M.F.Sc & PhD Programs in Fish Genetics & Breeding - Syllabus

Central Institute of Fisheries Education
Mumbai
### M.F.Sc. (Fish Genetics & Breeding) Major Courses

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<th>Code</th>
<th>Course Title</th>
<th>Credits</th>
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<td></td>
<td><strong>CORE COURSES</strong></td>
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<tr>
<td>1.</td>
<td>FGB 501 Principles of Genetics and Breeding</td>
<td>2+1</td>
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<td>2.</td>
<td>FGB 502 Population Genetics</td>
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<td>FGB 506 Fish Genetic Resources and Conservation</td>
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### PhD (Fish Genetics & Breeding) Major Courses

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<td>FGB 708 Advances in Cytogenetics</td>
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M.F.Sc Syllabus

MAJOR COURSES

1 FG   Principles of Genetics and Breeding (2+1)

Objectives:
For a broad understanding of the basic principles of Genetics and breeding that can be applied to fisheries management and aquaculture

Theory

Historical development of genetics and Physical basis of heredity; Mendelian principles: scope, limitation, probability of Mendelian inheritance; Modifications to Mendelian ratios; Genetic variation: causes and measurement; Chromosome theory of inheritance: genetic basis of determination of sex, Chromosome manipulation: ploidy induction, sex reversal, gynogenesis and androgenesis; Multiple alleles; Linkage and crossing over, recombination, interference; Modern concept of gene; DNA as genetic material, genetic code and protein synthesis, transfer and regulation of genetic information; Pleiotropy; Penetrance; Gene and genotypic frequency and factors affecting them, application of selection for performance improvement, Mutation: natural and induced, mutagens fate of mutant allele in the population; Cross breeding and genetic drift;

Practical

Exercises on Mendelian laws, multiple alleles and epistasis; Practical demonstration of chromosome manipulations, Linkage and crossing over, ploidy induction; Induction of gynogenesis and androgenesis; Sex reversal.

2 FG   Population Genetics   (2+1)

Objectives

Understanding the concepts of population and its structure for fisheries management and aquaculture

Theory

Genetics of population: individual vs. population, genetic structure of random mating populations; Hardy Weinberg principles: test of equilibrium, application and properties of equilibrium populations; Change in gene frequency under migration, mutation and selection; Effect of small population on gene frequency; Estimation of HW principle/equilibrium using various population genetic tools: phenotypic, protein, and DNA markers; Coefficient of genetic differentiation – $F_{ST}$, $R_{ST}$, $Q_{ST}$, $G_{ST}$ - their relative merits & demerits, Genetic similarity & distance, Genetic bottleneck and concept of Mutation drift equilibrium; Null alleles; Theory of path coefficients and analysis; Basis of relationships: independent and correlated causes; Inbreeding: types, methods of estimation and consequences; Genetic drift; Effective population size.

Practical
Exercises on various statistical procedures with emphasis on non-parametric distributions; Estimation of gene and genotype frequencies; Estimation of effect of mutation, migration and selection on equilibrium; Equilibrium in sex linked genes; Estimation of effective population size, rate of inbreeding, inbreeding co-efficient, path coefficient. Building of pedigree files; Statistical analysis in relation to genetic stock structure analysis with dominant and co-dominant markers; Type I and Type II markers, protein, mtDNA and nuclear DNA markers, EST markers.

3 FG  Quantitative Genetics  (2+1)

Objectives

Understanding the concepts of quantitative genetics and its applications

Theory

Quantitative genetics: scope and applications; Polygenes and major genes; Polygenic segregation and linkage; Quantitative and qualitative traits: mode of inheritance and continuous variation; Components of phenotypic value: population mean, genotypic value, average effect of gene and gene substitution; Breeding value: dominance and interaction deviations; Components of variation: additive and non additive interaction; Biometrical relationship among relatives; Genetic parameters: introduction, repeatability, heritability and genetic, phenotypic and environment correlations; Selection: effect on population structure, intensity of selection, response to selection, methods of selection; Genetic gain and correlated response; Utilisation of non-additive genetic variance; Heterosis: theories and estimation; Maternal effects; Diailele crossing; General and specific combining ability; Recurrent and reciprocal recurrent selection; Scale effects and their estimation; Progeny testing.

Practical

Properties of Variance, Covariance, Correlation and regression; ANOVA in genetic parameter estimation; Analysis of genetic variance; Estimation of heritability by half-sib, full-sib and mid-parent analyses; Repeatability and their accuracies; Estimation of genetic gain and their relative efficiencies; Procedures for estimating breeding values; Analysis of diailele crossing.

4 FG  Principles of Selection and Selection Methods  (2+1)

Objectives

Application of the genetic tools for genetic improvement of aquatic species

Theory

Selection: scope, application, role of genetics in fish selection and breeding; National and International scenario of selective breeding programs in fish; Selection: basis of selection, genetic gain; Response to selection and factors affecting response; Accuracy of selection; Selection limits; Renewed selection gain; Bidirectional selection; Aids to selection; Methods of selection; QTL and MAS; Construction of selection indices; Sire and dam evaluation; Realized heritability, repeatability and genetic correlations; Mating systems and genetic consequences; Inbreeding depression: causes and methods to overcome; Selection for threshold characters; Small stock and inbreeding effects; Out breeding: crossbreeding, utilization of heterotic effects; Application of genetic parameter information in formulation of breeding plans; Stock improvement plans; Development of new strains/synthetic population; Crossbreeding and hybridization; Selection and mating designs for
select traits: growth, disease resistance, color enhancement, fin characters.; Application of markers in selection programs, status and their relevance; Development of breeding plans for different population sizes and environments; Trends in fish breeding research. Domestication and inadvertent selection; Genotype X Environment interaction and its role in fish/shellfish breeding.

**Practical**

Estimation of genetic parameters; and construction of selection indices; Estimation of genetic, phenotypic and environmental correlations; Analysis of GCA and SCA; Estimation of heterosis and inbreeding depression; Estimation of G X E interaction; Designing and conducting the challenge test for disease resistance.

**Optional Courses**

1 FG  Fish Breeding     (2+1)

**Objectives**

Applications of genetic techniques for stock improvement

**Theory**

Historical development of fish breeding and domestication; Current status of aquaculture in world and India; Tagging and maintaining breeding records; Performance: growth, disease resistance, productive and reproductive traits and their inheritance; Study of growth curves and their components; Influence of non-genetic factors on growth; Endocrine control of reproduction; Synchronization of spawning; Effect of breeding program on genetic diversity of farmed animals; Present status of breeding, cross breeding in aquaculture; Broodstock management; Inbreeding depression and heterosis in various economic characters; Role of Breeders’ associations in national breeding programs; National breeding policy: Economic analyses of national breeding programs. Reproductive cycle, sex determination, age of maturity, hormone induced ovulation; Gonad developmental stages in fin/shellfish and levels of hormonal intervention; Seed quality and fish seed certification; Biosecurity.

**Practical**

Tagging methods; Construction of growth curves; Standardization of the performance records for genetic parameters estimations. Record keeping of stock; Breeding plan and design of breeding program from successful case studies; Morphometric analysis; Practicals on synchronization of spawning;

2 FG  Fish Genetic Resources and Conservation     (2+1)

**Objectives:**

Application of genetic principle in conservation and management of aquatic resources

**Theory**

Fish genetic resources: survey and distribution; Genetic diversity: importance, estimation and influencing factors; Characterization and evaluation: taxonomical, biochemical and molecular tools; Threatened aquatic species of India and world; Conservation and preservation of aquatic species: issues and strategies, endangered species as per the guidelines of IUCN; Breeding strategies of
threatened species for restocking and live gene bank; Data bank and Gene bank: concepts, objectives, resources, uses; Institutes and Societies associated with conservation; Impact of inbreeding on genetic diversity and conservation; Evolutionary potential and heritability; Importance of mutation, migration and their interaction with selection in conservation; Application of molecular genetic tools for management of small population for conservation; Genetics and management of wild and captive populations; Genetic management for re-introduction; In-situ and ex-situ conservation; Cryopreservation of sperm, eggs and embryos; Effective population size and population structure; Factors threatening indigenous species; IPR issues and patenting of genetic resources; Regulations regarding introduction of exotic germplasm; Export import rules and regulations on conservation of aquatic genetic resources; Fish quarantine – status, procedures, scope and significance; Convention on Biodiversity and Biodiversity Authority of India.

**Practical**

Tagging methods for population; Estimation of gene and genotypic frequencies; Estimation of genetic diversity and relatedness using molecular information; Application of molecular genetic markers for estimation of effective population size, rate of inbreeding and genetic bottleneck; Analysis of genetic variance in population; Morphometric analysis of stocks; Milt quality analysis; Cryopreservation of milt;

**3 FG Molecular genetic markers (1+1)**

**Objectives:**

Molecular genetic tools for selective breeding programs

**Theory**

Biochemical markers: allozyme polymorphism and application in estimating population genetic parameters; Molecular markers: RAPD, RFLP, AFLP, EST, SNP, minisatellites and microsatellites and application in population genetic analysis and gene mapping; DNA sequence polymorphism and related software for alignment and analysis; Molecular biology of Ig synthesis, genetic basis of antibody diversity: humoral B-cell immunoglobulins, T-cell receptors and MHC.

**Practical**

Allozyme electrophoresis; RAPD, RFLP, AFLP, minisatellites and microsatellites- DNA electrophoresis; Interpretation of gels and data analysis using various software; Estimation of linkage disequilibrium using molecular genetic data; Antibody titre estimation.

development of hybridomas and production of monoclonal antibodies;

**4 FG Basic concepts in Molecular Biology (1+1)**

**Objectives:**
Understanding the basic concepts of molecular genetics
Theory
Gene structure of DNA, replication, Protein synthesis; Operon concept, genetics of mitochondria and plasmids, transposons and intervening sequences, minisatellites and macro satellites, molecular mechanism of spontaneous and induced mutations, site directed mutagenesis, recombination in bacteria, fungus and virus, molecular mechanism of genetic recombination, transduction, transformation and conjugation, genetic code, mechanism of translation and its control, post translation modification. Control of gene expression in pro and eu karyotes

Practicals
Practical related to the theoretical aspects of the same

5 FG Cytogenetics (1+1)
Objective:
Understanding nucleic acid and the chromosome as the basic unit of the heredity

Theory
Introduction, historical background, importance, improved cytogenetic techniques; Chromosome theory of inheritance: chromosomal models and their ultra structure; Chromosomal movements and position effect; Sex determination, sex differentiation, sex chromatin and Lyon’s hypothesis; Chromosome numbers in fish and karyotyping; Chromosomal aberrations: genetic and evolutionary implications; Chromosome banding techniques; FISH; Cytogenetics and evolution; Genotoxicity assays (single cell electrophoresis, MNT, SCE).

Practical
Preparation of chromosome spreads; Karyotyping; Banding techniques; MNT, SCE, Comet Assay.

6 FG Bioinformatics (1+1)
Objectives:
Apply the information technology for the fish genetics studies

Theory
Introduction to bioinformatics: history, definition, scope and applications; Fields related to bioinformatics; Data base: mining tools, submission of DNA sequences; Sequence alignment and database searching, similarity search, FASTA, BLAST; Information networks: internet; Genbank sequence database, EBI-net; NCBI, Genome net; Genomics: genome diagnostics, genome projects, genome analysis; Proteomics: protein information resources, primary and secondary protein data bases, analysis packages, predictive methods, ESTs; Phylogenetic analysis; Comparative genome analysis; Microarray bioinformatics.
Practical

Internet search: retrieving information from different data base like NCBI, protein information sources; Preparation of data base; Use of genome analysis packages: genetics data base; Searching by similarity; Phylogenetic analysis; Accessing and submission to genebanks; BLAST, sequence alignments, comparisons

7 FG  Computer Applications in Fish Genetics  (1+2)

Objectives:

Application of software packages for genetic data analysis

Theory

File Transfer Protocols; Work stations; Application of spreadsheets in maintaining fish breeding records; Fish breeding data bases; Introduction to various computer packages used in genetic analyses: SAS, AsREML, PEST, SelAction; Hendersons’ models in breeding experiments; Software for molecular genetics data analysis; Bioinformatics; Bioinformatic applications and tools in fish genetics and breeding; ‘R’ statistical package

Practical

Data input, import, export, modification ;Spread sheet in breeding data management; Use of ML and Reml packages for various component estimation; Estimation of genetic parameters using various statistical packages like SAS, AsREML, PEST;, SelAction; Molecular data analysis using softwares like GENEPOP

8 FG  Cell and Tissue Culture  (1+1)

Objectives:

Understanding the basic principles and techniques of cell and tissue culture

Theory

Principles of sterile techniques and cell propagation; Different cell culture media: preparation and precautions; Primary cell culture techniques; Establishing cell lines: isolation, characterization, identification of cell lines; Pure culture techniques: morphology, cultural and biochemical characters of cell lines; Maintenance and preservation of cell lines; Propagation of cells in suspension cultures; Hybridoma technology: strategy and techniques, production of monoclonal antibodies.

Practical

Principles of sterile techniques and cell propagation; Preparation of different cell culture media; Primary cell culture techniques; Establishing cell lines: isolation, characterization identification of cell lines; Pure culture techniques; Maintenance and preservation of cell lines; Propagation of cells in suspension cultures; Hybridoma technology: strategy and techniques; Production of monoclonal antibodies.
Ph.D. FISH GENETICS & BREEDING

MAJOR COURSES

The focus will be on critical review of contemporary applied programs and journal articles - students are also expected to prepare a term paper for submission at the end of the semester.

CORE COURSES

FG Advances in Fish Breeding Core (2+1)

Objectives:

Critically evaluate the recent advances and development of breeding plans

Theory

Broodstock management; Controlled breeding and reproduction in commercially important fish and shellfish species; Endocrine control of reproduction; Artificial insemination in shrimp; Synchronisation of spawning; Cryopreservation of gametes; Estimation of heritability and repeatability; Phenotypic, genetic and environmental correlations; Tagging and maintaining breeding records; Growth curves and their components; Influence of non-genetic factors on growth; Factors influencing production and reproductive traits; Crossbreeding and hybridization; Threshold characters and their selection procedure; Breeding plans to exploit additive and non-additive genetic variation; Maternal influence and its estimation, genetic mechanisms in adaptation, measurement and adaptability indices; G X E interaction; Consequences of inbreeding and management of genetic variation in fish breeding program

Practical

Heritability estimation; Correlation between different traits; Selection and genetic gains; Inbreeding; Preservation of gametes; Synchronization of spawning; The focus will be on critical review of contemporary applied breeding programs and journal articles - students are also expected to prepare a term paper for submission at the end of the semester.

FG Selection Index Methodologies (2+1)

Objectives

Evaluate the efficiency of different selection methods

Theory

Past and present status of fish breeding; Strain comparison; Factors affecting the rate of genetic improvement; Performance testing; Correction and standardization of animal breeding data; Simultaneous prediction of breeding values for several animals; Recurrent and Recurrent Reciprocal Selection; Prediction of breeding values and environmental effects; LS, BLUP, REML methods, Multivariate Breeding Value Prediction; Selection based on gene of known large effect: QTL and
MAS; Breeding values for binary traits; Selection and breeding for disease resistance and survival analysis; Partial diallele analysis; Selection for single trait and multiple traits.

**Practical**

Diallele crossing; Estimation of breeding values; Construction of selection index; Least squares and BLUP methods for estimation of genetic and non genetic parameters; Application of various computer software for genetic analyses: SAS, AsREML, PEST, and SelAction; Estimation of genetic parameter, heritability, building of pedigree information

**FG Application of genetics in commercial aquaculture (2+1)**

**Objectives:**
Review of genetic improvement program to critically evaluate the impact on commercial aquaculture

**Theory**

Evaluation of International genetic improvement programs like GIFT Tilapia, Norwegian Salmon, *L. vennami*, Hungarian carp and National programs like Jayanti Rohu, Common carp, *P. monodon*: Socioeconomic impact, technological adoption, increased production, environment impact

**Practical**

Developing the protocols for evaluating the various impacts

**OPTIONAL COURSES**

**FG Research Methodology in Fish Genetics (1+1)**

**Objective**

Integration of the methodologies under various genetic approaches

**Theory**

**Practical**
FG Advances in Cytogenetics (2+1)

Objetives
Critically evaluate the advances in cytogenetics and their applications in genetic programs

Theory
Chromosomal theory of sex determination, sex differentiation; Diploid number of chromosome in finfish and shellfish; Karyotyping; Chromosomal aberrations: inherited and induced, structural and numerical; In-vitro techniques for chromosome handling; Advanced chromosome banding including Restriction Enzyme banding, fluorescent banding, CMAS3 staining, replication banding; Fluorescent in-situ hybridization; Genotoxicity assays including Sister chromatid exchanges, MNT, comet assay; Cytogenetics and fish evolution; Cytoplasmic inheritance; Cytogentic application in fish breeding programmes.

Practical
Preparation of chromosome spreads using in-vivo and in-vitro methods; Karyotyping; Banding methods: G, C NOR, Restriction Enzyme banding; Fluorescent banding, CMAS3 staining, replication banding; Screening the brooders for cytogenetic defects.

FG Molecular Breeding (1+1)

Objetives
Evaluate the advances in molecular breeding and their incorporation in genetic improvement programs

Theory
Exploitation of non additive genetic variance; Breeding for disease resistance; Survival analysis; Application of markers in fish breeding; Identification of QTLs and MAS; Cryopreservation of gametes and its applications; Chromosome and gene manipulation; Cross breeding and hybridization; Maintenance of variation; Radiation hazards; Genetic evaluation of exotics and quarantine procedures; Patenting methods, IPR issues related to fish genetic innovations.

Practical
Identification of QTLs; Gene mapping; molecular identification of stock; Radiation hazards and effect on genetic components, pedigree assigning using molecular data, estimation of genetic parameters using molecular data
FG Transgenic production and GMOs (1+1)

Objetives
Evaluate the current status in development of transgenics and their potential commercialisation

Theory
Principles of transgenic technology and transgenic production, its application to fisheries; Risk assessment; GMOs and biosafety regulations, gene therapy, designer ornamental fish strains; Biotechnological interventions in fish breeding; Ethical issues in GMOs: Cartigan protocol, National regulations on GMOs, Impact assessment of GMOs, transgenic containment.
Practicals:
Gene transfer experiments; Northern blotting, Southern blotting for integration and expression of transgene;
Demonstration of the electropration, microinjection, expression of the marker genes,

FG Linear Models in Fish Genetics (2+1)

Objetives
Applying the linear models in fish redding data

Theory
Matrix operations: determinants, inverse of matrix, linear equations, the matrix algebra of regression analysis; Analysis of non-orthogonal and multivariate data; Linear models: fixed effects, random effects; Mixed models: their application in estimation of genetic parameters; Model building and simulations.

Practical
Matrix operation, matrix inversion, matrix algebra of regression analysis; Analysis of non orthogonal and multivariate data; Least Square analysis in the one way classification; One way classification with regression and covariance; Two way classification with and without interactions; Multiple and nested classification; Maximum likelihood estimation of genetic parameters under linear and non linear models; Use of various statistical packages for genetic parameter estimations: SAS, REML, PEST, SelAction.
Broad Areas for Research in Masters Program

1. Genetic parameter estimation in selected species
2. Cytogenetic analysis (karyotyping and banding studies)
3. Pedigree analysis using molecular data
4. Population genetic structure of selected species

Broad Areas for Research in Masters Program

1. QTL analysis in selected species
2. Genetic variation studies in endangered species
3. Developing cryopreservation protocols for selected species
4. Evaluating the disease resistance
5. Evaluating the socioeconomic status of the genetically improved programs