biological processes of marine ecosystems*

CO2: *Explain the types and divisions of various marine habitats*

CO3: *Define the major forms of life in the sea and describe the characteristics that distinguish these forms across broad taxonomic and habitat ranges*

CO4: *Use and apply various sampling devices for marine biological studies*

CO5: *Collect, analyze, interpret and communicate marine scientific data.*

CO6: *Discuss the marine biodiversity, conservation status, laws and regulations*

CO/PO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	2	2	1	1	2	3	3
CO2	1	1	1	1	1	2	3
CO3	2	3	3	1	2	3	3
CO4	3	1	1	1	2	2	3
CO5	2	3	2	3	2	2	3
CO6	2	2	1	1	1	3	2

Unit I:

Introduction to Marine environment, History of marine biological investigations in India. Major expeditions and scientific investigations, Current and future marine research. Salient features of world oceans including Arabian Sea, Bay of Bengal and Andaman Sea. Zonation of marine environment, Physico-chemical features of Marine environment including tides, currents, waves, upwelling and monsoon cycles. Types and divisions of marine habitats – Basic concepts about coastal wetlands, Salt marshes, estuaries, mangroves, seagrass, coral reefs and deep-sea ecosystems. Extreme environments - Polar regions and hydrothermal, vents, Oxygen minimum zones, Mud Banks.

Unit II:

Marine living and non-living resources. Introduction to marine flora- microalgae, macroalgae, seagrass, salt marshes and mangroves and their distribution patterns in Indian EEZ. Primary production, Factors limiting primary productivity–physical and biological parameters, Regional and seasonal variations in primary productivity in different latitudes. Methods of estimation of primary production- Oxygen method, ^{14}C methods, Remote

sensing. New production and Regenerated production. Secondary and tertiary production in marine ecosystems. Indirect, Noninvasive methods of measuring marine primary production.

Systematic and general description of marine faunal groups. General features of the following Kingdom: Monera, Protista, Chromista, Fungi and Metazoa. Classification of major zooplankton and phytoplankton groups. Plankton in relation to fisheries, Plankton blooms, Toxic algae and its impact on fisheries.

Unit III:

A detailed description of various phyla of marine organisms with examples. Salient features of protozoa, cnidaria, ctenophora, helminthes, nematodes, polychaetes, nemertea, bryozoans, crustaceans, barnacles, ascidians and major groups of planktons. Salient features and morphology and biology of marine molluscs, echinoderms, protochordates and marine vertebrates with examples. Larval forms of various phyla and its dispersal, Wood borers and foulers, Types of coral reefs and its distribution in Indian EEZ and World Oceans.

Unit IV:

Marine biodiversity, Biodiversity valuation, Conservation status, Endangered marine organisms, CITES, Red data list and its categories. Regulations concerned with the conservation of marine fauna and flora. Marine sanctuaries, Marine Protected Areas (MPAs), Large Marine Ecosystems (LMEs) etc. Integrated Coastal Zone Management. International regulations related to maritime boundaries (UNCLOS, ANMJ, BBNJ etc.), Laws of Sea, EEZ and territorial waters. AI and Machine Learning for Marine Protection and Conservation. Sustainable Development Goals (SDGs) and oceans.

Unit V:

Marine benthos, Sampling and quantitative analysis of marine benthos - Sieves, Grabs, Box corers, Hydraulic corers, Dredges. Estimation of standing stock and biomass of benthos. Biodiversity and community structure analysis, species richness, succession, species equitability, species diversity and species dominance.

Data analysis and interpretation. Software related to biodiversity and community structure analysis. Census of marine life (CoML) – Barcoding ofmarine organisms, Ocean Biographic information system (OBIS), taxonomic databases (FishBase, SeaLifeBase, WORMS, CephBase, etc.).

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24-315-0102

Cytology and Fish Genetics (Core) Credit: 3

Outcome:

After completing the course, students will be able to:

CO1: *Apply knowledge in genetics, cell, and molecular biology to extend and expand understanding in these fields.*

CO2: *Describe the structures and functions of basic components of prokaryotic and eukaryotic cells, including cell division, gene organization, and gene expression control.*

CO3: *Explain various cell signalling processes and analyze how their dysregulation can lead to diseases such as cancer.*

CO4: *Discuss various genetic modifications and advancements in the field of fisheries, evaluating their impacts.*

CO5: *Review the current status of fish genetics and analyze the genetic approaches and technologies currently applied in fisheries.*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	3	2	2	3	1	3
CO2	2	2	1	1	2	1	2
CO3	2	2	1	1	2	1	1
CO4	1	3	2	1	1	2	1
CO5	2	2	3	2	1	1	3

Unit I:

Cellular organization and fundamental processes – Structure of eukaryotic cell. Membrane structure and function. Structural organization and function of intracellular organelles, Organization of genes and chromosomes. Cell division and cell cycle: their regulation and control. Concept of gene: Structure and function of genes. DNA: structure, replication, repair and recombination. RNA- Structure and functions. Central dogma: the flow of genetic information. Regulation of gene expression in prokaryotes and eukaryotes. Induced gene mutation. Transposons. Chromosome mapping.

Unit II:

Cell communication and cell signalling: General principles of cell communication, Major modes of direct communication - cell adhesion and roles of different adhesion molecules, cadherins, integrins, gap junctions, extracellular matrix. Extracellular signalling - Hormones and their receptors. Cell surface receptor, signalling through G-protein coupled receptors, signal transduction pathways, second messengers, regulation of signalling pathways. Bacterial chemotaxis, quorum sensing- autoinducers, quorum quenching. Cancer: characteristics of cancer cells, oncogenes, tumour suppressor genes, cancer and the cell cycle, virus-induced cancer, angiogenesis, metastasis, apoptosis, therapeutic interventions of uncontrolled cell growth.

Unit III:

Concept of fish genetics: Scope of applied fish genetics, Current status of fish genetics. Genetics of populations, genes & genotype frequencies, Factors affecting them. Qualitative and quantitative traits. Hardy-Weinberg principle and Genetic bottlenecks. Genetic similarity and Nei's genetic difference, Fish genetic resources, Breeding strategies for threatened species, In-situ and ex-situ conservation of aquatic genetic resources.

Unit IV:

Chromosome manipulation and Molecular Breeding in fishes. Sex control and sex reversal in fishes. Monosex population and its importance in culture. Triploidy development: the importance of triploidy in aquaculture. Genetic selection of high health brood stock. Selective breeding: National and International scenario, Genetic basis of selection for breeding, Threshold characters, Inbreeding and Crossbreeding, Estimation of inbreeding, F-statistics, Wahlund effect, Selection and mating designs for growth, Disease resistance, Colour

enhancement. QTS and MAS in selective breeding programmes. Production of SPF and SPR populations.

Unit V:

Application of Biotechnology in Aquaculture: Selective Breeding and Genetic Improvement of fishes. Marker-assisted selection. role of genomics in understanding the genetic basis of traits. Role of genomics in understanding the genetic basis of traits. Genetic Markers and DNA Fingerprinting in aquaculture. Genetic evaluation of broodstock by DNA markers - isozymes, RFLP, RAPD, AFLP, microsatellites, ESTs, mtDNA and Nuclear DNA markers, Transposable element markers. Development and applications of transgenic fish in aquaculture. Disease Resistance. Reproductive Biotechnologies. Aquatic Biotechnology and Environmental Monitoring - eDNA. Aquatic Genomic Resources and Databases. Ethical and Regulatory Considerations. Case Studies. Emerging Technologies-CRISPR-Cas9 gene editing in aquaculture.

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24-315-0103

Biochemistry (Core) Credit: 3

Outcome:

After completing the course, students will be able to

CO1*: Describe the structure, physicochemical properties and functions of the major Biological macro-molecules*

CO2: *Demonstrate a rigorous understanding of the metabolism of biomolecules, regulation of metabolic pathways and the relationship of metabolic processes in health and disease*

CO3: *Explain the role of biologically important molecules in cell structure and function*

CO4: *Analyse and formulate mechanisms of enzymatic reactions*

CO5: *Define and explain various biochemical techniques used in the characterization of different biomolecules*

CO6: *Describe the applications of advanced analytical instruments used in modern biochemical research*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	1	1	1	1	3	1	3
CO2	1	1	1	1	3	1	3
CO3	1	2	1	1	1	1	3
CO4	1	1	2	1	1	1	1
CO5	1	1	1	1	3	1	3
CO6	1	1	2	2	3	1	2

Unit I:

Basic concepts of Biochemistry: An overview, Types of chemical bonds, Bio-elements, Biomolecules and functions of biomolecules. Classification and physicochemical properties of carbohydrates. Structure, chemistry and biological roles of monosaccharides, disaccharides, homo and hetero- polysaccharides and other complex polysaccharides. Marine polysaccharides. Dietary carbohydrates. Digestion and absorption of carbohydrates. Outline of carbohydrate metabolism: glycogenesis, glycogenolysis, glycolysis, gluconeogenesis, HMP pathway, citric acid cycle, electron transport chain and oxidative phosphorylation.

Unit II:

Classification of Lipids. Structure and physicochemical properties of fats, oils and waxes. Fatty acid nomenclature, Characterization of fats and oils. Structure and biological roles of triglycerides, polyunsaturated fatty acids (PUFA), lipoproteins, phospholipids and sphingolipids. Chemistry and properties of Prostaglandins, leukotrienes, thromboxanes, sterols andsteroids, Fat-soluble vitamins. Digestion and absorption of triglycerides. Overview of lipid metabolism, Fatty acid biosynthesis and oxidation, ketone body metabolism, Reactions and ATP yield in β-oxidation of palmitic acid. Cholesterol metabolism.

Unit III:

Classification, structure and properties of standard amino acids. Essential and non-essential amino acids. Biological roles of non-protein aminoacids. Effect of pH on the ionic forms of alanine. Elementary study of the primary, secondary, tertiary and quaternary structures of proteins. Ramachandran Plot, Basic principles of the analysis of the amino acid sequence of polypeptides. Overview of amino acid metabolism: Aminoacid biosynthesis. Catabolism of amino acid nitrogen - transamination, deamination, ammonia formation and urea cycle. Catabolism of amino acid carbon skeleton.

Unit IV

Classification and nomenclature of enzymes. Effect of enzyme concentration, substrate concentration, temperature and pH on enzyme activity. Michaelis-Menten equation. The Double reciprocal plot. Determination of Km and Vmax values. Enzyme inhibitors, Competitive and Non-competitive inhibition, Allosteric modulation. Zymogens. Co-enzymes, cofactors & vitamins. Biochemical role of water and fat-soluble vitamins in metabolism.

Unit V:

Structure, composition and properties of nucleic acids: Chemical structure of purines, pyrimidines AMP, ADP and ATP. Primary and secondary structures of RNA and DNA. Nucleic acid metabolism. Outline study of replication and transcription of DNA. Structural features and biochemical functions of different types of RNA. The genetic code: Characteristics of the genetic code. Activation of amino acids and translation. Ribosomal events in translation. Fundamental study of recombinant DNA technology – Action of restrictionendonucleases, reverse transcriptase and DNA – ligase.

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22. https://nptel.ac.in/courses/104/102/104102016/
23. https://epgp.inflibnet.ac.in/Home/ViewSubject?catid=2

24-315-0104

Marine Biology - Practical (Core) Credit: 2

Outcome:

After completing the course, students will be able to

CO1: *Develop skills in the use of various sampling devices and software for marine biological studies*

CO2: *Apply the methods for collection, preservation and analysis of marine organisms*

CO3: *Develop Identification skills of economically important seaweeds, phytoplankton, zooplankton and Benthos*

CO4: *Understand and apply the various methods for the estimation of primary production*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	1	1	1	1	2	3
CO2	3	2	1	1	3	2	3
CO3	2	3	1	1	3	2	2
CO4	3	2	1	1	1	2	2

1. Theory and operation of equipment used for sampling water, sediment, plankton and benthos.
2. Water samplers - Nansen's reversing water bottle, Niskin water sampler.
3. Sediment samplers – Types of Grab samplers – Van Veen Grab, Peterson's Grab, Core samplers.
4. Plankton nets – Bongo nets – vertical and horizontal plankton sampling, phytoplankton nets.
5. Identification of economically important seaweeds - Identification of vegetative and reproductive structures.
6. Estimation of primary production: light and dark method, C^{14} method, Chlorophyll estimation.
7. Methods of collection and analysis of phytoplankton, zooplankton and Benthos - Preservation and analysis - Reporting on zooplankton collections - Preparation of whole mounts.
8. Identification of zooplankton.
9. Collection and identification of marine biofouling organisms
10. Visit Institutes connected with Marine Science.

24-315-0105

Biochemistry and Instrumentation - Practical (Core) Credit: 2

Outcome:

After completing the course, students will be able to

CO1: *Operate and utilize various types of microscopes and chromatography techniques.*

CO2: *Conduct quantitative and qualitative analyses of biomolecules using spectrophotometry and colorimetric methods*

CO3: *Apply molecular biology techniques such as PCR, RT-PCR, and gel electrophoresis.*

CO4: *Analyze and interpret data from biochemical assays and instrumentation for the study of proteins, carbohydrates, lipids, and nucleic acids.*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	2	1	1	3	2	2
CO2	2	1	1	2	3	2	2
CO3	3	2	1	1	3	2	3
CO4	2	2	1	1	3	2	3

1. Microscopes – Bright field, Dark Field, Fluorescence, Phase Contrastand Electron Microscopes. Microtome.
2. Chromatography – Paper, TLC, HPLC and GC, LC-MS.
3. Colorimeter
4. Spectrophotometer: UV-Visible, Fluorescence & Atomic absorption spectrophotometers.
5. pH meter, Salinometer, Water Quality Analyser.
6. PCR, RT-PCR and Gel Documentation system.
7. Kel-plus analyzer.
8. Particle size analyzer.
9. Electrophoresis: SDS-PAGE, Agarose gel electrophoresis.
10. Laminar Flow Chamber, Autoclave, Deep Freezers, Fermentor andLyophiliser.
11. Centrifuges, Environmental Chamber and Shaker Incubators.
12. General reactions of reducing sugars, starch, amino acids and proteins.
13. Systematic qualitative analysis to identify a given substance as starch, a reducing sugar, a protein or an amino acid.
14. Study of hydrolysis of starch by acid and by salivary amylase. Simpleexperiments on enzyme kinetics.
15. Quantitative colorimetric estimation of protein by Biuret methods.
16. Quantitative colorimetric estimation of protein by Lowry's method.
17. Quantitative colorimetric estimation of glucose by Ortho-Toludine Method
18. Quantitative colorimetric estimation of aminoacidsbyNinhydrinmethod.
19. Quantitative colorimetric estimation of Cholesterol by Zak's Method
20. Estimation of nitrogen by Micro Kjeldahl method.
21. Estimation of fat by Soxhlet method
22. Extraction and estimation of lipids in tissues.

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II SEMESTER

24-315-0201

Marine Microbiology (Core) Credit: 3

Outcome:

After completing the course, students will be able to

CO1: *Understand microbial structure, function, growth, control, and systematics.*

CO2: *Apply simulations to illustrate microbial growth and metabolism and analyze foodborne pathogens*

CO3: *Understand the roles and physiology of microbes in marine ecosystems and analyze their impact on the global biogeochemical cycle.*

CO4: *Apply methods to isolate, identify, and enumerate bacterial growth in the marine environment.*

CO5: *Evaluate and create solutions to issues related to seafood safety.*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	3	3	3	2	1	1
CO2	2	3	3	1	1	1	1
CO3	2	1	2	1	1	3	3
CO4	3	3	3	1	1	2	1
CO5	1	1	1	1	1	3	3

Unit- I:

Microscopy – Principles and types of light microscopes: Simple, Compound and Phase contrast microscopes, Dark field microscope, Transmitted and Epifluorescence microscope, Atomic Force Microscopy, Confocal microscopy. Electron microscopes- Principles and application. General characters of microorganisms. Morphology and fine structure of bacteria, archaea and fungi. Staining of bacteria and fungi- simple and differential staining. Viruses - structure, replication, classification, isolation andidentification.

Unit- II:

Cultivation of bacteria - cultivation of autotrophs and heterotrophs. Enrichment culture technique, pure culture. Methods of isolation and preservation of cultures. Growth and nutrition of bacteria. Reproduction- bacterial growth curve. Nutritional types of bacteria- measurement of growth, effect of environmental parameters on growth. Classification of bacteria. Criteria for classification. Bacterial Systematics. Phenetic and phylogenetic classification systems. Numerical taxonomy. Bergey's manual of determinative bacteriology. Control of microorganisms - control by physical agents, disinfectants and antibiotics.

Unit- III:

Introduction to Marine Microbiology. Characteristics of marine bacteria. Influence of physical and chemical factors on the distribution of marine microorganisms. Sample collection methods. Robotics in sample collection from deep sea, barophilic reactors for the collection and cultivation of deep-sea microbes. Estimation of marine microorganisms. Total plate count, Epifluorescence count, ATP assay.

Molecular techniques in microbial community structure analysis – Denaturing Gradient Gel Electrophoresis (DGGE), Amplicon sequencing, Terminal Restriction Fragment Length Polymorphism (T-RFLP). Fluorescence *in situ* hybridization (FISH). Box PCR. Molecular methods of microbial identification - 16S rRNA, Internal Transcribed Spacer (ITS), Nanopore sequencing. Metabarcoding and metagenomics. Microbial databases and microbial culture collections. - ARB, EZtaxon, NCBI, Greengenes, MTCC, ATCC.

Unit- IV:

Microbial ecology and biogeochemistry - Host-microbe interactions in the marine environment (commensalism, parasitism, mutualism, proto co-operation, reductive evolution, etc.). Bacterial bioluminescence and quorum sensing. Microbial fouling and corrosion. Microbiology of specialized ecosystems – hydrothermal vents, Deep sea. Extremophiles. Microbial loop. Marine viruses and their role in the ecosystem. Organic matter decomposition. Degradation of hydrocarbons and pesticides. Role of microorganisms in the biogeochemical cycling of elements - Carbon, Nitrogen, Sulphur, Phosphorous and Methane cycle.

Unit- V:

Quality assurance in seafood. Bacteria associated with food-borne diseases. Quality standards, the role of EIA, EIC, FSSAI, MPEDA etc., HACCP, FSMS, TQM. General aspects of microbial pollution in aquatic systems. Indicators and waterborne pathogens. Wastewater treatment -Sewage treatment – aerobic and anaerobic treatment methods

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24-315-0202

Fish and Fisheries (Core) Credit: 3

Outcome:

After completing the course, students will be able to

CO1: *Identify and define marine and inland fisheries and fishery resources of the world with special reference to India.*

CO2: *Discuss and describe the major aspects of fish biology and population dynamics*

CO3: *Explain and illustrate how physical and biological factors of aquaticecosystemsdetermine the abundance and distribution of fish population*

CO4: *Understand and outline various methods of fish harvest, post-harvest and marketing*

CO5: *Describe and discuss various regulatory measures and strategies for sustainable fishery resource management.*

CO6: *Estimate and manage the exploited fishery resources*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	2	3	1	1	2	3	3
CO2	2	2	1	1	1	2	3
CO3	3	3	1	1	1	2	3
CO4	1	1	1	3	3	1	3
CO5	1	1	1	1	2	2	3
CO6	2	3	1	1	1	2	3

Unit I:

Major fishery resources of the world, Global trends in production, Target and non-target fishery resources of Indian subcontinent (Fin fishes: Elasmobranchs, Oil sardines, Indian mackerel, Bombay duck, Tunas, Seer fishes, Pomfrets, Carangids, Silver bellies, Flat fishes, Ribbon fishes, Perch, Scieanids and Polynemids, Eels and Catfishes. Estuarine fishery - Milk fish, Mullet, Tilapia, Pearl spot. Shell fishes - Crustaceans – Shrimps, Crabs, Lobsters. Molluscs – Bivalves – Oysters – Pearl oyster and Edible Oyster, Mussels – *Perna viridis* and *Perna indica*, Clams. Gastropods – Chanks. Cephalopods – Squid, Cuttlefish and Octopus), Stradling stocks and non-conventional stocks, sports, game and ornamental fisheries. Classification of fishes with special emphasis on marine fishes.

Unit II:

Life history of important fish species, Food and feeding, Methods in food and feeding analysis, Reproductive biology, Maturity stages, Faecundity, Length-weight relationship,

Condition factor, Gonado somatic index, Age and growth, Determination of age and growth-direct and indirect methods, recruitment, Growth and mortality, Fish stock assessment-Analytical and holistic models in fish stock assessment. Computer software in stock assessment. Catch per unit effort, Maximum sustainable yield (MSY), Maximum Economic yield (MEY).

Unit-III:

An introduction to Fishery hydrography - Influence of fishery-independent factors El Nino Southern Oscillation (ENSO) - Upwelling and fisheries, Mudbanks, Climate change and fisheries, Application remote sensing and GIS in fisheries - potential fishing zones, Methods to increase fish productivity- Artificial upwelling, Ranching, artificial reefs and FADS. Habitat degradation and its impact on fisheries. Definition and dimensions of EEZ, Territorial water, Contiguous zone. Disaster management in fisheries sector.

Unit-IV:

Common fishing crafts and gears with special reference to Indian coasts. Methods of fish detection in the sea. Juvenile fishing, destructive gears, Bycatch and discards, Bycatch reduction devices, Turtle excluding devices, Supply, demand and price dynamics in fisheries sector. Domestic and export market of fish and fish products, Fish preservation – curing, canning, freezing and dehydration, processing and value addition in India. Fishery byproducts. WTO, Market trends and diversification. Blue economy.

Unit V:

Concepts and principles of fisheries management, Fisheries acts and legislations- MFRAs, Inland Fisheries Acts, UNCLOS, FAO-CCRF, IUU. Input (Access, type, number and power of fishing vessels) and output control measures (Total allowable catch, Catch quotas, ITQ, Licensing), Seasonal fishing bans-trawl bans and closed seasons, Mesh size regulations, Size limitation and MLS, Ecosystem-based fisheries management (EBFM), sustainability - Eco-labelling

References

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24-315-0203

Marine Pollution (Core) Credit: 3

Outcome:
After completing the course, students will be able to

CO1: *Describe the source, nature and diversity of marine pollutants*
CO2: *Discuss the uptake, fate and ecotoxicology of pollutants and contaminants*
CO3: *Explain the effects of pollutants on marine communities and riskassessment*
CO4: *Develop an understanding of different types of monitoring techniques for assessment of pollution effects and abatement methods*
CO5: *Explain the Environmental Impact Assessment and its developments in India*
CO6: *Explain how the laws and policies influence the marine ecosystems and develop an understanding of the laws and rules of pollution control*

CO/PO	PS01	PS02	PS03	PS04	PS05	PS06	PS07
CO1	2	2	-	-	-	3	3
CO2	1	3	1	1	2	3	3
CO3	2	2	1	2	3	3	3
CO4	1	2	2	2	2	3	3
CO5	1	1	1	1	3	3	2
CO6	1	1	1	1	1	2	1

Unit- I:

Marine Pollution: source, nature and diversity of pollutants. Heavy metals, petroleum hydrocarbons, polychlorinated biphenyls, polybrominated biphenyls, pesticides, radioactive compounds and other industrial wastes. Thermal pollution, Plastic Pollution and their impacts on fauna and flora.

Atmospheric stressors - increased CO_2 and Global climate change, ecological responses to CO_2 enrichment, effects of climate change on marine communities, effects of Nitrogen deposition and acidification, simulation models.

Uptake and fate of pollutants in the marine environment, bioavailability from water, factors affecting the bioaccumulation of contaminants – temperature influenced process, allometry and other factors.

Biotransformation of organic and inorganic pollutants, transport and abiotic transformation of chemical pollutants in biota, elimination mechanisms.

Unit- II:

History of Ecotoxicology. Stress – definition, stress included responses, biochemicals and cytological responses - cells, organs and tissue responses, bioenergetics as a mechanism of toxicity assessment. Biochemistry of toxicants, functional aspects of detoxification, organic compound detoxification – Phase I and Phase II, molecular effects and biomarkers, metallothioneins, stress proteins and proteotoxicity, oxidative stress andantioxidant response, genotoxicity and DNA modifications, repair of genotoxic damage, enzyme dysfunction and substrate pool shifts.

Unit- III:

Biological methods for the assessment of pollution effects - biomonitoring and biological integrity, indicator species, mussel watch, bioassay, experimental ecosystem modifications, Microcosm and mesocosm experiments.

Community ecotoxicology- introduction, definitions, trophic interactions in community ecology.

Risk assessment of contaminants – overview, definition, human risk assessment, hazard identification - data collection and data evaluation, exposure assessment, dose - response assessment, ecological risk assessment, ecological effects characterization.

Unit- IV:

Pollution monitoring systems and abatement, marine waste disposal systems, Standards for various types of effluents, National and international standards, Pollution abatement methods.

Environmental Impact Assessment, EIA guidelines - methodologies, tools and best practices, Indian Environments laws - Water Pollution Act. Ecoethics.

Unit- V:

Ocean and human health, the role of ocean in transporting human pathogens (ocean currents, ballast water), blue flagging of beaches, Microbial aspects of pollution monitoring, faecal indicator bacteria, Microbial source tracking of faecal pollution, Biodegradation of organic and inorganic pollutants, Coastal sanitation, Eutrophication and algal blooms. Transportation of pollutants in the food web. Ocean colour remote sensing and marine pathogen monitoring, Bioremediation strategies.

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24-315-0204

Marine Biotechnology (Core), Credit:3

Outcome:

After completing the course, students will be able to

CO1: *Analyze the scientific principles of genetic engineering and hybridoma technology, and evaluate their applications.*

CO2: *Explain the principles, protocols, and applications of marine genomics and proteomics and compare various instruments and sequencing platforms used in 'omic'. technologies*

CO3: *Evaluate various bioactive compounds and biomaterials from the marine environment, synthesize their screening, isolation, characterization processes, and assess the effectiveness of bioassays for screening biomolecules.*

CO4: *Describe the principles of cell culture, microbial fermentation, and algal biotechnology, and apply these principles to real-world applications*

CO5: *Demonstrate proficiency in isolation and cloning of DNA, and analyze and interpret DNA sequencing results using appropriate bioinformatics tools.*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	1	1	1	1	3	1	3
CO2	1	1	1	1	3	1	3
CO3	1	2	1	1	1	1	3
CO4	1	1	2	1	1	1	1
CO5	1	1	1	1	3	1	3

Unit- I:

Genetic engineering – Principles. Isolation of DNA, Restriction enzymes and Vectors. Cloning organisms. Splicing and insertion of DNA. Southern blotting. Genomic libraries. Polymerase chain reaction. Hybridoma technology – production of monoclonal antibodies and their applications. Applications of genetic engineering. Principles of bioremediation. Bioremediation of polluted soil and water ecosystems.

Unit- II:

Marine Genomics and Proteomics. Marine metagenomics – principle, protocol and applications. Marine model organisms. Differential gene expression. DNA microarray. Transcriptomics. Gene silencing techniques. siRNA technology. Role of Micro RNA in gene regulation. Next-generation sequencing technology. Protein identification by MALDI-TOF-MS peptide mass fingerprinting. Protein sequencing- Edman degradation. Structural proteomics: X-ray crystallography and NMR spectroscopy.

Unit- III:

Bioactive substances from marine organisms - alkaloids, terpenoids andsteroids. Nucleosides, peptides, depsipeptides, polyketides & macrolides. Antibacterial, antifungal, antiviral, anticancer and analgesic compounds. Methods for screening, isolation and characterization of marine natural products. High throughput and high content screening, Bioassays for screening biomolecules - Design of assays - Brine shrimp lethality assay, Cytotoxicity assay, Antimicrobial assays, Anticancer assays, Comet assay, MTT assay, Lactate dehydrogenase (LDH), Sulforhodamine B (SRB), Neutral Red uptake, Glucose uptake, Caspase assay, Antimitotic assay. Genomics of Marine Toxins - Paralytic shellfish poisoning (PSP), Neurotoxic shellfish poisoning (NSP), Diarrhetic shellfish poisoning (DSP), Ciguatera poisoning, Amnesic shellfish poisoning (ASP).

Unit- IV:

Cell and tissue culture – definition of primary, diploid, established, suspended and anchorage dependent cell cultures. Cell culture techniques - enzymatic disaggregation and explant culture techniques, open and closed systems, sub culturing, *in vitro* transformations and established cell lines. Preservation of established cell lines. Biomedical applications such as viral isolation and propagation. Toxicology – Cytotoxicity assay.

Unit- V:

Biomaterials from the marine environment – chitin, chitosan, oils and fats, surfactants, biopolymers and novel enzymes from marine organisms. Microbial Fermentation – bioreactors - upstream and downstream processes.Single cell proteins. Algal Biotechnology – Pharmaceutical application, antimicrobial compounds. Industrial products - fertilizers, micronutrients, alginates, agar, carrageenan, diatomaceous earth. Applications of algae in waste treatment. Photobioreactors - algae as food and feed, Bioethics, IPR and patenting issues

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24-315-0205
Marine Microbiology and Biotechnology – Practical (Core) Credits: 2

Outcome:

After completing the course, students will be able to

CO1: *Identify and enumerate bacterial populations and pathogens in marine environments using microbiological techniques.*

CO2: *Characterize marine bacteria through Biochemical techniques and advanced staining methods.*

CO3: *Evaluate water quality and assess microbial indicators in marine ecosystems using microbiological analyses.*

CO4: *Apply biotechnological tools for the molecular characterization and identification of marine organisms*

CO5: *Understand the principles and applications of cloning and recombinant expression Techniques*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	2	1	1	2	2	3
CO2	2	3	2	1	3	2	3
CO3	2	2	3	1	2	2	3
CO4	1	1	1	3	3	2	3
CO5	1	1	1	3	3	2	3

1. Basic microbiological techniques (sterilization, preparation of media, handling techniques etc.)
2. Estimation of the bacterial population in seawater, sediment and fish
3. Pure culture techniques – streak plate, pour plate and spread platetechniques.
4. Staining of bacteria - simple stain, Gram stain and endospore stain.
5. Demonstration of bacterial motility - hanging drop method and mannitol motility test.
6. Biochemical tests – Kovac's oxidase test, catalase test, marine oxidation fermentation tests.
7. Reaction in triple sugar iron agar.
8. Water quality analysis – MPN analysis of total coliforms, faecal coliforms and faecal streptococci.
9. Characterisation of *Escherichia coli* by IMViC (Indole test, methylred test, Voges - Proskauer test, citrate utilization) test.

10. Membrane filter test to detect coliform bacteria in water.
11. Production of exoenzymes by bacteria – gelatinase, amylase andlipase.
12. Nitrate reduction test.
13. Antibiotic sensitivity test.
14. Preservation of bacteria using cryopreservation and lyophilization
15. Estimation of indicators and pathogens in water/fishery products - most probable number method.
16. Detection of coliforms and pathogens - *Escherichia coli, Salmonella, Vibrio parahemolyticus, Vibrio cholerae, Staphylococcus aureus,* Faecal Streptococci.
17. Isolation of genomic DNA from prokaryotes and eukaryotes
18. Isolation of plasmid DNA
19. DNA quantification
20. Agarose gel electrophoresis
21. TA cloning - Restriction digestion, Preparation of competent cells, Purification of DNA from an agarose gel, DNA Ligation, Transformation of *E.coli* with standard plasmids, Cloning of genomic DNA in standard plasmid vectors, Confirmation of theinsert, Miniprep of recombinant plasmid DNA
22. 16s rRNA gene based identification of bacteria
23. 18s rRNA and CoI gene based identification of eukaryotes
24. Biological Databases – NCBI, EMBL, PDB.
25. DNA sequence analysis - BLAST Search, FASTA, CLUSTALW, Phylogenetic tree –MEGA

24-315-0206

Fish and Fisheries – Practical (Core) Credits: 2

Course Outcome (CO):

After completing the course, students will be able to

CO1: *Identification, classification and recording of marine and inland fishery resources*

CO2: *Record the biometrics of fishery resources*

CO3*:* *Demonstration and planning of onboard data collection for fishery resource management*

CO4: *Analysis of food and feeding of fishery resources*

CO5: *Determination of Fish age*

CO6: *Evaluation of reproductive biology of fishery resources*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	3	1	1	1	3	3
CO2	1	3	1	1	1	1	3
CO3	3	2	1	1	1	1	3
CO4	3	3	1	3	1	1	3
CO5	3	1	1	1	1	1	3
CO6	3	1	1	1	1	2	3

1. Identification of commercially important fishes, crustaceans andmolluscs.
2. Morphometric and meristic study of fish, shrimps and cephalopods
3. On board collection and identification of marine finfish and shellfish and report pertaining to the above aspects.
4. Gut content analysis of fish.
5. Age determination of fish - Mounting of scales and otolith.
6. Study of maturity stages, fecundity of finfish and shellfish.
7. Report on field visits – Fishing harbours, processing plants, central and state fisheries research institutes.
8. On-board fishing experience.

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III SEMESTER

24-315-0301

Fish Pathology (Core) Credit: 3

Outcome:

After completing the course, students will be able to

CO1: *Identify major fish and shellfish pathogens including bacterial, viral, fungal, and parasitic agents, and describe various methods of diagnosis, control, and treatment.*

CO2: *Identify and examine major bacterial and viral pathogens of finfishes and shellfishes.*

CO3: *Discuss various systems of finfishes and shellfishes with special reference to their pathological significance.*

CO4: *Explain the basic principles of fish and shellfish immunology, and understand the relevance of immune stimulation of farmed species.*

CO5: *Recognize the etiology and discuss the management of different non-infectious diseases in culture systems.*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	1	1	3	2	1	1
CO2	3	1	1	3	1	1	1
CO3	1	2	1	1	1	1	1
CO4	1	1	2	1	1	1	1
CO5	1	1	1	1	3	2	1

Unit- I:

Introduction to fish health and pathology - Definition of health and disease in fish, Predisposing factors – biotic and abiotic. Stress and general adaptations. General introduction to fish and shellfish diseases, Aquatic environment – Role of chemical, physical and biological aspects of water quality and their impact on fish health/disease outbreak. Host-pathogen- environment interaction.

Unit- II:

Overview of fish/crustacean immune system. Fish Immunity – antigens, antibodies, complement, reactive proteins, interferon, lysozyme. Cell mediated immunity – adaptive immunity. Structure and function of antibodies, immunization. Crustacean immunity. Prophenol oxidase system, superoxide anions, antimicrobial peptides.

Unit-III:

Infectious diseases: Microbial diseases in finfishes and shellfishes– bacterial, fungal, viral pathogens. OIE listed diseases. Parasitic infestations in fishes and shellfishes– protozoan, sporozoan, helminth and crustacean parasites. Clinical signs and symptoms. Transmission routes and vectors. Environmental factors influencing pathogen prevalence. Diagnostic methods. Disease prevention and control strategies in aquaculture. General husbandry practices. Emerging infectious diseases in fish and shellfish. Research advancements in disease diagnosis and treatment. Global perspectives on disease surveillance and management.

Unit IV:

Non-infectious diseases: Environmental and nutritional factors influencing fish health. Stress-related disorders in aquaculture. Nutritional pathology – nutritional requirements – Nutritional deficiencies and excesses. Diseases due to deficiency of proteins, carbohydrates, lipids, vitamins, minerals. Toxic components of diet – aflatoxins, dinoflagellate toxins, antibiotics, chemotherapeutic agents and binders. Environmentally induced abnormalities. Water quality parameters affecting fish health. Prevention and mitigation of environmental stress. Neoplasia in fishes and shellfishes.

Systematic pathology: Diseases of integument system, respiratory, blood vascular, digestive, excretory, nervous, reproductive, musculo-skeletal and endocrine systems.

Unit V:

Microbial diseases in fishes and shellfishes– bacterial, fungal, viral pathogens, Environmentally induced abnormalities. Parasitic infestations in fishes and shellfishes– protozoan, sporozoan, helminth and crustacean parasites. Clinical pathology and diagnosis of disease. Clinical laboratory examination of various body parts of fish and shellfish – examination of skin scrapings, gill and internal organs. Various serological diagnostic tools. Principle of ELISA and RIA. Molecular diagnostic tools – PCR, Real Time PCR. Control of fish diseases. Water quality management. Use of immune stimulants, prebiotics and probiotics, antibiotics and otherchemotherapeutics: – Methods of application. Drug delivery - bio encapsulation, micro-encapsulation. Fish vaccines.

Reference

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2. Edward, Kingsford. (1975). *Treatment of Exotic Marine Fish Diseases*. Palmetto Pub. Co.
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24-315-0302

Aquaculture (Core) Credit: 3

Outcome:

After completing the course, students will be able to

CO1: *Identify and describe various extensive, semi-intensive and intensive aquaculture practices in India and major commercially important aquaculture species.*

CO2: *Explain the basic principles of aquaculture engineering, farm/ hatchery management*

CO3: *Understand breeding and seed production of commercially important fishes.*

CO4: *Discuss about various live feeds and artificial commercial feeds, feed management and feeding strategies.*

CO5: *Understand best management practices and standard operating protocols to ensure biosecurity, aquaculture legislation and aspects of seed transportation.*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	1	3	3	3	2	1	1
CO2	2	2	1	3	2	1	1
CO3	2	2	3	3	2	1	1
CO4	2	3	3	3	2	1	1
CO5	1	1	1	3	2	3	3

Unit- I:

History and Scope of aquaculture - global and national scenario. Aquaculture for rural development. General principles of Aquaculture - Criteria for selection of species - commercially important aquaculture species in India. Classification of fish farms and farming techniques, Traditional farming practices in India: Pokkali Prawn filtration system and Bhasabada fisheries, Bheries, Kharlnads, Khazans. Recent trends in aquaculture: Integrated multi trophic aquaculture systems (IMTA), Recirculatory aquaculture system, Aquaponics, Biofloc, Ecosystem based approach to aquaculture.

Unit- II:

Aquaculture farming systems - Site selection, Nutrient and soil quality - pond system design and construction. Water supply and quality - Filters and Aerators. Cage and pen culture systems, Pre-stocking, stocking and post-stocking management. Natural finfish and shellfish seed resources of India and collection techniques. Hatchery - site selection and design. Hatchery techniques of finfish. Broodstock development and management of commercially

important freshwater, brackish water and marine fishes - Tagging, cannulation. Endocrine control of reproduction and induced breeding in finfishes and shellfishes.

Unit- II:

Breeding and seed production freshwater fishes: Carps, Snakeheads, Tilapia, Catfishes, Mahaseer, Fresh water prawns). Breeding and seed production Brackish/ Marine water fishes: Pearlspot, Seabass, Mullet, Milkfish, Groupers, Snappers, Cobia, Pompano). Shrimp seed production. Japanese and Galveston systems and other systems.

Unit IV:

Farming practices of Carps, Snakeheads, Tilapia, Catfishes, Mahaseer, Fresh water prawns, Milk fish, Mullets, Pearl spot, Asian sea bass, Crabs, Lobsters. Pearlspot, Seabass, Mullet, Milkfish, groupers, Snappers, Cobia, Pompano. Culture of shrimps, Crabs and Lobsters. Molluscan species for aquaculture – Mussels, Oysters and Clams - Role of mangrove ecosystem aquaculture and fisheries. Seaweed farming.

Unit V:

Live feeds in aquaculture, Mass production of live feeds: Microalgae, Artemia, Rotifer, Moina, Copepods, Worms etc. Feed and nutrition management, Natural and formulated feeds, weaning to artificial feeds, feeding strategies, rations and feeding methods, Manual and automatic feed dispersers, Demand feeding, Commercial feeds in aquaculture and feed formulation.

Unit VI:

Packing and transportation of fish and fish seed, Anaesthetics used in breeding and transportation, Biosafety and security measures, Best management (BMP) practices and standard operating protocols (SOP) for farm and hatchery management. Aquatic environment and animal health management. Use of antibiotics and usage policies in aquaculture. Sanitary and phytosanitary measures. Farm registration and licensing. Agencies, acts and rules in aquaculture. Introduction of exotic species for aquaculture, Quarantine measures, Seed certification. Ecolabelling and organic certification.

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24-315-0303

General Animal Physiology (Core) Credit: 3

Outcome

After completing the course, students will be able to,

CO1: *Define the basic concepts and processes of physiological regulations, from cellular to organismal level.*

CO2: *Explain the digestive system, endocrine system, respiratory system, reproductive system and identify their working mechanism and functions*

CO3: *Explain the osmoregulation in aquatic organisms and its ecological implications.*

CO4: *Describe and compare the physiological adaptations of marine organisms to carry out the required functions in their environment.*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	1	1	3	3	3	2	2
CO2	1	1	3	2	2	1	1
CO3	1	1	2	3	3	1	1
CO4	1	1	1	3	3	2	2

Unit- I:

Introduction to Animal Physiology - Major themes in Animal Physiology and overview of animal metabolism and reproduction, Factors influencing metabolism: nutritional state, temperature and body size.

Unit- II:

Respiratory system - Principles of gas exchange and design of respiratory structures. A general outline of the circulatory pattern among vertebrates and invertebrates. Blood – Respiratory pigments and oxygen transport. Carbon dioxide transport and acid-base balance. Haemolymph of crustacean. Respiration in fishes, crustaceans and molluscs. Mechanism of gill ventilation. Effect of salinity on oxygen uptake and metabolism. Accessory respiratory organs - respiration in mudflat fishes.

Unit- III:

Digestive system- Structure, function and physiology of digestive system and associated glands. Food and feeding habits of finfishes and shellfishes,

Qualitative and quantitative estimation of gut contents. Nutrition – Digestive

enzymes, Digestion in finfishes and shellfish.

Unit- IV:

Osmoregulatory system - Osmoregulation, water and salt balance: Basic problems and principles, Basic concepts of osmosis and diffusion. Water and salt balance in aquatic environments, Osmotic and ionic regulation in marine and estuarine animals. Osmotic and ionic regulation in migratory fishes. Excretion among fishes, crustaceans and molluscs.

Unit- V:

Reproductive system in finfishes and shellfishes- hormones regulating reproduction. Parental care. Endocrine system - General outline of theendocrine system in fishes. Mechanism of hormonal action at the cellular level. Hormones regulating osmoregulation and metabolism among fishes. Neurosecretion among crustaceans and molluscs. Endocrine control of water and salt balance. Bioelectricity - Electric organ in finfishes. Bioluminescence. Adaptive coloration of marine organisms.

References

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24-315-0304

Marine Ecology (Core) Credit: 3

Outcome

After completing the course, students will be able to,

CO1: *Describe the different ecological features of marine ecosystems in relation to the biotic and abiotic characteristics*

CO2: *Explain the nutrient cycles and exchanges in the marine environment*

CO3: *Describe the population characteristics, including biogeography and their interconnections*

CO4: *Understand and analyze the impact of climate change, globalization and human action on the marine environment*

CO5: *Explain and operate the different sampling designs and methods formarine ecological studies*

CO/PO	PS01	PS02	PS03	PS04	PS05	PS06	PS07
CO1	3	2	1	1	2	2	3
CO2	1	3	1	1	3	1	2
CO3	2	2	2	1	1	3	2
CO4	2	3	1	1	3	3	3
CO5	3	3	1	1	2	2	3

Unit- I:

Introduction and history of Marine Ecology. Important national and International marine institutes and personalities related to marine ecology. Physical and chemical features of the marine environment, Ecology of coastal and deep sea ecosystem. Nutrient cycles in the marine environment -Nutrient pools and exchanges, nitrogen cycle, carbon cycle, phosphorus cycle and silicon cycle. Carbon dynamics

Unit- II:

Population characteristics - natality, mortality, emigration and immigration. Population density and measurements, natural regulation of population size. r-selection and k-selection. Limitations of the population approach. Concept of yield. Species interactions - competition, predation and grazing. Bioinvasions, Biogeography of marine organisms.

Unit- III:

Concept of community - community as a unit of study and its characteristics, growth forms, succession, keystone species, dominant species. Stratification in marine communities. Concepts of the ecotone, organic production, standing crop, food web, trophic structure, energy flow, ecological pyramids and modelling.

Unit- IV:

Marine ecosystems and climate change - climate forcing on marine ecosystem, Climate change- adaptations and mitigations, Human impact on marine ecosystem, socio-ecological aspects of global warming and sea level rise. Marine ecosystem and marine resource management in the changing scenario. Marine geospatial planning and its applications.

Unit- V:

Sampling designs for marine ecological studies - Profiling a beach, underwater profiles and techniques. Sampling populations – sampling designs, physico-chemical parameters, timing of sampling, size of the sampling area, sample size.

Quantitative sampling – Various types of random sampling, quadrat method, fixed quadrat, point contact, line and belt transect, sequential sampling, rapid sampling methods, visual observation, cluster sampling, Strong method, Weinberg method and Mark/tag recapture method.

Quantitative analysis - Types, standardization and transformation of data. Diversity and related indices - species richness, diversity, evenness and dominance, niche breadth, niche overlap and concordance. Softwares used for quantitative analysis of ecological parameters.

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24-315-0305

Marine Ecology and Aquaculture - Practical (Core) Credit: 2

Outcome

After completing the course, students will be able to

CO1: *Identify various marine organisms and their ecological adaptations*

CO2: *Aquire expertise on various sampling methods and data processing software*

CO3: *Identify fish/shellfish species of aquaculture importance*

CO4: *Understand different aquaculture practices and hatchery operations*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	2	1	3	2	1	1
CO2	2	2	2	3	2	1	1
CO3	1	3	1	3	2	1	1
CO4	2	1	1	3	2	1	1

1. Morphological characteristics of fishes, crustaceans, molluscs and other invertebrates to identify their ecological adaptations.
2. Benthic fauna sampling and analysis
3. Software applications in marine ecology - PRIMER and other software in analysis of benthic biodiversity studies
4. Analysis of interstitial fauna. Identification of boring and foulingcommunities.
5. Report on field visit to a marine ecosystem and intertidal zone.
6. Identification of culture species of Finfish and Shellfish (prawns andmolluscs).
7. Induced breeding in fishes (carps).
8. Identification of larval stages of cultured fishes and shellfishes.
9. Live feed culture and artificial feed preparation.
10. Reports on field visit to Fish and Shrimp farms – Prawn filtration fields – Hatcheries – State and Central Fisheries Research Institutions.

24-315-0306

Fish Physiology and Pathology – Practical (Core) Credits: 2

Outcome

After completing the course, students will be able to:

CO1: *Apply physiological principles to measure oxygen consumption and ammonia excretion rates in aquatic animals under stress conditions.*

CO2: *Analyze pathological conditions in aquatic animals through necropsy, histological analysis, and microbiological screening for bacterial pathogens (Aeromonas, Vibrio).*

CO3: *Demonstrate proficiency in molecular and immunological techniques like PCR, ELISA, and immune parameter measurement for disease diagnosis in fish and shellfish.*

CO4: *Evaluate disease treatments and prophylactic measures based on stress-related studies and challenge experiments in fish and shellfish.*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	1	1	1	1	1	1
CO2	1	3	1	1	1	1	1
CO3	1	1	3	1	1	1	1
CO4	1	2	1	3	1	1	1

1. Oxygen consumption by fresh water fish.
2. Effect of stress (salinity and temperature) on oxygen consumption byfish.
3. Rate of ammonia excretion by aquatic animal.
4. Effect of salinity on ammonia excretion by aquatic animal.
5. Rate of filtration by bivalve mollusc (*Villorita cyprinoids*).General procedures for disease diagnosis
6. Necropsy examination to study internal organs of fish
7. Sampling, preparation of media and culture of pathogenic bacteria - Screening for bacterial pathogens (*Aeromonas* and *Vibrio*) in fishand shrimp.
8. Microscopic analysis of swab samples from infected fish and crustaceans.
9. Histological analysis of fish and shrimp tissues.
10. Measurement of immune parameters in shrimps.
11. Molecular and immunological techniques; Biochemical tests; PCR; ELISA; Agglutination test

12. Challenge experiments
13. Purification of virus- Detection of WSSV by PCR.
14. Stress related study of fish and shellfish
15. Disease treatments and Prophylactic measures

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IV SEMESTER

24-315-0401

Project work and Dissertation – (Core) Credits: 16

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ELECTIVE COURSES OFFERED BY THE DEPARTMENT

24-315-0106

Planktonology (Elective), Credit: 2

Outcome

After completing the course, students will be able to,

CO1: *Describe the major planktonic organisms in the ocean and outline their ecological adaptations.*

CO2: *Explain various planktonic organisms of Indian seas and compare the community variations between different habitats.*

CO3: *Identify and categorize methodological approaches appropriate for evaluating thebiomass and production of plankton.*

CO4: *Outlining various taxonomic methods used for identifying marine plankton*

CO5: *Illustrate the remote sensing and GIS applications for plankton and fishery monitoring and management.*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	3	1	2	1	3	2
CO2	2	3	1	2	1	3	3
CO3	3	2	1	1	1	3	3
CO4	2	2	2	2	2	3	3
CO5	1	1	1	1	1	2	3

Unit- I:

Plankton–Historical background. Classification of planktonic organisms. Adaptations to planktonic life. Major groups of plankton in the sea. Environmental and economic importance of plankton.

Unit-II:

Quantitative and qualitative studies of plankton. Methods used for the collection of plankton. Different types of plankton nets. Filtration efficiency of plankton nets. Plankton indicator devices. Plankton pump. Fixation and preservation of plankton samples. Sorting and counting procedure. Automated surveys in planktonology- FlowCAM, ZooScan, VPR.

Unit- III:

Latitudinal difference in zooplankton abundance. Study of phytoplankton and on zooplankton of Indian seas. Major taxa of phytoplankton and zooplankton in Indian waters. Shelled

planktonic protozoans. Food and feeding in zooplankton. Pelagic food chain and food webs. Reproduction in zooplankton. Community structure of holoplankton. Ichthyoplankton-diversity and seasonal abundance.

Unit- IV:

Inter-relationship between phytoplankton and zooplankton. Important groups of zooplankton in the sea. Seasonal and geographical distribution of plankton. Vertical and diurnal migration of zooplankton. Epizoism in marine plankton. Indicator organisms. Harmful Algal Blooms and its impacts on marine ecosystems. Planktonic deposits and oozes in the marine environment- calcareous and siliceous oozes, diatomaceous earth.

Unit- V:

Influence of biotic and abiotic factors on plankton. Ocean currents and plankton. Larval ecology. Marine pollution and its impact on plankton. Microplastics and plankton. Plankton and fisheries. Importance of plankton as a source of food in the sea. Application of remote sensing and GIS in plankton studies - Oceansat, Seawifs etc.

References

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2. Barnes, H. (1959). *Apparatus and Methods of Oceanography*. George Allen & Unwin.
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4. Colin, S. Reynolds. (2006). *Ecology of Phytoplankton*. Cambridge University Press. ISBN: 1139454897.
5. Castellani, Claudia, and Martin Edwards (eds.) (2017). *Marine Plankton: A practical guide to ecology, methodology, and taxonomy*, Oxford Academic.
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14. Harris, R. P., Wiebe, P. H., Lenz, J., Skjoldal, H. R & Huntley, M. (2000).
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18. Suthers, I.M., Rissik D & Richardson (2019). Plankton: Guide to Their Ecology and Monitoring for Water Quality. CRC Publishing, pp. 272. ISBN: 9780643097131
19. Todd, C.D & Layerack, M.S. (1991). *Coastal Marine Zooplankton*. Cambridge University Press.
20. Wickstead, J.W. (1965). *An Introduction to the Study of Tropical plankton*. Hutchinson Tropical Monographs. Hutchinson.

24-315-0107

Coral Reef Ecology (Elective), Credit: 2

Outcome:

After completing the course, students will be able to

CO1: *Define the diversity and distribution of coral reefs in relation tothe environment*

CO2: *Identify the corals and associated organisms in the coral reefecosystem*

CO3: *Illustrate and interpret the life habits and physiology of corals and their associations*

CO4: *Examine the major threats to coral reef ecosystems including anthropogenic activities and climate change*

CO5: *Evaluate the risk and vulnerability assessment of coral reefs*

CO6: *Appraise and formulate methods for conservation and management of coral reefs*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	3	1	1	1	3	3
CO2	3	3	2	1	3	3	3
CO3	3	2	1	1	1	1	3
CO4	3	3	1	1	1	1	3
CO5	3	1	1	1	1	1	3
CO6	3	1	1	1	1	2	3

Unit I:

Introduction to coral reefs: diversity, productivity, distribution and evolution. Distribution of coral reefs in India. Cnidarians - hydrozoans and anthozoans. Coral distribution and reef zonation. Biology of hard and soft corals. Species interaction and ecology of reefs. Photoacclimation and photoprotection.

Unit II:

Coral anatomy and physiology. Coral life history, feeding habits. Reproduction and recruitment in corals. Coral reef development. Interaction between corals and their symbiotic algae, Zooxanthellae. Loss of color at depth.

Unit III:

Major taxa living in coral reef ecosystems: Protists, Plants, Molluscs, Annelids (polychaetes); Crustaceans (lobsters, shrimps, crabs), Echinoderms, Sponges, Bryozoans, Morays/other eels. Reef fishes and Reef fish behavior. Predators, grazers, herbivores. Cleaning symbioses.

Unit IV:

Coral diseases – black band disease, pinkline syndrome, white band disease and yellow band disease. Current coral reef monitoring techniques. Coral reef decline and conservation, artificial reef systems. Coral immune system

Unit V:

Anthropogenic impacts on tropical marine ecosystems. Threats to coral reefs. Biofouling. Pollution of the marine environment – heavy metals, petroleum hydrocarbons. Impact of Climate change on coral reef -, Sea surface warming, Ocean Acidification. Resilience of coral reefs to climate change, phase shift, palaeoclimatology.

References

1. Birkeland, C. (1997). *Life and Death of Coral Reefs*. Chapman & Hall.
2. Davidson, O. G. (1998). *The Enchanted Braid Coming to Terms with Nature on the Coral Reef*. John Wiley & Sons, Inc.

3. Deloach, N. (1999). *Reef Fish Behaviour: Florida, Caribbean, Bahamas*. New World Publications, Inc.

4. Humann, P., &Deloach, N. (2002). *Reef Fish Identification: Florida, Caribbean, Bahamas*(3rdEdition). Jacksonville, FL: New World Publications.

5. Humann, P.,&Deloach, N. (2002). *Reef Coral Identification: Florida, Caribbean, Bahamas*(2nd Edition).Jacksonville, FL: New World Publications.

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7. Nybakken, J.W., &Bertness, M. D. (2004). *Marine Biology: An Ecological Approach* (6thEdition). Benjamin Cummings.

8. Smith, D.L., &Johnson, K. B. (1996). *A Guide to Marine Coastal Plankton and Marine Invertebrate Larvae*(2nd Edition). Kendall/Hunt Publishing Company.

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12. http://www.reefbase.org/

24-315-0108

Ornamental Fish Culture (Elective), Credit: 2

Outcome:

After completing the course, students will be able to

CO1: *Discuss the major groups of freshwater and marine ornamental fishes,their breeding, rearing of seeds and various genetic manipulations employed*

CO2: *Describe feeding regimes, live feed and formulated feed as well as to discuss various live feed culture methods*

CO3: *Explain the basics of construction, setting and maintenance of freshwater and marine aquarium and fish ponds*

CO4: *Summarize ornamental fish production, aquatic ornamental plant propagation as well as other organisms used in aquaria, itspropagation and export potential*

CO5: *Recognize major diseases of ornamental fishes, its etiology, control and treatment*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	2	1	3	2	1	1
CO2	3	2	2	3	2	1	1
CO3	3	2	3	3	2	1	1
CO4	3	2	1	3	2	1	1
CO5	3	1	1	3	2	3	3

Unit I:

Ornamental fish culture – history, status and scope. Major Groups of freshwater and marine ornamental fishes, their natural history, breedinghabits, food and feeding habits. Other groups of organisms used in aquaria and their propagation.

Unit II:

Aquarium plants and their propagations. Aquarium construction, setting and maintenance – fresh water and marine. Biological filters, aerators, decorative items and other accessories.

Unit III:

Design and construction for ornamental fish ponds, formulated feeds and feeding – live feeds and their production.

Unit IV:

Ornamental fish breeding and rearing of seeds. Hybridization and genetic manipulation. Common diseases of ornamental fishes and their control.

Unit V:

Establishment of commercial ornamental fish production unit – exportpotential. Ornamental fish trade, package, transport and quarantine.

References

1. Axelrod, H.R. (1967). *Breeding Aquarium Fishes*. Kerkwerve, Netherlands: Backhuys Biological Books.
2. Dick, Mills. (1981). *Illustrated Guide to Aquarium fishes* (Kingfisher) Littlehampton Book Services Ltd. ISBN 10: 0706361024.
3. Vincent, B. Hargreaves. (1978). *The Tropical Marine Aquarium*(1st Edition). David & Charles Publishers.
4. Hawkins, A.D. (1981). *Aquarium System.* London: Academic Press. ISBN 10: 0123333806 / ISBN 13: 9780123333803.
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6. https://www.agrifarming.in/ornamental-fish-farming-beginners
7. https://freshwater-aquaculture.extension.org/ornamentals/

24-315-0109

Biological Oceanography (Elective), Credit: 2

Outcome:

After completing the course, students will be able to

CO1: *Explain the history and recent developments of biological oceanography*

CO2: *Describe the salient ecological features of the marine ecosystems and the chemical and physical characteristics of sea water*

CO3: *Describe the current threats to marine biodiversity and the impact of climate change and human activities on the marine ecosystem*

CO4: *Discuss the environment laws and marine protected areas*

CO5: *Explain the international and national agencies and scientific organizations responsible for the conservation and management of marine life*

CO/PO	PS01	PS02	PS03	PS04	PS05	PS06	PS07
CO1	1	1	1	1	1	2	2
CO2	1	1	1	1	1	3	3
CO3	2	2	2	1	3	3	3
CO4	1	1	1	1	1	3	2
CO5	1	1	1	1	2	3	2

Unit I:

Introduction to Marine environment, History of marine biological investigations in India and major expeditions. Salient features of worldoceans including Arabian Sea, Bay of Bengal and Andaman Sea.

Zonation in marine environment, Physico-chemical features of Marine environment- tides, currents, waves, upwelling and monsoon cycles, Mud banks.

Unit II:

Salient ecological features of coastal ecosystems-wetlands, salt marshes, estuaries, mangroves, sea grasses, coral reefs, rocky and sandy shores, and deep sea ecosystems. Continental shelf and seabed, Extreme environments – polar regions and hydrothermal vents.

Unit III:

Marine living and non-living resources. Planktonic deposits and oozes in marine environment. Classification of marine organisms by habit and habitat.

Introduction to marine flora – microalgae, macroalgae, seagrass, salt marshes and mangroves and their distribution patterns in Indian EEZ. Systematic and general description of marine faunal groups. Indicator organisms, Plankton blooms, Toxic algae and its impact on fisheries.

Unit IV:

Marine biodiversity, Conservation status, Endangered marine mammals and sea turtles, CITES, Red data list and its categories. Regulations concerned with conservation of the marine fauna and flora. Marine sanctuaries, Marine Protected Areas (MPAs), Large Marine Ecosystems (LMEs), etc. Regulations related to maritime boundaries, EEZ and territorial waters.

Unit V:

Marine ecosystems and climate change - climate forcing on the marine ecosystem, human impact on marine ecosystem, socio-ecological aspects of global warming and sea-level rise. Marine ecosystem and marine resource management in the changing scenario.

References

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2. Barbara, Charton. (2007). *The Facts on File Dictionary of Marine Science. (Facts on File Science Dictionary),* Facts on File.
3. Charles B. Miller, Patricia A. Wheeler (2012). *Biological Oceanography* (2nd Edition). Wiley-Blackwell
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20. (7thEdition). Brooks Cole.
21. https://marinespecies.org
22. https://coml.org
23. https://boldsystems.org
24. https://obis.org/
25. https://www.sealifebase.ca/

24-315-0110

Applied Molecular Biology (Elective), Credit: 2

Outcome:

After completing this course, the students will be able to:

CO1: *Evaluate a comprehensive understanding of molecular biology, encompassing historical development, molecular processes, and the significance of molecular biology in various fields*

CO2: *Demonstrate proficiency in molecular biology techniques, including Recombinant DNA Technology, DNA isolation, PCR, gel electrophoresis, and spectrophotometry.*

CO3: *Apply molecular tools in marine biology and aquaculture, demonstrating the ability to identify microorganisms, perform DNA barcoding, and use molecular diagnostics in fish health.*

CO4: *Analyze advanced molecular biology techniques, including genomic approaches, Next-Generation Sequencing (NGS), mass spectrometry, CRISPR-Cas9, and systems biology.*

CO5: *Evaluate ethical considerations in molecular biology research, genetic engineering, and emerging technologies, emphasizing responsible scientific practices.*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	1	1	1	3	1	1
CO2	3	1	1	1	1	1	1
CO3	1	2	1	1	1	1	3
CO4	1	1	3	3	1	3	1
CO5	1	1	1	1	3	1	1

Unit I:

Introduction to Molecular Biology

Definition and historical development of molecular biology. Overview of molecular processes in living organisms- DNA replication, transcription, translation, and cellular signaling pathways. Significance and applications of molecular biology in various fields. Critical role of molecular biology in understanding marine ecosystems, biodiversity, and the adaptation of marine organisms to their environments. Key ethical considerations in molecular biology research.

Unit II:

Recombinant DNA Technology

Principles of Recombinant DNA Technology. DNA cloning techniques: restriction enzymes, vectors, and ligases. Construction of recombinant DNA molecules. Gene expression systems: promoters, enhancers, and expression vectors. Functional applications - development of genetically modified organisms (GMOs), gene therapy, and the production of recombinant proteins. Ethical Considerations in Genetic Engineering. Functional Applications in Marine Biology - Genetically modified marine organisms, recombinant proteins derived from marine organisms.

Unit III:

Instrumentation and Techniques

Principles of DNA isolation methods: phenol-chloroform extraction, silica-based methods. RNA extraction –methods, significance in studying gene expression and functional genomics. Expressed Sequence Tags (ESTs), Microarray Technology. Polymerase Chain Reaction (PCR): principles and applications. Advanced PCR techniques: quantitative PCR (qPCR), reverse transcription PCR (RT-PCR), touchdown PCR, hot start PCR, colony PCR, and multiplex PCR. Gel electrophoresis: principles, techniques, and applications. Spectrophotometry: quantification of nucleic acids and proteins. Nucleic acid sequencing methods. Protein sequencing methods.

Unit IV:

Applications of Molecular Tools in Marine Biology and Aquaculture

Molecular Identification Methods for Microorganisms- bacteria, fungi, viruses - 16S rRNA, and Internal Transcribed Spacer (ITS) regions. DNA barcoding for species identification. Molecular diagnostics in fish health - detection of pathogens, monitoring disease outbreaks. Principles and applications of eDNA- tracking the presence of aquatic organisms, monitoring biodiversity, and assessing environmental health. Molecular approaches in aquatic ecology. 16S rRNA typing methods - microbial community profiling.

Unit V:

Emerging Trends and Applications

Principles and applications of advanced molecular biology techniques: Genomic approaches- Metagenomics, Proteomics, Metabolomics, Lipidomics. Multi-Omics Approaches. Next-Generation Sequencing (NGS) and its applications. Technological Platforms in Mass Spectrometry - MALDI-TOF, LCMS & NMR technological platforms. CRISPR-Cas9 and gene editing technologies. Systems biology: integrating molecular data for a holistic understanding. Ethical Considerations in Emerging Technologies.

24-315-0207

Aquarium Plants and Culture of Fish Food Organisms (Elective)Credit: 2

Outcome:

After completing the course, students will be able to

CO1: *Describe the major groups of aquatic plants and its significance to aquaculture*

CO2: *Explain various methods of live feed culture*

CO3: *Discuss different groups of plants relevant to aquaculture and its propagation*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	2	1	1	3	2	1	1
CO2	1	2	2	3	2	1	1
CO3	1	2	1	3	2	1	1

Unit I:

Aquatic plants – introduction – brief classification. Ornamental plants- exotic and indigenous. Introduction to algae – brief classification. Blue economy.

Unit II:

Study of different groups of plants relevant to aquaculture – Microalgae (Phytoplankton) – important microalgal groups.

Unit III:

Macroalgae (seaweeds) and Seagrass. Commercially important seaweedsand their culture.

Unit IV:

Microalgal culture – laboratory methods – isolation – culture media etc.

Mass culture of important fresh water and marine microalgal live feed organisms – green algae – blue-green algae, spirulina, diatoms and phyto flagellates.

Unit V:

Candidate species of zooplankton in freshwater and marine habitats – infusoria, cladocerans, rotifer, tubifex, brine shrimp, chironomids and earthworms.

References

1. James, P.S.B.R. (1987). *Seaweed Research and Utilization in India*(Bulletin NO. 41). CMFRI.
2. Paulraj, R. (1997). *Handbook on Aquafarming: Aquaculture Feed.* Manual. MPEDA, Cochin.
3. Riuemer, D. N. (1984). *Introduction to Fresh Water Vegetation*. USA: AVI Publishing Company.
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7. Sorgeloos, P., & Kulasekara Pandian, S. (1984). *Culture of Live Food Organism with Special Reference to Artemia Culture* (special publication No. 15). CMFRI.
8. Venkataraman, G.S., Goyal, S.K., Koushik, B.D & Chaoudhary, P. (1974). *Algae form and function*. New Delhi: Today and Tomorrow's Printers and Publishers.

24-315-0208

Marine Conservation Biology (Elective), Credit: 2

Course Outcome (CO):

After completing the course, students will be able to

CO1: *Define the marine ecosystem and the major forms of life in thesea.*

CO2: *Explain the major threats to biodiversity in our seas and implement proper solutions for conserving biodiversity*

CO3: *Create awareness of protecting our marine environment and marine organisms.*

CO4: *Design various strategies, conservation policies and legislations.*

CO5: *Plan ecosystem-based conservation and management utilizing appropriate tools.*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	2	2	1	1	2	3	3
CO2	2	2	1	2	2	3	3
CO3	2	2	1	1	2	3	3
CO4	1	1	1	1	2	3	3
CO5	2	2	1	2	2	3	3

Unit I:

Introduction to marine ecosystems - polar, temperate and tropical. Structure, function and dynamics of marine ecosystems from coastal zone systems (estuaries, lagoons, mangrove forests, grassbeds, coral reefs) to deep ocean benthic communities.

Unit II:

Biological components of marine ecosystems - plankton, nekton and benthic communities. General ecological roles of key organisms.

Marine biota- complex life cycles, spawning behaviour, developmental stages, larval dispersal and recruitment.

Unit III:

Major threats to marine ecosystem diversity and function – overexploitation, pollution, climate change, diseases. Global warming, Ocean Acidification, Eutrophication, Harmful algal blooms, Dead zones and Oil spills.

Unit IV:

Urban development and habitat destruction. Habitat fragmentation and degradation. Evolutionary impacts of the decline in biodiversity on ecosystem structure and function. Population regulation - catastrophic declines and community shifts. Invasive species - Vectors for the transportof invasive species. Efforts to control invasive species.

Unit V:

Restoring marine ecosystems – ecosystem - based conservation and management. Tools to preserve, manage and restore marine ecosystems - Marine protected areas, re-introduction of species, control of alien species. Current management of marine species and tourism. Population dynamics of marine species and its implication on the management and conservation of species. Valuing ecosystem services. Impediments to conservation. Sea ethics. Marine conservation regulations and laws.

References

1. Avise, John. (2003). *The Best and the Worst of Timesfor Evolutionary Biology*. Bioscience. 53:247-255.
2. Cote, I.M.,& Reynolds, J. D. (Eds.). (2006). *Coral Reef Conservation*. CambridgeUniversity Press.
3. Glover, L.K., &Earle, S. (Ed.) (2004). *Defying Ocean's End: An Agenda for Action*. Island Press: Washington D.C. ISBN 1-55963-755-2. XXII.
4. Karen, McLeod.,& Heather, Leslie. (2009). *Ecosystem-Based Management for theOceans.* Island Press
5. Norse, E.A.,& Crowder, L.B (Eds.). (2005). *Marine Conservation Biology: The Science of Maintaining the Sea's Biodiversity*. Island Press.
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7. http://www.coml.org/

24-315-0209

Ornamental Fish Culture and Live Feed Organisms - Practical(Elective), Credit: 2

Outcome:
After completing the course, students will be able to

- ***CO1:*** *Identify common freshwater and marine ornamental fishes, aquarium plants, and other organisms.*
- ***CO2:*** *Apply principles of aquarium construction, setting, and maintenance for freshwater and marine aquariums.*
- ***CO3:*** *Design and fabricate biological filters, formulate and prepare feeds, and culture live feeds for ornamental fishes.*

CO4: *Implement breeding techniques for ornamental fishes and manage the rearing of fish larvae.*

CO5: *Diagnose common diseases in ornamental fishes, apply treatment protocols, and implement prophylactic measures*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	2	1	1	1	2	3	3
CO2	2	1	1	1	2	3	3
CO3	2	1	2	1	2	3	3
CO4	1	1	1	2	2	3	3
CO5	1	1	1	2	2	3	3

1. Identification of common freshwater and marine ornamental fishes, aquarium plants and other organisms.
2. Aquarium construction setting and maintenance of fresh water and marine aquarium.
3. Fabrication of biological filters, feed formulation and preparation, feeding, live feed culture.
4. Breeding of ornamental fishes and rearing of seeds.
5. Diagnosis and treatment of common diseases in ornamental fishes, prophylactic measures.
6. Identification of important aquatic plants.
7. Methods of identification, isolation and culture of selected live feedorganisms.
8. Decapsulation techniques and hatching methods of brine shrimpcysts.

24-315-0210

Discovery of Marine Drug and Nutraceuticals (Elective), Credit: 2

Outcome:

After completing the course, students will be able to

CO1: *Explain the importance of marine environment as source of novel bioactive compounds (Understand)*

CO2: *Develop suitable methods for isolation and characterization of marine natural products (Apply)*

CO3: *Develop suitable bioassays for screening bioactivities of marine natural products (Apply)*

CO4: *Describe genomic approach used for discovering novel bioactive compounds (Understand)*

CO5: *Summarize various marine derived chemical compounds and their bioactivity. (Understand)*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	1	1	1	3	3	3
CO2	3	3	1	1	2	3	1
CO3	1	1	1	1	3	3	3
CO4	1	1	1	1	3	3	3
CO5	1	1	1	1	3	3	3

Unit I:

Marine Natural products as Drug Leads: Natural products as Drug lead, Marine Environment as a source of natural products, Marine chemical ecology; Bioprospecting deep-sea, polar ocean, twilight zone, symbiotic microorganisms. Challenges in natural product research. Dereplication tools in Natural Product research; GNPS and Modern Applications with Molecular Networking, Natural Product Atlas, AntiBase, MarinLit, BioMAP

Unit II:

Isolation and Characterization of Marine Natural Products: Isolation and separation of marine natural products (MNP) from marine flora and fauna; extraction methods; bioassay-guided fractionation; chromatographic separation, Types of chromatographic separations (TLC, paper, Flash Chromatography, HPLC), HPLC method development for Isolation, Column selection, Characterization of lead compounds, LC-MS, NMR. Mass Spectrometry, interpretation of LC-MS and NMR data.

Unit III:

Drug Screening Platforms and Bioassays: Drug target identification and validation, Assay development for bioactivity screening, High throughput and high content screening strategies: In vitro biochemical and cell-based assays; Reporter Gene based Assays. Chromogenic assays; Fluorescence assays; Fluorescence polarization; Homogenous time-resolved fluorescence assays; Fluorescence resonance energy transfer (FRET), BRET. Anticancer activity screening assays: DNA laddering assay; TUNEL Assay, SRB Assay, MTT assay; LDH assay; Caspase assay; NCI-60 anticancer screening programme; Antibacterial assays; quorum sensing and biofilm inhibition assays, antifungal assays; antiviral assays; Anti-inflammatory assays; Assays for tropical diseases.

Unit IV:

Source and nature of marine bioactive compounds: Diversity of marine organisms, sources of bioactive compounds, Chemical diversity of marine compounds, Marine Toxins, Marine enzymes; pigments; neutraceuticals; Marine biominerals; Biomineralized structures; Biocomposites; Biopolymers- polysaccharides, chitin, marine collagens. Marine-derived drugs in use, their use and mode of action.

Unit V:

Marine Genomics and marine natural products: Biosynthetic pathways, Polyketide synthase (PKS I & amp; II) non-ribosomal peptide synthetase, hybrid pathways, Mevalonate pathway, Biosynthetic gene cluster (BGC) identification, Secondary Metabolite. Unique Regions

Finder (SMURF), antiSMASH, Cryptic Natural Products- its induction. Metagenome-based MNP discovery, synthetic biology approach for MNP synthesis. Marine genetic resources, IPR, access and Benefit Sharing: National Biodiversity Act, National Biodiversity Strategy, resource utilization, Intellectual Property Rights (IPR), access and Benefit-sharing, Convention on Biological Diversity (CBD), United Nations Convention on the Law of the Sea (UNCLOS), conservation and sustainable use of marine biodiversity in Areas Beyond National Jurisdiction.

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24-315-0211

Marine Genomics (Elective), Credit: 2

Outcome:
After completing the course, students will be able to

CO1: *Develop an understanding of marine model organisms, omics approaches, sequencing techniques, and sequencing platforms.*

CO2: *Apply genomics tools to understand marine biodiversity.*

CO3: *Extend understanding of the genomics of marine microbes.*

CO4: *Understand the significance and application of genomics in aquaculture.*

CO5: *Understand the methods of gene regulation and techniques in transcriptomics.*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	1	1	1	3	1	1
CO2	1	1	3	1	1	1	3
CO3	1	2	1	1	1	1	1
CO4	1	1	1	3	1	3	1
CO5	1	1	1	1	2	1	1

Unit I:

Fundamentals of Genomics

Principles and applications of various omic approaches: Genomics, Metagenomics, Transcriptomics, Proteomics, Metabolomics, Nutrigenomics, Conservation genomics, Comparative genomics, Developmental genomics, Aquaculture genomics, Immunogenomics, Pharmacogenomics, Ecological and evolutionary genomics. Multi-Omic Approaches. Whole genome sequencing. Single cell sequencing. DNA sequencing platforms - Sanger sequencing, Next-Generation Sequencing (NGS) and its applications. Mass Spectrometry - MALDI-TOF, LCMS & NMR technological platforms. Bioinformatics Tools for Omic Data Analysis.

Unit II:

Marine Genomics

Definition and scope of marine genomics. Historical development and milestones in marine genomic research. Genomic approaches in marine biology. Genome programmes in marine biology. Marine model organisms. Emerging and future genome models for marine biosystems. Marine biodiversity exploration employing genomics. Case studies of marine organism genomics, Whole Genome Sequence of Atlantic Cod, Puffer Fish Genome, Genomes of crustacean, Seaweed Genome. Whole Genome Sequence of Diatom. Developmental and evolutionary genomics.

Unit III:

Microbial Genomics

Introduction to Microbial Genomics. Metagenomics and single-cell genomic approaches for unculturable microorganisms – Principles and applications. Functional Genomics of Marine Microbes. Comparative analysis of microbial genomes in marine ecosystems. Principles of ecogenomics and its application. Microbial genomes - Archaea genome, Bacterial genome, Fungal genome, Marine viral metagenomics. Metagenomic analysis of environmental water samples, Metagenomics to map ocean biodiversity. Microbial sequencing methods, Whole genome microbial sequencing, 16SrRNA sequencing, shotgun metagenomics.

Unit IV:

Aquaculture Genomics

Aquaculture Genomics – History, Development, Ethical Considerations, Major Challenges and Opportunities. Impacts of microbial communities on Aquaculture production and health. Manipulating microbial communities for improved Aquaculture production. Applications of metagenomics in Aquaculture. Applications of transcriptomics in Aquaculture research and production. Genomic approaches in aquaculture - Whole genome sequencing, Transcriptomic and proteomic approaches, Genome editing techniques. Ethical issues, controversies and challenges in Aquaculture Genomics. Future Prospects and Trends in Aquaculture Genomics

Unit V:

Functional Genomics

Introduction to functional genomics. Transcriptomics - History of transcriptomics, Principle and applications. Transcriptome, Single cell transcriptomics. Techniques in transcriptomics-, EST, SAGE/CAGE, DNA microarray, RNA-Seq. Marine Transcriptomics. High-throughput genetic approaches to assessing gene function, RNAi, MicroRNAs, Gene Expression studies. Differential gene expression. Micro-array. Proteomics. Metabolomics. Comparative Transcriptomics.

24-315-0307

Seafood Microbiology and Quality Control (Elective), Credit: 2

Outcome:

After completing the course, students will be able to

- ***CO1:*** *Infer various microbiology related hazards in fish processing*
- ***CO2:*** *Explain different aspects of quality management systems and evaluation techniques for seafood*
- ***CO3:*** *Describe seafood quality assurance and quality assurance systems*
- ***CO4:*** *Locate various regulatory bodies in quality control*
- ***CO5:*** *Discuss the basic concepts and principles of quality standards asapplied to international trade*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	2	1	1	2	1	1
CO2	2	2	1	1	2	1	1
CO3	2	1	1	1	2	1	1
CO4	1	1	1	3	2	1	1
CO5	1	1	1	2	2	1	1

Unit-I:

Food as a substrate for microorganisms. Factors affecting growth of microorganisms in food – pH, water activity, oxidation-reduction potential, nutrient content, inhibitory substances and biological structure. Combined effect of factors affecting growth.

Unit- II:

Contamination of Fish – microflora of fish, cross-contamination from processing surfaces, water and ice. Cross-contamination from personnel in seafood processing units. Preservation of Fish – Use of heat, low temperature, irradiation and drying. Use of preservatives. Spoilage of fish and other seafoods – Factors affecting kind and rate of spoilage, evidences of spoilage, bacteria causing spoilage. Spoilage of special kinds of fish and seafoods.

Unit- III:

Pathogenic microorganisms in seafood. Microorganisms of public health significance – Faecal coliforms, Faecal Streptococci, *Vibrio parahaemolyticus, Vibrio cholerae, Salmonella, Listeria monocytogenes,Clostridium perfringens, Staphylococcus aureus*.

Unit- IV:

Quality control concepts in the seafood industry – Good Manufacturing Practices (GMP's), Standard Sanitation Operational Procedures (SSOP's), Food Safety Management Systems (FSMS), Total Quality Management and ISO systems. Concept of Hazard Analysis Critical Control Point (HACCP).

Unit- V:

Regulatory bodies in quality control. Role of Export Inspection Agency (EIA), Export Inspection Council (EIC), Marine Products Export Development Authority (MPEDA) and Bureau of Indian Standards (BIS). International Regulatory bodies – US Food and Drug Administration (USFDA) and the World Health Organisation (WHO). Quality standards of seafood for export to the European Union, USA, Japan and Australia.

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24-315-0308

Marine Botany (Elective), Credit: 2

Outcome:

After completing the course, students will be able to

CO1: *Describe the classification of micro and macroalgae, discuss their physiology, reproduction and identify ecological importance.*

CO2: *Explain the spatio-temporal variations in marine primary production and relate to the potential environmental drivers*

CO3: *Discuss on wetlands and its ecosystem services with reference to saltmarshes, seagrass, mangroves etc.*

CO4: *Explain harmful/ toxic algal blooms, its dynamics and impacts on marine environment as well as to develop mitigation measures.*

CO5: *Identify seaweed resources of India, its taxonomy and economic importance.*

CO6: *Apply various culture techniques for microalgae as live feed in aquaculture and for developing biofuel production techniques.*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	3	3	3	3	3	3
CO2	2	2	1	1	2	3	3
CO3	3	3	1	1	2	3	3
CO4	3	2	3	3	3	3	3
CO5	3	3	1	2	1	3	3
CO6	1	2	3	3	3	3	3

Unit- I:

Introduction to marine flora- general account, distribution, habit and habitat. Marine plant communities- –adaptations of planktonic algae, periphyton, microphytobenthos, epiphytes, seaweeds, seagrasses, salt marsh communities and mangroves. Periphyton in aquatic environment. The role of various plant communities in the marine food chain.

Systematics and characteristics of seagrasses, salt marshes and mangroves. Mangrove ecosystems, types, stratification, importance, degradation and restoration. Mangrove physiology. Kelp forest. Ecosystem services of seagrasses, salt marshes and mangroves. Blue carbon, carbon sequestration and its relevance.

Unit- II:

Marine algae: General account, habits and habitats, cellular organization, reproduction.

Microalgae: Collection, preservation, methods of estimation of standing crop, qualitative analysis with special reference to Cyanophyceae, Bacillariophyceae, Chlorophyceace, Haptophyceae, Cryptophyceae and Dinophyceae.

Macroalgae (Seaweeds): Taxonomy and Morphology of economically important seaweeds, structure, reproduction and life cycle of seaweeds with special reference to Chlorophyceae, Phaeophyceae and Rhodophyceae. Classification and pigment composition characteristics of macroalgae. Seaweeds associated with coral reefs.

Unit- III:

Marine fungi and Lichens: General account, classification, distribution and abundance. Role of fungi in the marine environment – fungal diseases of plants and animals. Potential bioactive compounds from marine fungi. Marine Lichens – general account.

Unit- IV:

Algal blooms - white and red water phenomena. Harmful and toxic algal blooms. Impact of algal blooms on the marine environment. Dynamics of algal blooms, major factors inducing the formation of algal blooms. Major bloom-forming phytoplankton. Algal blooms and climate change.

Microbial aspects of algal blooms. Detection of algal blooms by remote sensing. Winter cooling and algal blooms in the Arabian Sea. *Trichodesmium* bloom. Diazotrophs.

Unit- V:

Algal culture: Microalgae - the importance of microalgal cultivation, culture enclosures, isolation, purification, culture media, sterilization, sub-culturing,mass culturing, synchronous culture, continuous culture, tank culture, *in situ* culture and pond culture. Algae-bacterial interactions. Biofuel production.

Macroalgae: methods of cultivation, culture of green, brown and red algae. Seaweeds in food chain and safety in seaweed consumption. Global production of macroalgae. Economic importance of seaweeds. Seaweed resource of India. Utilization of seaweeds– agar-agar, carrageenan, agarose etc. Single cell protein. Value added products.

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24-315-0309

Health management in aquaculture (Elective) Credit: 2

Outcome:

After completing the course, students will be able to

CO1: *Identify the etiology and management of various infectious and non-infectious diseases in culture systems.*

CO2: *Describe the essential principles of aquatic animal health management, biosecurity, and specific issues associated with the system.*

CO3: *Recognize the significance of national and international instruments in quarantine, disease reporting, and surveillance and their application in the transboundary movement of aquatic organisms.*

CO4: *Develop the expertise necessary to understand the health problems encountered in aquatic animals and to cater to the needs of the aquaculture industry.*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	3	1	1	1	1	1	1
CO2	1	3	2	1	1	1	1
CO3	1	1	3	1	1	1	1
CO4	1	2	1	3	1	1	1

Unit I:

General introduction to fish and shellfish health management. Significance of fish diseases in relation to aquaculture. Host-pathogen-environment relationship. Water quality management and fish health. Role of stress in disease development.

Unit II:

Review of various diseases of finfish and shellfish significant to aquaculture. OIE listed fish and shellfish diseases. Vertical and horizontal

transmission of diseases. Disease monitoring, surveillance, epidemiology, quarantine, certification and import risk analysis.

Unit III:

Diagnosis and therapy of fish and shellfish diseases. Commonly used drugs/chemicals in aquaculture, drug delivery. Administration and mode of action of pathogen-specific drugs, drug resistance, drug regulation in India.

Unit IV:

Disease control and management. Prophylactic approaches - Probiotics in aquaculture, mode of action, pond probiotics, gut probiotics, pre-biotics. Immunostimulants – Source, diversity and mode of application. Antimicrobials for health management. Bioremediators – mode of action. Vaccines in aquaculture –Types and mode of administration. Use and abuse of antibiotics and chemicals in health management. Antimicrobial peptides and its applications in aquaculture.

Unit V:

Application of health management protocols and biosecurity principles in aquaculture. Seed certification. Fish health and quarantine systems. Quarantine protocols and facilities, Broodstock and seed quarantine measures, Quarantine of aquatic animals and premises. SPF and SPR stocks– principles, development and applications. Long term strategy in health management; recent advances in disease control and management in aquaculture.

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24-315-0310

Advanced Taxonomy and Phylogenetics of Marine Organisms (Elective) Credit: 2

Outcome:

After completing the course, students will be able to

CO1: *Define and analyze advanced taxonomic concepts*

CO2: *Discuss and explain in-depth molecular phylogenetic investigations*

CO3: *Apply and interpret state-of-the-art molecular techniques*

CO4: *Analyze the samples using advanced imaging and morphometric methods*

CO5: *Formulate and integrate big data and bioinformatics*

CO6: *Apply and interpret functional genomics and transcriptomics data*

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
CO1	1	2	1	1	2	3	3
CO2	2	2	1	2	3	3	3
CO3	1	1	1	1	3	2	3
CO4	1	1	1	1	3	2	3
CO5	1	2	1	1	3	2	3
CO6	1	2	1	1	3	2	3

Unit I:

Advanced Taxonomic Techniques - Emerging trends in marine taxonomy - Integrating traditional and high-throughput molecular approaches - Taxonomic challenges and controversies in the genomic era.

Unit II:

High-Throughput Sequencing and Metabarcoding - Principles and applications of next-generation sequencing - Metabarcoding for rapid biodiversity assessment - Environmental DNA (eDNA) analysis in marine ecosystems.

Unit III:

Advanced Imaging and Morphometric Analysis - High-resolution imaging techniques in marine taxonomy - 3D morphometrics and geometric morphometrics - Image analysis software for taxonomic identification.

Unit IV:

Functional Genomics and Transcriptomics - Transcriptomic approaches to understanding marine organism functions - Functional genomics in the context of marine adaptation - Applications of RNA-Seq in marine taxonomy. Environmental Genomics and Microbiome Analysis - Metagenomics for studying microbial communities in marine environments - Microbiome analysis of marine organisms - Eco-genomic approaches to understanding host-microbe interactions.

Unit V:

Machine Learning and Artificial Intelligence in Taxonomy - Applications of machine learning in marine organism classification - AI-driven data analysis for taxonomic inference - Challenges and ethical considerations in using AI for taxonomy.

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