



✓ Secretary
12/8

UNIVERSITY OF CALCUTTA

Notification No. CSR/95 /2026

It is notified for information of all concerned that in terms of the provisions of Section 54 of the Calcutta University Act, 1979, (as amended), and, in the exercise of his powers under 9(6) of the said Act, the Vice-Chancellor has, by an order dated 05.08.2026, approved the full Syllabus of 2-year (Four Semester) M.Sc. for the Course of Study in Marine Science , under NEP guidelines, as laid down in the accompanying pamphlet.

The above syllabus shall take effect from the academic session 2026-2027 and onwards.

SENATE HOUSE

Kolkata-700073

12.08.2026

12/08/2026

Prof.(Dr.) Debasis Das

Registrar

UNIVERSITY OF CALCUTTA
M.Sc. Marine Science Course Structure & Syllabus
Semester System Following NEP20 (Effective from Academic Session 2026-27)

Course Code	Topics / Subjects	Th/Pr	IA	Marks	Credit
	SEMESTER I				
MRS411	Fundamentals of Physical Oceanography	40	10	50	4
MRS412	Fundamentals of Chemical Oceanography and Marine Geology	40	10	50	4
MRS413	Fundamentals of Marine Biology and Ecological Processes	40	10	50	4
MRS414	Introduction to Ocean Technology and Marine Sensors	40	10	50	4
MRS415	Practical in Marine Geology, Marine Chemistry, Marine Biology and Ocean Technology	40	10	50	4
	Total			250	20
	SEMESTER II				
MRS421	Ocean Dynamics, Synoptic Meteorology	40	10	50	4
MRS422	Ocean Processes & Coastal Zone Management	40	10	50	4
MRS423	Marine Microbiology, Biotechnology and Brackish water Aquaculture	40	10	50	4
MRS424	Ocean Geomatics and Artificial Intelligence	40	10	50	4
MRS425	Practical in Marine Microbiology, Biotechnology and Brackish water Aquaculture	40	10	50	4
	Total			250	20
	SEMESTER III				
MRS511 A to E	Research Course work-I (Any one) (A) Specialization in Physical Oceanography (B) Specialization in Chemical Oceanography (C) Specialization in Geological Oceanography (D) Specialization in Biological Oceanography, (E) Specialization in Ocean Technology & Geomatics with AI	40	10	50	4
MRS512	Research Course work-II : Modelling and Computational Methods in Oceanography	40	10	50	4
MRS513	Proposal writing and seminar on Indian Knowledge System in Marine Science	40	10	50	4
MRS514	Practical in Oceanographic Modelling and Geomatics with AI	40	10	50	4
MRS515	Practical in Marine Ecology and Environmental Monitoring	40	10	50	4
	Total			250	20
	SEMESTER IV				
MRS521	Research/Dissertation/Internship			250	20
	GRAND TOTAL			1000	80

SEMESTER-I

MRS 411: Fundamentals of Physical Oceanography

Water Masses, Mixing & Ocean Circulation Fundamentals: Physical properties of seawater, T–S diagrams, Forces governing ocean circulation, Ekman theory and Ekman transport, Geostrophic motion, Barotropic and baroclinic conditions, Inertial currents, Convergence and divergence, Relationship among density, pressure and dynamic topography.

Ocean Waves: Types of ocean waves, Wind-generated waves in the oceans and their characteristics, Deep and shallow water wave theory, Wave processes - Propagation, refraction, reflection, diffraction, Wave spectrum and wave forecasting, Wave transformation in shallow water, Breakers, surf, rip currents, Littoral currents.

Tides: Tide-producing forces and their magnitudes, Tidal theories - equilibrium & dynamic theories & their manifestation, Tides and tidal currents in shallow seas, estuaries and rivers.

Estuaries: Classification and circulation, Mixing, Sedimentation and salinity intrusion, Pollution dispersal in estuaries and nearshore areas, Sea-level rise and coastal vulnerability (introductory).

MRS 412: Fundamentals of Chemical Oceanography and Marine Geology

Chemistry of Seawater: Molecular properties of water, transport processes, thermodynamic properties, composition of seawater, salinity, chlorinity, conservative and non-conservative elements, residence time, and nutrient distribution.

Estuarine Geochemistry: Global water balance, aquatic systems, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), pH, Eh, carbonate system, estuarine mixing, particle dynamics, ocean acidification, and geochemical behavior of elements.

Marine Geology: Earth's structure, ocean basin morphology, continental margins, abyssal plains, trenches, ridges, heat flow, oceanic crust, sea-floor spreading, plate tectonics, mantle convection, hydrothermal circulation, and marine mineralization.

Marine Ichnology and Stratigraphy: Principles and applications of ichnology, trace fossils, marine stratigraphy, sedimentary correlations, and their significance in paleo environmental interpretation.

MRS 413: Fundamentals of Marine Biology and Ecological Processes

Marine Organisms and Adaptation: Plankton, nekton, benthos (classification, characters and ecological importance), Zooplankton Grazing; Adaptation of intertidal organisms; Rocky shores, sandy shores & muddy shores.

Marine Ecosystem: Ecosystem structure and energy flow: Ecological pyramids, Primary and secondary production: Concept of primary production (photosynthesis in oceans), Factors controlling primary production, Secondary production (zooplankton and higher trophic levels). Overview of marine faunal groups: Major marine faunal groups (protozoa to vertebrates), General characteristics and ecological roles.

Microbial Food Web: Role of bacteria and dissolved organic matter (DOM). Seaweeds and their ecological and economic importance.

Mangrove Ecosystems: Distribution and characteristics, Protective and ecological role of mangroves.

Marine Biodiversity and conservation: Marine biodiversity patterns (coastal vs open ocean), Threats to marine biodiversity; effect of Ballast in the marine environment. Ecosystem services of oceans: Importance for human well-being and sustainability. Sustainable Marine Resource Management and Conservation in Alignment with SDG 14 (Life Below Water).

MRS 414: Introduction to Ocean Technology and Marine Sensors

Ocean observation systems and marine monitoring platforms: research vessels, survey ships, onboard laboratories, buoys, floats, and satellite-based observation systems; active and passive remote sensing for ocean observation; observed parameters including SST, SSH, ocean colour, winds, and waves; telemetry, real-time monitoring, and basic ocean data management.

Marine sensors and measurement techniques: sensors for temperature, salinity, pressure, currents, waves, optical properties and acoustic observations; CTD systems, current meters, wave sensors, echo sounders and multi-parameter probes; fundamentals of remote sensing sensors including ISRO, MODIS, NOAA, Landsat and Sentinel series; sensor accuracy, precision, resolution and calibration; sensor-platform integration and observing systems; data acquisition, signal processing and validation.

Marine systems and applications: GNSS/GPS navigation, echo sounding, radar systems, satellite communication, coastal and offshore structures, desalination technologies, marine corrosion, and marine renewable energy; applications in coastal management, fisheries support, resource assessment, environmental monitoring, and operational oceanography.

MRS 415: Practical in Marine Geology, Marine Chemistry, Marine Biology and Ocean Technology

- Practical identification of common minerals, rocks, sedimentary structures, and marine fossils in hand specimens;
- Interpretation of topographic, geological, and bathymetric maps.
- Measurement of strike, dip, dip direction, and location fixing using a clinometer compass.
- Determination of chlorinity by argentometric method and estimation of salinity using Salinometer and Refractometer.
- Determination of dissolved oxygen (DO) by Winkler's titrimetric method and calculation of percentage oxygen saturation in the marine environment
- Determination of carbonate, bicarbonate, and free carbon dioxide levels in aquatic systems using pH and alkalinity measurements
- Identification of Marine Phytoplankton, Zooplankton, Invertebrates, and Vertebrates
- Identification of Mangrove Species and Seaweeds
- Familiarization with oceanographic instruments and sensor systems: current meter, echo sounder, GPS, and multi-parameter water quality probes, and other field sensors.
- Marine data acquisition and sensor handling; calibration and maintenance
- Simulation-based exercises on instrument deployment, field observation planning, and multi-sensor data collection
- Submission of Field Visit Report.

SEMESTER II

MRS 421: Ocean Dynamics, Synoptic Meteorology

Ocean Circulation: Gyres and boundary currents, Subtropical gyres and western boundary currents, Equatorial current systems, Wind-driven coastal currents, Thermohaline circulation and global conveyor belt, Indian monsoonal currents, upwelling and downwelling. Role of sea surface temperature (SST).

Tropical Meteorology: Synoptic systems, Global wind systems, Structure of atmosphere, trade wind inversion, ITCZ. Tropical cyclones - structure and development, classification and life cycle of cyclones, Impact of cyclones on coastal regions. Jet streams: types (tropical easterly, subtropical westerly), Role of jet streams in weather systems, low-level jet, Somali jet. Concept and definition of monsoon, Air-sea interaction, and its role in monsoon dynamics. Monsoon trough and depressions, Indian monsoon: Monsoonal circulation in the Indian Ocean, Onset, advance, withdrawal, break, and active phases, Southwest and Northeast monsoon. Concept of ENSO (El Niño/ La Niña and Southern Oscillation) and Indian Ocean Dipole (IOD).

Introduction to Python programming: Features of Python programming language –basic syntax, data types, variables, and operators, mathematical operations using math module, string operations, control operations, list, tuple, set, and dictionary sequences, print function, input function, control structures (if-else, loops), user-defined functions, modules, file handling, 2-D and 3-D plotting, labels, axis control, scatter plot, line plot, bar chart, pie chart, contour plot, surface plot.

MRS 422: Ocean Processes & Coastal Zone Management

Elemental Cycling and Oceanic Processes: Chemical weathering and its coupling with the global carbon cycle and climate. Oceanic particle fluxes, production, their variation, and modern techniques of estimation; cycling of trace metals: sources, sinks, ligand interactions, and biological roles; air-sea exchange of gases: controlling factors (wind, temperature, solubility pump vs biological pump interactions); biological pump and carbon sequestration.

Chemical Oceanography of Special Environments: Hydrothermal vent systems: fluid chemistry, Oxygen minimum zones (OMZs), Anoxic basins: redox gradients, nitrogen loss processes (denitrification, anammox), HNLC regions and nutrient limitation: iron limitation and ecosystem response.

Sediment–water interface: early diagenesis and benthic fluxes of nutrients and metals, Sediment pore water chemistry: early diagenesis and benthic fluxes of nutrients and metals.

Coastal landforms: rocky and sedimentary coasts, Beach morphology and morphodynamics, Coastal dunes and barrier systems, Coastal zone classification.

Coastal Processes & Sedimentation: Sediment sources and transport in coastal zones, Erosion, accretion, and shoreline changes, Deltas and lagoons, Tidal flats and marshes, Marine sediments: types, sources, and distribution, Sedimentary structures and depositional processes, Diagenesis of marine sediments.

Coastal Zone Management: Principles of coastal zone management (ICZM) and sustainability, strategies, and coastal structures. Coastal Regulation Zone (CRZ) notification (India); Impacts of coastal construction on the coastal zone; construction of Jetties, Breakwaters, sea walls, groynes, revetments, etc., Environmental Impact Assessment (EIA) in coastal areas.

MRS 423: Marine Microbiology, Biotechnology, and Brackish Water Aquaculture

Marine Microbiology and Molecular Ecology: Marine microbial diversity and extremophiles, measurement of growth, Kinetics, Molecular tools in marine ecology (PCR, metagenomics, eDNA), Harmful algal blooms and toxin production, Biofilms and marine biofouling, Symbiosis in marine organisms, Role of microbes in nutrient cycling and bioremediation.

Marine Biotechnology and Sustainable Applications: Marine natural products and bioactive compounds, Bioprospecting and drug discovery, Marine enzymes and industrial applications, Aquaculture biotechnology and genetic improvement, Algal biotechnology and biofuel production, Ethical, legal, and environmental considerations in marine biotechnology.

Brackish Water Fisheries Management: Present status and scope of coastal fisheries and aquaculture, Site selection, Layout planning and design of fish farm, Pond Preparation, Stocking & Feeding management, Traditional, Semi-intensive and intensive culture. Common diseases of marine and estuarine fin fishes and shell fishes; Control and prevention of diseases. Fish processing technology: Freezing, Drying, Canning & Reducing.

MRS 424: Ocean Geomatics and Artificial Intelligence

Ocean geomatics fundamentals: remote sensing principles, electromagnetic spectrum, ocean sensors and satellite systems for optical, thermal and microwave observations; GIS concepts, spatial data models, marine spatial data acquisition, bathymetric mapping, coastal mapping, GPS/GNSS applications, spatial visualization and marine cartography.

Geospatial analysis and modelling: satellite preprocessing; digital image processing, classification, feature extraction, time-series analysis, spatial interpolation, multi-criteria decision analysis, shoreline change, coastal vulnerability assessment, marine habitat mapping, spatial simulation, and case studies from Indian and global oceans.

Artificial intelligence and machine learning in marine science: supervised and unsupervised learning, regression, classification, clustering, pattern recognition, anomaly detection and spatial prediction; applications in water quality, fisheries, algal blooms, coastal risk and climate variability; data preparation, model training, validation, accuracy assessment and ethical considerations.

MRS425: Practical in Marine Microbiology, Biotechnology, and Brackish Water Aquaculture

- Sterilization methods and preparation of microbiological culture media, including agar slants and stab cultures for microbial isolation and maintenance.
- Enumeration, isolation, identification, and classification of microorganisms from marine water, marine sediments, mangrove litter, and spoiled fishery products of marine and estuarine origin using serial dilution and standard microbiological techniques
- Microscopic examination, Gram staining and identification of unknown microorganisms using biochemical tests, including carbohydrate fermentation, indole, Voges–Proskauer (VP), methyl red (MR), citrate utilization, catalase, oxidase, and antibiotic susceptibility tests
- Bioinformatics: Idea of gene bank study, primer design through Benchling or SnapGene, and use of related computer programming. Idea about homologous gene and NCBI BLAST
- Estimation of protein, carbohydrate, lipid and oxidative stress biomarkers from marine and estuarine finfishes and shell-fishes.
- Identification of larvae, fry, fingerlings, juveniles, and adults of marine and estuarine finfishes and shellfishes.
- Preparation of feed charts using cast net sampling data for brackish water aquaculture farms and estimation of Feed Conversion Ratio (FCR).
- Visit to coastal shrimp farm: reporting on layout of the farm, seed collection, preparation of shrimp plots, transportation of larval and post-larval shrimps, rearing techniques and their management, etc.

SEMESTER III

MRS 511A to E: Research Course Work-I (Anyone from the following)

MRS 511 A: Specialization in Physical Oceanography

MRS 511 B: Specialization in Chemical Oceanography

MRS 511 C: Specialization in Geological Oceanography

MRS 511 D: Specialization in Biological Oceanography

MRS 511 E: Specialization in Ocean Geomatics with AI and Technology

MRS 511 (A): Specialization in Physical Oceanography

Advanced Wave and Tidal Dynamics: Wave dispersion and group speed, Wave energy, Spectral analysis of ocean waves - energy distribution and wave-wave interactions, Nonlinear wave processes and wave breaking dynamics, Wave-current interactions and coastal implications, Giant waves, Advanced tidal analysis - harmonic constituents and residual circulation, Tidal asymmetry and mixing in coastal and estuarine systems.

Coastal and Estuarine Dynamics: Coupled physical processes in coastal zones - wave-tide-current interaction, Coastal circulation modelling and nearshore hydrodynamics, Sediments of shallow-water environments, Sediment transport dynamics - Factors controlling the movement of sediment, Sediment erosion, transport and deposition, Estuarine circulation - stratification, salt balance, and exchange processes (quantitative approach), Sediment distribution in estuaries, Tidal channels of estuaries.

Geophysical Fluid Dynamics: Continuum Mechanics, Fluid properties, Units of measurement, Pressure, Density, Specific weight, specific volume, specific gravity, Viscosity, Surface tension, Newtonian and Non-Newtonian fluids, Lagrangian and Eulerian methods of description of fluid flow, stream lines, streak lines and trajectories Fundamental forces - Pressure gradient, Coriolis, gravity, friction, Equations of motion and continuity- Navier-Stoke's equations, Geostrophic and gradient flows, Thermal wind concept, Vorticity, divergence and circulation, Potential vorticity and applications, Boundary layer dynamics and turbulence, Wave motions - Gravity, inertia and Rossby waves, Instabilities - Barotropic and baroclinic, Dimensionless numbers - Reynolds, Rossby, Froude, Richardson, Sverdrup, Stommel and Munk theories.

Wind-driven circulation theories: Ekman theory, Sverdrup balance, western boundary intensification (analytical treatment), Thermohaline circulation: water mass formation, overturning circulation, and variability.

Near-Shore Dynamic: Harbour resonance and seiches, Tsunami and wave-structure interaction, Beach stability and nourishment.

Tropical ocean-atmosphere systems: ENSO dynamics and monsoon-ocean interaction, Indian Ocean dynamics: intra-seasonal variability, upwelling systems, and dipole phenomena, Role of oceans in climate variability and change. Natural hazards - Cyclones, storm surge, tsunamis, cloudbursts, Prediction and mitigation, Ocean energy - Tidal energy, OTEC, wind power.

Numerical methods in ocean modelling: discretization, stability, and error analysis, Finite difference method (FDM), different numerical schemes of FDM - FTFS, FTBS, FTCS, upwind, Lax and Lax-Wendroff schemes, CFL stability condition, Arakawa grids.

Advanced ocean modelling: Modelling buoyancy oscillation - inertial currents - advection model, Diffusion model – stability analysis - advection-diffusion model – Peclet number, Ekman model - mixed layer models, Shallow water equations - shallow water models, Ocean General Circulation Models.

MRS 511 (B): Specialization in Chemical Oceanography

Dissolved and Particulate Organic Compounds in Seawater: Their origin and distribution; ecological effects and fate in the seawater; organic carbon cycle, molecular constituents of organic matter in the ocean, lipids, Amino acids and proteins in seawater, carbohydrate lignin and other low oxidation products; dissolved organic matter and their photo-oxidation. Chromophoric dissolved organic matter (CDOM) and Fluorescent dissolved organic matter (FDOM).

Particle fluxes and biogeochemical cycles: Oceanic particle fluxes its variation and techniques of estimation; benthic fluxes and their distribution; formation and distribution of marine carbonates; Biogeochemical cycles of carbon, nitrogen, phosphorus and silicon in the marine environment. Aerosol and its composition, formation, transformation and transport of aerosol; properties of the sea surface microlayer. Production of radiatively active gases in the marine environment and its effect on atmospheric composition and climate; Inter-relationships between ocean circulation, primary productivity and chemical composition of the atmosphere & the ocean.

Radioactive tracers/Stable isotopes in marine chemistry: Radioactive decay series and their application to geochronological studies; application of stable isotopes in biogeochemical studies and uses of chemical tracers in oceanography. Radioactive tracers in estuarine chemical studies.

Blue carbon: Carbon sequestration in the coastal systems, Contribution to the global carbon budget, Carbon sequestration potential in the Indian Sundarbans.

Chemistry of marine natural products: Biomedical Aspects; chemical and pharmacological properties of bioactive substances in marine organisms, carbohydrates and their derivatives in red and brown algae, aliphatic acids and their derivatives in marine organisms, steroids and their use as biomarkers, nitrogenous compounds in invertebrates, nucleosides from sponges, biopolymers.

Analytical instrumentation: Errors and precision of analytical methods used in chemical analyses. Analytical techniques and the application of different instruments, such as AAS, GC, HPLC, FTIR, Mass Spectrometry, TOC analyzer, and coulometer, in chemical oceanographic studies.

MRS 511 (C): Specialization in Geological Oceanography

Ocean Basins, Structure & Evolution: The Shape and main features of ocean basins, Ocean Ridges – Ridge topography, The deep ocean floor –Abyssal plains, seamounts, Aseismic ridges, The Evolution of ocean basins. Indian basins- Bombay high, Bengal basin, Andaman basin and Krishna-Godavari basin

Structure and Formation of Ocean Lithosphere : Formation of oceanic lithosphere, segmentation of oceanic spreading axes; a plausible model for lithospheric growth.

Hydrothermal Circulation in Oceanic Crust : The nature of hydrothermal circulation. Chemical changes during hydrothermal circulation; Black smokers, white smokers and warm water vents.

Ocean floor metamorphism: Definitions, concept, importance of ocean floor metamorphism for the genesis of sulphide deposits.

Paleoceanography and Paleoclimate: Approaches to paleoceanographic reconstruction, Proxy indicators: Microfossils, isotopes, geochemical tracers, Reconstruction of monsoon variability using marine records, Opening and closing of ocean gateways (Cenozoic), Sea-level processes and changes, Methods of paleo sea surface temperature reconstruction.

Petroleum and natural gas: Origin, occurrence and structural control of petroleum and natural gas reservoirs. Gas hydrates. Brief idea on Indian occurrences.

Marine Resources and Environmental Concerns: Marine mineral resources and their distribution, Natural resource exploration and exploitation, Environmental impacts of resource extraction, Conservation of non-renewable resources, Groundwater pollution and over-extraction effects, Land subsidence and groundwater depletion.

Climate System and Geological Hazards: Climate of India: Indian monsoon system, Western disturbances, and droughts. Climate variability: El Niño and La Niña impacts. Geological hazards: Earthquakes, volcanism, landslides, tsunamis, floods, avalanches, cloudbursts. Hazard prediction and mitigation strategies.

MRS 511 (D): Specialization in Biological Oceanography

Spectrum of marine Organisms: Marine plants & animals; description, classification, distribution and habitats. Abiotic factors, Biotic factors, Physiological ecology, human affairs, Microalgae and their communities; Macro algal communities, Benthic organisms: salient features of foraminifera, radiolarian, peripheral, coelenterates, Polychaeta, molluscs, crustaceans, echinoderms, protochordates and chordates of marine inhabitants and their adaptations to marine environments; plankton: culture, importance, ecological and economic benefits.

Population dynamics: Patchiness in phytoplankton distribution; grazing; phytoplankton species succession; The evolutionary ecology of phytoplankton; Seasonal changes and breeding of the holoplankton; breeding of the meroplankton; Vertical migration of zooplankton; The food, feeding, and respiration of zooplankton.

Ecological Processes and Key Ecological Concepts: Ecological succession (primary & secondary), Species diversity (alpha, beta, gamma diversity), Keystone species, Lotka-Volterra model (predator-prey interactions and competition); Carrying capacity; Population growth models (exponential & logistic); population regulation mechanisms.

Mangroves: Adaptation, threats and conservation strategies with global and regional case studies; Effect of physico-chemical variables and climatic factors on mangroves; Resistance of mangroves against sea level rise, cyclones and tidal surges.

Coral reefs: Distribution and limiting factors; Coral structure and diversity; Nutrition and production in reefs; Production estimates; Formation and growth of reefs; Coral predators and predation on reefs; Destruction and conservation of reefs.

Energy Flow and Mineral Cycling: Food chains and energy transfer; The microbial loop; A comparison of marine and terrestrial production; Mineral cycles (nitrogen and carbon) in the marine environment.

Marine and estuarine living resources: Seaweeds, finfish, and shellfish resources: types, culture, management, livelihood generation, marketing, and concept of cost-benefit analysis.

Deep-Sea Ecology: Faunal composition and its adaptation to the deep-sea environment. Species diversity and biomass: characteristics of deep-sea microorganisms adapted to extreme environments. Rates of biological processes.

Marine Biodiversity and Conservation: Definition and levels (genetic, species, ecosystem); Importance and measures of biodiversity in marine and estuarine environments; and marine and estuarine biodiversity hotspots of India. Threats and conservation strategies applicable to marine and estuarine biodiversity: in-situ conservation, Ex-situ conservation, in vitro conservation, marine protected areas (MPAs), ecosystem-based management, policy frameworks.

Toxicodynamic, Bioassays, Bioremediation, and Bioindicator: The trophic transfer of metals and Organic pollutants in marine systems. Biological features involved in metal concentration are observed in marine organisms. Metal detoxification in marine organisms and prediction of metal toxicity from bioassays; Concept and types of bioassays, LC50, LD50 determination, Occurrence. Bioremediation: Definition and principles, Types: In-situ, Ex-situ, Microbial bioremediation (bacteria, fungi), Phytoremediation; Bioindicator-Concept and significance of Indicator species for pollution monitoring (lichens, algae, benthic organisms); ecological impacts of Harmful algal blooms (HABs).

Marine Biotechnology and Genetics: Replication, Transcription, Translation, DNA fingerprinting and barcoding, genomics, proteomics and functional proteomics, concept of the BET test, GMO, etc.

MRS 511 (E): Specialization in Ocean Geomatics with AI and Technology

Ocean Observation and Geospatial Data Integration: Integrated satellite-sensor-platform observation systems; retrieval and interpretation of SST, chlorophyll-a, turbidity, sea surface height, winds, waves, and ocean colour; optical, thermal, and microwave remote sensing; multi-source geospatial datasets; integration of satellite, in-situ, and numerical model observations for marine and coastal applications.

Geospatial Data Processing and Spatial Modelling: Digital image preprocessing, feature extraction, and GIS-based marine mapping; raster and vector data models; spatial interpolation, time-series analysis, and geostatistics; Google Earth Engine (GEE)-based cloud processing; coastal vulnerability assessment, shoreline dynamics, marine habitat mapping, and visualization of oceanographic datasets.

Artificial Intelligence and Predictive Ocean Modelling: Machine learning techniques including regression, classification, clustering, and time-series prediction; deep learning fundamentals, feature engineering, model training, and validation; integration of Remote Sensing, GIS, and AI for water quality prediction, fisheries forecasting, mangrove mapping, coastal hazards, climate variability studies, and operational decision-support systems.

MRS 512: Research Coursework-II (Modelling and Computational Methods in Oceanography)

Data Collection, Analysis, and Interpretation: Methods of data collection tools and techniques, sampling selection, sampling errors and precision, data processing, statistical analysis, interpretation, and reporting of results.

Descriptive Statistics: Measures of central tendencies: Mean, Median, and Mode, Quantiles. Measures of Variability: Variance, Standard deviation, skewness, Kurtosis. Probability, Distribution functions: Binomial Distribution, Poisson Distribution, Normal Distribution, t-distribution, F-distribution, χ^2 -distribution.

Statistical inferences: Correlation, Regression, Curve fitting, Estimation of parameter, Hypothesis Testing, Chi-squared tests, z-test, t-Test, ANOVA, Statistical Quality Control (SQC), Time series analysis of oceanographic data: trends, filtering, spectral methods (FFT), Multivariate statistical techniques: PCA, Empirical orthogonal functions (EOF), advanced regression and model validation techniques.

Modelling: Numerical modelling of decay problem, Newton's law of cooling population growth - exponential and logistic, Models of production, growth, and multiple reacting species in aquatic ecosystems in estuary and ocean, viz. Lotka-Volterra model, Nutrient uptake-the Michaelis-Menten model, Droop model and Monod model for growth and nutrient supply.

MRS 513: Proposal Writing and Seminar on Indian Knowledge Systems in Marine Science

Students will prepare research proposals and deliver seminars on Indian Knowledge Systems (IKS) in Marine Science. The course develops essential skills in scientific proposal writing, oral presentation, and critical evaluation of research while introducing students to the principles and applications of IKS in marine science. It emphasizes the integration of traditional ecological knowledge with modern scientific approaches to promote the sustainable management, conservation, and restoration of marine and coastal ecosystems.

MRS 514. Practical in Oceanographic Modelling and Geomatics with AI

- Data importing and preprocessing: Introduction to ocean data sources (Argo floats, satellite data), Accessing and downloading datasets from ocean data portals (NASA, NOAA, MOSDAC, INCOIS, GEBCO, PSMSL), Data formats (CSV, NetCDF), Reading, visualizing, and interpreting SST, MSLP, SSS, SSH, bathymetry, and tide data, Basic quality control and data interpretation.
- Python programming: Use of scientific libraries (NumPy, SciPy, Matplotlib, Pandas – introductory), solving algebraic and differential equations, and computing eigenvalues and eigenvectors of a matrix.
- Data Analysis (using software Python/R):
Correlation, Regression, Curve fitting, Hypothesis Testing, Chi-squared tests, z-test, t-Test, ANOVA, Statistical Quality Control (SQC), Multivariate statistical techniques: PCA; Empirical orthogonal functions (EOF); Advanced regression and model validation techniques.

- Time series analysis of oceanographic data: trends, filtering, spectral methods (FFT); Time-series filtering and spectral analysis using Python libraries. Numerical modelling of the growth and decay problem using the finite difference method.
- Satellite and GIS-based marine data processing in GEE Platform; acquisition and preprocessing of ISRO, MODIS, NOAA, Landsat, Sentinel, and in-situ datasets; preparation of SST, chlorophyll-a, bathymetry, shoreline, coastal zone, and thematic oceanographic maps.
- Geospatial analysis and visualization; handling of raster, vector, gridded, and NetCDF datasets; GIS-based interpolation, and spatial modelling exercises; and satellite-derived products.
- GEE and AI-based applications; Google Earth Engine workflows for ocean and coastal data analysis; integration of satellite, field, and sensor datasets; basic ML model implementation for prediction, classification, and anomaly detection in marine datasets.
- Research assessment and reporting; case study analysis using real-time or archived oceanographic datasets; visualization of results using maps, graphs, and time series; preparation of technical reports, interpretation of outputs, and presentation of findings.

MRS 515. Practical in Marine Ecology and Environmental Monitoring

- Training in in situ field observations, operation of multiparameter water quality probes and other field sensors, marine data acquisition, instrument deployment, field survey planning, and environmental data collection.
- Collection, preservation, and laboratory processing of phytoplankton and zooplankton samples for qualitative and quantitative analysis, taxonomic identification, and estimation of abundance, biomass, and diversity indices using standard taxonomic keys
- Measurement of in-situ Gross Primary Productivity, Net phytoplankton and Nano phytoplankton productivity.
- Estimation of chlorophyll, total suspended matter (TSM), and colored dissolved organic matter (CDOM) in marine and estuarine waters using standard analytical methods.
- Identification of marine flora (microalgae, macroalgae, seagrasses, and associated plant species) and marine fauna (marine invertebrates and vertebrates, including commercially important fishes and prawns)
- Morphometric Characterization of Mangroves and their associates.
- Estimation of chlorophyll, carbon and antioxidant activity in mangrove leaves using standard analytical methods
- Estimation of dissolved inorganic nutrients (Phosphate-P, Nitrate-N, Nitrite-N, and reactive silicate) in seawater using spectrophotometric techniques.
- Estimation of calcium and magnesium by EDTA/EGTA titrimetric methods
- Submission of the field visit report.

SEMESTER IV

MRS 521: Research/Dissertation/Internship

The student shall undertake a research project/dissertation/internship under the supervision of a recognized guide. Upon completion, the dissertation/project, duly forwarded by the concerned Institute/Department/Supervisor, shall be submitted to the Head, Department of Marine Science, University of Calcutta, for evaluation by both internal and external examiners. The assessment will include continuous assessment, project submission, presentation, defense, and viva voce.

Suggestive Reading

- Abraham, E.P. and Loder, P.B. (1972). Cephalosins and Penicillins (E.H. Flynn, ed.) Academic Press, London.
- ACDP/REP/183/18 UNDP/FAO, Rome (1983). Fish Feeds and Feeding in developing
- Alder, H. (1977). Introduction to Probability and Statistics (6th edn.). San Francism, Freeman.
- Al-Hajj, A.B. and Farmer, A.S.D. (9184). Shrimp Hatchery Manual. Safut Kuwait Institute for Scientific Research.
- Austin, B. (1987). Deep Sea Microbiology. In Methods in Aquatic Bacteriology B. Austin (ed.), Wiley: Chichester.
- Abhishek Mukherjee and Tarun Kumar De (2017): A Scholastic Guide to Indian Seaweeds. ISBN - 978-3-330-02453-3. Published by Lambert Academic Publishing House, Germany. Copyright@ OmniScriptum GmbH & CO. KG. pp. 421.
- Abhishek Mukherjee and Tarun Kumar De (2017): Use of Diatoms as Bio monitors in Hooghly Estuary, Bay of Bengal, India. ISBN - 978-3-330-02831-9. Published by Lambert Academic Publishing House, Germany. Copyright@ OmniScriptum GmbH & CO. KG. pp. 205.
- Baily, R.A. Clark, H.M. Ferris, J.P. Krause, S. Strong, R. L., Chemistry of the Environment, 1978, Academic Press, New York
- Bardach, J.E.; Ryther, J.H. and Mclarney, W.O. (1972). Aquaculture. John Wiley and Sons. Inc. New York.
- Barnes, H. (ed.) 1972. Oceanography and Marine Biology, George Allen and Union, London.
- Baturin G.N. (1988). The geochemistry of manganese nodules in the oceans. D. Reides Publishing Co. Berlin, 342p.
- Bertnus et.al (2001). Marine Community Ecology. Sinaver Associates, Inc.
- Bird, E.C.G. (1969). Coasts, M.I.T. Press, Cambridge, Mass.
- Bishop, C.M. (2006). *Pattern Recognition and Machine Learning*. Springer
- Bowen, H. J. M. Environmental Chemistry of the elements, 1979 Academic Press, London.
- Brock, I.D. and Madigan, M.T. (1988). Biology of Microorganisms, 5th edn. Prentice Hall, Englewood gliffs, N.J.
- Broecker, W.S. and Peng. T.S. 1983 Tracers in the sea, Eldigio Publication.
- Candie, K.C. (1982). Plate Techains and crustal surch Programm Press Inc. New York, 310 p.
- Chakrabarty, A. M. (1982). Biodegradation and Detoxification of Environmental Pollutants. CRC Press.
- Clark, R. B., Marine Pollution, 5th Ed. 2001, Oxford University Press.
- Clarke, G. M. (1980). Statistics and Experimental design. Edward Arnold. London.
- Clinton, J. Dawes (ed.) 1998. Marine Botany. C. Van Den Hoek; Mann, D.G. & Jahns, H.M. (eds.) 2000. An Introduction to Phycology.

- Clu sas, I.J. (1985). Fish Handling, Preservation and Processing in the Tropics. Part I and II., Tropical development and Research Institute, London.
- Coates, D. R. (eds.) 1973. Coastal Geomorphology. State University of New York, Binghamton, New York.
- Condie, K. (1982) Plate Tectonics & Crustal Evolution. Pergamon Press Inc., New York 310p.
- Crachnel, A.P. (1982). Remote sensing application in Marine Science and Technology. D. Reidel Publishing C.
- David L. Kirchman, (2000). Microbioal Ecology of the Oceans, Wiley Liss, New York.
- Dawson, E.Y. (1966). Marine Botany: An Introduction, Holt, Rinehart & Winston, New York.
- Defant, A. (1961). Physical Oceanography. Vol. I-II. Pergamon Press, Oxford.
- Degens, E.T. (1965) Geochemistry of sediments Prentice Hall. New York.
- Dela Cruz, C.R. (1983). Fish pond engineering a technical manual for small and medium scale coastal fish farm in South East Asia. South Chaina Sea Fisheries Development and Coordinating Programme, SCS Manual, Manila.
- Dietrich, G.; Kalle, K.; Krauss, W. and Siedfer, G. (1980). Oceanography, 2nd Edition. John Wiley & Sons, New York, Chichester, Brisbane, Toronto.
- Dursma, E.K. and Dawson, R (ed) 1981 Marine Organic Chemistry – Evolution, Composition, Interactions and chemistry of organic matter in seawater. Elsevier Scientific Publishing Company. Amsterdam, Oxford, New York, 521 pp.
- Dyrssen, D. and Jogner, D. 1972. The changing chemistry of the Oceans. Almquist & Wiksell, Stockholm, and Wiley Interscience Division, New York, London, 365pp.
- Eckart, C. (1960). Hydrodynamics of Oceans and atmosphere. Pergamon Pess, Oxford.
- Elliot, J.A. (1999). An introduction to sustainable Development. Dontledge, London.
- Emery, W.J., & Thomson, R.E. (2001). *Data Analysis Methods in Physical Oceanography*. Elsevier
- Fakowski, P.G. and Woodham, A.D. (1992). Primary Production and Biogeochemical Cycles in the Sea. Plenum Press, New York.
- FAO (1980). The artificial Propagation of Warm water fin fishes manual for extension. E. Waynarovich and L. Horvath.
- Fingerman, M.; Nagabhushanam, R. and Thompson, M.R. (1998). Recent advances in Marine Biotechnology, Vol-2. Environmental Marine Bio-technology. Oxford and I.B.H. Publishing Pvt. Ltd., New Delhi.
- Fraden, J. (2016). *Handbook of Modern Sensors: Physics, Designs, and Applications*. Springer
- Friedman, G.M. & Sanders J.E. (1978) Principles of Sedimentology Wiley & Sons.
- Friedrich, H. (1969). Marine Biology, Sidgwick & Jackson, Ltd., London.
- Gerasimov. G.V. and Antonova, M.T. (1979). Technochemical Control in the Fish Processing Industry. Amerind Publ. Co. Pvt. Ltd. New Delhi, Bombay, Kolkata, New York.
- Govinda, T.K. (1985). Fish processing Technology. Oxford and IBH Publ. Co. New Delhi.

- Grasshoff, K. 1976 Methods of seawater analysis. Verlag Chemie, Weinheim.
- Gunstone, F.D. (1983), Lipids in Foods: Chemistry, Biochemistry and Technology. Pergamon Press.
- Halstead, B.W. (1967). Poisonous and Venomous Marine Animals of the World, Vol.2. U.S. Govt. Print Office, Washington, D.C.
- Halver, J.E. (1972). Fish Nutrition. Academic Press, New York.
- Horst, D. Schulz and Marthias Zabel (Eds) Marine Geochemistry, 2000, Springer-Verlag.
- Imai, T. (1977). Aquaculture in Shallow Seas: Progress in Shallow Sea Culture. Oxford IBH, Publ. Co. New Delhi, Bombay and Kolkata.
- Jamandro, T.J. and Rabanal, H.R. (1975). Engineering aspects of brackishwater aquaculture in the South Chaine Sea Region. SCS/75/WP/16.
- James, G., Witten, D., Hastie, T., & Tibshirani, R. (2021). *An Introduction to Statistical Learning*. Springer
- Jhingran, V.G. (1988). Fish and Fisheries of India. Revised Second Edition. Hindustan, Publishing corporation, Delhi.
- Kalnay, E. (2003). *Atmospheric Modeling, Data Assimilation, and Predictability*. Cambridge
- Kemp, P.F.; Sherr, B.F.; Sherr, E.B. and Cole, J.J. (1993). Handbook of Methods in Aquatic Microbial Ecology. Lewis Publishers Boca Raton.
- Kennett, P (1982) Marine Geology. Prentice – Hall Inc. New Jersey, 813 p
- Kinne, O. (1970). Marine Ecology (ed.). Vol.1: Environmental factors. Wiley Interscience, New York.
- Kohlmeyer, J. and Kohlmeyer, E. (1979). Marine Mycology: The Higher Fungi. Academic Press: New York.
- Kurian, C.V. and Sebastia, V.O. (1976). Prawn and Prawn Fisheries of India. Hindustan Publ. Co., New Delhi.
- Le Pichon, X.; Francheteak, J. and Bonnin, J. (1973). Plate tectonics, Elsevier Publishing Co., Amsterdam.
- Lee, D.C.C. and Wichins, J.F. (1991). Curstaccean Farming Oxford Fishing News Books, Blackwell Sci. Publ. Ltd.
- Lehninger, A. 2. (1980). Practical Biochemistry for students. Laypec Brothers, New Delhi.
- Leivinton, J.S. (1982). Marine Ecology. Prentice – Hall.
- Lewis, A. (1971). Biostatistics. East West Press, New Delhi.
- Lewis, J.R. (1964). The Ecology of Rocky Shores. English Universities Press Ltd., London.
- Lillesand, T., Kiefer, R., & Chipman, J. (2015). *Remote Sensing and Image Interpretation*. Wiley
- Lisitzin, A.P. (1972) sedimentation in the world oceans. Tulsa, Okla, special publication (K.S. Rodolfo, ed.)
- Longhurst, A.R. (1981). The ecology of rocky shores. English Universities Press Ltd., London.
- Mann, K. H. (1982). Ecology of Coastal Waters: A Systems Approach. Blackwell Scientific Publications.

- Marshall, K.C. (1976). *Interfaces in Microbial Ecology*. Harvard University Press: Cambridge.
- Martin, S. (2014). *An Introduction to Ocean Remote Sensing*. Cambridge University Press
- Mehler, H. R. and Cordes, E.H. (1971). *Biological Chemistry*. Harper and Row, New York.
- Mero, J.L. (1965). *Mineral resources of the sea*. Elsevier, Amsterdam, 312 p.
- Milero, P.H. (1971). *Fish and shellfish farming in Coastal waters*, fishing News (Books) Ltd., London.
- Mitchell, R. (2000). *Marine microbial ecology*. Wiley, New York.
- Muir, J.F. and Roberts, R.J. (1985). *Recent Advances in Aquaculture*. Vol. II. Beckenham V.J., Croom Helm, London.
- Muir, J.F. and Roberts, R.J. (1988). *Recent Advances in Aquaculture*. Vol. III. Croom Helm, London.
- Nandi, N.C. and Pramanik, S.K. (1994), *Crabs and Crab Fisheries of Sundarban*. Hindustan Publishing Corporation, Delhi.
- Neumann, G. and Pierson, W.J. (1966). *Principles of Physical Oceanography*. Prentice – Hall, Englewood cliffs, New Jersey.
- New, M.B. (1987). *Feed and Feeding of Fish and Shrimp*. ACDP/REP/84/26 UNDP/FAO, Rome.
- Nybokken, J.W. (1971). *Readings in Marine Ecology*. Harper and Row, New York.
- Odum, E.P. (1971). *Fundamentals of Ecology*. W.B. Saunders, Philadelphia.
- Osborne, P.L. (2000) *Tropical Ecosystem and Ecological concepts*. Cambridge Univ. Press, 464 p.
- Paul, J.H. (2001). *Marine Microbiology: Methods in Microbiology*. Vol.30. Academic Press.
- Pelhick, J. (1984). *An introduction to Coastal Geomorphology*, Arnold, London.
- Phillips, R.C. and McRoy, C.P. (eds.) 1980. *Handbook of Seagrass Biology; An Ecosystem Perspective*. Gerland STPM Press.
- Pickard, G.L. (1979). *Descriptive Physical Oceanography*. Pergamon Press, Oxford, 3rd edition.
- Pillay, T.V.R. and Dill, Wm. A. (1976). *Advances in Aquaculture*. Fishing News Books Ltd., Farnham, Surrey, England.
- Prescott, L.M; Harley, J.P. and Klien, D.D. (1997). *Microbiology*, 2nd edn. Wm. C. Brown Publishers, Duluque, Iowa. Publishing Co. Pvt. Ltd. Calcutta.
- Quiniton, E.T. (1989). *Prawn Hatchery Design and Operation*, SEAFDEC Aquaculture Ext. Man. (9): 47 p. 2nd edn.
- Rabindran, K. (1985). *Harvest and Post-Harvest Technology of Fish*, Society of Fisheries, Technologies, India.
- Rajamanickan G.V. & Tooley, M.J. (eds) (2001). *Quaternary Sea-level variation, shoreline displacement and coastal environment*. New Academic Publishers, Delhi.
- Raymont, J.E.G. (1980). *Plankton and Productivity in the Oceans*, 2nd Edition, Vol.1 & 2. Pergamon Press.

- Rice, J. A. (1995). Mathematical Statistics and Data Analysis, 2nd edn. Duxbury Press, Belmont.
- Riley, J. P. and Skirrow, G. (1975). Chemical Oceanography. Eds. Vol. 1, 2 & 4. Academic Press, London.
- Roberts, R.J. (1978). Fish Pathology. Bailliere Tindall, London.
- Robinson, I.S. Satellite Oceanography – An Introduction to Oceanographers and Remote Sensing Scientists.
- Rone P, Bostrom K. Lambier, L & Smith K.L (1989) Hydrothermal processes at Sea floor spreading Centres. Plenum Press 796 p.
- Ross, D A (1982) Introduction to Oceanography. Prentice Hall. New York.
- Roy, S. (1981) Manganese Deposits, Academic Press London 392 p.
- Seawater: its composition, properties and behaviours 1989. The Open University, Walton Hall, Milton Keynes, MK7 6AA, England.
- Shigeno, K. (1978). Problems in Prawn culture. Ameriad Publ. Co. Pvt. Ltd., New Delhi.
- Shreve, N. J. (1967). Chemical Process Industries, 3rd Ed. Mc.Graw-Hill, New York.
- Sieburth, J. McN. (1979). Sea Microbes. Oxford University Press: New York.
- Smith, J. M. (1975). Models in Ecology. Cambridge University Press.
- Steers, J. A. (ed.) 1971. Applied Coastal Geomorphology. M. I. T. Press, Cambridge, Mass.
- Steers, J. A. (ed.) 1971. Introduction to Coastline Development. M. I. T. Press, Cambridge, Mass.
- Stewart, R.H. (2008). *Introduction to Physical Oceanography*. Texas A&M University
- Strickland, J. D. H. and Parsons, T.R. 1972, A practical handbook of seawater analysis. Fisheries Research Board of Canada, Ottawa, 311 pp.
- The Open University (1977) Oceanography – an introduction to the oceans. Pergamon Press, Oxford. 188 p.
- The Open University (1991) Ocean Chemistry and Deep Sea sediments. Pergamon Press, Oxford, 134 p.
- Weatherly, A.H. (1972). Growth and Ecology of Fish Populations. Academic Press. London, New York.
- Wheaton, F.W. (1987). Aquaculture Engineering. Robert E.Krieger Publ. Floride.
- Wheaton, F.W. and Lawson, T.B. (1985). Processing of Aquatic Food Products. Wiley Inter, Science, New York.
- White, A.; Handler, P. and Smith, E.L. (1976). Principles of Biochemistry. McGraw Hill Co. New York.
- Yuan, S. W. Foundation of Fluid Mechanics.
- Zaitsev, V.P. (1962). Reservation of Fish Products by Refrigeration. U.S. Department of Commerce.
- Zar, J. H. (1999). Biostatistical Analsys. Prentice & Hall Inc. Englewood Cliffs, New Jersey.
- Zenkovich, V. P. (1967). Processes of Coastal Development. Oliver and Boyd, Edinburgh.