

**Syllabus of Courses for Master of Science (MS) in three branches for  
the session 2018-2019 and 2019-2020**

**Department of Fisheries  
Faculty of Biological Sciences  
University of Dhaka**

One year Master of Science (MS) will be offered and the degree will be in three branches which are as follows:

Name of the Branch:

1. *Aquaculture*
2. *Fisheries Biology and Genetics*
3. *Fisheries Management*

Course no 501-506, 510 & 514 are compulsory and 507-509 are optional. Students have to choose one course from the optional courses. Course no 511 and 512 are for Project Group (A) and course no 513 is for Thesis Group (B).

## Course Outline

Name of the Branch: Aquaculture (AQ)

### Distribution of Courses

Course no	Title	Credit
<b>Compulsory course</b>		
AQ 501	Aquaculture Production Systems	3
AQ 502	Aquaculture Feed Technology	3
AQ 503	Aquatic Animal Health Management	3
AQ 504	Reproductive Aquaculture and Aquatic Seed Production	3
AQ 505	Aquaculture Genomics and Biotechnology	3
AQ 506	Statistical Applications in Aquaculture	3
<b>Optional course (any one)</b>		
AQ 507	Immunology and Aquaculture Pharmacology	2
AQ 508	Sustainable Aquaculture and Environmental Management	2
AQ 509	Aquaculture Project Management	2
Sub Total (a)		20

### Project group (A)

FM 510	Seminar presentation	2
FM 511	Project (Project - 2 credits; Project presentation - 1 credit)	3
FM 512	Practical	3
FM 514	Viva-voce	2
Sub-Total (b)		10
<b>Grand Total (a+b)</b>		<b>30</b>

### Thesis group (B)

FM 510	Seminar presentation	2
FM 513	Thesis (Thesis - 4 credits; thesis presentation - 2 credits)	6
FM 514	Viva-voce	2
Sub-Total (c)		10
<b>Grand Total (a+c)</b>		<b>30</b>

## Course Outline

### Distribution of Courses

Name of the Branch: Fisheries Biology and Genetics (FBG)

Course no	Title	Credit
<b>Compulsory course</b>		
FBG 501	Biology of Finfish and Shellfish	3
FBG 502	Fish Reproductive Biology and Endocrinology	3
FBG 503	Aquaculture Biotechnology and Biosafety Regulation	3
FBG 504	Biosafety Regulation	3
FBG 505	Immunopathology and Vaccine Development	3
FBG 506	Fish Population and Conservation Genetics	3
<b>Optional course (any one)</b>		
FBG 507	Bioinformatics in Fisheries	2
FBG 508	Research Design and Genetic Data Analysis	2
FBG 509	Laboratory Techniques in Molecular Biology and Genetics	2
Sub Total (a)		20

#### Project group (A)

FM 510	Seminar presentation	2
FM 511	Project (Project - 2 credits; Project presentation - 1 credit)	3
FM 512	Practical	3
FM 514	Viva-voce	2
Sub-Total (b)		10
<b>Grand Total (a+b)</b>		<b>30</b>

#### Thesis group (B)

FM 510	Seminar presentation	2
FM 513	Thesis (Thesis - 4 credits; thesis presentation - 2 credits)	6
FM 514	Viva-voce	2
Sub-Total (c)		10
<b>Grand Total (a+c)</b>		<b>30</b>

## Course Outline

### Distribution of Courses

#### Name of the Branch: Fisheries Management (FM)

Course no	Title	Credit
<b>Compulsory course</b>		
FM 501	Inland Fisheries Management	3
FM 502	Coastal and Marine Fisheries Management	3
FM 503	Aquatic Pollution, Climate change and Fisheries	3
FM 504	Population Dynamics and Aquatic Systems Modelling	3
FM 505	Fisheries Policy and Governance	3
FM 506	Research Methodology and Statistical Application in Fisheries	3
<b>Optional course (any one)</b>		
FM 507	Geospatial Technology in Fisheries	2
FM 508	Aquatic Ecosystems, Biodiversity and Conservation	2
FM 509	Fisheries Economics and Business	2
Sub Total (a)		20

#### Project group (A)

FM 510	Seminar presentation	2
FM 511	Project (Project - 2 credits; Project presentation - 1 credit)	3
FM 512	Practical	3
FM 514	Viva-voce	2
Sub-Total (b)		10
<b>Grand Total (a+b)</b>		<b>30</b>

#### Thesis group (B)

FM 510	Seminar presentation	2
FM 513	Thesis (Thesis - 4 credits; thesis presentation - 2 credits)	6
FM 514	Viva-voce	2
Sub-Total (c)		10
<b>Grand Total (a+c)</b>		<b>30</b>

**Name of the Branch: Aquaculture (AQ)**

**AQ 501      Aquaculture Production Systems**

**Credit: 3**

1. **Role of aquaculture:** Status of aquaculture, Production systems, future and challenges
2. **Functions and characteristics of aquaculture:** Differences in aquatic and terrestrial livestock, Ecological services provided by aquaculture production systems, Diversity of aquaculture animals, Temperature classifications of aquacultured animals, Temperature control, Providing oxygen and Waste control in aquaculture systems, Aquaculture systems as providers of natural foods
3. **Characterization and categories of aquaculture production system:** Open systems, Semi-closed systems, Closed systems, Hybrid systems
4. **Culture of crocodiles, spirulina, Seaweeds**
5. **Recirculating aquaculture:** Overview of system engineering, Culture tanks, Waste solids removal, Settling basins and tanks, Mechanical filters, Granular media filters, Disposal of the solids, Biofiltration, Aeration and oxygenation, Carbon dioxide removal, Monitoring and control, Recirculation system design, Stocking density, Conclusion
6. **Biofloc based aquaculture production systems:** Bioflocs, Oxygen dynamics, Resuspension, mixing, and sludge management, Nitrogenous waste products, Temperature, Feeds and feeding, Economics and Sustainability
7. **Aquaponics:** System design, Fish production, Solids, Biofiltration, Hydroponic subsystems, Sump, Construction materials, Component ratios, Nutrient dynamics, Vegetable selection, Crop production systems, Pest and disease control, Approaches to system design, Economics, Prospects for the future
8. **Brackishwater Aquaculture:** Shrimp, prawn crab culture
9. **Policy and Governance in aquaculture:** Introduction role of aquaculture governance, sustainability, types of aquaculture governance, Importance and trends in aquaculture governance - The importance governance governance models, Governance pyramid in aquaculture - pillars and principles of aquaculture governance, role of government in aquaculture governance, Legislative framework of aquaculture - regulatory framework of aquaculture operation, regulations for managing aquaculture operation, Licence policies, regulations for marketing aquaculture products, Role of other stakeholders in aquaculture governance - community groups and participation, NGOs, producers associations, Strategies and their governance - Integrated coastal zone management, promotion of foreign investment, promotion of large companies, promotion of clusters and nucleus farms, Governance measures - Data collection, Research, risk analysis and subsidiary, Policy instruments - supply-side instruments, capital and credit constraints, feed and seed constraints, demand-side policy instruments, Challenges - Certification, industrial concentration, offshore aquaculture, social licence, climate change, international trade

## 10. Environmental impact assessment and monitoring in aquaculture

11. **Aquaculture insurance:** Introduction, Aquaculture insurance industry stakeholders and their roles, Aquaculture policy types and conditions, Aquaculture insurance - development constraints and opportunities, The process of insurance market, Developing the market for aquaculture insurance

### References

1. Tidwell, J H (etd) 2012. Aquaculture Production Systems. Wiley-Blackwell and World Aquaculture Society. 421 pp.
2. Jerry, D R. 2014. Biology and Culture of Asian Seabass *Latescalcarifer*. CRC Press. 317 pp.
3. FAO (Food and Agriculture Organization) 2007. Fisheries Technical Paper 496.
4. FAO (Food and Agriculture Organization) 2014. Fisheries and Aquaculture Technical Paper 577.
5. FAO (Food and Agriculture Organization) 2009. Fisheries and Aquaculture Technical Paper 527.

### AQ 502 Aquaculture Feed Technology

Credit: 3

1. **Introduction of fish nutrition;** nutritional requirements of culturable fishes and shellfishes; proteins and amino acid; lipids and fatty acid; carbohydrates, vitamins, minerals and water.
2. **Sources of nutrition:** naturally produced food in ponds; food produce through fertilization and supplementary feeding and complete artificial feeding.
3. **Digestibility study of fish feed:** Digestion co-efficient, determination of nutrient digestibility, apparent and true digestibility, factors affecting digestibility.
4. **Energy metabolism in cultivated fishes and crustaceans:** unit of measurement and definition of terms, partitioning of biological energy, energy flow in animal system, specific dynamic action (SDA), energy metabolism in fish, energy requirement of fish, factors affecting energy requirement of fish, dietary energy sources.
5. **Broodstock nutrition:** energy partitioning for reproduction, protein requirement of broodstock, effect of dietary quality on reproductive output, known nutritional requirements of some broodstock fishes.
6. **Feed stuffs:** Conventional and unconventional feed stuffs, dietary ingredients available in Bangladesh. Proximate composition of dietary ingredients and fertilizers. Naturally occurring and adventitious toxins feed stuff.
7. Non nutrient dietary components, water, hormone, antibiotics, fibers, binders, antioxidants, pigments and feeding stimulants
8. **Food formulation, preparation and processing - supplementary and complete diets:** feed formulation and preparation for cultivable species, feed milling process, effect of processing on the Nutritional value of feed, quality control in feed

manufacture, manufacture of compounded feeds in developing countries, Feed storage.

9. **Feeding methods for supplementary and complete diets:** Selection of feed ingredients feed preparation supplemental feeding and natural productivity, feeding level and frequency. Economics of supplemental and complete feeding.
10. **Techniques and methodologies for fish feeding experiments:** Control environmental studies and field studies

## References

1. De Silva, S.S. and Anderson, T.A., 1995. Fish Nutrition in Aquaculture. Chapman & Hall, London, 319 pp.
2. Halver, J.E. 1998. Fish nutrition. Academic press. New York, 798pp.
3. Hefner, B., 1990. Nutrition of Pond Fishes. Cambridge University Press, Cambridge, 388 pp.
4. AOAC, 1990. Official Methods of Analysis-15th Edition, Association of official Analytical Chemists, Washington DC.
5. Goddard, S., 1996. Feed Management in Intensive Aquaculture, Chapman & Hall, Dept. BC, 115 Fifth Avenue, New York, NY 10003, 194 pp.
6. Guillaume, J., Kaushik, S., Bergot, P. and Metailler, R., 2001. Nutrition and Feeding of Fish and Crustaceans. Praxis Publishing, Chichester, UK, 408 pp.
7. Lovell, T., 1998. Nutrition and Feeding of fish. Kluwer Academic Publishers, 3300 AH Dordrecht, The Netherlands, 267 pp.
8. New, M.B., 1987. Feed and Feeding of Fish and Shrimp. ADCP/REP/87/26, UNDP/FAO, Rome, 275pp.
9. Steffens, W., 1989. Principles of Fish Nutrition. Ellis Hordwood Ltd., West Sussex, 384pp.
10. Tacon, A.G.J., 1990. Standard Methods for the Nutrition and Feeding of Farmed Fish and Shrimp. Argent Laboratories Press, Washington, 454 pp.
11. Tacon, A.G.J. and Basurco, B., 1997. Feeding Tomorrows Fish. CIHEAM/FAO/IEo, Zaragoza (Espana), 307 pp.
12. Webster, C.D. and Lim, C.E., 2002. Nutrient Requirements and Feeding of Finfish for Aquaculture. CABI Publishing, CAB International, Wallingford, Oxon OX10 8DE, UK, 448 pp.

**AQ 503**

**Aquatic Animal Health Management**

**Credit: 3**

1. **Basics of fish and shellfish health management:** purpose, aquaculture production, trans-boundary movement of aquaculture species and associated pathogen transfer, pathogen transfer and economic significance, international conventions and codes of practice.
2. **Epidemiology:** Epidemiology in aquatic animal health management, classical and molecular approach in epidemiological studies

3. **Disease zoning:** surveillance and reporting, purpose description of zones, requirement for disease-free zoning, practical application of zoning in Bangladesh, issues to consider during zoning
4. **Contingency planning:** import risk analysis (IRA), government/institutional level contingency planning, farm-level contingency planning, development and implementation
5. **Methods for disease control and management:** Fish health and quarantine systems & certification, processes, pathogen containment facilities, health examinations, capacity and institutional implications
6. **Diagnosis of diseases:** levels of disease diagnosis, applications of histopathology, antibody probes and molecular techniques in the diagnosis and control of fish diseases, applications of biotechnology to novel diagnostics for aquatic animals
7. **Biotechnological approach to fish health management:** application of genomics, proteomics and metabolomics
8. **Biosecurity strategies in aquatic animal health:** country and farm level biosecurity measures, issues need to consider in biosecurity planning and implementation
9. OIE, FAO, NACA technical guidelines for aquatic animal health management
10. **National strategies and policy frameworks:** regional capacity building for disease management, legislative frameworks, harmonization with international standards

#### References

1. FAO Fisheries Technical Paper (402) 2000. Asia Regional Technical Guidelines on Health Management for the Responsible Movement of Live Aquatic Animals and The Beijing Consensus and Implementation Strategy.
2. Bancroft, J.D. and Stevens. A. 1990. Theory and practice of histological techniques (3<sup>rd</sup> edition), Churchill living stone. Edinburgh. UK. Woo, P.T.K. and D.W. Bruno, 1999. Fish diseases and disorders (Vol.3). CABI Publishing.

#### **AQ 504 Reproductive Aquaculture and Aquatic Seed Production Credit: 3**

1. **Reproduction in fishes:** Introduction, Sexuality in fishes, Sexual dimorphism, Reproductive cycle, Reproductive strategies, Fecundity and spawning, Courtship and mating, Style of reproduction, Hormonal control of reproduction
2. **Gamete extraction technique:** Reproduction and control of ovulation, spermiation and spawning in cultured fish, methods of sperm collection
3. **Sperm and egg quality evaluation:** Sperm quality assessment, egg quality determination
4. **Artificial fertilization in aquaculture species: Normal practice to chromosomal manipulation**
5. **Cryopreservation of fish gametes:** Chilled storage of sperm and eggs, Basic principles of fish spermatozoa cryopreservation, Cryopreservation of oocytes, Cryobiological material and handling procedures\
6. **Protocols for sperm cryopreservation**
7. **Genetic improvement of the stock**
8. **Seed production of Major carps, Chinese carps, common carp, catfishes**
9. **Seed production of tilapia**



## 10. Breeding and seed production of ornamental fishes

## 11. Seed production of tiger shrimp and giant prawn

### References

1. Cabrita E, Robles V and Harraez P (etd). 2009. Methods in Reproductive Aquaculture Marine and freshwater species. CRC press. 549 pp.
2. Thomas, PC, Rath SC, and Mohapatra KD. 2003. Breeding and seed production of fin fish and shell fish. Daya Publishing House. 402 pp.

### AQ 505 Aquaculture Genomics and Biotechnology

Credit: 3

1. **Fundamental principles of molecular biology, genomics and biotechnology:** Overview, advantages of fish in biotechnological research, and applications of genetic engineering and biotechnology in fish. Recombinant DNA technology: Restriction endonucleases, creation of recombinant DNA molecules, gene cloning; construction of DNA library.
2. **Basic molecular laboratory methods:** Molecular techniques: Electrophoresis, Southern blotting, Northern blotting, Western blotting, hybridization of nucleic acids; Polymerase Chain Reaction (PCR). DNA markers: Principles and techniques of RFLP, RAPD, AFLP and microsatellite DNA markers and their applications
3. **Application of genomics and proteomics in aquaculture:** selective breeding, hybridization, chromosome set manipulation, gene transfer technologies, molecular techniques, proteomics technologies applied to aquaculture, proteomics to evaluate quality of aquaculture species, proteomics to assess the potential risks associated to aquaculture
4. **Aquaculture-related applications of DNA microarray technology:** Principles of Microarrays, Spotted Array Design and Construction, Array Design and Construction, Experimental Sample Labeling and Hybridization, Microarray Research in Aquaculture Species, Future Directions of Microarray Research, Considerations When Starting Microarray Research, Applications for Salmonid DNA Microarrays
5. **Mapping genomes of aquaculture species (finfish, shellfish and molluscs):** Marker-Assisted Selection (MAS) for Aquaculture species: Introduction, Definition and Theory of Marker-assisted Selection (MAS), Requirements and Limits of MAS Implementation, Parentage Testing, Species Identification, and Marker-assisted Introgression, MAS Developments in Aquaculture, Applications and Limitations in Aquaculture
6. **Functional genomics:** Introduction, The Concept of Functional Genomics, Approaches to Functional Genomics, Functional Correlation of Gene Positions, Expression Quantitative Trait Loci Analysis, Functional Inference by Comparative Genome Analysis, Gene Pathway Analysis, Profiling of DNA-Protein Interactions and Epigenetic Modifications, Direct Test of Gene Functions, Functional Genomics Approaches Suitable for Aquaculture
7. **Sequencing the genome of aquaculture species:** Sanger's dideoxynucleotide chain termination method (the enzymatic method), Maxam-Gilbert sequencing method, Pyrosequencing and the 454 sequencing platform, The 454 sequencing platform, The Solexa sequencing platform, Next Generation DNA Sequencing Technologies and Applications, Library Construction for Next Generation Sequencing

8. **Bioinformatics in Aquaculture:** Introduction, Sequence Alignment, Genome Analysis, Microarray Analysis
9. **Genomic tools for broodstock improvement:** Chromosome Manipulation, Production of gynogenes, androgenes, induced triploids, induced tetraploids, production of supermale and monosex population and their applications.
10. **Gene transfer/transgenesis technology in aquaculture:** Transgenesis: Production of transgenic fish in aquaculture, Gene selection, methods of gene transfer in fish, genomic integration and expression of transgenes, release and management of transgenic individuals, applications of transgenics.
11. **Ethics in aquaculture biotechnology:** Bioethics and moral virtues, biosafety of transgenic fish
12. **Biotechnological applications in molluscs and shellfish aquaculture:** Production of Monoclonal antibodies, Nucleic Acid Probe technology, Animal vaccine development and production, New technologies

### References

1. Liu ZJ. Editor, *Aquaculture Genome Technologies*, pp.551, Blackwell Publishing, 2007, Ames, IA. ISBN: 978-0-8138-0203-9. This book has been translated into Chinese language by Bao et al. and published by the Chinese Chemical Publishing, 2011.
2. Liu ZJ. Editor, *Next Generation Sequencing & Whole Genome Selection in Aquaculture*, pp.221, Wiley and Blackwell Publishing, 2011, Ames, IA. ISBN: 978-0-8138-0637-2
3. Saroglia M and Liu ZJ, editors, *Functional Genomics in Aquaculture*, pp. 407, Wiley and Blackwell Publishing, 2012, Ames, IA. ISBN 978-0-4709-6008-0

### AQ 506

### Statistical Applications in Aquaculture

**Credit: 3**

1. **Introduction:** Definition of statistics, Definition of data, Types of data, Accuracy and precision, Significant figures, Significance of Statistical study, limitations
2. **Data processing:** Classification, Variables, Frequency distribution, Graphs, Graphs of frequency distribution
3. **Measures of Central Tendency:** Means (Arithmetic mean, Geometric mean, Harmonic mean, Weighted mean), Median, Mode
4. **Measures of dispersion:** Absolute measures, Range, Mean deviation, Standard deviation, Variance, Standard error of the mean, Coefficient of variation, Decile, Quartile, Percentile
5. **Distribution:** Normal, binomial, poisson, t- and f- distribution, sampling, Skewness and kurtosis
6. **Experimental designs:** CRD, CRBD, Latin square and split plot designs.
7. **Test statistics:** a) T-tests: One Sample Hypothesis, two and paired sample hypotheses b) ANOVA (multiple sample hypothesis) - single factor ANOVA, Two factor ANOVA, Nonparametric ANOVA.
8. **Multiple comparisons:** The Tukey Test, DMRT, Newman-Keuls test, Multivariate analysis
9. **Correlation and regression:** Types of correlations, Degree of correlations, Coefficient of correlation, Co-efficient of determination, Types of regression

## References

1. Hoshmand, R.A. 1994. Experimental research design and analysis A practical approach for Agricultural and natural Sciences. CRC press.
2. Zar, J.H. 1984. Biostatistical Analysis. 4<sup>th</sup> Edition. Prentice-Hall INC.
3. Dytham, C. 1999. Choosing and using Statistics: A Biologist's Guide. Blackwell.
4. Egna, HS and Boyd, CE (Etd). Dynamics of pond aquaculture. CRC Press. 325-375 pp.

## AQ 507

## Immunology and Aquaculture Pharmacology

Credit: 2

1. **Immune system of fish:** Introduction, specific and non-specific immune response, factors influencing the immune response, Innate and adaptive immunity in teleost fish, Antibody and cell mediated immunity in fish and shellfish, Immunological control of fish diseases, Immunostimulants for Aquaculture Health Management
2. **Antimicrobial peptides and their potential therapeutants in aquaculture,** Immune related genes of aquaculture species, Impact of aquatic genomics on fish immunology
3. **Safety of fish medicines:** Aspect of safety. Safety of the target species, safety of the operator, safety of the consumer and safety of the environment. Legislation related to drug usage.
4. **Vaccines:** Methods of vaccination in fishes, types of vaccines, adjuvants; Immunization against infectious diseases of fish caused by viral, bacterial, fungal and parasitic pathogens,
5. **Antibacterial drugs:** Selection of antibacterial drugs, bacterial resistance; Group characteristics, uses with dose rate, toxicology, pharmacokinetics and pharmacodynamics of tetracyclines, penicillins, marolides, sulfonamides, potentiated sulfonamides, quinolones and fluoroquinolones, nitrofurans and chloramphenicols.
6. **Chemotherapeutic agents and their uses:** Systemic anti-protozoal agents: Fumagilin, niroimidazoles. Externally applied antimicrobial agents: Formalin, malachite green, leteux-meyer mixture, Chloramines-T, copper sulfate. Ectoparasiticides: Organo phosphorus compounds, hydrogen peroxide, ivermectin, cyprmethrin, benzyl ureas.
7. **Anesthetics:** Uses and mode of action of MS-222, Benzocaine and other anesthetic agents. Properties of hypnotics and sedatives.

## References

1. Treves-Brown KM. 2000. *Applied Fish Pharmacology*. Kluwer Academic Publishers, Dordrecht, 310 pp, 0-412-62180-0

2. Ross, LG and Ross, B. 2008. Anesthetics and sedative Techniques for aquatic animals. Blackwell Publishing, 222 pp.

**AQ 508                    Sustainable Aquaculture and Environmental Management                    Credit: 2**

1. **Concept of sustainability and sustainable management:** FAO code of conduct for responsible fisheries and aquaculture, Ecosystem approach to aquaculture (EAA), Better management practices for aquaculture.
2. **Nature of environmental impacts:** Impact of fisheries and aquaculture on environment, mitigating and managing the negative impacts, Waste production in aquaculture and their management, EIA (environmental impact assessment) for aquaculture projects
3. **Siting and Design of Farms for sustainable management:** Species and System Selection for Sustainable Aquaculture, open water IMTA
4. Impacts of exotic and invasive aquaculture species and their mitigation
5. **Application of GIS and remote sensing for sustainable aquaculture development:** stakeholder analysis, joint assessment and decision making, joint financial and economic assessment
6. **Sustainable rural, urban and peri-urban aquaculture:** Sustainable livelihood approaches, vulnerability, resilience, adaptive and alternative development pathways, aquaponics, urban RAS
7. **Economic decision making in sustainable aquaculture development:** guiding principles for aquaculture sector planning, supporting new development paradigms
8. Research, planning, regulation and administration for sustainable aquaculture development

**References**

1. Stuart W. Bunting. 2013. Principles of Sustainable Aquaculture: Promoting Social, Economic and Environmental Resilience
2. T.V.R. Pillay. 2004. Aquaculture and the Environment, Second Edition
3. John E. Bardach. 1997. Sustainable Aquaculture, John Wiley & Sons

**AQ 509                    Aquaculture Project Management                    Credit: 2**

1. Principles of aquaculture systems and management, Scope of aquaculture project management, organization for project formulation and management
2. Management functions and activities: Management styles and attributes of successful managers, Contingency theory, management skills and productivity, aquaculture projects compared with those for agriculture
3. Feasibility of projects: various aspects to check feasibility of projects, Decision making tools and computer assisted project management, project decision matrix
4. Project Life cycles and production strategies, Project design, technical and social-economic investigations, reconnaissance and preliminary project design,

5. Logical framework approach (LFA) in project management: Steps, checking project design, uses of LFA
6. Overview of project implementation, Project identification, preparation and appraisal, analysis of expected results, financial, economic, social and environmental impact
7. Project documentation and submission, preparation and submission of the project report
8. Project appraisal, project negotiation, fulfilment of conditions, project agreement, project profitability criteria.

## References

1. James W. Meade, Aquaculture Management
2. Insull, D.; Nash, C.E., Aquaculture project formulation. FAO Fisheries Technical Paper. No. 316. Rome, FAO. 1990. 129p.
3. Wickramanayake, Ebel. 1994. How to check the feasibility of projects, Asian Institute of Technology, Bangkok
4. NORAD. 1992. The logical framework approach (LFA)-Handbook for objectives-oriented planning, Norwegian agency for development cooperation.

**AQ 512**

**Practical**

**Credit: 3**

1. Application of Environmental impact assessment tools
2. RAS, Biofloc, Aquaponics system design and farms demonstration
3. Visit to crocodiles, spirulina and seaweeds farms
4. Measurements of pH, Temperature, Conductivity, Salinity, Transparency, Turbidity and Solids
5. Analysis of dissolved oxygen concentration, ammonia, nitrite and nitrate nitrogen, Phosphorus
6. Determination of Primary productivity
  - i) Oxygen method
  - ii) Chlorophyll a method
7. Determination of Moisture and dry matter, Ash, Crude protein, Crude lipid, Crude fibre
8. Determination of nutrient digestibility, apparent and true digestibility
9. Feed formulation and preparation for cultivable species
10. Techniques and methodologies for fish feeding experiments
11. Diagnosis of diseases by histopathology, antibody probes and molecular techniques
12. Sperm and egg quality evaluation, Protocols for sperm cryopreservation
13. Visit hatchery for hands-on training on breeding and seed production of commercially important finfish and shellfish species
14. Molecular techniques: Electrophoresis, Southern blotting, Northern blotting, Western blotting, hybridization of nucleic acids; Polymerase Chain Reaction

(PCR). DNA markers: Principles and techniques of RFLP, RAPD, AFLP and microsatellite DNA markers

**15.** Bioinformatics in Aquaculture: Introduction, Sequence Alignment, Genome Analysis, Microarray Analysis

**16.** Use of various statistical software viz., SPSS, STATA, R

**17.** Hands-on training on various aquaculture project formulation

## Name of the Branch: Fisheries Biology and Genetics (FBG)

**FBG 501**

**Biology of finfish and shellfish**

**Credit: 3**

1. **Fish and Shellfish resources:** Overview of the fish and shellfish resources of Bangladesh and world, economic importance of the major fish and shellfish resources, habitat needs for the sustenance of shellfishes.
2. **Biology:** Life history, food and feeding habits, age and growth, sexuality and reproduction, breeding behaviour of the following indigenous and exotic fishes (a) *Labeo rohita* (b) *Gibelion catla* (c) *Hypophthalmichthys molitrix* (d) *Tenualosa ilisha* (e) *Clarias batrachus* (f) *Pangasius pangasius* (g) *Anabas testudineus* (h) *Monopterus albus* (i) *Tor tor* (j) *Channa striatus* (k) *Oreochromis niloticus* (l) *Barbonymus gonionotus* (m) *Scoliodon Spp* (n) *Lates calcarifer*
3. **Fish migration:** Types of migration, preconditions for migration, migration of anadromous and catadromous fishes with special emphasis on *Tenualosa ilisha* and *Anguilla bengalensis*.
4. **Effects of environmental factors on the biology of fishes:** Adaptation of fishes to different environments- adaptation to changes in salinity and to estuarine conditions, cavernicular adaptations and adaptation to drought conditions.
5. **Crustacea:** General body plan, size and form, natural distribution and numerical abundance, habits and habitat. Commercial species available in Bangladesh, morphological features, food and feeding habits, shell formation and regeneration, age and growth, condition index, reproduction and development of prawn/shrimp (*Macrobrachium rosenbergii* and *Penaeus monodon*), mud crab (*Scylla serrata*), lobster (*Thenus orientalis*) and cray fish (*Procambarus clakii*).
6. **Mollusca:** External morphology, natural distribution and numerical abundance, habits and habitats, Food and feeding habits, shell formation and regeneration, age and growth, condition index, reproduction and development of Gastropoda (*Pila globosa*), Bivalvia (*Lemellidens marginalis* and *Crassostrea virginica*) and Cephalopoda (*Loligo edulis* and *Octopus vulgaris*). Biology of pearl formation; natural and artificial mechanisms of pearl formation.
7. Environmental impacts on the biology of finfish and shellfish.

### References

1. Bone, Q. 2008. Biology of Fishes. Taylor and Francis, 450p.
2. Lagler, K.F., J.E. Bardach, R.R. Miller and D.R.M. Passino. 1977. Ichthyology (2<sup>nd</sup> Edition). John Willey and Sons Inc, New York, 506p.
3. Barton, M. 2000. Bond's Biology of Fishes. 3<sup>rd</sup> Ed. Thomson Brooks, 912p.
4. Chan, T.Y. 1998. Shrimps and prawns. *In*: Carpenter, K.E. and Niem, V.H. (eds.). The living marine resources of the western Pacific, Vol. 2., FAO, Rome, pp. 851-971.
5. Arrigaton, J.C.V., J.V. Huner, J.M. Griessinger, D. Lacroix, P. Gondouin and M. Autrand. 1994. Warm-water crustaceans, The Macmillan Press Ltd., London and Basingstoke, 160p.
6. Bliss, D.E. 1983. The biology of crustacean. Vol. 8: Environmental adaptations. Academic press. New York, 383p.

1. **Functional morphology of fish gonads:** Primordial germ cells and sex differentiation, morphology and composition of eggs, egg membrane and micropyle, morphology of sperm; gonadal development.
2. **Gametogenesis:** Oogenesis and folliculogenesis, primary oocyte growth, cortical granule formation, vitellogenesis, pigment formation, spermatogenesis and biology of sperm: sperm production, biochemistry of sperm, sperm motility and metabolism, sperm survival and maturation.
3. **Viviparity in fishes:** Viviparity and gestation- evolutionary considerations, viviparity among the chondrichthyes, internal fertilization, ovoviviparity, viviparity among the teleosts and maternal-embryonic relationship.
4. **Reproductive behavior of fish and shellfish:** Pheromones, sex recognition and behavior, territory and space recognition, courtship, nest building and parental cares; Environmental factors and social factors influencing ovulation and spermiation, Effects of water pollution in fish reproduction system.
5. **Fish endocrine system:** Methods of study, assay of hormones, hormone synthesis, release and transport, receptor mechanisms, hormone action mechanisms, hormonal interrelations; Neuroendocrinology, Pituitary gland: anatomy and histophysiology, secretions, functions and mechanisms; Endocrinology of fish gonad: histology of testes, chemistry of androgens, regulation of testicular functions, biology of spermatozoa, environmental and sexual periodicity; Histology of the fish ovary, biochemistry of the ovarian hormones, endocrine control of ovary, vitellogenesis of eggs, hormonal control in egg maturation.

## References

1. Hoar, W.S. and Randall, D.J., 1984. Fish Physiology Vols. IXA and IXB. Academic Press.
2. Potts, G.W. and Wootton, R.J. (eds), 1984. Fish Reproduction: Strategies and Tactics. Academic Press, London.
3. Hoar, W.S., Randall, D.J., and Donaldson, E.M. (eds.), 1983. Fish Physiology Vol. IXA and IXB. Academic Press.
4. Heath, A.G., 1987. Water Pollution and Fish Physiology. CRC Press.
5. Muir, J.F. and Roberts, R.J., 1993. Recent Advances in Aquaculture IV. Blackwell Science Publication.
6. Hoar, W.S. and Randall, D.J., 1988. Fish Physiology Vol. XI (B).
7. Matty, A.J., 1985. Fish Endocrinology. Croom Helm, London, Sydney. TIMBER PRESS Portland, Oregon.
8. Zohar, Y. and Breton, B. (eds.), 1988. Reproduction in Fish: Basic and Applied Aspects in Endocrinology and Genetics. INRA Press, Paris.
9. Rankin, J.C., Pitcher, T.J., and Duggan, R. (eds.), 1983. Control and Processes in Fish Physiology. Croom Helm, London.
10. Shukla, A. N., 2009. Hormones of Fishes. Discovery Publishing House Pvt Ltd.
11. Turner, C.D. and J.T. Bagnara. 1976. General Endocrinology (6th edition). W.B. Saunders Company, London and Toronto.
12. Barrington, E.J. and C.B. Jorgensen (eds). 1968. Perspectives in Endocrinology. Academic Press, London and New York.
13. Bentley, P.J. 1982. Comparative Vertebrate Endocrinology (2nd edition),



Cambridge University Press, London.

14. Billard, R. and Gall, G.A.E., 1995. The Carp: Aquaculture Vol. 129. Elsevier.
15. Hoar, W.S. and D.J. Randal. 1969. Fish Physiology Vol. III. Academic Press, New York.
16. Melamed, P. and N. Sherwood. 2005. Hormones and their Receptors in Fish Reproduction. World Scientific Co. Pte. Ltd.
17. Norris, D. 2010. Hormones and Reproduction of Vertebrates. Vol. 1/5. Elsevier.
18. Squires, E. J. 2010. Applied Animal Endocrinology. 2nd Ed. CABI.

### **FBG 503 Aquaculture Biotechnology and Biosafety Regulations Credit: 3**

1. **Transgenesis:** GMO fish, spatial and temporal regulation of transgene expression in fish, antifreeze protein gene transfer-promises, challenges, and lessons from nature, potential applications of transgenic fish to environmental monitoring and toxicology, application of transgenic fish- tilapia for xenotransplantation, transgenic fish for environmental monitoring and toxicology, transgenesis for fish growth enhancement
2. **Test and post-release monitoring of genetically modified organisms (GMOs):** Testing of GMOs under containment, Confined field trials, Post-release monitoring of GMOs, GMO traceability and labelling - a need for commercial monitoring, Monitoring GMO imports and transboundary movements, recently developed techniques to avoid environmental and human health concerns
3. **Algal biotechnology:** single cell protein, hydrocolloids, agarose, carrageen alginates and other byproducts, marine enzyme sources and their applications, marine lipid source and their applications
4. **Broodstock Improvement:** Genomic tools for understanding the molecular basis of production-relevant traits in finfish, advances in genomics and genetics of penaeid shrimp, genetic and genomic approaches to major carp broodstock management.
5. **Gene bank and conservation:** Cryopreservation of gametes and embryos.
6. **Biotechnology in Fish diseases:** The application of genomics, proteomics, and metabolomics to studies of fish health, antimicrobial peptides and their potential as therapeutants in aquaculture, adaptive immunity in finfish, structural biology and functional genomics of the shrimp white spot syndrome virus and Singapore grouper iridovirus, DNA vaccines for viral diseases of farmed fish and shellfish.
7. **Embryogenesis and Stem Cells:** Egg transcriptome, the maternal legacy to the embryo, application of fish stem cell technology to aquaculture and marine biotechnology, culture of fish head kidney mononuclear phagocytes and muscle satellite cells, valuable models for aquaculture biotechnology research, germ cell transplantation in fish: basic biology and biotechnological applications.
8. **Legal aspects in Biosafety:** Overview of existing legal frameworks on biotechnology and biosafety, International Frameworks on Biosafety, Considerations of legal relevance to drafting national frameworks on biosafety, International Agreements Related to Biosafety
9. **Regulatory Management:** Establishing National Regulatory Systems, Infrastructure and Human Resource Development, Reducing Compliance Cost, Regional Cooperation

## References

1. Fish Genetics and Biotechnology – Ayappan et al . ICAR publication
2. Fisheries Biotechnology – W.S. Lakra
3. Aquaculture Biotechnology- Garth L. Fletcher, Matthew L. Rise. Copyright © 2012 John Wiley & Sons, Ltd.
4. Aquaculture and fisheries biotechnology- Rex A Dunham. CABI Publishing 2011
5. Bio technology and genetics in fisheries and aquaculture. ANDY BEAUMONT, k.HOARE. . Wiley-Blackwell; 2 edition (April 26, 2010)
6. Biosafety Guidelines of Bangladesh Gain report number BG4006
7. Kavita Gupta, J.L. Karihaloo and R.K. Khetarpal Biosafety Regulations of Asia-Pacific Countries, Asia-Pacific Association of Agricultural Research Institutions Asia-Pacific Consortium on Agricultural Biotechnology Food and Agriculture Organization of the United Nations
8. Alessandra Sensi, Oliver Brandenburg, Kakoli Ghosh, Andrea Sonnino FAO Biosafety resource book (Module C) Risk analysis
9. Oliver Brandenburg, Alessandra Sensi, Kakoli Ghosh, Andrea Sonnino FAO Biosafety resource book (Module D) Test and post-release monitoring of genetically modified organisms (GMOs)
10. Anna Milena Zivian, Alessandra Sensi, Carmen Bullón CaroFAO Biosafety resource book (ModuleE) Legal aspects

## FBG 504

## Molecular Genetics

Credit: 3

1. **Introduction to molecular biology:** Scope and branches of molecular biology.
2. **Molecular organization of chromosomes:** Chromosome proteins- histones, non-histones, nucleosome- morphology and function, chromatin organization- chromatin fiber and loops, chromosome band, chromosome condensation, heterochromatin.
3. **The genetic material:** Physical and chemical structure of DNA and RNA, DNA replication, repair and recombination mechanisms- the geometry and enzymology of DNA replication, the polymerization process and error correction.
4. **Gene expression:** Transcription- synthesis of mRNA, RNA polymerase- structure and function, splicing and processing of RNA molecules; translation the genetic code, codons and features, tRNA and aminoacyl synthetases, polypeptide synthesis. protein structure and functions.
5. **Regulation of gene expression:** regulation of gene expression- strategies of gene control, pre- and post-transcriptional modification.
6. **Gene mapping in fish:** Gene mapping techniques: genetic linkage analysis, centromere mapping, cytogenetics and physical mapping, DNA based technologies and physical mapping, Microsatellites: genetic markers for the future.
7. **Gene mining:** Identification of genes responsible for novel proteins, recombinant DNA technology for the large scale production of novel proteins, pharmaceutical, cosmetic and nutraceuticals and their use in drug designing - for various finfish and shellfish bacterial and fungal toxins. genetic manipulation in fisheries (production of disease and stress resistant fish)
8. **Mutation:** Types and notations, biochemical basis of mutants, mutagenesis, mutation hot-spots.

9. **Molecular Genetics in Fisheries:** Developments in molecular genetic techniques in fisheries, molecular genetics and the stock concept in fisheries, the role of molecular genetic markers in the management of cultured fishes

## References

1. Alberts, B., D. Bray, J. Lewis, M. Raff, K. Roberts and J.D. Watson. 2008. *Molecular Biology of the Cell*. (5th Edition). Garland Publishing Inc. New York and London.
2. Freifelder, D. 1987. *Molecular Biology* (2nd ed.). Jones and Bartlett Publishers, Inc. Boston Portola Valley.
3. Lewin, B. 1997. *GENES VI*. Oxford University Press. Oxford, England.
4. Carvalho, G.R. and Pitcher, T.J. 2012. *Molecular genetics in fisheries*. Springer Science & Business Media.
5. Darnell Jr, J., H. Lodish and D. Baltimore. 1995. *Molecular Cell Biology*. W.H. Freeman and Co., New York.
6. Hochachka, P.W. and T.P. Mommsen (eds). 1993. *Biochemistry and Molecular Biology of Fishes*. Vol. 2. Elsevier Science Amsterdam-London-New York-Toronto.
7. Kumar, H.D. 1998. *Molecular Biology*. Vikas Publishing House Pvt Ltd., New Delhi, India.
8. Lawrence, B.S. and S.J Lamont (eds). 1996. *The Major Histocompatibility Complex Region of Domestic Animal Species*. CRC Press, 319p.
9. Watson, J.D., M. Gilman, J. Witkowski and M. Zoller. 1992. *Recombinant DNA*. Scientific American Books, Newyork, 626p.
10. Watson, J.D., N.H. Hopkins, J.N. Roberts, J.A. Steitz and A.M. Weiner. 1987. *Molecular*

## FBG 505

## Immunopathology and Vaccine Development

Credits: 3

1. **The Innate and adaptive Immune system of Fish:** Introduction, innate immunity in fish, cytokines in innate immunity, interferons, the complement system, adaptive immunity in fish, immunoglobulins and B lymphocytes, T lymphocytes, cytotoxic T-Cells, helper T-Cells
2. **Antigens and antibody:** Structure and, types, epitopes, haptenes. Fine structure, classes with structure and functions of antibody, antigenic determinants on immunoglobulins, antigen-antibody reaction- precipitin reactions, agglutination reactions, pathogenicity and virulence, sources of infection, transmission of disease producing organisms, portals of infection, immunity to bacteria, fungi and parasites Role of stress and host defense mechanism in disease development.
3. **Immunostimulation of fish & Crustaceans:** Introduction, immune system of crustaceans, immunostimulants of fish and crustaceans
4. **Fish Immunostimulation, History & types of fish vaccine:** types, mechanism of action, modes of administration. immunoassays, immunodiffusion, ELISA, immunofluorescence, introduction, aquaculture, immunology, disease prevention, scientific production – reviews and conferences, successes and failures, the pioneers, non-replicating vaccines, replicating vaccines, DNA vaccines, mucosal vaccination of fish, side-effects of vaccination

5. **Vaccination as a Preventive Measure:** Introduction, biosecurity and vaccination, use of vaccination in aquaculture, vaccination against different diseases, herd immunity, economic considerations, risk assessment, the market for fish vaccines
6. **Adjuvants in Fish Vaccines:** Introduction, vaccine formulations, principles of adjuvant actions, antigenic component, adjuvants, antigen delivery systems, delivery vehicles, emulsion vaccines, biodegradable particulate delivery systems, fusion protein delivery system, immunomodulators, stabilizers
7. **Development, Production and Control of Fish Vaccines:** Introduction, manufacturing license, vaccine development, development of tests, transfers, manufacturing
8. **Legal Requirements and Authorization of Fish Vaccines:** Introduction, manufacturer authorization, food safety – maximum residue limits, genetically modified organisms, dna vaccines, prohibition of use of certain vaccines, use of vaccines that are not authorized, autogenous vaccines, regional rules and competent authorities, the european union and connected eea countries, united states of america, japan, other relevant organizations: OIE, FAO, WHO

### References

1. Roitt, I et al. 2012. Immunology, 8<sup>th</sup> edition, Elsevier publication.
2. Alexandra Adams, 2016. Fish Vaccines, 1<sup>st</sup> edition, Springer publication
3. R. Gudding, A. Lillehaug and Ø. Evensen, 2014. Fish Vaccination, Weley Blackwell publication.

**FBG 506**

**Fish Population and Conservation Genetics**

**Credit: 3**

1. **Genetic constitution of a population:** Hardy-Weinberg equilibrium; factors altering gene and genotype frequencies.
2. **Genetic variation within a subdivided population:** Quantitative measures of differentiation, genetic distance.
3. **Interpreting genetic variation detected by electrophoresis:** Basic principles; genotypic data from electrophoresis; strengths and limitations of electrophoretic data for studying protein loci.
4. **Natural hybridization and gene introgression in fishes:** methods of detection; genetic interpretation of hybridized population.
5. **Use of genetic markers in stock composition analysis:** General principles and applications; Molecular markers: restriction fragment length polymorphism (RFLP), amplified fragment length polymorphism (AFLP), random amplified polymorphic DNA (RAPD), mini and microsatellite VNTRs; DNA bar-coding and environmental DNA marker.
6. **Genetics of endangered species:** Finite population size and genetic drift; the effect of genetic drift, the founder effects and bottlenecks effective population size: separate sexes, variation in number of gametes, inbreeding, variation in time, age structure, neighborhood size, genetic aspects of endangered populations.
7. **Genetic management and conservation of fish:** Conservation of exploited and endangered fishes; cryopreservation and gene banking.

## References

1. Crow, J.F. and Kimura, M., 1970. An Introduction to Population Genetics Theory. Harper and Row Publishers, New York.
2. Falconer, D.S. and Mackay, T.F.C., 1996. Introduction to Quantitative Genetics (4rd Edition) Longman, UK.
3. Ryman, N. and Utter, F (editors) 1987. Population Genetics and Fishery Management.
4. Washington Sea Grant Program, University of Washington Press, Seattle and London.
5. Chapman, B. (Editor), 1985. General and Quantitative Genetics. Elsevier Science Publishers, B.V. Amsterdam-Oxford-New York-Tokyo.
6. Hartl, D.L. and Clark, A.G., 1989. Principles of Population Genetics (2nd edition). Sinauer Associates, Sunderland.
7. Hedrick, P.W., 1985. Genetics of Populations. Jones and Bartlett Publishers, Inc. Boston.
8. Kirby, L.T., 1990. DNA Fingerprinting: An Introduction. W.H. Freeman and Co. Saltlake City, UT.
9. Mayden, R.L. (Editor), 1993. Systematics, Historical Ecology, and North American Freshwater Fishes. Stanford University Press, Stanford, USA.
10. Mustafa, G. 1999. Genetics in Sustainable Fisheries Management. Blackwell Science Ltd.
11. Roberts, D.F. and De Stefano, G.F. (Editor), 1986. Genetic Variation and its Maintenance. Cambridge University Press.
12. Soule, M.E. (Editor), 1987. Viable Populations for Conservation. Cambridge University Press.
13. Turner, B.J. (Editor), 1984. Evolutionary Genetics of Fishes. Plenum Press.
14. Whitmore D.H. (Editor) 1990. Electrophoretic and Isoelectric Focussing Techniques in Fisheries Management. CRC Press.

**FBG 507**

**Bioinformatics in Fisheries**

**Credit: 2**

1. **Introduction:** Concepts, scope and applications; fields related to bioinformatics.
2. **Bioinformatics databases:** NCBI, nucleotide sequence databases, protein sequence databases, sequence motif, protein structure databases and gene bank sequence database, EBI-net, genome net.
3. **Genomics:** Genome diagnostics, genome projects, genome analysis, knockout of genes.
4. **Proteomics:** Protein properties, protein structural analysis- PyMol, gene ontology, databases; primary and secondary protein data bases, analysis packages, predictive methods, mass spectrometry.
5. **Molecular phylogeny and evolution:** Phylogenetic analysis and methods. microarray ESTs.

6. **Internet search:** BLAST, FASTA, retrieving information from different database like NCBI, protein information sources; preparation of data base.
7. **Use of genome analysis packages:** Phylogenetic analysis; accessing and submission to gene banks.

## References

1. Bioinformatics Basics: Applications in Biological Sciences and Medicine by Rashidi, H.H. and Buehler, L.K.
2. Bioinformatics, A Practical Guide to the Analysis of Genes and Proteins, A.D. Baxevanis and B.F. Ouellette
3. Bioinformatics: A Biologist's Guide to Biocomputing and the Internet Stuart M. Brown
4. Bioinformatics: Sequence and Genome Analysis, David W. Mount
5. Discovering Genomics, Proteomics, and Bioinformatics: Malcolm Campbell, A.
6. Introduction to Bioinformatics : Arthur M. Lesk
7. Introduction to Bioinformatics, Attwood, T.K. and Parry-Smith, D.J.

## FBG 508: Research Design and Genetic Data Analysis

**Credit: 2**

1. **Experimental design:** Completely randomized design, randomized block design, Latin square and split plot designs, analysis of variance: single factor and multiple factor ANOVA, multiple comparisons.
2. **Test of hypothesis:** One sample hypothesis, two and paired sample hypotheses, ANOVA (multiple sample hypothesis) - single factor ANOVA, two factor ANOVA, nonparametric ANOVA, multiple comparisons.
3. **Genome wide association studies (GWAS):** Rationale for taking a GWAS approach, subject and sample considerations, genotype data collection technologies, resources of interest for GWAS.
4. **Gene expression studies:** Candidate gene expression studies, rationale for taking a candidate gene expression approach, candidate gene selection, expression data collection technologies, global gene (genome wide) expression approach, microarrays, serial analysis of gene expression.
5. **Epigenetic studies:** Rationale for taking an epigenetic/epigenomic approach, subject and sample considerations, epigenetic and epigenomic data collection technologies, histone modification analysis, bisulfite-conversion based methylation analyses, restriction endonuclease-based methylation analysis, next generation sequencing (NGS) for histone modification analysis, next generation sequencing (NGS) for methylation analysis.
6. **Individual identification:** Introduction, Bayes' theorem, inbreeding and relatedness, paternity testing, forensic testing, mixed samples, error rates.
7. **Linkage:** Introduction, distances between genes, estimation of recombination, genetic map construction, linkage disequilibrium mapping, exercises.
8. **Phylogeny construction:** Distance matrix methods, parsimony methods and likelihood methods, bootstrap of phylogenetic tree.

9. **Recent novel approaches for population genomics data analysis:** The NGS revolution in population genomics, NGS methods, restriction-site associated DNA sequencing (RADseq), exon capture (DNA enrichment), RNAseq, whole genome sequencing, filtering sequencing errors, filtering PCR duplicates, filtering loci with inconsistent depth of coverage, genotype calling, the importance of using Linux command line and scripting.

## References

1. Hillis, D.M., Moritz, C. and Mable, B.K., 1996. *Molecular Systematics* (2nd Edition). Sinauer Associates, Inc. Publishers, Sunderland, MA, USA.
2. Weir, B.S., 1990. *Genetic Data Analysis: Methods for Discrete Population Genetic Data*. Sinauer Associates, Inc. Publishers, Sunderland, MA, USA.
3. Zar, J.H., 1996. *Biostatistical Analysis* (3rd Edition). Prentice-Hall International, Inc.
4. Francisco Azuaje, 2005. *Data Analysis and Visualization in Genomics and Proteomics*. John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester.
5. BRUCE S. WEIR 1990. *Genetic Data Analysis II Methods for Discrete Population Genetic Data*. Sinauer Associates, Inc. Publishers Sunderland, Massachusetts.
6. Lynch, M. and Walsh, B., 1997. *Genetics and Analysis of Quantitative Traits*. Sinauer Associates, Inc. Publishers, Sunderland, MA, USA.
7. Mead, R., 1988. *The Design of Experiments*. Cambridge University Press.
8. Miyamoto, M.M. and Cracraft, J. (Editors), 1991. *Phylogenetic Analysis of DNA Sequences Data*. Oxford University Press. New York.
9. Nei, M., 1987. *Molecular Evolutionary Genetics*. Columbia University Press, New York.
10. Sokal, R.R. and Rohlf, F.J., 1981. *Biometry* (2nd Edition) Freeman, San Francisco.
11. Steel, R.G.D. and Torrie, J.H., 1980. *Principles and Procedures of Statistics*. McGraw Hill International Editions.
12. Waterman, M.S. (Editor), 1989. *Mathematical Methods for DNA Sequences*. CRC Press, Boca Raton FL.
13. Weir, B.S. (Editor), 1983. *Statistical Analysis of DNA Sequence Data*. Marcel Dekker, New York.
14. Baumgartel et al 2011. *Molecular Genomic Research Designs*. *Annu Rev Nurs Res*. 2011 ; 29: 1–26.
15. K Imberly R. Andrew S And Gordon Luikart 2014. Recent novel approaches for population genomics data analysis. *Molecular Ecology* (2014) 23, 1661–1667

## **FBG 509 Laboratory Techniques in Molecular Biology and Genetics Credit: 2**

1. **Introduction:** Introduction to laboratory instruments, lab safety and regulations, lab biochemical calculations, preparation of stock solution.
2. **Spectrophotometry:** Absorption spectra in the visible range as a means of identification, extinction coefficients, conversion factors and finding the concentration of an unknown using a standard curve
3. **Nucleic Acid:** DNA and mRNA isolation from tissue, methods for quantification, DNA sequencing and sequence analysis, sequence verification and alignment of sequence data, electrophoresis, Pulsed Field Gel Electrophoresis (PFGE), Southern Blotting, Northern Blotting, DNA probes, Hybridization and non-radioactive probe detection, polymerase chain reaction (pcr); types, theory and practical applications in fisheries, principles in primer designing, mutagenesis using pcr, gene editing (CRISPR/Cas9)
4. **Gene Cloning:** Molecular cloning vector, restriction endonuclease and homologous recombination guided cloning, ligation and transformation, antibiotic selection, clone screening, transfer vector, expression vector, cloning genes, plasmid gene libraries, cDNA and expression libraries
5. **Protein:** Expression of protein, purification techniques, SDS-PAGE, native PAGE, gel filtration, Western Blot, ELISA, enzymatic assay, study of protein structure, directed evolution for novel proteins

### **References**

1. Recombinant DNA, 3rd Edition by J.D. Watson, et al.
2. Gene Cloning & DNA Analysis by Brown, 6th edition, ©2001, Blackwell Publishing.
3. Cold Spring Harbor Laboratory Research notebook, ©1999 Jones & Bartlett, Publishers
4. Applied Molecular Genetics by Miesfeld, ©1999 Wiley-Liss

## **FBG 512**

### **Practical**

### **Credit: 3**

1. Isolation and quantification of DNA, RNA, karyotyping and purification of proteins,
2. Amplification of DNA, cDNA
3. Gel electrophoresis of DNA, RNA, Southern blotting, Northern blotting, SDS-PAGE of protein, Western blotting
4. Bioinformatics: Primer design, sequence analysis, phylogenetic tree construction, study of protein 3D structure by using PyMol, molecular docking
5. Gene cloning: competent cell preparation, Plasmid isolation and purification, transformation, screening of clones
6. Production of mono sex tilapia
7. Cryopreservation technique
8. Brood bank establishment and management



- 9.** Gene transfer using micro-injection, bioplastics etc
- 10.** Data analysis: gene expression, Microarray etc.
- 11.** Vaccine administration in fish
- 12.** Florescence In-Situ Hybridization

## Name of the Branch: Fisheries Management (FM)

### FM 501 Inland Fisheries Management

Credits: 3

1. **Overview:** Concept of inland fisheries management; Status of inland fisheries resources and their economic importance; versatile use of inland water bodies.
2. **Aquaculture in inland water bodies:** Techniques, extension, problems and solution.
3. **Use of biotechnology in fisheries:** Inland aquatic ecosystems, species and resources restoration, conservation and management.
4. **Status survey, alteration and impact analysis:** Fishery survey of rivers, lakes, floodplains and wetlands; alteration of inland water fish habits, alteration impacts on fisheries resources and socio-economic environments.
5. **Constraints, intricacies and mitigation:** Existing problems and intricacies in inland fisheries, fishing rights and conflicts; its mitigation measures, management techniques for sustainable fisheries management and conservation measures.
6. **Hilsa fishery:** Current status in Bangladesh; fishing techniques; marketing, processing and exporting; management techniques and conservation measures; economic significance.
7. **Major carp spawn fishery management:** Parent stock; spawning grounds; drafting of spawns; nursery grounds, environmental requirements: Assessment and management of environmental impact on spawning; hatching and larval survival strategies.
8. **Sustainable livelihood and socioeconomic condition of fishers:** Concept of livelihood; livelihood assets, constraints and outcomes; sustainable livelihood approach (SLA) in the context of small-scale fisheries, socio economic conditions of fishers and role in inland fisheries management.
9. **Climate change and sustainable management strategy:** Impacts of climate change on inland fisheries resources; fisheries management and conservation strategies in changing climate.
10. **National conservation policy, programs and participatory role of agencies:** Legal status of the national policy and programs for inland fisheries conservation and management; role of government, NGOs, fishery cooperatives and other stakeholders for resource development, exploitation and sustainable fisheries management policy. Trans boundary river management, Halda river management, RAMSAR convention.

### References

1. Agüero, M., S. Huq, A.K.A. Rahman and M. Ahmed. 1989. Inland Fisheries Management in Bangladesh. DOF, BCAS, ICLARM, Dhaka. 52 pp.
2. Cowx, I.G. (ed.) 1995. Stock Assessment in Inland Fisheries. Fishing News Books, UK. 108 pp.
3. Cowx, I.G. 1999. Management and Ecology of River Fisheries. Fishing News Books, UK. 432 pp.
4. King, M. 1995. Fisheries Biology, Assessment and Management. Fishing News Books, UK. 352 pp.

5. Templeton, R.G. 1994. Freshwater Fisheries Management. Fishing News Books, UK. 190 pp.

## **FM 502 Coastal and Marine Fisheries Management**

**Credits: 3**

1. **Introduction:** Key concepts around conservation and sustainable management of fisheries resources, goals of coastal and marine fisheries management present and future.
2. **Coastal and marine fisheries resources:** aquatic habitats, fishing grounds, biodiversity, people and institution; coastal aquaculture and mariculture
3. **Problems and vulnerability of coastal and marine fisheries:** Pollution, erosion, siltation, alien species, climate variability and change, overfishing, inequality, lack of technology and governance; vulnerability and risk assessment methods.
4. **Sustainable management of coastal and marine fisheries:** SDGs related to coastal and marine fisheries, economic sustainability, social sustainability and environmental sustainability
5. **Fish stock assessment:** TAC (Total allowable catch); ITQ (Individual Transferable Quota); ITQ to sustain small scale and coastal fisheries, bio-economic models in fisheries management.
6. **Conservation of coastal and marine resources:** Conservation of Aquatic habitats, species, environment. Approaches, policies and legislations for conservation: payment for ecosystem services, ecosystem-based management of coastal and marine fisheries, fish sanctuary, marine protected areas (MPA): Concept of MPA, principles and objectives of MPA. Impact of MPA on marine bio-diversity. Role of stakeholders in MPA management. MPAs in Bangladesh.
7. **Application of biotechnology in coastal and marine fisheries:** aquatic ecosystems, species and resources restoration, conservation and management.
8. **Improving socio-economic conditions of fisheries dependent people:** Challenges and opportunities for both males and females
9. **Co-management of coastal and marine fisheries:** Benefit sharing, equity, gender, fishers right, citizen science
10. **Integrated coastal zone management:** Concept of ICZM. Evaluation of integrated Coastal Zone Management (ICZM) in Bangladesh and other countries; Issues and challenges and conflict of managements of coastal zone and deep sea.
11. **International and national policies and legislations:** Objectives, goals and important articles of United Nations Convention on Law of the Sea (UNCLOS), Bangladesh coastal and marine fisheries acts and ordinances. Challenges and opportunities for improvement of regulations.

## **References**

1. King, M 1996. Fisheries Biology, Assessment and Management. Fishing News Books, Blackwell Science Ltd. UK.
2. Sparre, P & Venema, S.C. 1992. Introduction to tropical fish stock assessment. FAO Fish Tech. Pup. 306/ 1 Rev. 1.
3. Grafton, Q. R (2010) Handbook of marine fisheries conservation and management. Oxford University Press.
4. McClanahan, T.R. and Castilla, J. R. (2007) Fisheries management. Blackwell
5. Pomeroy, R.S. and Rivera-Guieb, R. (2007) Fisheries co-management: CAB International.

6. Gray, T.S. (ed) (2005) Participation in Fisheries Governance (ed).Springer.
7. Payne, A.I.L., O'Brien, C.M. and Rogers, S.I. (eds) (2004) Management of shared fish. Blackwell
8. Walters, C.J. and Martell, S.J.D. (2004) Fisheries ecology and management. Princeton University Press.
9. Nybakken, J.W. and Bertness, M.D., 2005. Marine biology: an ecological approach. 6<sup>th</sup> edition, San Francisco: Benjamin Cummings.

**FM 503      Aquatic Pollution, Climate change and Fisheries      Credits: 3**

1. **Types and sources of aquatic contaminants/pollutants:** Major classes and sources of pollutants, Pesticides (organochlorine, organophosphorus), Heavy Metals, Persistent Organic Pollutants (POPs), DDT, PCBs, HCH, HCB, Dirty Dozens, Phthalates, Endocrine Disrupting Chemicals (EDCs), Polycyclic Aromatic Hydrocarbons (PAHs), Oils, Hydrocarbons, Polychlorinated dibenzo(p)dioxin and furan (PCDD/F), Monobutyltin, dibutyltin and tributyltin (MBT, DBT and TBT), Emerging pollutants, Thermal Pollution, power plants, desalination plants, cooling plants, Types of radioactive waste, Hazardous Waste Pollution, Marine litter, Microplastic pollution, Aquatic pathogens and nuisance organism.
2. **Environmental fate of pollutants:** Biogeochemistry and pollutants, rare earth elements and pollution, fate of wastes and Pollutants, Biotransformation, Detoxification, and Biodegradation, Organic enrichment, Agricultural runoff, Eutrophication.
3. **Assessment of aquatic pollution:** Principles and methods for the study of toxicity effects. Factors affecting toxicity, Acute and chronic toxicity, lethal and sub-lethal responses. Static Bioassays, Flow through technique, Dose-Response relationship, LC50, LD50, Bioaccumulation, Biomagnification, Bioconcentration Factor (BCF').
4. **Effects of aquatic pollution:** Effects on biotic community, Genetic damage and molecular response to pollution, Molecular process and physiological response to pollution, mutagenicity, cyto-genotoxicity. Chromosomal aberration, apoptosis, comet assay, micronucleus assay, imposex, Toxicological case studies. Public health effects; biological impact of' contaminants, Impact on reproduction, Impact on individual, Population and community, Population ecology to socio-economic and human health issues.
5. **Aquatic pollution Issues:** National, regional and international issues. Monitoring of aquatic pollution, Water quality standards, different monitoring programs, Mussel Watch, Pollution Prevention and control, Pollution Abatement, indicator species and their role. Marine Pollution monitoring and assessment, Management of Marine Pollution.
6. **Risk Management:** Risk Assessment, Factors triggering risk assessment, Hazard identification, Dose-response evaluation, Exposure assessment, Risk characterization, Concepts of Environmental Risk Management, Recovery,

rehabilitation, and reclamation, Application of basic risk management principles, Biotechnology for water pollution control.

7. **Policies and Legislation:** Aquatic pollution Policies and Legislation in Bangladesh, Prevention of pollution-national and international regulations, agreements, protocols, guideline, conventions.
8. **Key issues and concepts around climate change:** greenhouse gases and effects, mitigation, impact, adaptation, risk, disaster, vulnerability, resilience.
9. **Climate change scenarios:** past, present and future, both global and Bangladesh perspectives; uncertainties in climate change model projections.
10. **Climate Anomalies:** El Nino, La Nina and the Southern Oscillation (ENSO), North Atlantic Oscillation (NAO), Pacific Decadal Oscillation (PDO), Indian Ocean Dipole (IOD).
11. **Impacts of climate change on fisheries globally and Bangladesh:** Impacts on aquatic biodiversity, habitats, ecosystem functioning, and dependent livelihoods.
12. **Adaptation, resilience and disaster risk reduction to climate change:** Habitats and dependent people: community based adaptation, ecosystem based adaptation especially use of aquatic biodiversity for adaptation, engineering based solutions, grey-green approach, climate proofing. Incremental and transformational adaptation.
13. **Climate change mitigation:** global, regional and national levels
14. **Agreements, legislations and policies to tackle climate change:** Paris agreement, IPCC, COP, SDG goal 17, BCCSAP, NAPA, NAP, National communication to adaptation, NDC, loss and damage

## References

1. Water Pollution: Causes, Effects and Control, revised edition, 2006. P. K. Goel, New Age International.
2. Water Pollution, Agarwal S. K. 2005, APH Publishing.
3. Principles of Ecotoxicology. 3rd Edition, 2006. C.H. Walker, S.P. Hopkin, R.M. Sibly & D.B. Peakall (Eds.), Taylor & Francis, New York, NY.
4. Environmental Toxicology. 2002. D.A. Wright and P. Welbourn. Cambridge University Press, New York, NY.
5. David, P.P., Epifanio, J.M., Marsden, J.E. and Caussen, J.E. 1995. Protection of Aquatic Biodiversity. Oxford and IBH Pub. Co. New Delhi.
6. Jeffries, Michael J., Biodiversity and conservation. Routledge, London, 1997.
7. Khan, T.L.; Al-Ajmi, Dhari N. Global biodiversity conservation measures. Pointer publishers, Jaipur, 1999.
8. Kumar, HarDarshan. Biodiversity and sustainable conservation. Oxford IBH publishing Co. Pvt. Ltd., New Delhi 1999.

## FM 504 Fish Population Dynamics and Aquatic Systems Modelling Credits: 3

1. **Scope:** Scope of fish population dynamics and recent theories of fish population dynamics.
2. **Acoustic assessment of fish abundance and distribution:** Catch per unit effort as an index of stock in numbers or weight, spatial distribution, temporal

distribution, bathymetric distribution, factors affecting distributions, relative abundance, marking and tagging, components of underwater acoustics, the sonar equation, preparations for fish stock assessment, application of acoustics to fish stock assessment, additional applications of acoustics, developing technologies.

3. **Length, weight and associated structural indices:** Sampling and measuring considerations, weight-length relationship, indices of condition, weight models, length-frequency histograms, length-frequency indices.
4. **Determination of Age and Growth:** Objectives, approaches to aging fish, growth determination, validation and verification of marks on hard parts.
5. **Underwater observation:** Techniques and equipment, safety and training, environmental influences, applications.
6. **Advances in underwater biotelemetry:** Telemetry systems, methods of attaching transmitters, methods of tracking, sampling and data processing.
7. **Ecosystem modeling:** Principles and application of ecosystem models in fisheries management, significance and approached to end ecosystem models, basics of NPZ, Ecopath, Ecosim, and Ecospace, reduced gravity model, various types of grids, computation of time step for integration, physical processes involved in modeling of upper ocean, OGC Models - POM, MOM and ROMS models.
8. **Modeling ecosystem dynamics:** Lotka-Voleterra models; Nutrient-phytoplankton-zooplankton (NPZ) models; Application to contrasting ecosystem scenarios (N. Atlantic vs N. Pacific).
9. **Fish Stock assessment:** Commercially and ecologically important fishes of the Bay of Bengal.

## References

1. Lagler, K.F. 1956. *Freshwater Fish Biology*. Second Edition, William C. Brown Co., Dubuque Iowa. 421p.
2. Murphy, B.R. and D.W. Willis, editors, 1996. *Fisheries techniques*, 2<sup>nd</sup> ed., American Fisheries Society, Bethesda, Maryland.
3. Rounsefell, G.A. and W.H. Everhart. 1953, *Fishery Science: Its method and Applications*. John Willey & Sons. Inc. New York. 444p.
4. King, M 1996. *Fisheries Biology, Assessment and Management*. Fishing News Books, Blackwell Science Ltd. Uk.
5. Gulland J.A. 1982 *Fish Stock Assessment*.
6. Pauly. D. 1981. *Fish Population Dynamics in Tropical Waters*.
7. Sparre, P & Venema, S.C. 1992. *Introduction to tropical fish stock assessment*. FAO Fish Tech. Pup. 306/1 Rev.1.
8. Collie, J.S., Botsford, L.W., Hastings, A., Kaplan, I.C., Largier, J.L., Livingston, P.A., Plagányi, É., Rose, K.A., Wells, B.K. and Werner, F.E., 2016. Ecosystem models for fisheries management: finding the sweet spot. *Fish and Fisheries*, 17(1), pp.101-125.

**FM 505**

**Fisheries Policy and Governance**

**Credits: 3**

1. **Introduction:** Current fisheries governance systems of Bangladesh. Governance of inland fisheries, freshwater aquaculture, shrimp culture, rivers, floodplains, baor, haor, Kaptailake, Beel, coastal fisheries and marine fisheries.

2. **Overview of the current legislative documents related to fisheries:** Bangladesh Fisheries Protection and Conservation Act 1950 and its amendments, ordinances and rules, Marine Fisheries Ordinance (and rules) 1983, Bangladesh Fisheries Development Corporation Act, 1973, Mobile Court Ordinance 2007, Wildlife Conservation Act 2012, Territorial Waters and Maritime Zones Act, 1974, The Bangladesh Environment Conservation Act 1995, Bangladesh Water Act 2013 etc.
3. **Fisheries related national, regional and international policy:** National Fisheries Policy 1998, Jalmahal Policy 2009, National Shrimp Policy 2014, Bangladesh Environmental Policy 1992, Five Year Plan, FAO code of conduct for responsible fisheries, Bangladesh Environmental conservation strategy 2013, Transboundary policy, International Law of the Sea, United Nation Convention on Straddling Fish Stocks and Highly Migratory Fish. RAMSAR convention and its importance for wetland conservations. RAMSAR sites of Bangladesh, SDGs goals and targets related to fisheries.
4. **Fisheries policy and law formulation processes:** ensuring the voice of real fishers, marginal farmers and sustainability.
5. **Governance systems and fisheries programmes:** Flaws in current governance systems and fisheries programs in Bangladesh and ways of overcoming them.
6. **Bangladesh fisheries in 2020s, 2030s and 2040s:** challenges, opportunities, strategies and action plans.
7. **Digital fisheries:** use of digital technology in production, use and distribution of fisheries resources – current status and future potential.
8. **Top down versus bottom up approaches in fisheries governance:** governing through community-based and co-management of fisheries, public-private partnership, NGOs, fishing community.
9. **Fisheries Bank, Insurance and social safety:** Fisheries Bank, Insurance and potential social safety programs for fisheries dependent people.

## References

1. Sustainable Inland Fisheries Management in Bangladesh Hans A. J. Middelorp, Paul M. Thompson, Robert S. Pomeroy -
2. The Common Fisheries Policy The Quest for Sustainability by Ernesto PenasLado
3. Directorate General for Fisheries of the European Commission Brussels, Belgium
4. Schweiger, L. (2010). The evolution of the Common Fisheries Policy: Governance of a Common-Pool Resource in the Context of the European Integration. Institute for the European Integration. *Austrian Academy of Sciences. Working Paper No 07/2010*. November 2010, 88 p.
5. Kurlansky, M. (1997). *Cod: A Biography of the Fish that Changed the World*. Penguin Books, New York, 294 pp.

## FM 506 Research Methodology and Statistical Application in Fisheries Credits: 3

1. **Introduction:** Definition, objectives, motivation of research, types of research, research and scientific method, criteria of good research, problems encountered by researchers in Bangladesh.
2. **The Research Problem:** Concepts, conducting literature review, selecting the problem, techniques involved in defining a problem, development of hypothesis.
3. **Research design:** Features of good design, concept and development of research plan: Sampling design–sampling strategy, methodology and types of design of

the program, sampling and survey, census. Experimental designs: CRD, CRBD, Latin square and split plot designs.

4. **Measurement and scaling techniques:** Types of data, Measurement in research - measurement scales, sources of error in measurement, tests of sound measurement, technique of developing measurement tools, Scaling - meaning of scaling, scale classification bases, important scaling techniques, scale construction techniques.
5. **Methods of data collection, processing and analysis:** Collection of primary and secondary data, selection of appropriate method for data collection, guidelines for interviewing, questionnaire and schedule, social and participatory methodologies in peoples' participation, interpretation of results, graphical representation and tabulation.
6. **Role of computer in Research:** Introduction to different software tools, open source tools, use of SPSS, R packages, PRIMER and graphical tools, introduction to programming and coding languages.
7. **Correlation and Regressions:** Pearson's Correlation, Spearman's Rank Correlation, Multiple Regression, Multiple Correlation, auto-correlation, and Partial Correlation, Simple Linear Regression, The Straight-Line Relationship When There is Inherent Variability, Regression toward the Mean.
8. **Univariate and multivariate analysis:** Parametric procedures and their applications, T-tests, ANOVAs and MANOVA, PERMANOVA, Multiple comparisons: Tukey Test, HSD test, DMRT, Newman-Keuls test.
9. **Analysis of non-parametric data:** Coding, applying weight to data, Kruskal-Wallis test. Wilcoxon rank sum test, Mann-Whitney U-test.
10. **Time series analysis:** Characteristics of time series data, application and prediction, smoothing, box average and moving average method.
11. **Ordination methods:** Purpose and applications, PCA, CCA and cluster analysis.
12. **Mathematical modelling:** Curve fitting, Mathematical modelling for assessment of aquatic systems and fisheries.
13. **Legal and ethical issues in research:** Principles and importance, ethical issues in research, data management, falsification, confidentiality and anonymity, authorship rules, plagiarism and conflict of interest.
14. **Reporting research:** Scientific reports, reviews, short communication, case studies, web page, booklet and leaflet, structure and development of a Manuscript and Book.

## References

1. Experimental research design and analysis A practical approach for Agricultural and natural Sciences. 1994. Hoshmand, R.A. CRC press.
2. Biostatistical Analysis. 1984. Zar, J.H. 4th Edition. Prentice-Hall INC.
3. Research methodology. 2013. C.R. Kothari and Garg G. 3<sup>rd</sup> ed., New Age International Publishers, New Delhi, India.
4. Kumar, R. 2011. Research Methodology: a step-by-step guide for beginners (3rd edition). London, UK: TJ International Ltd, Padstow, Cornwall.
5. Laake, P., Benestad, HB. & Olsen, BR. Research Methodology in the Medical and Biological Sciences. Academic Press, Elsevier, London, 2007
6. Shamoo, A. och Resnik, D. (2009). Responsible Conduct of Research. (Second edition) Oxford University Press.
7. Blackburn, S. 2003. Ethics: a very short introduction. Oxford: Oxford University Press. 120 p.



8. Hermerén, G. 2011. Good research practice. Vetenskapsrådets Rapportserie 3: 2011. Stockholm: Vetenskapsrådet. (<https://publikationer.vr.se/produkt/good-research-practice/>) 129 p.
9. Joon Ha Kim, 2016. Environmental Data Analysis and Practice, Balaban Desalination Publications; First edition

**FM 507**

**Geo-spatial Technology in Fisheries**

**Credits: 2**

1. **Introduction to Remote Sensing and GIS:** Introduction to the fundamentals of Geospatial Technology, Principles of remote sensing and GIS, Roles of remote sensing, GPS and GIS in fisheries research, planning and management.
2. **Remote sensing of the sea:** The general principles of remote sensing of the sea; Sensor calibration; Atmospheric correction; Positional registration; Oceanographic sampling for “sea truth”; Image processing.
3. **Aquatic Applications of Infrared Measurement of Surface Temperature:** Infrared radiometry, Interpretation of sea surface temperature, Advanced Very High Resolution Radiometer (AVHRR), Multi-Channel Sea Surface Temperature (MCSST) algorithm, Geostationary Operational Environmental Satellites (GOES), Coast Watch sea surface temperature data source and software.
4. **Aquatic Applications of Radar-altimeters:** Basic principles of satellite altimetry, TOPEX/Poseidon satellite, Sea Surface Height: Geoid, Tides, Geostrophic circulation; Sea Surface Roughness: Microwave scatterometer, Synthetic Aperture Radar
5. **Aquatic Applications of Water Color:** Basic principles of satellite measurements of ocean color, Coastal Zone Color Scanner (CZCS); Sea-viewing Wide Field-of-view Sensor (SeaWiFS); Moderate resolution Imaging Spectroradiometer (MODIS); Patterns of phytoplankton distribution in the World Ocean.
6. **GIS:** Components of Geographic Information Systems (GIS), GIS related special hardware and software, Roles of GIS in fisheries research, planning and management, Major functions of GIS instrumental setup of a GIS laboratory. Relation between GIS and RS. Raster and Vector GIS.
7. **GIS Functional Elements:** Data acquisition, Preprocessing, Data management: advancement in data management, Characteristics of DBMS, Advantages of databases, Database design, DBMS structure, RDBMS, Data joining and linking. Data layering or superimposing.
8. **Maps:** Base map and thematic map, Purpose of a map and map scale, Map sources in Bangladesh, Map features and characteristics, Map projections, Map interpretation.
9. **Data quality and Product generation:** Importance of data quality, Data processing and metadata, Sources of data error, Remedies of data error, Primary data and secondary data.
10. **GIS Application:** EcoGIS-GIS tools for ecosystem approaches to fisheries management, EIA, Technology dissemination, GIS technology and spatial analysis in coastal zone management.

## References

1. Getting to Know ArcGIS (4th Edition) Authors: Michael Law, Amy Collins, Publisher: ESRI Press (July 2015, © 2015), ISBN-13: 978-1589483828; ISBN-10: 1589483820.
2. Geographic Information Systems and Science (4th Edition) Authors: Paul A. Longley, Michael F. Goodchild, David J. Maguire, David W. Rhind Publisher: Wiley (March 2015, ©2016).
3. Campbell, James B. 2011. Introduction to Remote Sensing, 5th edition. New York. The Guilford Press. ISBN 978-1609181765.

## FM 508      Aquatic Ecosystems, Biodiversity and Conservation      Credits: 2

1. **General ecological theory:** Modern concepts and scope - descriptive, functional and evolutionary perspectives; history of ecology, ecosystems, methods and approaches.
2. **Freshwater and Floodplains Ecology:** Limiting factors; ecological classification of freshwater organisms, lakes and other water bodies; general models of production in lentic and lotic habitats; trophic relationship. Characteristics and types of floodplains; energy flow, modification of floodplain ecosystems and conservation.
3. **Estuarine ecology:** Concepts and nature of estuary; classification; biota and productivity; tidal marshes and mangrove swamps, trophic subsidy.
4. **Coastal and Marine Ecology:** Zonation; abiotic factors - tides, temperature, salinity, wave action; biotic factors - abyssal communities, pelagic communities, supra-tidal, inter-tidal and sub-tidal communities. Phytoplankton and seaweeds; zooplankton, benthos, neuston, decomposer-bacteria, fungi. Ecology and importance of coral reefs.
5. **Biodiversity:** Basic concepts, importance and conservation needs. Types of biodiversity. Classification of aquatic animals and plants.
6. **Threats to aquatic biodiversity:** concept, depletion and causes of threatening bio-diversity, IUCN categories of threatened species. Extinction and speciation processes.
7. **Assessment of biodiversity:** Species richness, evenness determination; Biodiversity assessment methods, Quantifying biodiversity, Biodiversity indices: Shannon-Weiner index, Simpson's index, Margalef's index, Menhinick's index, Brillouin index, McIntosh's index, Berger-Parker index.
8. **Biodiversity conventions and conservation:** Traditional knowledge and biodiversity conservation. Concepts of Marine protected areas. Ecological critical area, Wild life sanctuaries, National Parks and Biosphere Reserve, International and national efforts to conserve biodiversity (Kyoto protocol, Ramsar convention, CITES, CBD, NBCF, etc.).
9. **Biotechnological needs for biodiversity conservation.** *Ex situ* and *In situ* methods of conservation, Genetical and evolutionary principles in conservation. Gene banks, germ-plasm banks, genome sequence.

## References

1. Krebs, C.J. 1985. Ecology: The Experimental Analysis of Distribution and Abundance. 3<sup>rd</sup> Edition. Harper & Row Publishers, New York. 800 pp.
2. Moss, B. 1998. Ecology of Freshwaters Man and Medium, Past to Future. 3<sup>rd</sup> Edition. Blackwell Science, London.
3. Odum, E.P. 1971. Fundamentals of Ecology. W.B. Saunders Co. 574 pp.
4. Barnes, R.S.K. and R.N. Hughes. 1988. An Introduction to Marine Ecology. 2<sup>nd</sup> Edition. Blackwell Scientific Publications Inc., Oxford, England. 351 pp.
5. Levinton, J. 2009. Marine Biology: Function, Biodiversity, Ecology. 3<sup>rd</sup> Edition. Oxford University Press.
6. Mann, K.H. 2000. Ecology of Coastal Waters, with Implications for Management. Blackwell Scientific Publications Inc., Oxford, England. 406 p.
7. Nybakken, James and Bertness, Mark, Marine Biology: An Ecological Approach, Marine Biology: An Ecological Approach, Sixth Edition, Benjamin Cummings(2004)

**FM 509**

**Fisheries Economics and Business**

**Credits: 2**

1. **Basic economics:** Introduction to fisheries economics, basic economic terminologies, micro and macroeconomics, positive and normative economics, environmental economics, resource, scarcity, production, demand. supply, and economic equilibrium, the operation of a firm in a competitive industry, the production possibility curve, indifference curve, consumer budget, consumer equilibrium, general economic equilibrium, price discrimination and distortions, contribution of fisheries sector to the economic development of the country.
2. **Fundamentals of fisheries economics:** Basic concept, the production function in a fishery, the basic economic model of a fishery, the model with a variable price of fish, Maximum Economic Yield (MEY), sustainable yield and economic surplus, the fishery when viewed as part of the whole economy, economic growth and sustainable development, economic analysis of fisheries development.
3. **Fisheries production and harvesting:** Production of fisheries products, factors of production, potential production, cost of fish production, production efficiency and profit efficiency measures, constraints in fish production, economic optimal harvesting, fishing vessel economics, optimal vessel effort.
4. **Managing fisheries businesses:** Starting a business, marketing fisheries products, developing a business plan for fisheries businesses, monitoring economic and financial performance of fisheries businesses, banking system and financing a fisheries businesses, managing cash flow, managing capital assets in fisheries businesses, managing risk in fisheries businesses, managing labor.
5. **Economic and financial analysis of fisheries businesses:** The enterprise budget and partial budgeting in fisheries, financial statements: balance sheet and income statement, cash flow analyses, linear programming; cost minimization, profit maximization investment analysis (capital budgeting), lending in fisheries business.

6. **Blue economy:** Concepts, transition, applications, challenges and opportunities in the context of the Bay of Bengal.
7. **Fisheries regulation:** Goals of fishery regulation program, economic analysis of regulatory techniques, effect of regulations on share rate, fishing licenses and quotas, the complete economics of regulation, the process of developing fisheries management policy, regulation of national and international fisheries.

### References

1. Economics, Roger A. Arnold, 2008, Thomson Higher Education, USA.
2. Economics of Aquaculture, Singh RKP, 2003, Daya Publishing House, Delhi, India.
3. Economics of Aquaculture, Curtis M. Jolly and Howard A. Clonts, 1993, Food Products Press, New York, USA.
4. Aquaculture Economic Analysis: An Introduction, Yung C. Shang, 1990, The World Aquaculture Society, USA.
5. Fisheries Economics and Management, Ola Flaaten, 2010, Norwegian College of Fishery Science, University of Tromsø, Norway.
6. Economic analysis tools and fisheries management: some methodological remarks, Gianluigi Gallenti, Marta Cosmina, Sonia Prestamburgo.
7. Anderson L.G. (1986) The Economics of Fisheries Management, The Johns Hopkins University Press, Baltimore, Maryland.

**FM 512**

**Practical**

**Credits: 3**

### Research Methodology and Statistical Application in Fisheries

- a) Collection of fisheries samples and data
- b) Analysis of fisheries data using statistical technique
- c) Mathematical modelling of aquatic ecosystems and fisheries using software
- d) Qualitative data analysis using NVivo software

### Inland Fisheries Management

- (a) Preparation of questionnaire/interview schedule for collection of data on socio-economic condition and preparation of report.
- (b) Preparation of participatory tools (PRA, RRA, FGD, LGD etc.) to collect data from rural areas and writing report.
- (c) Field trip to rural areas to observe rural fisheries dependent people's livelihoods and collection of data and writing report.
- (d) Fresh water pond construction, culture and management; semi-intensive, intensive and super-intensive.
- (e) Case studies on some FCD/I projects for impact assessment for example, Baral Basin Project including Char ghat regulator; Narsingdi-Narayanganj FCDI project. Case studies on fish pass at Maulaivi Bazar/Tangail. Case studies on some impacts of dams on fisheries. Case studies on some impacts of industries

on fisheries. Case studies on some impacts of land use change and fish habitat destruction due to development projects.

### **Coastal and Marine Fisheries Management**

- (a) Acquaintance with the different types of fishing crafts and gears in Bangladesh.
- (b) Examination of net materials, marketing and mending of nets.
- (c) Basic net design, determination of mesh size, net depth and length, knot spacing and hanging ratio.
- (d) Techniques of net preservation.
- (e) Catching techniques of commercially important inland and brackish water fish and shell fish of Bangladesh.
- (f) Freshness test of fish and shell fish.
- (g) Design of industrial fishing craft
- (h) Environment friendly efficient fishing crafts and materials design
- (i) Construction of coastal shrimp farm and culture techniques.
- (j) Natural collection of brackish water fish and shrimp seed and their rearing techniques and

### **Aquatic Pollution and Environmental Risk Management**

- (a) Chemical analysis of water sampling methods; determination of dissolved oxygen, free carbon dioxide, pH, alkalinity, total hardness, phosphate, nitrate, nitrite, ammonia, iron, silicate and salinity.
- (b) Lethal and sub lethal effects of pollutants on aquatic organisms, evaluation of toxicity tolerance, bioassay.
- (c) Methods of bioassay, determination of LC50, LD50; Probit analysis

### **Climate Change and Fisheries**

- (a) Case study on impacts of climate change on fisheries
- (b) Estimation of risk, vulnerability, resilience and adaptation
- (c) Calculation of loss and damage in fisheries sector

### **Fish Population Dynamics and Aquatic Systems Modelling**

- (a) Estimation of fish population by mark-recapture method, determination of fish age from scale, determination of fish length from scale length by back calculation, determination of length-weight relationship and condition factor.
- (b) Hands-on training on FiSAT, Ecosim, Ecopath
- (c) Mathematical modelling of primary production, trophic levels and fish population

### **Fisheries Policy and Governance**

- (a) An orientation and visit to different organization related to fisheries development.
- (b) Analysis of policy and legal documents
- (c) Field trip to fisheries project areas to observe rural development activities in the field situation with emphasis on fisheries.
- (d) Evaluation of the outputs and outcomes of fisheries projects

### **Geospatial Technology in Fisheries**

- (a) Using ArcGIS or related geospatial software for GIS analysis using fisheries related data

- (b) Satellite and radar images analysis
- (c) GIS mapping

### **Aquatic Ecosystems, Biodiversity and Conservation**

- (a) Determination of primary productivity (Gran Method/Chlorophyll a method)
- (b) Collection and identification of freshwater and marine animals and plants of Bangladesh.
- (c) Impact of human interferences on the alteration of aquatic ecology
- (d) Assessment of threatened fish and other aquatic species

### **Fisheries Economics and Business**

- (a) Estimation of elasticity of supply and demand.
- (b) Cost analysis of a firm.
- (c) Linear Programming; Profit maximization and cost minimization problems.
- (d) Use of appropriate business models for consumer friendly marketing
- (e) Development of equitable benefit sharing mechanisms for different fisheries stakeholders especially for fishing communities