BIOLOGICAL SCIENCES (BIOL)

Degrees Offered: Ph.D., M.S.

This program is offered in Durham.

The Biological Sciences Graduate Program offers M.S. and Ph.D. degrees in Biological Sciences, with options in Integrative and Organismal Biology and Marine Biology.

Integrative and Organismal Biology (IOB)

This option offers a home to students interested in basic organismal biology in all of its diverse aspects (physiology, neurobiology, behavior, cell biology, genetics, evolution, ecology, systematics, etc.), in both terrestrial and aquatic environments. Modern biology employs approaches and tools ranging from molecular to ecological levels to gain a deep understanding of organismal functions and adaptations. Students in IOB approach their studies with a focus on organisms, and apply whatever tools are necessary to answer thematic and specific questions. Students interested in combining hands-on biological projects with research on teaching and learning biology at the post-secondary level should choose this option.

Marine Biology (MB)

This option is intended for students interested in marine, coastal, and estuarine ecosystems, and the organisms that inhabit them, at all levels of inquiry. Some faculty at UNH study/use marine organisms as model systems for molecular phylogeny, cellular metabolism, and neurobiology; others focus on the structure and function of marine ecosystems. Faculty interests range from basic research to applied areas such as aquaculture and fisheries. Many combine the two.

Related programs

Students interested in fields such as agriculture and animal science should review programs available through the Department of Agriculture, Nutrition, and Food Systems (https://colsa.unh.edu/agriculture-nutrition-food-systems); those interested in molecular biology and genomics should review programs in the Department of Molecular, Cellular and Biomedical Sciences, including Genetics and Molecular & Evolutionary Systems Biology (https://colsa.unh.edu/mcbs); those interested in ecosystems, wildlife, and forestry should review programs in the Department of Natural Resources and the Environment (https://colsa.unh.edu/natural-resources-environment), including Natural Resources and Earth Systems Science (NRESS) (https://www.unh.edu/nressphd).

Admission Requirements

Applicants ordinarily will have completed an undergraduate major in biology or a related field. A basic array of courses including general biology, development, ecology, genetics, morphology, and physiology is recommended. Applicants should have completed organic chemistry and a semester each of calculus and physics. Applicants whose preparation does not meet these criteria can be admitted to the program, but may need to remedy any deficiencies via courses that do not give graduate credit. Applicants must submit scores from the general test of the Graduate Record Examination (GRE), taken within the past five years. The GRE subject test is not required.

All applicants are strongly encouraged to communicate with potential advisors (https://colsa.unh.edu/biological-sciences/people) as part of the application process. Identifying an advisor is normally a prerequisite for admission.

Research and Facilities

The Biological Sciences graduate program is enhanced by research in other departments and institutes across the University.

These include the School for Marine Sciences and Ocean Engineering (https://marine.unh.edu) and its associated programs and facilities:

- N.H. Sea Grant Program (http://seagrant.unh.edu);
- the Center for Collaborative Science (https://marine.unh.edu/center-for-collaborative-science);
- the Institute for the Study of Earth, Oceans, and Space (http://www.eos.unh.edu) (EOS);
- the UNH Center for Coastal and Ocean Mapping (http://ccom.unh.edu) (CCOM);
- the Joint Hydrographic Center (https://marine.unh.edu/program/center-coastal-and-ocean-mapping/joint-hydrographic-center); and
- the Ocean Processes Analysis Laboratory (http://www.opal.sr.unh.edu) (OPAL).

There are five aquatic laboratories:

- Jackson Estuarine Lab (https://marine.unh.edu/facility/jackson-estuarine-laboratory),
- Judd Gregg Marine Research Complex (https://marine.unh.edu/facility/judd-gregg-marine-research-complex),
- Anadromous Fish and Aquatic Invertebrate Research Lab (https://marine.unh.edu/facility/anadromous-fish-and-aquatic-invertebrate-research-laboratory-affar-lab) (FAAIR),
- the Aquaculture Research Center (http://colsa.unh.edu/dbs/zooology/facilities) (ARC), and
- the Shoals Marine Laboratory (http://marine.unh.edu/SML) (SML).

The Center for Freshwater Biology (http://cfb.unh.edu) (CFB) jointly administers (with the UNH Cooperative Extension) the Lakes Lay Monitoring Program (https://extension.unh.edu/programs/lakes-lay-monitoring-program), which is dedicated to the preservation and sound management of lakes through citizen-based monitoring and research.

The University of New Hampshire Collection of insects and other arthropods (http://unhcollection.unh.edu) is the largest arthropod depository and research collection in Northern New England (700,000 specimens and growing). Over 12,000 species are represented from different regions of New England, featuring many specimens collected from the White Mountains.

In addition, research in plant biology and agriculture is carried out in the Macfarlane Research Greenhouses (https://colsa.unh.edu/nhaes/macfarlane-research-greenhouses), the Hodgdon Herbarium (http://www.unh.edu/herbarium), and UNH's agricultural facilities (https://www.colsa.unh.edu/nhaes/facilities).

The Hubbard Center for Genomic Studies (http://hcgs.unh.edu) provides training and research in comparative and environmental genomics, with a special emphasis on novel model species. It provides expertise in constructing DNA libraries, DNA sequencing, fragment analysis, and the analysis of gene expression.

https://colsa.unh.edu/biological-sciences
Programs

- Biological Sciences: Integrative and Organismal Biology (Ph.D.)
  (http://catalog.unh.edu/graduate/programs-study/biological-sciences/biological-sciences-integrative-organismal-biology-phd)
- Biological Sciences: Marine Biology (Ph.D.)
  (http://catalog.unh.edu/graduate/programs-study/biological-sciences/biological-sciences-marine-biology-phd)
- Biological Sciences: Integrative and Organismal Biology (M.S.)
  (http://catalog.unh.edu/graduate/programs-study/biological-sciences/biological-sciences-integrative-organismal-biology-ms)
- Biological Sciences: Marine Biology (M.S.)
  (http://catalog.unh.edu/graduate/programs-study/biological-sciences/biological-sciences-marine-biology-ms)

Courses

Animal Sciences (ANSC)

ANSC 801 - Physiology of Reproduction
Credits: 4
Comparative aspects of embryology, anatomy, endocrinology, and physiology of reproduction. Lab.

ANSC 808 - Ruminant Nutritional Physiology
Credits: 3
Anatomy of the ruminant gastrointestinal tract, physiological factors related to rumen function, and microbial and whole-body metabolism of carbohydrates, protein, and lipids. Prereq: general microbiology or equivalent.

ANSC 810 - Dairy Nutrition
Credits: 4
Feeding and related management of dairy cows, nutrients and their use, digestive anatomy, physiology, energy systems, forage quality and conservation methods, metabolic disorders, ration balancing. Prereq: principles of nutrition; nutritional biochemistry or equivalent, permission.

ANSC 815 - Physiology of Lactation
Credits: 4
Examines the biological and biochemical influences of the lactation process. Emphasis on the physiological effects of environments, hormones, and nutrition on milk synthesis and secretion, mammary physiology, and maternal response. Prereq: physiology of reproduction, permission.

ANSC 818 - Mammalian Physiology
Credits: 4
Advanced study of the systems that control mammalian functions with emphasis on cellular and molecular mechanisms. Includes the nervous, muscular, cardiovascular, renal, gastrointestinal, and endocrine systems. Prereq: BMS 501 or BMS 503-504; GEN 604. Permission required.

ANSC 824 - Reproductive Management and Artificial Insemination
Credits: 4
Focus on goals and fundamentals of reproductive management of horses, dairy and livestock animals, and, through experience, development of competency in performing modern breeding techniques for equine or bovine reproduction. Permission required. Special fee. Lab.

ANSC 827 - Advanced Dairy Management I
Credits: 4
Advanced management evaluation of milking procedures, reproduction, nutrition, mastitis, and calf and heifer management. Prereq: principles of nutrition, permission.

ANSC 828 - Advanced Dairy Management II
Credits: 4
Advanced management evaluation of dairy cattle, housing, milking equipment, milk quality, record keeping, herd health, financial, personnel management, environmental issues. Visits to farms in the area to provide critical assessments of dairy farm businesses. Prereq: advanced dairy management I, permission. Special fee.

ANSC 853 - Cell Culture
Credits: 5
Principles and technical skills fundamental to the culture of animal and plant cells, tissues and organs. Introduction to the techniques of subculturing, establishing primary cultures, karyotyping, serum testing, cloning, growth curves, cryopreservation, hybridoma formation and monoclonal antibody production, and organ cultures. Application of cell culture to contemporary research in the biological sciences. Prereq: general microbiology and lab. Special fee. Lab.

ANSC 895 - Investigations
Credits: 1-4
Investigations in genetics, nutrition, management, diseases, histology, equestrian management/agribusiness, physiology, cell biology, microbiology, dairy management, or teaching experience. May be repeated up to a maximum of 4 credits. Prereq: permission.

ANSC 899 - Master’s Thesis
Credits: 1-6
Master’s students must enroll for a total of 6 credits of this course. Students may enroll in 1-6 credits per semester. Cr/F.

ANSC 900 - Contemporary Topics in Animal, Nutritional, and Biomedical Sciences
Credits: 1
An informal forum for graduate students to gain experience in evaluating the current literature of a contemporary topic. (Also offered as NUTR 900.) May be repeated for a maximum of 2 credits. Offered both fall and spring semesters. Cr/F.

ANSC #913 - Contemporary Topics in Immunobiology
Credits: 2
Topical lectures, seminars, and assigned reading emphasizing recent advances in immunology. May be repeated for a maximum of 4 credits. (Offered in alternate years.)

ANSC 995 - Non-thesis Investigations in Animal Science
Credits: 1-4
Advanced investigations in a research project, exclusive of thesis project. Elective only after consultation with the instructor. May be repeated for a maximum of 4 credits. Offered both fall and spring semesters.

ANSC 999 - Doctoral Research
Credits: 0
Cr/F.
Biology (BIOL)

BIOL 801 - Plant Physiology
Credits: 5
Structure-function relationship of plants, internal and external factors regulating plant growth and development, plant hormones, plant metabolism, water relations, and mineral nutrition. Prereq: introductory botany or concepts of plant growth; one year of college chemistry (e.g., general chemistry); organic chemistry or biochemistry; or permission.

BIOL 802 - Techniques in Plant Physiology and Biochemistry
Credits: 4
The course provides hands-on experience with instrumentation and experimental procedures for analysis of plant growth and metabolism. Experiments demonstrate the regulation of plant growth and development in response to environmental and chemical factors, analysis of cellular contents and processes, and use of modern instrumentation for physiological and biochemical studies. The experiments deal with plant water relations, photosynthesis, plant hormones, enzyme kinetics, using spectrophotometry, aseptic procedures, and liquid and thin-layer chromatography. Prereq: BIOL 411 and BIOL 412, or permission of instructor. Special fee.

BIOL 804 - Plant-Microbe Interactions
Credits: 3
This course provides an overview of the molecular, cellular and biochemical factors underlying the interactions of plants with various microbes, including bacterial fungal, oomycete and viral pathogens, and mutualistic symbionts, such as mycorrhizal fungi and rhizobium. Unifying themes underlying disease, resistance, and symbiosis are emphasized. Prereq: BIOL 411 and BIOL 412, BMS 503 and BMS 504 or GEN 604.

BIOL 805 - Molecular and Cellular Neurobiology
Credits: 4
The overarching goal of this course is to examine the molecular and cellular mechanisms underlying neuronal function. This course builds on fundamental knowledge in neuroscience. Students will be exposed to primary literature regarding the most advanced techniques in neuroscience, with emphasis in cellular and molecular processes. Students will learn how different model organisms have been used to understand neurons. Graduate students should have a strong background in chemistry, biochemistry and cell biology, and must obtain permission to register.

BIOL 809 - Plant Stress Physiology
Credits: 3
Examines the physiological and biochemical mechanisms of plant response to abiotic stresses including drought, salt, high and low temperature, visible and ultraviolet radiation, heavy metals, and air pollutants. Discusses current hypotheses, agricultural and ecological implications. Prereq: plant physiology; biochemistry; or permission.

BIOL 811 - Applied Biostatistics II
Credits: 4
Design and analysis of biological and ecological research experiments. "Real world" studies used to discuss the identification of hypotheses, appropriate experimental design, and the application of statistical analyses including ANOVA, ANCOVA, correlation and regression, cluster analysis, classification and ordination techniques. Theoretical statistical concepts tailored to consider student's own thesis and dissertation research, allowing statistical problems to be addressed at various stages of the research process. Common computer packages used for analyses. Prereq: BIOL 528; permission.

BIOL 813 - Biochemistry of Photosynthesis
Credits: 4
The physiology and biochemistry of photosynthesis in higher plants and microorganisms: light reactions, electron transport, membrane structure and function, carbon assimilation pathways, energy conservation, and metabolic regulation. Agronomic and ecological aspects of photosynthesis are examined. Prereq: plant physiology or biochemistry. (Not offered every year.)

BIOL 820 - Plant-Animal Interactions
Credits: 4
This course will explore interactions between plants and animals and their evolutionary consequences on individual organisms as well as on ecological communities. Readings from the primary literature will serve as case studies to discuss hypotheses related to plant-animal interactions, the methods employed to test these hypotheses, and the conclusions drawn from these experiments. A weekly discussion session will be used as a grant-writing workshop, with activities designed to help students prepare an NSF-style grant as the culminating course project. Prereq: BIOL 411 and BIOL 412.

BIOL 827 - Animal Communication
Credits: 4
This course examines the principles underlying how animals communicate with each other and why they communicate the way they do by using perspectives drawn from a broad range of disciplines including physics, chemistry, ecology, psychology, economics, and behavioral ecology. Students will explore the primary literature, and work in teams to conduct independent research. The course is intended for advanced undergraduate or graduate students interested in neuroscience and behavior, evolution, wildlife and conservation biology, or zoology. Prereq: BIOL 412.

BIOL 829 - Agricultural Waste Management
Credits: 4
The management of agricultural wastes is crucial in the development of sustainable agricultural practices. This course covers principles of managing, handling, treating, and applying animal manures and organic byproducts from an agricultural system perspective. Topics include waste characterization, descriptions of systems and technology, utilization of wastes as resources (land application, composting electricity generation, fertilization, etc.), land application principles, preparations of waste management plans, and potential impacts to the environment. Prereq: SAFS 502 or permission of instructor.

BIOL 852 - Mycology
Credits: 4
Classification, identification, culturing, life histories, and ecology of fungi, from slime molds to hallucinogenic mushrooms; the significance of fungi in human history, from their contribution to the art of bread making and alcoholic fermentation to their destructiveness as agents of deadly diseases of plants and animals. Prereq: principles of biology I, II or introduction to botany, or equivalent. Special fee. Lab.

BIOL 858 - Plant Anatomy
Credits: 5
Anatomy of vascular plants from a functional/developmental point of view with emphasis on Angiosperms. Basic cell and tissue structure of plant organs will be covered as well as the importance of chaos, fractals, scaling, mechanical stress and environmental factors in determining the role anatomy plays in the biology of plants. Prereq: principles of biology or introductory botany. Lab. Special fee. (Not offered every year.)
**Earth, Oceans and Space (EOS)**

**EOS 810 - Introduction to Astrophysics**  
*Credits: 4*  
Review of the sun, stars, Milky Way, external galaxies, and expansion of the universe. Recent discoveries of radio galaxies, quasi-stellar objects, cosmic black-body radiation, x rays, and gamma rays precede a discussion of Newtonian and general relativistic cosmological models, steady-state big-bang theories, and matter-antimatter models. (Also offered as PHYS 810.) (Alternate years only.) Cr/F.

**EOS #844 - Biogeochemistry**  
*Credits: 4*  
Examines the influence of biological and physical processes on elemental cycling and geochemical transformations from the molecular to the global scale, involving microorganisms, higher plants and animals and whole ecosystems; factors that regulate element cycles including soils, climate, disturbance and human activities; interactions among the biosphere, hydrosphere, lithosphere, and atmosphere; transformations of C, N, S, and trace elements. Prereq: one semester each of biology and chemistry. (Also offered as NR 844.)

**EOS 895 - Topics**  
*Credits: 1-4*  
Study on an individual or group basis of topics not covered by the other listed courses. Topics may include any area relevant to interest in Earth, ocean, atmospheric, and space studies. (May be repeated.) Lab.

**EOS 896 - Topics**  
*Credits: 1-4*  
Study on an individual or group basis of topics not covered by the other listed courses. Topics may include any area relevant to interest in Earth, ocean, atmospheric, and space studies. (May be repeated.) Lab.

**EOS 901 - Seminar**  
*Credits: 1*  
Introduction to the fundamental components of the Earth system, such as the biosphere, cryosphere, hydrosphere, and its environment in space. Basic concepts are presented in a lecture format by selected EOS faculty according to their research specialization. To familiarize the student with the literature in earth, oceans, and space science and engineering, students are expected to contribute to a discussion of current topics of interest in the literature. Cr/F.

**EOS #954 - Heliospheric Physics**  
*Credits: 3*  
The solar wind and its effects on cosmic rays. The basic equations of the solar wind: mass, momentum, angular momentum, and energy balance. Transport processes. Waves, shocks, and instabilities in the solar wind. The basic equations of energetic particle transport. Solar modulation of solar and galactic cosmic rays. Interaction of energetic particles with shock waves. Salient data are reviewed. (Normally offered every other year.) Also offered as PHYS 954.

**EOS 995 - Special Topics**  
*Credits: 1-4*  
**EOS 996 - Special Topics**  
*Credits: 3-4*  
See description for EOS 995.
Marine, Estuarine and Freshwater Biology (MEFB)

MEFB 817 - Lake Ecology
Credits: 4
Introduction to the ecology of freshwater systems with emphasis on lakes. Origins of lakes and the effects of watersheds on lake chemistry and nutrient cycling are explored. Other topics include the impact of human disturbances on productivity and aquatic food webs and methods used for the management and restoration of lakes. Comparisons are made of the structure and functions of lake ecosystems found in temperate, tropical and arctic regions. Prereq: general biology.

MEFB 819 - Field Studies in Lake Ecology
Credits: 4
Ecology of lakes and other freshwater habitats examined through field studies. Emphasizes modern methods for studying lakes, analysis and interpretation of data, and writing of scientific papers. Seminars on research papers and student presentations of class studies. Field trips to a variety of lakes, from the coastal plain to White Mountains; investigate problems, such as eutrophication, acidification, biodiversity and biotoxins. Capstone experiences include interaction with state agencies, lake stakeholders and the submission of written manuscripts for publication. Prereq: introductory biology. Special fee. Lab.

MEFB 822 - Marine Phycology
Credits: 4
Identification, classification, ecology, and life histories of the major groups of marine algae, particularly the benthtonic marine algae of New England. Periodic field trips. Prereq: principles of biology or elementary botany or survey of the plant kingdom. Lab. (Not offered every year.) Special fee.

MEFB 825 - Marine Ecology
Credits: 4
Marine environment and its biota, emphasizing intertidal and estuarine habitats. Includes field, laboratory, and independent research project. Prereq: general ecology; permission. Marine invertebrate zoology, oceanography, and statistics are desirable. Special fee. (Not offered every year.)

MEFB 827 - Algal Physiology
Credits: 3
Survey of major topics in the physiology and biochemistry of marine and freshwater algae including nutrition, metabolic pathways, reproductive physiology, storage and extracellular products, cell inclusion, growth, and development. Prereq: introduction to biochemistry or permission. (Not offered every year.)

MEFB 832 - Lake Management
Credits: 4
Lectures and seminars on interpreting lake water quality, developing a natural history inventory for lakes, the process of creating a lake management plan, and resolution of conflicting uses of lakes. Students develop lake management plans in cooperation with governmental agencies and lake associations. Guest speakers from State agencies and non-governmental organizations. Introduction to and use of GIS (Geographic Information Systems) methods for the analysis of lakes and watersheds. Presents lake management issues from scientific and social science points of view. Open to students from all disciplines. Special fee. Lab.

MEFB 847 - Aquatic Plants in Restoration/Management
Credits: 4
A field-intensive class focusing upon freshwater and marine vascular plants with an emphasis on species commonly associated with ecological restoration, the identification and conservation of rare species, and the adaptations and management of invasive species of aquatic habitats in New England. Field trips emphasize the flora of various wetland habitats, including open water and vegetated fresh water wetlands, as well as coastal and estuarine habitats. Lectures and readings examine the current trends in research and management focusing upon specific taxa and pertinent facets of their taxonomy, physiology, and natural history. Prereq: BIOL 566 or permission. Special fee.

Natural Resources (NR)

NR 801 - Ecological Sustainability and Values
Credits: 4
Deeper more fundamental philosophical questions, including spiritual values questions, are being asked concerning the ecological/environmental challenge of our time; its causes and resolution. Aspects of this challenge-environmental education, energy, food, agriculture, and natural resources-analyzed with ethics and values approaches. Students develop ways of responding to problem identification and resolution.

NR 802 - Workshops
Credits: 1-4
Short-term courses (generally a few days to two weeks) offered off campus, covering a broad variety of environmental and natural resource topics. May be repeated. Special fee required depending on topic. Prereq: permission required.

NR 803 - Watershed Water Quality Management
Credits: 4
Principles of land use as they relate to water quality and quantity. Lectures focus on biogeochemical cycles and the watershed approach to land and water resource management. Labs and field trips focus on methods of water sampling and analysis. One year of chemistry is recommended. Prereq: freshwater resources or watershed hydrology, or permission. Special fee. Lab/field trips.

NR 806 - Soil Ecology
Credits: 4
Examines the ecological relationships between soil microorganisms and their biotic and abiotic environment, with emphasis on the role of soil microorganisms in biogeochemical cycling. Specific objectives are to examine the biodiversity present in soil systems, factors controlling microbial community composition and diversity, and linkages between soil microbial communities, soil physical properties, and soil organic matter and nutrient cycling dynamics. Prereq: Introduction to principles of biology, general chemistry or equivalent, or permission. Lab. Special fee.

NR 807 - Environmental Modeling
Credits: 4
Environmental Modeling introduces students to a range of key mathematical and computer modeling concepts and the ways they can be used to address important scientific questions. The course is divided into four topical sections: Population and Community Ecology. Hydrology, Biogeochemistry, and Ecosystems. In each section, modeling concepts and skills are presented together with environmental information to emphasize the linkage between quantitative methods and relevant scientific results. Prereq: MATH 425. (Also listed as EOS 807.)
NR 810 - Endangered Species Seminar
Credits: 2
This seminar provides students with an interactive class of student presentations and guest lectures by endangered-species biologists. Emphasis is placed on biological, sociological, economic, and political factors that influence endangered-species policy. Prereq: basic ecology/biology; permission. Special fee.

NR 811 - Wetland Ecology and Management
Credits: 4
Analysis of the natural resources of coastal and inland wetlands and environmental problems caused by human use and misuse of these ecosystems. Groups will collect field data to summarize the structure and function of four wetland types within a management context. Special fee. Lab. Prereq: general ecology; watershed water quality management; or permission. Special fee. Lab/field trips.

NR 812 - Mammalogy
Credits: 4
Evolution, ecology, behavior, physiology and diversity of mammals. The focus of the course is on conceptual issues, such as the relation of structure, function, physiology and ecology of species; reproductive physiology and life history strategies; and the evolution of mating systems and social structure. Familiarity of mammalian groups to the family level and identification of local fauna to species will be required. Prereq: BIOL 411 and BIOL 412 or equivalent. Lab. (Not offered every year.) Special fee.

NR 818 - Law of Natural Resources and Environment
Credits: 3
Federal and state environmental statutory and administrative law, its application, strengths and weaknesses, and options for future amendment.

NR #819 - Wetlands Restoration and Mitigation
Credits: 3
Assesses the problems of wetlands loss and learning how to repair the damage. Asks what steps can be take. Does restoration work, can habitat value be replaced, what constitutes equivalent mitigation? Field experience and theoretical background in restoring marine and freshwater environments. First half of course involves field trips to visit and sample mitigation and restoration sites. Second half focuses on student projects using the scientific method to address wetland issues. Prereq: NR 811 or permission. Special fee. Lab/field trips. (Not offered every year.)

NR 820 - International Environmental Politics and Policies for the 21st Century
Credits: 4
Students examine policies for managing human activities to sustain the health of regional ecosystems and planetary life-support systems. Selected problems of the international commons (oceans, marine resources, atmosphere, migratory species); global and regional carrying capacity (population, resource consumption), internationally shared ecosystems (trans-boundary watersheds, water-bodies, tropical forests); and the relevant international institutions and politics for policy formation, conflict resolution, and implementation. Using a policy-analytic framework, students develop case studies to assess international policies and institutional arrangements to achieve the objectives of Agenda 21—Earth Summit Strategy to Save the Planet. Prereq: permission.

NR 824 - Resolving Environmental Conflicts
Credits: 4
Theories and practices of environmental dispute settlement. Roles of public, non-governmental and governmental organizations. Effectiveness of public participation initiatives in influencing public policy decisions and/or resolving environmental conflicts. Alternative approaches to consensus (policy dialogues, joint problem solving; strategic planning; negotiation, mediation) as well as litigation. Specific cases are critiqued and evaluated; conflict resolution skills are developed. Students observe and/or participate in ongoing local decision processes. Prereq: permission. Lab. Special fee.

NR 829 - Silviculture
Credits: 4
The science and art of establishing, growing, and tending forests to meet multiple objectives. Basics of forest stand dynamics applied to the problems of timber management, wildlife habitat, water quality, and carbon sequestration. Prereq: NR 425 and NR 527 or permission. Special fee.

NR 830 - Terrestrial Ecosystems
Credits: 4
Processes controlling the energy, water, and nutrient dynamics of terrestrial ecosystems; concepts of study at the ecosystem level, controls on primary production, transpiration, decomposition, herbivory; links to Earth-system science, acid deposition, agriculture. Prereq: forest ecology and introduction to botany or principles of biology, or permission.

NR 834 - Tropical Ecology
Credits: 4
This course introduces students to the ecology of different tropical ecosystems, and involves students in analyzing and interpreting ecological field data and remotely sensed data. An important emphasis is to understand patterns and processes across scales—-from individual plants to ecosystems and landscapes. The also addresses important global issues in the tropics, including climate change, land use change, diverse ecosystem services, and sustainable resource management.

NR #835 - Land Conservation Principles and Practices
Credits: 4
Students gain practical knowledge, understanding and experience in land conservation planning and implementation of options for land protection based on current practice in New Hampshire. By interacting with practitioners, students learn what it takes to implement successful land conservation projects, and conservation stewardship requirements and practices. Permission. Special fee. Lab.

NR 836 - Tropical Ecology and Conservation
Credits: 4
This intensive field course in Costa Rica introduces students to the science and practice of tropical ecology and conservation. The course includes visits to major tropical biomes, including cloud forest, rainforest, dry forest, and diverse aroecosystems. A focus in on understanding how ecological information is scaled from trees to ecosystems and landscapes, and the impact of climate change and land management. Students conduct a project on a topic of interest, involving data collection, analysis, and interpretation. Special fee.

NR #838 - Wildlife Policy and Management
Credits: 4
Local, regional, and national issues and strategies in policy and administration. Contemporary issues including land management, commercialization of wildlife, overpopulation, endangered species, wildlife diseases, and professionalism. Prereq: permission. Special fee. Lab.
NR 840 - Inventory and Monitoring of Ecological Communities
Credits: 4
Provides an introduction to the major concepts associated with monitoring change in ecological communities. Students develop an appreciation for such issues as: identification of appropriate baselines for comparison; use of indicator species; the tools used to inventory common, rare, and secretive species; how trend data are analyzed; and the implications of failing to detect an indicator species. Restricted to senior wildlife majors others by premission. Special fee. Lab.

NR 844 - Biogeochemistry
Credits: 4
Examines the influence of biological and physical processes on elemental cycling and geochemical transformations from the molecular to the global scale, involving microorganisms, higher plants and animals and whole ecosystems; factors that regulate element cycles including soils, climate, disturbance and human activities; interactions among the biosphere, hydrosphere, lithosphere, and atmosphere; transformations of C, N, S, and trace elements. Prereq: one semester biology and two semesters chemistry or permission. (Also offered as EOS #844.)

NR 845 - Forest Management
Credits: 4
Forest land ownership; management objectives; forest inventory regulation and policy; forest administration; professional responsibilities and opportunities. Restricted to Natural Resources majors. Lab. Special fee.

NR 849 - Forest Inventory and Modeling
Credits: 4
Applied sampling and statistical techniques for assessing current forest conditions and predicting future growth, yield, and structure. Topics include plot and point sampling, ecological inventory, and evaluation of site quality and stand density. Prereq: MATH 420 and BIOL 528. Special fee.

NR 851 - Aquatic Ecosystems
Credits: 4
Energy flow and nutrient cycling in streams, rivers and lakes, with an emphasis on understanding the control of primary productivity, decomposition and community structure by both hydrologic and biotic drivers. Role of aquatic ecosystems in carbon and nitrogen budgets at watershed, regional, and global scales. Impacts of environmental changes such as global climate change and urbanization on aquatic ecosystems. Lab. Prereq: General Ecology.

NR 857 - Remote Sensing of the Environment
Credits: 4
Practical and conceptual presentation of the use of remote sensing and other geospatial technologies for mapping and monitoring the environment. This course begins with the use of aerial photographs (photogrammetry, and photo interpretation) and includes measures of photo scale and area, parallax and stereo viewing, object heights, flight planning, photo geometry, the electromagnetic spectrum, camera systems and vegetation/land cover mapping. The course concludes with an introduction to other geospatial technologies including digital image analysis, global positioning (GPS), and geographic information systems (GIS). Conceptual lectures are augmented with practical homework assignments and hands-on lab exercises. Prereq: algebra. Special fee. Lab.

NR 859 - Digital Image Processing for Natural Resources
Credits: 4
Introduction to digital remote sensing, including multispectral scanners (Landsat and SPOT) radar, and thermal imagery. Hands-on image processing including filtering, image display, ratios, classification, registration, and accuracy assessment. GIS as it applies to image processing. Discussion of practical applications. Use of ERDAS image-processing software. Knowledge of PCs required. Prereq: NR 857 or equivalent and permission.

NR 860 - Geographic Information Systems in Natural Resources
Credits: 4
This course in geographic information systems (GIS), covers advanced theory, concepts, and applications of GIS for natural resource and related disciplines. Discussion of database structures, data sources, spatial data manipulation/analysis/modeling, data quality and assessment. Students conduct a project of their design exploring aspects of GIS most useful to them. Lecture emphasizes concepts and applications through a text and selected peer-reviewed articles. Lab uses the latest version of ArcGIS software and provides hands-on experience. Prereq: introductory GIS course. Permission required.

NR 861 - Environmental Soil Chemistry
Credits: 4
Chemical transformations in soils are the basis for soil fertility and plant productivity in natural and managed ecosystems, and also influence key ecosystem processes including soil organic matter turnover and soil-atmosphere exchange of trace gases. This class will explore soil chemistry processes and transformations related to soil nutrient cycling, plant nutrient acquisition, and other critical environmental services. Prereq: a course in soil science or instructor permission.

NR 882 - Forest Health
Credits: 4
Forests cover over 30% of the land surface of the Earth and are incredibly important ecologically, economically, and to the health of the planet. While forests show great capacity to withstand disturbance, these ecosystems are increasingly threatened worldwide by climate change, native and introduced insects and disease, poor management practices, land clearing, drought, fire, and pollution. This course offers an overview of the dominant threats to forests, their causes and consequences, and options for monitoring, management, and mitigation. Special fee.

NR 883 - Forest Communities of New Hampshire
Credits: 4
A hands-on field course designed to introduce students to the diverse forest community types of New Hampshire. Topics include: 1) field identification of forest types using different classification systems and keys; 2) identification of characteristic plant and animal species; 3) the roles of climate, geology, soils, natural disturbance, forest management, and biotic factors in determining forest community type; 4) primary and secondary succession, including old-growth. Prereq: One course in ecology or environmental biology or permission. Special fee.

NR 887 - Advanced Topics in Sustainable Energy
Credits: 4
This course will engage students in advanced topics in sustainable energy. Course reviews basic structure of our energy system, energy markets and economics, and the environmental, economic and technological of our energy landscape. Focus will be on electricity and building use with introductions to the transportation system. Students will gain the knowledge to evaluate innovations in technology, policy and financing necessary to implement sustainable energy goals from conservation and efficiency to renewables and energy storage. Prereq: NR 507 or CHE 410 or POLT 444.
NR 897 - Special Topics
Credits: 1-4
An experimental course for the purpose of introducing a new course or teaching a special topic for a semester in an area of specialization in natural resources. Permission required. Special fee on some sections.

NR 899 - Master's Thesis
Credits: 1-10
Usually 6 credits, but up to 10 credits when the problem warrants. Cr/F.

NR 902 - Ecological Ethics and Values
Credits: 4
Increasingly fundamental philosophical questions, including spiritual values questions, are posited concerning the ecological/environmental challenge of our time, its causes, and its resolution. Examination of these questions, put forth with ethics and values approaches. Students work to develop responses to both problem identification and resolution.

NR 903 - Approach to Research
Credits: 2
Provides incoming graduate students with an overview of the scientific method, peer review, and various research approaches and methods. Ethics, institutional and individual responsibilities, and effective communication are also addressed in a seminar and discussion format. Cr/F.

NR 904 - Survey Research Methods
Credits: 2
Theoretical foundations and practical considerations in conducting survey research. Methods for obtaining high-quality responses using current technology. Topics include questionnaire design, survey implementation, and strategies for reducing errors encountered in the conduct of surveys.

NR 905 - Grant Writing
Credits: 2
The ability to secure financial support for research and outreach activities is becoming increasingly important. This course is intended for graduate and post-graduate level students who need to write proposals for their graduate work or to gain external funding from government agencies. Students will gain in-depth understanding of the proposal writing process through class discussions, insights shared by UNH faculty, and by writing a research proposal following the entire process.

NR 909 - Analysis of Ecological Communities and Complex Data
Credits: 4
This course introduces you to a suite of tools appropriate for analyzing and interpreting multivariate data arising from agroecological (and other ecological) research. In this course we cover a variety of multivariate analyses, including clustering, ordination (principal components analysis, nonmetric multidimensional scaling, correspondence analysis), group comparisons (multi-response permutation procedures, PerMANOVA, indicator species analysis, discriminant analysis, mantel test), and other hypothesis-driven techniques, including structural equation modeling.

NR 910 - Forest Stand Dynamics
Credits: 4
Discussion and presentation on forest dynamics to include soil-site quality evaluation, individual tree growth, stand growth and yield, stand and forest management, and related resource politics. (Not offered every year.)

NR 912 - Sampling Techniques
Credits: 2-4
Techniques of sampling finite populations in environmental sciences; choice of sampling unit and frame, estimation of sample size, confidence limits, and comparisons of sample designs. Prereq: Applied statistics or equivalent. (Not offered every year.)

NR 913 - Quantitative Ecology
Credits: 4
Applied quantitative techniques: basic concepts in probability and statistics applied to ecological systems; population dynamics; spatial patterns; species abundance and diversity; classification and ordination; production; and energy and nutrient flow. Prereq: calculus, statistics, and ecology. (Not offered every year.)

NR 915 - Coastal Challenges Sci-Policy
Credits: 2
This seminar introduces TIDES students to the environment in which they will develop an understanding of the organization and workings of NOAA's Estuarine Research Reserve System, how this system serves the research needs of coastal communities and how the NERRS collaborate with other coastal and estuarine programs (e.g. Coastal Zone Management, National Estuarine Program), and develop strategies to solve coastal problems. The course involves field work at NERRS and other coastal areas in ME, NH and MA. Permission.

NR 916 - Linking Decision-making and Coastal Ecosystem Science
Credits: 4
Integrating coastal ecosystem science, policy and management is the focus of this course, designed as an inquiry-based collaborative learning laboratory, with both classroom and field components. Students explore ways to effectively link knowledge to action(s) designed to address complex coastal and related watershed problems, including those related to climate change. We examine both theories and practices that are more likely to foster the production and use of salient, credible and legitimate knowledge that is trusted by scientists/technical experts, citizens and decision-makers and thus likely to meet the needs of and be used by the decision-makers. In addition to developing an understanding of criteria used to judge the adequacy of ecosystem-based knowledge and its relevance to support decisions, students are exposed to a range of models for analyzing complex problems, including the process of joint fact finding and other collaborative problem solving mechanisms. These are examined and tested by the students. Students develop specific problem assessment, communication, and process skills, and examine and evaluate a range of specific cases through in class simulations and practical applications relevant to real world initiatives. Original case studies of specific current coastal issues are undertaken to test their models. Permission required.

NR 917 - Coastal Ecosystem Science Policy and Management Internship
Credits: 6
TIDES Program Internship is served at a National Estuarine Research Reserve, Coastal Community or NEP where TIDES program graduate student interns help facilitate collaborative learning and problem solving with scientists, decision-makers and coastal resource users, assist with information transfer, and help coastal communities plan for and protect coastal and estuarine related resources. TIDES M.S. students only.

NR 947 - Current Issues in Ecosystem Ecology
Credits: 2
Examines current issues in ecosystem ecology and biogeochemistry by weekly discussion of primary research articles. Topics covered include elemental interactions in biogeochemical processes, mechanisms regulating nitrogen losses from terrestrial ecosystems, and hydrologic-chemical interactions in streams and groundwater. Cr/F.
NR 965 - Community Ecology  
Credits: 4  
This course investigates how community properties - species richness, and abundance distribution - are influenced by evolutionary history, landscape phenomena such as dispersal and migration, and local factors such as the physical environment, disturbance, competition, predation, and positive interactions. Mechanistic models of community dynamics, including succession, are discussed. The influence of species diversity on ecosystem function is discussed, and all aspects of the course are related to conservation science.

NR 993 - Natural and Environmental Resources Seminar  
Credits: 1 or 2  
Presentation and discussion of recent research, literature, and policy problems in the natural and social sciences influencing resource use. Cr/F.

NR 995 - Investigations  
Credits: 1-4  
Investigations in Natural Resources may include topics in environmental conservation, forestry, soil science, water resources, and wildlife management. Permission required.

NR 996 - Natural Resource Education  
Credits: 1  
Responsibilities include set-up, teaching, and grading of one lab section per week or equivalent lecture experience. Required of all M.S. degree students in the department. Cr/F.

NR 997 - Special Topics  
Credits: 1-4  
An experimental course for the purpose of introducing a new course or teaching a special topic for a semester in an area of specialization in natural resources. Permission required. Special fee on some sections.

NR 998 - Directed Research  
Credits: 1-4  
Student designs and conducts original research that culminates in a paper of publishable quality. Alternative to NR 899 for those choosing non-thesis degree option. Cr/F. IA (continuous grading). May be repeated up to a maximum of 4 credits.

PBIO 899 - Master's Thesis  
Credits: 1-10  
May be repeated up to a maximum of 10 credits. Cr/F.

PBIO 985 - Advanced Topics  
Credits: 1-6  

PBIO 995 - Investigations  
Credits: 1-6  

PBIO 997 - Graduate Seminar  
Credits: 1  
Tips and techniques for effective communication in science. Discussions and practice in oral and written communication, including presentations at scientific meetings, seminars, grant proposals, abstracts, dissertations, and research papers. Cr/F.

PBIO 999 - Doctoral Research  
Credits: 0  
Cr/F.

Zoology (ZOOL)  
ZOOL 808 - Stream Ecology  
Credits: 4  
Ecological relationships of organisms in flowing water; streams as ecosystems. Lectures on physical and chemical features of streams, floral and faunal communities, and factors controlling populations of benthic invertebrates. Laboratory exercises employ both field and laboratory experimental techniques. Weekly seminars on original research papers. Special fee. (Not offered every year.)

ZOOL 810 - Ichthyology  
Credits: 4  
An introduction to the evolution, systematics, anatomy, physiology, and ecology of fishes, with an emphasis on New England species. Prereq: principles of biology or equivalent. Lab. (Offered alternate years.) Special fee.

ZOOL 833 - Behavioral Ecology  
Credits: 4  
Behavioral adaptations of animals to their environment including the evolution of behavior and behavioral genetics; foraging and competition for resources; reproductive ecology, mating systems and parental care; and the evolution of cooperative behavior. Examples include both vertebrates and invertebrates. Emphasis is on critical understanding of concepts as exhibited in oral and written exercises. Students conduct independent investigations. Prereq: animal behavior or ecology or evolution course. Lab. (Offered in alternate years.)

ZOOL 836 - Genes and Behavior  
Credits: 4  
Genes and behavior examines the genetic underpinnings of animal behavior, and how behavior evolves on a genetic level. The course primarily relies on readings from the primary literature, using examples from laboratory model organisms, animals in their natural habitats, and humans. Topics include aggressiveness, social behavior, personality, parental care, communication, mating behavior, novelty seeking behavior, and foraging. This interdisciplinary course examines these behaviors at multiple levels, including genomics, population genetics, molecular genetics, epigenetics, endocrinology, and neurobiology. Prereq: GEN 604 and ZOOL 713 or equivalent.
ZOOL 845 - Biology and Diversity of Insects  
Credits: 4  
The lecture examines the unique biologies and structure of insects, the most diverse group of organisms. The laboratory project is based on past public requests for an understanding of aquatic insect biodiversity in streams. Experience in sampling, sorting, and identifying aquatic insects is developed, and an understanding of biodiversity indices is developed for a formal report and presentation. Prereq: BIOL 411 and 412 or equivalent. Special fee. (Not offered every year).

ZOOL 850 - Biological Oceanography  
Credits: 4  
Biological processes of the oceans, including primary and secondary production, trophodynamics, plankton diversity, zooplankton ecology, ecosystems and global ocean dynamics. Field trips on R/V Gulf Challenger and to the Jackson Estuarine Laboratory. Prereq: one year of biology or permission of instructor. (Also offered as ESCI 850.) Special fee. Lab. (Not offered every year.)

ZOOL 872 - Fisheries Biology  
Credits: 3  
Principles of fisheries science, with emphasis on techniques used to assess the biological characteristics of exploited fish populations and the use of such information for fisheries management. Prereq: ZOOL 810; permission. (Not offered every year.)

ZOOL 873 - Physiology of Fish  
Credits: 4  
Investigation of the physiological processes responsible for maintaining homeostasis in fishes. Focus is on the function and regulation of the major organ systems during stress and environmental adaptation. Topics include reproduction, osmoregulation, digestion, endocrinology and sensory perception.

ZOOL 877 - Neuroethology  
Credits: 3  
Survey of fundamental concepts and recent discoveries in neurobiology. Topics include structure and function of neurons, development, cellular basis of behavior (sensory and motor systems), neuropharmacology, and neural plasticity (learning). Prereq: principles of biology I and II or permission. Physiology also desirable.

ZOOL 895 - Advanced Studies  
Credits: 1-4  
Independent study in various areas, including but not limited to: animal behavior; departmental biology; ecology; electron microscopy; evolution; genetics; histology; history of biology; invertebrate biology; neurobiology and behavior; physiology; teaching practices; underwater research; vertebrate biology; biological techniques. Course sections for advanced work, individual or group seminar. May include reading, laboratory work, organized seminars, and conferences. Prereq: permission of department chairperson and staff concerned.

ZOOL 899 - Master's Thesis  
Credits: 1-10  
Prereq: permission of department chairperson and prospective supervisor. May be repeated up to a maximum of 10 credits. Cr/F.

ZOOL 997 - Seminar  
Credits: 1-2  
Reports on recent zoological literature. Subject fields are those listed under ZOOL 895 and ZOOL 896; not all areas available every semester. Cr/F.

ZOOL 998 - Seminar  
Credits: 1-2  
Reports on recent zoological literature. Subject fields are those listed under ZOOL 895 and ZOOL 896; not all areas available every semester. Cr/F.

ZOOL 999 - Doctoral Research  
Credits: 0  
Cr/F.

Faculty  
https://colsa.unh.edu/biological-sciences/people