MARINE SCIENCE PROGRAM

Aims and Scope of the Graduate Program

The Marine Science (MarS) Program takes advantage of KAUST's location on the Red Sea, a living laboratory with great potential for exciting science. The program offers two primary academic tracks, one focused on the study of the biology and ecology of the multitude of marine life forms, and a second track focused on the interactions of the physical marine environment with atmospheric and climatic conditions. There is an intentional focus on the local Red Sea system, both as a primary study system and as a system with which general concepts from other marine systems can be compared.

The goal of the Marine Science Program is to develop an integrated understanding of the Red Sea's ecosystem, including fundamental biology at the molecular and genomic levels, symbiosis with algae and prokaryotes (Bacteria and Archaea), associated communities of fish and corals, and the physical and chemical environment that impacts and shapes them. This understanding could have an impact on global carbon cycling, endangered species, and how we manage the harvesting of resources from the oceans.

Master's Degree

The M.S. program in MarS provides a strong introduction to Marine Science with courses on the fundamentals of marine science and oceanography. The program comprises two tracks: (1) Marine Biology and Conservation and (2) Ocean Physics and Modeling. Degree coursework includes lectures, seminars, laboratory classes and fieldwork. Both tracks require a Master's thesis.

Students in the M.S. program in MarS are required to complete at least 36 credits. Entering MarS students are required to take two MarS core courses (listed below) during their first semester.

The remaining course requirements are technical electives, directed research, and thesis credits. At least 12 units of formal coursework, exclusive of directed research or thesis credits, are required. At least 12 credits of thesis (MarS 297) must be earned.

A multi-disciplinary Marine Science Seminar Series runs continuously; it features seminars offered by MarS faculty, staff, students, and visitors. Credit is not awarded, but two semesters of satisfactory participation (and registration in MarS 298) are required to complete the MarS degree.

Marine Biology and Conservation Track
Core Courses

Students in the Marine Biology and Conservation Track are required to follow the curriculum outlined below. If a student can provide evidence of graduate-level training in the same subject at a previous institution, he/she is invited to apply for and may be awarded academic credit for a course. The core courses are:

1. Core Curriculum: (9 credits) Three core courses from the core curriculum listed below;

- MarS 221 Marine Life
- MarS 228 Structure and Function of Marine Ecosystems
- MarS 235 Introduction to Physical Oceanography

2. Elective Curriculum: (15 credits) One to five courses (3-15 credits) as agreed to with the student's advisor. Typically, this will be three MarS courses (9 credits) and 6 credits comprised of Directed Research (MarS 299) and/or Thesis (MarS 297) credits.

3. Research/Capstone Experience: (12 credits) A minimum of 6 credits of thesis research (MarS 297) is required although it is expected that a student will enroll in 12 credits of M.S. thesis work. With permission of the M.S. thesis advisor, a student who enrolls in only 6 credits of thesis research may use one of the following options to earn the 6 remaining credits of degree requirements:

    - **Internship:** 6 credits of research-based summer internship (administered as directed research, MarS 299)
    - **Non-Technical Broadening Experience Courses:** 3 to 6 credits of courses that broaden a student's M.S. experience.
    - **Ph.D.-Level Courses:** 6 credits of MarS courses numbered 300 or greater. Any course in the Ph.D. core requirements that is passed with a minimum grade of B– may be used towards meeting the core Ph.D. requirements of the Marine Science program if the student chooses to continue for a Ph.D. degree in Marine Science at KAUST.

Students are permitted to register for more than 12 credits of M.S. thesis research as necessary and with the permission of the thesis advisor.

Evaluation of satisfactory completion of M.S. thesis work is performed by a committee comprising the M.S. thesis advisor and two other faculty members. The chair of the committee must be a faculty member within the Marine Science program. The evaluation of M.S. thesis credits is through a pass or a fail grade. The requirement of a public seminar based on the student's work is left to the discretion of the M.S. thesis advisor. For additional details on thesis requirements and committee formation, see General Degree Program Guidelines.

The student is responsible for scheduling the thesis defense date with his/her supervisor and committee members. It is advisable that the student submits a written copy of the thesis to the thesis committee members at least two weeks prior the defense date.

Suggested elective course options for students in this track include:

- MarS 212 Geophysical Fluid Dynamics I
- MarS 217 Marine Genomics
- MarS 218 Marine Microbiology
- MarS 226 Coral Reef Ecology
- MarS 229 Marine Microbial Ecology
- MarS 230 Ecological Genomics
- MarS 243 Ecology and Management of Marine Fisheries
- MarS 245 Special Topics in Marine Science
- AMCS 210 Introduction to Statistics and Biostatistics

- B 201 Biophysics
- B 202 Plant Biology
- B 205 Protein Structure and Function
- B 208 Biochemistry
- B 209 Molecular Genetics
- B 224 Fundamental of Cell Biology
- EnSE 202 Environmental Chemistry
- EnSE 203 Environmental Microbiology

Ocean Physics and Modeling Track
Core Courses

Students in the Ocean Physics and Modeling Track are required to follow the curriculum outlined below. If a student can provide evidence of graduate-level training in the same subject at a previous institution, he/she is invited to apply for and may be awarded academic credit for a course.

1. Core Curriculum: (12 credits) MarS 221 Geophysical Fluid Dynamics I, MarS 221 Marine Life plus two courses from the curriculum listed below;

    - ErSE 301 Geophysical Fluid Dynamics II
    - MarS 235 Introduction to Physical Oceanography
    - ErSE 253 Data analysis in Geosciences
    - ErSE 306 Ocean Physics and Modeling
    - ErSE 203 Geophysical Continuum Mechanics

2. Elective Curriculum: (12 credits) Four additional courses as agreed to with the student's advisor. At least two of these courses must come from:

    - MarS 228 Structure and Function of Marine Ecosystems
    - ErSE 213 Inverse Problems
    - ErSE 307 Atmospheric Chemistry and Transport
    - ErSE 324 Parallel Scientific Computing in Earth Science
    - EnSE 213 Environmental Organic Chemistry
    - EnSE 201 Air & Water Quality
    - ErSE 353 Data Assimilation

3. **Research/Capstone Experience**: (12 credits) A minimum of 6 credits of thesis research (MarS 297) is required although it is expected that a student will enroll in 12 credits of M.S. thesis work. With permission of the M.S. thesis advisor, a student who enrolls in only 6 credits of thesis research may use one of the following options to earn the 6 remaining credits of degree requirements:

    - **Internship:** 6 credits of research-based summer internship (administered as directed research, MarS 299)
    - **Non-Technical Broadening Experience Courses:** 3 to 6 credits of courses that broaden a student's M.S. experience.
    - **Ph.D.-Level Courses:** 6 credits of MarS courses numbered 300 or greater. Any course in the Ph.D. core requirements that is passed with a minimum grade of B– may be used towards meeting the core Ph.D. requirements of

the Marine Science program if the student chooses to continue for a Ph.D. degree in Marine Science at KAUST.

Students are permitted to register for more than 12 credits of M.S. thesis research as necessary and with the permission of the thesis advisor.

Evaluation of satisfactory completion of MS thesis work is performed by a committee comprising the M.S. thesis advisor and two other faculty members. The chair of the committee must be a faculty member within the Marine Science program. The evaluation of M.S. thesis credits is through a pass or a fail grade. The requirement of a public seminar based on the student's work is left to the discretion of the MS thesis advisor. For additional details on thesis requirements and committee formation, see General Degree Program Guidelines.

The student is responsible for scheduling the thesis defense date with his/her supervisor and committee members. It is advisable that the student submits a written copy of the thesis to the thesis committee members at least two weeks prior the defense date.

Degree of Doctor of Philosophy

In accordance with KAUST regulations, the Ph.D. program in MarS includes the following requirements:

1. Successful completion of Ph.D. coursework;
2. Designating a research advisor;
3. Submitting and presenting a dissertation proposal; and
4. Preparing and submitting a doctoral dissertation and successfully defending it.

Coursework Requirements

Students seeking to earn a Ph.D. in MarS must satisfy the coursework requirements for the program. In addition to the M.S. in MarS coursework requirements, the Ph.D. program requires a minimum of 6 credit hours of coursework at the 300-level or above (excluding MarS 397 and MarS 399), and 60 hours of dissertation research. If a student is admitted to the Ph.D. program in MarS after obtaining a Master's degree from a university other than KAUST, some or all of the M.S. coursework requirements may be waived, based on University guidelines, with the approval of the student's advisor and the dean.

In addition all Ph.D. students must participate in the Marine Science Seminar Series. The seminar series does not bear academic credit but students are expected to attend and participate.

Designation of a Research Advisor

If a student is admitted to the Ph.D. program without a research advisor, an interim advisor will be assigned. The student must identify a permanent research advisor within six months of enrollment in the program.

Dissertation Proposal

Within six months of enrollment, the student is required to submit a formal research proposal. This proposal must be 5000-7000 words in length and include the following sections: (1) Literature Review; (2) Background; (3) Methods; (4) Objectives; (5) Expected Outcomes; and (6) Timeline.

The research proposal must be presented in a public seminar and will be assessed by the dissertation committee. This requirement must be completed within six months of enrollment.

Dissertation Committee

A dissertation committee is formed by the student under the guidance of the advisor. Chaired by the advisor, the committee must include three other members. The committee members must agree to interact with the student to discuss the student's progress. The student must submit an annual written progress report to the dissertation committee. All committee members must be designated as dissertation readers.

Dissertation

The student must prepare and submit a doctoral dissertation on original research conducted by the student. To proceed to the dissertation defense, three of the four committee members must approve the submitted thesis.

Dissertation Defense

The student must schedule a dissertation defense after the dissertation has been submitted. The dissertation defense will include a defense of the doctoral dissertation and a test of the candidate's knowledge in the specialized field of research. The format of the dissertation defense will be a public seminar presented by the candidate, with an open question and answer period, followed by a private examination by the dissertation committee. The possible outcomes of the exam are pass, conditional pass, or fail.

MARINE SCIENCE (MarS) COURSE DESCRIPTIONS

MarS 201 Survey of Marine Science: An introductory course in marine science history and topics, covering many broad aspects of oceanography. These aspects include biology, chemistry, geology, and physics, among others, and this course will explore how these various fields of study are similar and/or different from their non-marine counterparts. The course assumes no prior experience in marine science. There is an emphasis on modern techniques, seminal papers, and a special focus on the Red Sea. The course will also highlight work conducted in KAUST's Red Sea Research Center. An optional field trip may be organized.
Prerequisite: None.

MarS 212 Geophysical Fluid Dynamics I (Cross-listed as ErSE 201): Introductory description of the Earth's climate system, governing equations of mass and momentum conservation, equation of state, thermodynamic equation, wave kinematics, dispersion, group velocity, sound waves, gravity waves, effect of rotation, equations of motion in spherical coordinates, primitive equations, Boussinesq approximation, changing vertical coordinate, asymptotic analysis and scaling, geostrophic balance, thermal wind, static instability, boundary layers in atmosphere and ocean.
Prerequisite: ME 200a and ErSE 203 or consent of instructor.

MarS 217 Marine Genomics and Bioinformatics: Genome science is the study of the structure, content, and evolution of genomes. This course deals with organization of genomes, genome sequencing, genomic variation, gene expression and functional genomics with a particular emphasis on marine organisms and how to apply this field to study marine science.
Prerequisite: Undergraduate course in molecular biology, genetics, evolution, or bioinformatics. Students from programs other than MarS must have instructor permission to register for this course

MarS 221 Marine Life: An overview of marine biology that surveys the diversity of marine habitats, major groups of taxa inhabiting those habitats and the general biology of the various taxa. Topics include the production and consumption of organic material in the ocean, as well as factors controlling those processes. Species diversity, structure of marine food webs and the flow of energy within different marine habitats will be detailed and contrasted.
Prerequisite: Undergraduate course in ecology, zoology, or marine science. Students from programs other than MarS must have instructor permission to register for this course.

MarS 226 Coral Reef Ecology: This course will cover coral reef distributions, biogeography, and ecological processes important to reefs. Basic coral anatomy and physiology will be discussed. Reef fishes and their interaction with coral communities will be highlighted, along with coral reef fisheries. Modern threats to coral reefs, including thermal bleaching, ocean acidification, and diseases of corals will be examined with particular emphasis on processes affecting the future status of reef communities.
Marine Life (MarS 221) is a prerequisite for this course.

MarS 228 Structure and Function of Marine Ecosystems - This course gives an overview of marine ecology. It addresses the global production and distribution of plankton and fish, the vertical distribution of both pelagic and benthic organisms as well as predator-prey interactions among organisms in different habitats. It describes ecosystems from the intertidal zone to the deep sea and outlines ecological principles governing the distributions of organisms and their adaptations to be successful in the different environments.
Marine Life (MarS 221) is a prerequisite for this course.

MarS 229 Marine Microbial Ecology: This course covers recent developments in the field of marine microbial ecology and will give an overview on structure and function of microbial communities in the oceans including discussions on novel methods, results and hypotheses. Among the topics covered are: Photoheterotrophic bacteria, marine bacteria and the carbon cycle, UV radiation effects on microbes and microbial processes, uptake and regeneration of inorganic nutrients by marine heterotrophic bacteria, bacterivory: interactions between bacteria and their grazers, symbiosis and mixotrophy among pelagic microorganisms, marine viruses and their ecological impact, the Global Ocean Survey of Marine Metagenomics, single cell activity in marine bacterioplankton.
Environmental Microbiology (EnSE 203) is a prerequisite for this course.

MarS 230 Ecological Genomics: Ecological genomics describes the application of genomic tools (high throughput sequencing, microarrays, quantitative PCR, etc.) to solve questions of ecology. Its purpose is to increase understanding of the responses and interactions of organisms to the environment and to one another by analyzing genomic sequences, gene expressions and genome evolution. This course will give an overview over the methods utilized and the questions asked by ecological genomics with a particular emphasis on marine ecological genomics.

MarS 235 Introduction to Physical Oceanography: This course provides an introduction to oceanography and includes the following topics: Ocean basins, major currents and water property distributions; properties of seawater: equation of state, temperature and salinity analysis; basic dynamical ideas: hydrostatic balance, Coriolis force, geostrophy, turbulence; forcing of the ocean: solar radiation, winds, heat and freshwater fluxes; Ekman transport; the observed ocean: major currents, gyres, meridional overturning, eddies, sill flows, upwelling, monsoons, equatorial

motions, El Niño, marginal seas; time dependence: inertial oscillations, long gravity waves, Rossby waves; tides: astronomical forcing, basin modes, local resonances, tidal mixing.

MarS 243 Ecology and Management of Marine Fisheries: Reviews basic ecological principles applied to fisheries management with the aim of promoting sustainable fisheries and marine conservation. Topics include fish life history and population dynamics and the community and ecosystem-level responses to fishing and natural variability, with special emphasis on coral reef fisheries.

MarS 245 Special Topics in Marine Science: Reviews current topics in marine science, particularly relying on scientific journal publications to provide case studies, illustrative examples, classic studies, and controversial findings pertinent to specific fields within marine science. The course will feature an emphasis on primary literature searches, reading and assessment of primary literature, and presentation skills.

MarS 297 Thesis (increments of 3 units): Masters-level research leading to a formal written dissertation and oral defense thereof.

MarS 298 Marine Science Seminar Series: Seminar series focusing on special topics within the field, highlighting work and studies presented by faculty, staff, visiting scientists, or students.

MarS 299 Directed Research: Masters-level supervised research.

MarS 317 Advanced Marine Genomics and Bioinformatics: Genome science is the study of the structure, content, and evolution of genomes. This course deals with organization of genomes, genome sequencing, genomic variation, gene expression and functional genomics with a particular emphasis on marine organisms and how to apply this field to study marine science. As a PhD level course, assessment of students and participation expectations will be commensurate with the level of student experience.
Prerequisites: Undergraduate course in molecular biology, genetics, evolution, or bioinformatics.

MarS 323 Advanced Topics in Pelagic Ecology: The course will address one or a few central topics in pelagic ecology in-depth. It will primarily be based on seminars in which the students will present and discuss scientific papers. The aims are to acquire knowledge of the state-of-the-art of current research questions, as well as to train communication skills and the ability to critically read research papers. Assessment includes a final oral exam.
Prerequisite: Undergraduate course in marine science. Students from programs other than MarS must have instructor permission to register for this course.

MarS 326 Advanced Coral Reef Ecology: This course will cover coral reef distributions, biogeography, and ecological processes important to reefs. Basic coral anatomy and physiology will be discussed. Reef fishes and their interaction with coral communities will be highlighted, along with coral reef fisheries. Modern threats to coral reefs, including thermal bleaching, ocean acidification, and diseases of corals will be examined with particular emphasis on processes affecting the future status of reef communities. As a PhD level course, assessment of students and participation expectations will be commensurate with the level of student experience.
Marine Life (MarS 221) is a prerequisite for this course, or consent of instructor.

MarS 329 Advanced Marine Microbial Ecology: This course covers recent developments in the field of marine microbial ecology and will give an overview on structure and function of microbial communities in the oceans including discussions on novel methods, results and hypotheses. Among the topics covered are: Photoheterotrophic bacteria, Marine Bacteria and the Carbon Cycle, UV radiation effects on Microbes and Microbial Processes, Uptake and Regeneration of Inorganic Nutrients by Marine Heterotrophic Bacteria, Bacterivory: Interactions between Bacteria and their Grazers, Symbiosis and Mixotrophy Among Pelagic Microorganisms, Marine Viruses and their ecological impact, Global Ocean Survey of Marine Metagenomics, Single

cell activity in marine bacterioplankton. As a PhD level course, assessment of students and participation expectations will be commensurate with the level of student experience.
Environmental Microbiology (EnSE 203) is a prerequisite for this course, or consent of instructor.

MarS 330 Advanced Ecological Genomics: Ecological genomics describes the application of genomic tools (high throughput sequencing, microarrays, quantitative PCR etc.) to solve questions of ecology. Its purpose is to increase understanding of the responses and interactions of organisms to the environment and to one another by analyzing genomic sequences, gene expressions and genome evolution. This course will give an overview over the methods utilized and the questions asked by ecological genomics with a particular emphasis on marine ecological genomics. As a PhD level course, assessment of students and participation expectations will be commensurate with the level of student experience.

MarS 331 Symbiotic Microbial Associations in Marine Systems*:* Many marine eukaryotes developed symbiotic associations with microbes to gain a fitness advantage over their competitors. This class reviews principles of symbiosis in marine and terrestrial systems and discusses in detail associations of microbes with sponges, squids, plankton, fish, tubeworms, mussels and clams, leaf slugs, algae, corals, and zooplankton.
Environmental Microbiology (EnSE 203) is a prerequisite for this course, or consent of instructor.

MarS 343 Advanced Ecology and Management of Marine Fisheries: Reviews basic ecological principles applied to fisheries management with the aim of promoting sustainable fisheries and marine conservation. Topics include fish life history and population dynamics and the community and ecosystem-level responses to fishing and natural variability, with special emphasis on coral reef fisheries. As a PhD level course, assessment of students and participation expectations will be commensurate with the level of student experience.

MarS 345 Advanced Special Topics in Marine Science: Reviews current topics in marine science, particularly relying on scientific journal publications to provide case studies, illustrative examples, classic studies, and controversial findings pertinent to specific fields within marine science. The course will feature an emphasis on primary literature searches, reading and assessment of primary literature, and presentation skills. As a PhD level course, assessment of students and participation expectations will be commensurate with the level of student experience.

MarS 389 PhD Transfer Course: Credit may be awarded at the discretion of the academic advisor and thesis supervisor in cases where a student has taken a suitable PhD-level course at another institution. The subject of the course should be highly relevant to the student's proposed area of research. A student planning to take such a course while enrolled as a KAUST PhD student must obtain prior approval of the supervisor and academic advisor.

MarS 397 Dissertation
PhD Dissertation (increments of 3 units): PhD-level research leading to a formal written dissertation and oral defense thereof.

MarS 398 Marine Science Seminar Series: Seminar series focusing on special topics within the field, highlighting work and studies presented by faculty, staff, visiting scientists, or students. As a PhD level course, assessment of students and participation expectations will be commensurate with the level of student experience.

MarS 399 Directed Research
Doctoral-level supervised research.