bulletin of
Duke University
2002-2003
Nicholas School of the Environment and
Earth Sciences
The Mission of Duke University

James B. Duke's founding Indenture of Duke University directed the members of the University to “provide real leadership in the educational world” by choosing individuals of “outstanding character, ability and vision” to serve as its officers, trustees and faculty; by carefully selecting students of “character, determination and application;” and by pursuing those areas of teaching and scholarship that would “most help to develop our resources, increase our wisdom, and promote human happiness.”

To these ends, the mission of Duke University is to provide a superior liberal education to undergraduate students, attending not only to their intellectual growth but also to their development as adults committed to high ethical standards and full participation as leaders in their communities; to prepare future members of the learned professions for lives of skilled and ethical service by providing excellent graduate and professional education; to advance the frontiers of knowledge and contribute boldly to the international community of scholarship; to promote an intellectual environment built on a commitment to free and open inquiry; to help those who suffer, cure disease and promote health, through sophisticated medical research and thoughtful patient care; to provide a wide range of educational opportunities, on and beyond our campuses, for traditional students, active professionals and life-long learners using the power of information technologies; and to promote a deep appreciation for the range of human difference and potential, a sense of the obligations and rewards of citizenship, and a commitment to learning, freedom and truth.

By pursuing these objectives with vision and integrity, Duke University seeks to engage the mind, elevate the spirit, and stimulate the best effort of all who are associated with the University; to contribute in diverse ways to the local community, the state, the nation and the world; and to attain and maintain a place of real leadership in all that we do.

Adopted by the Board of Trustees on February 23, 2001.
The information in this bulletin applies to the academic year 2002-2003 and is accurate and current, to the extent possible, as of August 2001. The university reserves the right to change programs of study, academic requirements, teaching staff, the calendar, and other matters described herein without prior notice, in accordance with established procedures.

Duke University does not discriminate on the basis of race, color, national and ethnic origin, disability, sexual orientation or preference, gender, or age in the administration of educational policies, admission policies, financial aid, employment, or any other university program or activity. It admits qualified students to all the rights, privileges, programs, and activities generally accorded or made available to students. The university also does not tolerate harassment of any kind.

Questions, comments or complaints of discrimination or harassment should be directed to the Office of the Vice-President for Institutional Equity, (919) 684-8222. Further information, as well as the complete text of the harassment policy, may be found at http://www.duke.edu/web/equity/.

Duke University recognizes and utilizes electronic mail as a medium for official communications. The university provides all students with e-mail accounts as well as access to e-mail services from public clusters if students do not have personal computers of their own. All students are expected to access their e-mail accounts on a regular basis to check for and respond as necessary to such communications, just as they currently do with paper/postal service mail.

Information that the university is required to make available under the Student Right to Know and Campus Security Acts may be obtained from the Office of University Relations at 684-2823 or in writing to 615 Chapel Drive, Box 90563, Duke University, Durham, North Carolina 27708.

Duke University is accredited by the Commission on Colleges of the Southern Association of Colleges and Schools (1866 Southern Lane, Decatur, Georgia 30033-4097; telephone number 404-679-4501) to award baccalaureates, masters, doctorates, and professional degrees.
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University Administration

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Calendar*

2002

**August**
19 Orientation for fall semester– Durham
19-23 Registration of new and nonregistered returning students
26 Fall semester classes begin– Durham
26 Orientation for fall semester– Marine Laboratory
28 Fall semester classes begin– Marine Laboratory

**September**
6 Drop/ add ends

**October**
14-15 Fall break
30 Registration begins for spring semester, 2003

**November**
22 Registration ends for spring semester, 2003
23 Drop/ add begins
27 Thanksgiving recess (begins at 12:40 p.m. Wednesday)
27 Graduate classes end

**December**
2-8 Graduate reading period
9-14 Final examinations
14 Fall term ends at Marine Laboratory

2003

**January**
6 Orientation for spring semester
7 Registration of new and nonregistered returning students
8 Spring semester classes begin– Durham and Marine Laboratory
22 Drop/ add ends

**February**
28 Session 1 of Beaufort-2-Bermuda at Marine Laboratory ends

**March**
8-16 Spring Break
13 Session 2 of Beaufort-2-Bermuda at Marine Laboratory begins

**April**
2 Registration begins for fall semester, 2002
18 Registration ends for fall semester, 2002
18 Spring semester classes end
19 Drop/ add begins
19 Graduate reading period begins
27 Graduate reading period ends
28 Final Examinations begin

**May**
3 Final Examinations end
3 Spring term ends at Marine Laboratory
9-11 Commencement
12 First summer term begins at Marine Laboratory

**June**
13 First summer term ends at Marine Laboratory

**July**
7 Second summer term begins at Marine Laboratory

**August**
8 Second summer term ends at Marine Laboratory

*The dates in the calendar are tentative and subject to change.*
TO THE PROSPECTIVE STUDENT

When we entered this new millennium, more than 6 billion people shared the planet with us, and the world seems destined to add another 3 billion citizens during the lifetime of our current students. Our challenge will be to provide food, shelter, and peace to the expanding human population, while maintaining the fabric of biodiversity in the natural ecosystems that sustain life on this planet. To meet this challenge we need the best-trained professionals in science and policy to understand and tackle complex environmental issues, here and abroad.

The master’s and doctoral programs in the Nicholas School of the Environment and Earth Sciences are designed to educate and to train environmental professionals – those who will work within the private and public sector to sustain the environment, and those who will work within academic and other research institutions to understand the human impact on our planet. Our undergraduate majors offer an exciting opportunity for students to enter a variety of disciplines that focus on environmental problems and their solutions. No other environmental school in the United States offers the breadth of expertise that you will find in the Nicholas School: our faculty’s research spans the atmosphere and oceans, the deep earth and its surficial sediments, and the plant, animal and microbial life that maintain the stable conditions for the persistence of life on Earth. Our students gain fundamental understanding of how the biosphere world works and an interdisciplinary framework that allows them to put that knowledge to work in the world of policy, law and economics.

Our recent graduates live and work across the nation, where, daily, they make a difference in environmental protection, sustainable resource management, and the dissemination of fundamental knowledge about the Earth. Our planet is better for it!

Come explore the Earth’s environment with us. As a student in the Nicholas School, you will join those who strive to create a better world for the future.

William H. Schlesinger
Dean, Nicholas School of the Environment and Earth Sciences
Introduction

The mission of the Nicholas School of the Environment and Earth Sciences is education, research and service to understand basic earth and environmental processes, to understand human behavior related to the environment and to inform society about the conservation and enhancement of the environment and its natural resources for future generations. Intrinsic to this mission are (1) a commitment to interdisciplinary approaches, (2) a commitment to objective and, where possible, quantitative approaches, (3) a commitment to principles of ecological integrity, (4) a commitment to the sustainable use of natural resources, and (5) a commitment to environmental education at all levels. The overall objective is to assist in the definition and resolution of problems confronting society, through excellence in natural resource and environmental education and research.

The school's emphasis is on defining objectives for natural resource science and management, understanding the interrelated constraints—physical, biological, chemical, ecological, economic, legal and social—and devising and testing alternative management solutions. This approach to natural resource education is pursued through research, formal courses, field studies, and seminars, and informally through interaction with practicing professionals by a variety of means.

Research and problem solving are integral to the school's mission. The faculty is engaged in a dynamic program of research, much of which is focused on contemporary natural resource and environmental issues, both terrestrial and marine, that are regional, national, and global in scope. Students are also encouraged to involve themselves in real world problems. As part of their professional degree requirements, students must complete a master's project requiring independent research and problem analysis.

Teaching and research in the Nicholas School are focused within the following curriculums: coastal environmental management; environmental toxicology, chemistry and risk assessment; forest resource management; resource ecology; resource economics and policy; water and air resources; the ocean sciences; and the earth sciences. These programs are designed for students drawn from a wide variety of undergraduate backgrounds in the natural and social sciences, forestry, engineering, business and environmental studies. Program requirements enable all students to acquire the basic technical skills, scientific knowledge, insight and methods of analysis for resolving natural resource and environmental problems.

As a professional school within a private university, the Nicholas School is able to foster independent consideration of natural resource and environmental issues without the political pressures often brought to bear upon public institutions. As part of a major research university, the school is able to add a significant dimension to teaching and research through cross-campus interdisciplinary degree programs, faculty appointments, and cooperative projects.

Additional enrichment is available through relevant departments at neighboring universities, as well as through agencies and institutions at the Research Triangle Park and in the Beaufort-Morehead City area. These opportunities for study and professional interaction place Duke in an enviable position among schools of resource science and management and greatly enhance the quality of its programs.
Alumni of the Nicholas School hold leadership positions in public agencies, environmental and forestry consulting firms, private industry, and not-for-profit organizations throughout the nation and the world.

**History**

Duke University developed from Union Institute, a small school established in 1838 in Randolph County, North Carolina. The name was changed to Normal College in 1851, and in 1859, to Trinity College. The college was moved to Durham in 1892. With the establishment of the James B. Duke Indenture of Trust in 1924, Trinity College became Duke University. At the outset, the university developed around a core of undergraduate programs.

In 1932, forestry instruction was offered for students of Trinity College, and in 1938 the School of Forestry was established as a graduate professional school under the direction of Dean Clarence F. Korstian. The Master of Forestry and Doctor of Forestry degrees were offered initially and later the A.M., M.S., and Ph.D. were offered through the Graduate School. The school’s forestry program has been fully accredited by the Society of American Foresters since 1939.

Dr. Korstian joined the faculty in 1931 as the first director of the Duke Forest. Brought to Durham by Dr. William P. Few, president of Duke at the time, Dr. Korstian set out to develop a demonstration and research forest that would serve as a model for owners of small tracts of timber in the South. During the 1930s the faculty of the school was gradually expanded to include a number of research foresters who made substantial contributions to forestry in the Southeast. This faculty established and brought early recognition to the school.

Growing national concern with natural resources and environmental problems led to a new teaching and research emphasis in ecology in the 1970s. In 1974 the name was changed to the School of Forestry and Environmental Studies and a new degree was added, the Master of Environmental Management.

Duke University’s Marine Laboratory also had its beginnings in the 1930s when Dr. A.S. Pearse and colleagues from Duke were attracted to Pivers Island and its surrounding abundance of marine life for their summer field studies. The island afforded an excellent location for a field station and through the subsequent efforts of Dr. Pearse and others, the land was acquired for the Duke University Marine Laboratory. Construction began and by 1938 the first buildings were erected. Originally, the laboratory served only as a summer training and research facility. Today, it operates year-round to provide training and research opportunities to about 3,500 persons annually, including undergraduate, graduate and professional students enrolled in the university’s academic programs; visiting student groups who use the laboratory’s facilities; and scientists who come from North America and abroad to conduct research.

In 1991, the School of Forestry and Environmental Studies was combined with the Duke University Marine Laboratory to form the School of the Environment. The new school is an unprecedented university commitment to interdisciplinary education and research in environmental science, policy, and management. It is the only private graduate professional school of its type in the country. The school became the Nicholas School of the Environment in 1995 after a generous gift from Duke alums Peter and Virginia Nicholas.

In 1997, a new Division of Earth and Ocean Sciences was created when the former Department of Geology, previously a part of Trinity College of Arts and Sciences, joined the school. This department also dates from the 1930s when Dr. Willard (Doc) Berry became the first geologist at Duke University. By the 1960s the Department of Geology had established itself as a center for the study of sedimentary geology. Today, the Division of Earth and Ocean Sciences is known for its work in climate change, solid earth processes and surface processes, and its faculty and students conduct research all over the world, from the Hess Deep in the Pacific Ocean to the 4000m+ altitudes of the South American Altiplano.
With the addition of Earth and Ocean Sciences, in December 1991 the Nicholas School added Earth Sciences to its name to more accurately reflect the scope of its programs.

Location

Duke University is situated on the outskirts of Durham, a city of more than 223,000 inhabitants, in the central Piedmont region of North Carolina. The Appalachian escarpment lies approximately 100 miles to the west of Durham and the coastal plain is but a short distance to the east. The Duke Marine Laboratory is located 180 miles to the east of Durham, on Pivers Island within North Carolina’s Outer Banks, adjacent to the historic town of Beaufort. The school is thus ideally situated near areas of ecological and topographic diversity that offer many opportunities for study as well as recreation.

Piedmont North Carolina is characterized by a rolling, forested topography interspersed with small farms and rural communities in addition to the state’s largest cities. The climax forests of the piedmont are hardwoods; however, human disturbance has resulted in the establishment of many forests of the native southern pines.

The southern Appalachians are widely known for their unusual history, picturesque topography, and wide range of flora and fauna. Here the typical hardwood forests that dominate at lower elevations give way to forests of spruce and fir at higher elevations. The region’s numerous recreation areas are widely used for hiking, fishing, skiing, and other outdoor activities.

The coastal plain of North Carolina, well known for its agricultural production, is used extensively by many of the nation’s forest industries for plantations of the native pines. Coastal wetlands and estuaries, now recognized as one of the nurseries of world fisheries, offer abundant and valuable natural resources. North Carolina’s Outer Banks and the barrier islands of the other southeastern states serve as protection for these coastal waters. The rapidly increasing population and development in this region make proper management of its natural resources particularly important to the nation.

Because of the school’s central location near these regions of vital ecological importance, students are afforded the opportunity to study many current environmental problems in the field. Both the opportunity and the challenge exist to analyze these pressing problems and to develop sound approaches to their management.

Facilities

The Nicholas School of the Environment and Earth Sciences is headquartered in the Levine Science Research Center, an interdisciplinary research facility situated at the corner of Science Drive and Research Drive on the West Campus. The building includes state-of-the-art classrooms, research laboratories and instrumentation supporting both teaching and research for the programs offered by the school. A lounge, reading room, and computer laboratories are provided for students. The Division of Earth and Ocean Sciences occupies newly renovated laboratories in the Bluestone Building (also known as Old Chemistry) on the West Campus. Fully equipped modern teaching and research facilities for the ocean sciences are available at the school’s coastal campus in Beaufort, N.C.

Computer Facilities

The Nicholas School works with Duke’s Office of Information Technology to enable students, faculty and staff to reach their academic and research goals through technology. OIT provides all Nicholas School students, faculty and staff with e-mail and maintains DukeNet, a high-speed network with wireless access points connecting computers to resources throughout campus and on the Internet. The school maintains PC and
UNIX computing facilities for students on both the Durham and Beaufort campuses, with file storage space, laser and color inkjet printers, scanners and access to the Internet. Research labs and staff and faculty offices are networked as well.

The Marine Lab in Beaufort is connected to DukeNet via a T1 line, providing access to the same resources as on the main campus. The lab houses a Sun Sparc station as well as two Duke University public access clusters, MAC and IBM-PC, all connected to the Internet. Available for use are 13 586-based workstations and two MACs with word processing and statistics programs.

Other schoolwide services include access to the Internet data network and the Cray Y-MP/432 and massively parallel computing at the North Carolina Supercomputing Center and other supercomputer centers. Access to Duke's IBM ES/9000 mainframe computer is also available through the Computer Assist Center.

Libraries. The combined university libraries, including the main Perkins Library and seven other school or branch libraries, contain more than 4,534,000 volumes. About 150,000 volumes are added annually. The collection includes about 11,000,000 manuscripts and over 2,000,000 public documents.

The Biological and Environmental Sciences Library, located in the Biological Sciences Building, contains over 170,000 volumes and receives nearly 1,000 periodicals related to natural resources and the environment.

The Pearse Memorial Library on the Beaufort campus is a branch library of the Duke University library system. It provides access to print and electronic resources that support interdisciplinary education and research with a primary focus on the marine environment. Electronic resources include online bibliographic databases for searching the scientific literature, a rapidly increasing number of online full-text journals, and the Duke online catalog. The library currently subscribes to 60 research journals and maintains holdings of approximately 23,000 volumes. Two NT workstations with laser printing capability and a general access photocopier are provided for public use.

The library actively participates in interlibrary loan and document delivery arrangements with the Triangle universities and other national and international academic institutions and research centers. Additional cooperative agreements exist with the National Ocean Service Center for Coastal Fisheries and Habitat Research, the University of North Carolina Institute of Marine Sciences, and the University of North Carolina at Wilmington.

Greenhouses and the Phytotron. Adjoining the Biological Sciences Building on Duke's West Campus are excellent facilities for biological investigations under controlled conditions. The phytotron contains 50 separately controlled growth chambers and greenhouses that can be used to grow plants under a variety of environmental conditions. The phytotron is one of few such facilities in the United States.

Research Triangle Park. Numerous industrial and governmental organizations have established research facilities in the Research Triangle Park, 10 miles from the Duke campus. Government facilities include the National Environmental Research Center of the Environmental Protection Agency, the Forestry Sciences Laboratory of the United States Forest Service Southeastern Forest Experiment Station, and the National Institute of Environmental Health Sciences. These laboratories provide opportunities for student research and internships in some of the nation's most advanced research facilities.

Coastal Resources. The Beaufort-Morehead City area provides location for five facilities that collectively house one of the higher concentrations of marine scientists in the nation. These are the University of North Carolina's Institute of Marine Sciences, the North Carolina State University Seafood Laboratory, the North Carolina Aquarium at Bogue Banks, North Carolina Division of Marine Fisheries; and the National Oceanic and Atmospheric Administration's National Marine Fisheries Service, Beaufort Laboratory. This concentration of marine scientists provides a critical mass for the pursuit of science and education.
Neighboring Universities. Through a reciprocal agreement, Duke students may supplement their education in forestry and the environmental sciences by taking courses in related fields at the University of North Carolina in Chapel Hill, North Carolina State University in Raleigh, and North Carolina Central University in Durham. Graduate students of Duke University and the University of North Carolina at Chapel Hill are granted library loan privileges in both universities.

The Duke Forest

The Duke Forest is the university's outdoor laboratory for teaching and research in the natural sciences. It is comprised of almost 8,000 acres of land in six divisions. A short drive from campus will take one well into many parts of the Durham Division, and a network of roads and fire trails makes almost all areas of the forest easily accessible.

The forest lies primarily in Durham and Orange counties, near the eastern edge of the piedmont plateau, and supports a cross section of the woodlands found in the upper coastal plain and lower piedmont of the Southeast. A variety of timber types, plant species, soils, topography and past land use conditions are represented. Elevations range from 260 to 760 feet. Soils of the region are derived from such diverse parent materials as metamorphic rock of the Carolina slate formation, granite, Triassic sedimentary rock, and basic intrusives.

The Duke Forest, as it is known today, had its origins in the mid-1920s when the university administration bought many small farms and interspersed forest land as buffer areas for the main campus and as an investment for the future. The forest was placed under intensive management in 1931 by Dr. Clarence Korstian, its first director. In its early development, several basic objectives were emphasized: (1) demonstration of timber management techniques on a practical and economic basis, (2) development of an experimental forest for research in the sciences associated with timber growing, and (3) development of the area as an outdoor laboratory for students of forestry.

Modification of these early objectives has arisen, in part, through a greatly increased interest and dependence on the forest for research in the areas of zoology, botany, and ecology by faculty and students at Duke and neighboring universities. Background information useful to researchers is provided by the forest; it covers such features as soils, topography, inventory, plantation, and cultural records as well as a bibliography of past and current studies. Current work on problems associated with developmental pressures at the urban-rural interface and integrated approaches to natural resource management have multiplied the forest's value and benefit as a resource.

The forest also serves in an educational and recreational capacity for residents of the Durham and Chapel Hill communities. Hiking, picnicking, jogging, and nature study are particularly popular pastimes.

This natural outdoor laboratory is an invaluable supplement to the instructional, research, and recreational facilities of the school, the university, and the region. The Duke Forest—in terms of its size, diversity, proximity to campus, and more than seventy years of accumulated research data is a natural resource unequaled at any other academic institution.
Faculty
Core Faculty

Paul A. Baker, Ph.D., Professor of Geology; B.A., Geology, University of Rochester; M.S., Geology, Pennsylvania State University; Ph.D., Earth Sciences/Marine Geology, University of California, San Diego
E-mail: pbaker@duke.edu

The primary theme of Dr. Baker's research is the geochemistry of fluids and sediments, especially for the purposes of understanding sedimentary diagenesis, the depositional history of sediments, or the reconstruction of past climate. Some of Dr. Baker's work on modern processes is done at sea utilizing oceanographic research vessels. Typically, this may include observations of pore-fluid geochemistry and sedimentology of materials collected by box coring, piston coring or deeper drilling. Some of his work on modern processes is done in the laboratory by experimental hydrothermal syntheses of common diagenetic mineral phases and observation of the conditions of their formation. His studies of ancient rocks utilize more traditional procedures: measuring and sampling of stratigraphic sections in the field and complete mineralogical, chemical, and isotopic analyses of these samples in the laboratory. Because of the diverse nature of the methodology employed for these studies, Dr. Baker (by necessity and by choice) is a geological generalist.

Richard T. Barber, Ph.D., Harvey W. Smith Professor of Biological Oceanography and Professor of Botany and Zoology; B.S., Zoology and Botany, Utah State University; Ph.D., Biological Science, Stanford University
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Dr. Barber's research in carbon cycling by ocean processes has implications for climate regulation. At Duke he investigates the interrelationship of large-scale thermal dynamics and ocean basin productivity, emphasizing (1) how biological and physical processes contribute to the exchange of carbon dioxide between the ocean and the atmosphere and (2) how the "biological pump" transfers carbon into the deep sea. With current field work being carried out on cruises in the southern ocean, his research group is focusing on the role of physical conditions in regulating primary production and phytoplankton performance. He is also investigating the role of a single micronutrient, iron, in the regulation of primary production in a part of the ocean, the equatorial Pacific, where a high nutrient/low chlorophyll character persists despite physical and chemical conditions which otherwise favor high productivity.

He is in residence at the Marine Laboratory.
Celia J. Bonaventura, Ph.D., Professor of Cell Biology; B.A., Zoology, San Diego State University; Ph.D., Biochemistry, University of Texas, Austin
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Most of Dr. Celia Bonaventura's research is in the area of structure/function relationships of oxygen and electron-transport proteins. This continues to be her primary area of research, with an increasing focus on environmental perturbations of structure and function. Her research makes use of structural assays and complementary measurements of rapid reaction kinetics and equilibria, using UV MS and fluorescence spectroscopy and spectroelectrochemistry. Through comparison of human proteins with proteins of species inhabiting diverse environments, studies by Dr. Bonaventura and collaborators have increased the understanding of structural mechanisms that allow respiratory proteins to satisfy widely different physiological and environmental demands. Her current research concerns aspects of environmental toxicity associated with free-radical interactions with respiratory proteins and structural alterations of respiratory proteins that are indicative of exposure to xenobiotics.

She is in residence at the Marine Laboratory.

Joseph Bonaventura, Ph.D., Professor of Cell Biology; B.A., Zoology, San Diego State University; Ph.D., Biochemistry, University of Texas, Austin
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Dr. Joseph Bonaventura's research involves marine organisms found in diverse environments. Biochemical studies on the structural and functional diversity of these organisms have been shown to be paralleled by diversity at the molecular level. Red cells and respiratory proteins of marine organisms are being studied in order to increase the understanding of molecular adaptations and the mechanisms that give rise to functional flexibility. The kinetics and equilibria of ligand binding to hemoglobins, hemocyanins, and cytochrome c oxidase are studied with emphasis on the reactivity of these proteins as regulated by metabolic effectors. These studies are complemented by work in the Protein Engineering and Technology Laboratory where properties of chemically modified, crosslinked, and immobilized forms of biologically active molecules are characterized. Recent research concerns the development of a synthetic blood substitute for humans. The project involves a detailed study of structure-function relationships in the human hemoglobin molecule and includes site-directed mutagenesis of hemoglobin genes. A new focus concerns the biochemistry of nitric acid in the human body and the development of a hypothesis of how this simple molecule might act as a regulator of the biosphere.

He is in residence at the Marine Laboratory.
Dr. Boudreau’s research has focused on understanding the crystallization of large layered intrusions, with particular attention on the Archean Stillwater complex in Montana. Although the classic bodies such as the Stillwater Complex have been extensively studied for many years, there is still little agreement on how the rocks formed. Besides the intriguing problems proposed for the crystallization of magmas, these intrusions are host to important mineral reserves of Cu, Ni, Cr, Ti and the platinum-group elements. Much of Boudreau’s recent work has investigated the degassing history of these intrusions and the role of volatiles in the formation of the platiniferous ore zones hosted by both the Stillwater Complex and the Bushveld Complex in South Africa. He and his coauthors have shown that the halogen geochemistry of Stillwater and Bushveld hydrous mineral phases is distinctly much more Cl-rich than are seen in other, barren, layered intrusions. Current work is investigating the details of the stratigraphic variation of the halogens and the possibility of redistribution of Cl-complexed trace elements. Another set of studies has focused on the mechanisms by which igneous layering may develop. These attempt to show that many examples of igneous layering may develop slowly over time and have more textural affinity with metamorphic differentiation layering.

Dr. Christensen is interested in the effects of disturbance on the structure and function of populations and communities. Ongoing studies include an analysis of patterns of forest development following cropland abandonment as these are affected by environment, stand history, and plant demographic patterns. This research focuses on the historical data sets and resources of the Duke Forest. He is also conducting research on the southeastern coastal plain and western Sierra Nevada focused on a comparison of biogeochemical and community responses to varying fire regimes. These studies are aimed at an understanding of the evolutionary and ecosystem consequences of fire and the application of such information in the development of wilderness management and policy protocols. In addition, Dr. Christensen is conducting research on the use of remote sensing systems, such as synthetic aperture radar, to evaluate long-term changes in forest ecosystems.
James S. Clark, Ph.D., Hugo Blomquist Professor of Biology and Earth and Ocean Sciences; B.S., Entomology, North Carolina State University; M.S., Forestry, University of Massachusetts; Ph.D., Ecology, University of Minnesota
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Dr. Clark’s research focuses on how global change affects forests and grasslands. Current projects include studies of how recurrent drought has affected vegetation cover and fire in the Northern Plains and how aridity and fire have shaped the composition of North American temperate and boreal forests during recent millennia. Long-term experiments and monitoring studies in the southern Appalachians demonstrate how disturbance and climate gradients control the dynamics of 20th century forests. Analyses of forest succession at Duke University’s Free Air CO₂ Experiment (FACE) are being used to assess how changing atmospheric chemistry is affecting the trajectory of change in modern pine forests.
Dr. Clark holds joint appointments in earth and ocean sciences and botany.

Bruce H. Corliss, Ph.D., Professor of Earth & Ocean Sciences; B.A., Geology, University of Vermont; M.S., Oceanography, University of Rhode Island; Ph.D., Oceanography, University of Rhode Island
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Dr. Corliss was on the staff of the Woods Hole Oceanographic Institution for six years before joining the Department of Geology in 1984. As a geological oceanographer, he is interested in Cenozoic paleoceanography and studies marine microfossils and deep-sea sediments. His early work dealt with the distribution of Quaternary deep-sea benthic foraminifera in the Southern Ocean and their relationship with present and past deep bottom water circulation patterns.
This effort was followed by studies of Eocene-Oligocene paleoceanography based on the analysis of microfossils and sediments from Deep Sea Drilling Project samples. An ancillary aspect of his research has been in deep-sea sedimentation. A study of Cenozoic sedimentation in the Pacific was based on a synthesis of sedimentological, geochemical, and paleontological data from a red clay sequence. A second sedimentological study dealt with carbonate sedimentation beneath the Antarctic Circumpolar Current. Dr. Corliss’ current research deals with the ecology of living deep-sea benthic foraminifera using data from box core samples taken on a number of oceanographic cruises in the Atlantic, Pacific, and Arctic Oceans.
Larry B. Crowder, Ph.D., Stephen Toth Professor of Marine Biology; B.A., Biology and Mathematics, California State University, Fresno; M.S., Ph.D., Zoology, Michigan State University
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Dr. Crowder's research centers on predation and food web interactions, mechanisms controlling recruitment variation in fishes, and on population modeling in conservation biology. He has studied food web processes in estuaries and lakes, and has used observational, experimental and modeling approaches to understand these interactions in an effort to improve fisheries management. He is a member of the Program Management Committee for SABRE (South Atlantic Bight Recruitment Experiment), a NOAA-funded project that focuses on identifying the unique characteristics of survivors of a cohort of fishes, then links those characteristics to physical or biological variability. He has also been involved in population modeling and data analysis to address various management scenarios for threatened and endangered species. He and his students have developed life-history population models to address various management problems including exotic species introductions, acidification, habitat modification, bycatch and harvest for both freshwater and marine fishes. He is in residence at the Marine Laboratory.

Thomas J. Crowley, Ph.D., Nicholas Professor of Earth Systems Science; B.A., Geology, Marietta College; M.S., Ph.D., Geological Sciences, Brown University
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Dr. Crowley received his Ph.D. in marine geology and is a specialist in the study of past climate change. Although his initial studies involved observations of ice changes in the ocean circulation and sediments, he has devoted considerably more of his time over the last few years to modeling climate fluctuations on different time scales—ice age, tectonic, and most recently decadal-centennial changes of the last 1,000 years. These modeling studies often involve collaborative efforts with different specialists—for example, atmospheric and ocean scientists, and ice sheet and carbon cycle modelers. Because of his observational background he is particularly interested in comparing model results with observations to determine how well we can explain past environmental variations. His most recent work has focused on modeling the very extensive late Precambrian glaciation (600 million years ago), which occurred at a critical transition in the evolution of life—the first appearance of multi-celled animals. A second topic involves causes for climate change over the last 1,000 years. In this effort his results indicate that, although solar variability and volcanism can explain many variations in climate over the last 1,000 years, only greenhouse gas forcing from fossil fuel emissions can explain the magnitude of the late 20th century temperature change. These studies fit in nicely to another of Dr. Crowley's avocations—utilizing the geologic record to obtain a better perspective on assessing the significance of global warming projections for the 21st century.
Richard T. Di Giulio, Ph.D., Professor of Environmental Toxicology; B.A., Comparative Literature, University of Texas; M.S., Wildlife Management, Louisiana State University; Ph.D., Wildlife Biology, Virginia Polytechnic Institute and State University
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Dr. Di Giulio's research is focused upon biochemical and cellular responses of aquatic animals to environmental stressors, particularly contaminants. The laboratory is concerned with both basic studies of mechanisms of contaminant metabolism, adaptation and toxicity, and with the development of sensitive, mechanistically-based indices of exposure and toxicity that can be used in biomonitoring of free-living organisms. The long-term goal of this research is to bridge the gap between fundamental toxicological research and the development of mechanism-based approaches for monitoring environmental health. Relatedly, he seeks to utilize the comparative biology paradigm to elucidate linkages between human and ecosystem health.

Key specific areas of research include (1) comparative biochemical toxicology, particularly microsomal metabolism, phase I and II metabolism, and free radical biology among vertebrates and macroinvertebrates; (2) the elucidation of mechanisms underlying genotoxic and mutagenic effects of contaminants; (3) the application of oxygen free radical theory to the assessment of impacts of contaminants on aquatic organisms, particularly fishes; (4) the elucidation of mechanisms underlying adaptations by aquatic animals to environmental stressors, including contaminants, “costs” of such adaptations and genetic consequences; (5) effects of contaminants on reproduction and development in fishes; and (6) the development of mechanistically-based indices, or “biomarkers,” for the detection of excess exposures to, and sublethal effects of, contaminants in natural systems.

Richard B. Forward, Jr., Ph.D., Lee Hill Snowdon Professor of Zoology; B.S., Biology, Stanford University; Ph.D., Biology, University of California, Santa Barbara
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Dr. Forward and his students investigate the behavior and physiology of estuarine and coastal zooplankton. This includes the photobehavior, photophysics, behavioral rhythms, diurnal vertical migration, and horizontal migration of crustacean and fish larvae. Past studies have worked with crustaceans and chaetognaths to determine the effects of temperature, salinity, and feeding on phototaxis and geotaxis, salinity perception, and polarized light perception. Field studies have looked at horizontal and vertical distributions as related to environmental factors. Additional studies involve rhythms in egg hatching by crustaceans. Types of rhythms, flexibility, and the involvement of peptide pheromones are being considered.

He is in residence at the Marine Laboratory.
Jonathan H. Freedman, Ph.D., Associate Professor of Environmental Toxicology; B.A., Microbiology, Rutgers University; M.S., Ph.D., Molecular Pharmacology, Albert Einstein College of Medicine
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Dr. Freedman's research program is directed toward understanding the regulatory processes controlling an organism's response to environmental stress. In particular, he is interested in how individual cells and whole organisms respond when they are exposed to toxic concentrations of transition metals.

His current focus is directed toward understanding how cadmium induces the expression of dozens of different genes, which encode proteins with functions ranging from repairing intracellular damage to DNA, lipids and proteins to activating signal transduction cascades. He is investigating these processes using mammalian cultured cells and as a model multicellular system the microscopic soil nematode Caenorhabditis elegans. C. elegans is an excellent model organism for studying the effects of environmental toxicants on development, signal transduction and gene regulation in a whole organism. Results from this research will help elucidate:

- Mechanisms of transition metal induced disease, developmental abnormalities, and carcinogenesis.
- How organisms adapt to increasingly toxic environments.

A second area of research focuses on understanding the mechanism that controls the expression of the low molecular weight, metal-binding protein metallothionein. Multiple signaling pathways, including those involved in metalloregulation, response to oxidative stress, development and cell-specificity, must coordinately interact to activate metallothionein transcription. Regulatory processes controlling metal-inducible expression of the metallothionein genes in cultured cells and C. elegans are being examined. In vivo techniques, including the generation of transgenic nematodes, in situ hybridization, immunofluorescence and gene structure analysis are being used to monitor gene activity, RNA accumulation and protein expression. Defining these mechanisms are essential to understanding metal-responsive gene regulation and the roles of transition metals in human carcinogenesis.

Ronie Garcia-Johnson, Ph.D., Assistant Professor of Environmental Policy; B.A., History and Literature, Harvard University; Ph.D., Political Science, University of Michigan
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Dr. Garcia-Johnson studies global environmental politics and policy. She is especially interested in understanding the ways transnational actors (including government bureaucrats, activists in non-governmental organizations, business consultants, scholars, and multinational corporation executives) diffuse environmental ideas and values and shape the prospects for international cooperation. Her new book Exporting Environmentalism is based on case studies of the chemical industry in the United States, Brazil and Mexico. She is currently conducting a project to investigate the transnational dissemination of pollution prevention policy approaches in Latin America. She is also a member of a Duke team conducting research on global environmental and social certification institutions.
Peter K. Haff, Ph.D., Professor of Geology and Civil and Environmental Engineering; B.A., Physics, Harvard University; Ph.D., Physics, University of Virginia
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Dr. Haff applies quantitative modeling techniques including computer simulation to describe and predict the course of natural geological processes that occur on the surface of the earth. His research interests include the physics of blowing sand, the motion of sand dunes, the mechanics of sedimentary bedforms, and the transport of sedimentary particles by flowing water. Field work being carried out by Dr. Haff on desert pavements in the southwest U.S. shows that these ancient geomorphic surfaces are dynamically active today. Understanding the dynamics and history of desert pavement provides a framework for assessing the stability of these extensive desert landforms and for interpreting paleoclimatic events that have influenced their development. Dr. Haff is also studying the effects of human disturbance on natural landscapes. Field experiments and observations are being carried out in the Mojave Desert in California in an attempt to assess the future prospects for this desert environment as human activity there continues to expand.

Patrick N. Halpin, Ph.D., Assistant Professor of the Practice of Landscape Ecology; B.A., International Studies, MPA, International Management, George Mason University, Ph.D., Environmental Sciences, University of Virginia
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Dr. Halpin's research interest is in landscape ecology, GIS and remote sensing, and conservation management. His research activities include spatial analysis of environment and vegetation patterns; Geographic Information Systems analysis; ecological applications of remote sensing; urban ecology and protected area management. Dr. Halpin has conducted research on the international impacts of global climate change in montane environments. He is currently a principle investigator in research projects sponsored by the NASA, NSF, and TNC. These projects involve the spatial analysis of environmental change in urban environments, spatial analysis of forest structure, and conservation applications of GIS. Dr. Halpin has a special interest in the application of GIS and spatial analyses to environmental problem solving in terrestrial and marine research and management problems.

Gary S. Hartshorn, Ph.D., Professor of the Practice of Tropical Ecology; B.S., Biology, Moravian College; M.S., Botany, North Carolina State University; Ph.D., Forest Resources, University of Washington
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Dr. Hartshorn is president and CEO of the Organization for Tropical Studies (OTS), a 56-member consortium of universities and research institutions headquartered at Duke. OTS owns and operates three biological field stations in Costa Rica, offers graduate field courses in Brazil, Costa Rica, and Peru as well as an undergraduate study abroad program in Costa Rica.

Dr. Hartshorn maintains long-term research interests in tropical forest dynamics,
biodiversity conservation, dominance-diversity patterns and sustainable forest management.

**Robert G. Healy**, Ph.D., Professor of Environmental Policy; B.A., M.A., Ph.D., Economics, University of California, Los Angeles

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Dr. Healy works on land-use and environmental policy in the United States and developing countries. Before coming to Duke in 1986, he was senior associate at The Conservation Foundation/World Wildlife Fund in Washington, D.C. His past research has resulted in books on state land-use planning, coastal zone management in California, rural land markets, national forest policy, resource and environmental problems of agriculture, and environmental policy in developing countries. He has a continuing interest in land use policy in fast-growing areas, particularly the U.S. South and rural areas affected by rapid migration or by tourism. Dr. Healy teaches courses on U.S. land use policy and on protected area issues in the U.S., Canada and Mexico. His current research deals with integration of rural tourism with the marketing of sustainable agricultural products. He currently serves as director of Duke's Center for North American Studies.

**David E. Hinton**, Ph.D., Nicholas Professor of Environmental Quality; B.S., Zoology, Mississippi College; M.S., Ph.D., Anatomy, University of Mississippi

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Dr. Hinton's research interests are cellular biology of responses of developing and adult fishes to environmental pollutants. Studies with embryonic and larval life stages are designed to advance our understanding of the biologic properties of these organisms as they develop. This information is being used to understand how exposure to foreign compounds leads to developmental toxicity and to a lack of recruitment of young-of-the-year fishes to populations. Mechanisms of responses are stressed and the endpoints include acute and chronic states. Gender-specific aspects of normal and abnormal hepatic growth are investigated in small, aquarium species and involve specific, inbred strains as well as outbred populations. One long-standing focus is a structural model of the tubular livers of lower vertebrates. Determining how the tubular organization of the liver of fishes is related to patterns of exposure and effect and leads to more accurate descriptions of pollutant-induced toxicity. The similarity of the tubular liver of fishes and neonatal liver of mammalian species is being used to investigate the remodeling of the latter into the adult, laminar form. By focus on these small surrogate fishes, we are able to create laboratory simulations of multiple stressors, mimicking complex exposure patterns facing wild populations. Applications of organismal biology to ecotoxicology have increasingly become a theme of Dr. Hinton's work.
Robert B. Jackson, Ph.D., Associate Professor of Botany and of Environment; B.S., Chemical Engineering, Rice University; M.S., Plant Ecology, M.S., Statistics, Ph.D., Plant Ecology, Utah State University
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Dr. Jackson studies the physiological controls on ecosystem functioning and feedbacks between global change and the biosphere. Ongoing research projects in his lab include a study of grassland responses to a continuous gradient in atmospheric CO₂ (200-550 ppm), global studies of root and soil attributes, and the use and improvement of ecological models and GCMs to examine feedbacks with global change. He examines the consequences of vegetation change using a series of 10-m deep soil cores through the central U.S. and a cave project that combines molecular biology, stable isotopes, and physiological measurements to identify the rooting depth and resource uptake of different plant species and ecosystem types. He leads research projects for two core projects of the International Geosphere Biosphere Programme, Global Change and Terrestrial Ecosystems (GCTE) and Biosphere Aspects of the Hydrological Cycle (BAHC).

Zbigniew J. Kabala, Ph.D., Associate Professor of Civil Engineering and of Environment; M.S., Numerical Methods and Programming, Adam Mickiewicz University, Poznan, Poland; M.S., Civil Engineering, Technical University of Poznan, Poznan, Poland; M.A., Civil Engineering, Water Resources Program; Ph.D., Civil Engineering and Operations Research, Water Resources Program, Princeton University
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Dr. Kabala’s principal research interests cover stochastic and deterministic theory of fluid flow and contaminant transport in saturated and unsaturated heterogeneous porous media, theory of related measurements, field and laboratory studies in subsurface hydrogeology, stochastic fields and processes, numerical and analytical methods and sensitivity analysis. Dr. Kabala’s current research focuses on developing new measurement techniques for characterization of porous media, recovering contaminant release histories from current plume observations and stochastic modeling of water and solute transport in saturated and unsaturated heterogeneous formations and cracking soils. Among his novel aquifer characterization techniques are the dipole-flow test (DFT), the dipole-flow test with a tracer (DFTT), and the transient flowmeter test (TFMT).

Jeffrey A. Karson, Ph.D., Professor of Geology; B.A., Geology, Case Institute of Technology; M.S., Ph.D., Geology, State University of New York, Albany
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Dr. Karson joined the Duke faculty in January 1986 after seven years as a member of the scientific staff at Woods Hole Oceanographic Institution. The central theme of his research is structural and tectonic analysis of rift and transform plate boundaries. His approach involves the systematic collection of geological data in order to determine the geometry, chronology, and mode of formation of outcrop-scale deformation structures.
and their relation to crustal processes that operate on a regional scale. In order to gain insights into the evolution of rifts and transforms, Dr. Karson has worked in several different environments. In the East African Rift System, detailed structural studies define the geometry and kinematics of active rifting and the birth of a rifted continental margin. Investigations of the ocean-continent transition and coastal dike swarms of the Tertiary East Greenland volcanic rifted margin are underway in collaboration with the Danish Lithosphere Center. Along the Mid-Atlantic Ridge and East Pacific Rise, spreading centers and intervening transform faults are examined from the perspective of the submersible ALVIN and various other seafloor mapping tools. Studies of ophiolite complexes, ancient oceanic lithosphere exposed in mountain belts, reveal the deep structure of crust and upper mantle produced by seafloor spreading. Integrating these diverse studies has proven to be useful in developing new models of crustal deformation in extensional and strike-slip tectonic regimes.

Prasad S. Kasibhatla, Ph.D., Associate Professor of Environmental Chemistry; B.S., Chemical Engineering, University of Bombay; M.S., Ph.D., Chemical Engineering, University of Kentucky
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Dr. Kasibhatla has fifteen years of experience in tropospheric chemistry and transport modeling. His modeling studies have focused on elucidating the factors affecting regional air quality and the global atmospheric budgets of reactive nitrogen compounds, ozone, carbon monoxide, and sulfur compounds. One particular area of interest for Dr. Kasibhatla is the effects of anthropogenic emissions on atmospheric composition and reactivity, as well as on marine and terrestrial ecosystems.

Gabriel G. Katul, Ph.D., Associate Professor of Hydrology; B.E., Civil Engineering, American University of Beirut; M.S., Civil Engineering, Oregon State University; Ph.D., Civil Engineering, University of California, Davis
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Dr. Katul’s research broadly focuses on surface hydrology and transport phenomena in the environment. In particular, he is interested in how carbon dioxide, heat, momentum, and water vapor are exchanged between terrestrial ecosystems and the atmosphere. His work is centered around understanding the dynamic interaction between hydrologic, radiative, ecophysiological, and atmospheric turbulent transport processes governing these exchange rates.

Recent projects include quantifying (1) the multiscale structure of biosphere-atmosphere exchange, (2) the role of coherent turbulent eddy motion on mass and energy exchange processes, and (3) the impact of hydrologic and climatic perturbations on biosphere-atmosphere mass and energy transfer. Dr. Katul and his students address these questions using a combination of novel field experiments and numerical models.
Richard F. Kay, Ph.D., Professor of Biological Anthropology and Anatomy and of Environment; B.S., Anthropology and Zoology, University of Michigan; M. Phil., Ph.D., Geology and Geophysics, Yale University

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Dr. Kay's current research interests center on the evolutionary history of the Order Primates. He is especially interested in further documenting the fossil history of Neotropical monkeys, whose history is particularly poorly known. Another focus of his research has been the use of quantitative methods to understand the dietary adaptations of the teeth of living primates. Dr. Kay is chairman of Duke's Department of Biological Anthropology and Anatomy.

Robert O. Keohane, Ph.D., James B. Duke Professor of Political Science and of Environment; B.A., Social Sciences, Shimer College; Ph.D., Political Science, Harvard University

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Dr. Keohane's research focuses on the role of international institutions, including international environmental regimes such as the Montreal Protocol on Substances that Deplete the Ozone Layer and organizations such as the Global Environment Facility. He is interested in the conditions under which such institutions form and gain membership and authority. His research is also designed to explore how such institutions can become effective in promoting concern about the environment, facilitating international environmental cooperation, and strengthening national environmental policies. A recent project, Institutions for Environmental Aid (ed. Keohane and Levy) explored the operation of institutions designed to promote environmental protection in poor countries by transferring resources from richer ones. His current research includes participation in a project on global environmental assessments, which is designed to explore the conditions that affect these exercises, and their effects on environmental policy and behavior. He also works on other issues involving the roles played by institutions in American foreign policy and world politics more generally.

William W. Kirby-Smith, Ph.D., Associate Professor of the Practice of Marine Ecology; B.S., Biology, University of the South; Ph.D., Zoology, Duke University

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Dr. Kirby-Smith's research interests involve effects of land development on estuarine water quality, invertebrate zoology, benthic ecology and estuarine ecology. His recent research projects include the following: (1) ecology of rock outcrop communities on the continental shelf; (2) effects of salt marsh modifications on plant, invertebrate, fish and bird communities; (3) influence of pine plantation drainage on water quality and benthic invertebrates in receiving estuarine headwaters; (4) effects of agricultural development upon hydrology, water quality and biology in estuarine headwaters; and (5) the fate of fecal coliform bacteria in storm water runoff and estuarine headwaters. Additional research interests include the physiology of suspension feeding and its ecological consequences in estuaries.

He is in residence at the Marine Laboratory.
**Emily M. Klein**, Ph.D., Associate Professor of Geology; B.A., English, Barnard College; M.A., M. Phil., Ph.D., Geology, Columbia University  
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Dr. Klein's research focuses on the geochemistry of ocean ridge basalts, using diverse tools of major and trace element and isotopic analyses. The goals of her research are to understand the processes that lead to the creation of the ocean crust, the physical and chemical characteristics of the sub-ridge mantle, and the ways that the Earth evolves chemically through time. Her work ranges from global-scale studies of basalt composition and their correlation with physical parameters of the ridge to detailed studies of basalts collected using the *Alvin* submersible.

Dr. Klein's current research projects include mapping and sampling expeditions to the Chile Ridge, which is currently being subducted beneath the Chile Trench, and geochemical studies of dike, gabbro and lava samples collected during an *Alvin* dive program to the Hess Deep rift in the equatorial Pacific. Other on-going or recently completed projects include analyses of basalts from the Pacific-Antarctic Ridge, the Mid-Atlantic Ridge, the East Pacific Rise and the Australian-Antarctic Discordance.

**Kenneth R. Knoerr**, Ph.D., Professor of Environmental Meteorology and Hydrology; B.S.F., Forestry, University of Idaho; M.F., Ph.D., Forestry, Yale University  
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Dr. Knoerr's historical research interests have been in environmental meteorology and hydrology, concerned with a number of issues related to the management of forest lands. For many years his research focused on the processes by which forests interact with the atmosphere. This research emphasized the development of physical models for plant-environment interaction. In addition, there was an extensive micrometeorological experimental effort to collect data to help validate these models.

Recently his research has focused on an investigation of forest fires where unexpected fire behavior entrapped firefighters, often with the loss of some lives. This unexpected fire behavior can be the result of unexpected weather events or the result of not understanding the potential flammability of the forest fuels. This is a retrospective investigation of more than 100 fires in this century to evaluate the common causes of these entrapments.

**Loraine U. Kohorn**, Ph.D., Visiting Assistant Professor; B.A. Biology, Brown University; PhD. Biology, University of California at Los Angeles  
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Dr. Kohorn is primarily interested in plant conservation, with current research efforts focused on plant species protection in China. In conjunction with the World Conservation Union (IUCN) and Chinese botanists she is editing *A Status Survey and Conservation Action Plan for Plants of the Chinese Region*. Dr. Kohorn is currently active in conservation planning in Orange County and has served as chair of the Orange County Com-
mission on the Environment. She is also conducting a long-term study of the demographic dynamics of *Trillium catesbaei* in Orange County. Past research has focused on plant reproductive ecology and physiological ecology in desert species, and on effects of elevated carbon dioxide on early successional plant communities. Dr. Kohorn holds a joint appointment in the Nicholas School and the Department of Biology.

Randall A. Kramer, Ph.D., Professor of Resource and Environmental Economics; B.A., Economics, University of North Carolina; M.E., Economics, North Carolina State University; Ph.D., Agricultural Economics, University of California, Davis
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Dr. Kramer's research focuses on benefit cost analysis, the role of natural resources in economic development and the economics of ecological services. Two projects in Indonesia are focused on the economics of tropical and coastal resources. One study in northern Sulawesi is focused on the effects of human population growth and migration on the sustainable use of coastal resources. This study is also examining how public and community-based fisheries management affects economic activity. A second set of studies in Indonesia is on the economics of protected areas, with an emphasis on nature-based tourism, agricultural and forest extraction in buffer zones and watershed protection benefits. In North Carolina, Dr. Kramer's current work is concentrated on water resource issues. One study is examining economic and ecological criteria for selecting sites for wetlands restoration. Another current project is investigating public attitudes toward water quality protection on the Catawba River in western North Carolina.

Michael L. Lavine, Ph.D., Associate Professor of Statistics and Decision Sciences and of Environment; B.S., Mathematics, Beloit College; M.S., Mathematics, Dartmouth College; Ph.D., Statistics, University of Minnesota
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Dr. Lavine holds joint appointments at Duke in statistics (primary) and the environment (secondary). His primary research interests are in robust, nonparametric and spatial Bayesian statistical theory and environmental statistical applications.

Edward D. Levin, Ph.D., Associate Professor of Psychiatry and Behavioral Sciences and of Environment; B.A., Psychology, University of Rochester; M.S., Physiological Psychology, University of Wisconsin; Ph.D., Environmental Toxicology, University of Wisconsin
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Dr. Levin’s primary research effort is to understand basic neural interactions underlying cognitive function and to apply this knowledge to better understand cognitive dysfunction and to develop novel therapeutic treatments.

The three main research components of his laboratory are focused on the themes of the basic neurobiology of learning and memory, neurobehavioral toxicology and the development of novel therapeutic treatments for cognitive
dysfunction. Currently his principal research focus concerns nicotine and the basic effects of nicotine on cognitive function. Dr. Levin's group is continuing with more mechanistic studies in rat models using selective lesions, local infusions and neurotransmitter interaction studies. They have found that nicotine improves memory performance not only in normal rats, but also in rats with lesions of hippocampal and basal forebrain connections.

**Elwood A. Linney**, Ph.D., Professor of Microbiology and of Environment; B.S., Engineering Physics, University of Illinois; M.S., Biophysics, Michigan State University; Ph.D. Molecular Biology, University of California, San Diego  
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Dr. Linney’s laboratory focuses upon signal transduction during embryogenesis. Previously the laboratory focused upon mouse embryogenesis but recently the laboratory has directed its efforts on the zebrafish model so that live gene expression could be captured using transgenic zebrafish models, fluorescent reporter genes and fluorescence microscopy. Transgenic fish are being produced via DNA microinjection and through pseudotyped retroviral vector infection of zebrafish embryos. The laboratory has produced several transgenic fish models which express green fluorescent protein reporter genes in response to retinoids and estrogens. These models are being used to study the role of these signal transduction pathways during development. In addition, the models are being examined to determine whether they could be used as biosensors for environmental toxicants that impact upon the retinoid and estrogen pathways. Through these model systems one should be able to examine the direct effects of environmental toxicants on gene expression in live, developing organisms. Since other species of small fish have uniquely positive properties for toxicological studies, these transgenic techniques are now being applied to other fish models such as *Fundulus heteroclitus*.

**Daniel A. Livingstone**, Ph.D., James B. Duke Professor of Zoology and of Earth and Ocean Sciences; B.S., Biology, M.S., Zoology, Dalhousie University; Ph.D., Zoology, Yale University  
*Email: livingst@duke.edu*  
Dr. Livingstone studies the circulation and chemical composition of lakes in tropical Africa and how the distribution and abundance of organisms are affected by them. The aim is to understand tropical lakes as climatically-controlled ecological systems, and especially how the environment controls the properties of lake sediments. This understanding is used with cores taken from lake sediments to work out the history of changing climate and changing vegetation. The ultimate aim is two-fold: to understand global climatic change and to see how the climatic history of Africa has affected the plants and animals that live there. Among the most interesting of those organisms are *Homo sapiens* and its hominid ancestors.
M. Susan Lozier, Ph.D., Truman and Nellie Semans Associate Professor of Earth and Ocean Sciences; B.S., Chemical Engineering, Purdue University; M.S., Chemical Engineering, Ph.D., Oceanography, University of Washington  
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Dr. Lozier's research lies in the field of physical oceanography. The overriding direction of her research is toward an evaluation of the ocean as a reservoir for climate signals. By understanding the extent to which climatic anomalies spread from their source region, and the rapidity of that spreading, Dr. Lozier aims to determine the effectiveness of the deep ocean as a climatic reservoir for heat. Toward this end, her research is aimed at answering how climatic signals are transmitted throughout the global ocean, with a particular emphasis on the North Atlantic basin, a choice dictated by this basin’s unparalleled data density and its overriding importance to the global climate. A current research emphasis is on the study of the climatological property fields in an effort to assess the impact of recirculations on the distribution of climate signals. Dr. Lozier also studies cross frontal mixing mechanisms in the ocean. Currently, she is studying the dynamics of shelfbreak flow in an effort to understand how properties such as heat, sediment and nutrients are transported from the shelf to the open ocean.

Lynn A. Maguire, Ph.D., Associate Professor of the Practice of Environmental Management; A.B., Biology, Harvard University; M.S., Resource Ecology, University of Michigan; Ph.D., Ecology, Utah State University  
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Dr. Maguire's current research uses a combination of methods from decision analysis, environmental conflict resolution and social psychology to study environmental decision making. Dr. Maguire focuses on collaborative decision processes where values important to the general public and stakeholders must be combined with technical analysis to determine management strategies. These studies evaluate both the substance of environmental decisions—how well the resulting management actions reflect public values and available science—and the process of environmental decision making—how well the mechanisms used to involve the public achieve social justice goals. Dr. Maguire and her students have been applying these approaches to collaborative decision processes for public land management and for water quality management in North Carolina and elsewhere.

Peter E. Malin, Ph.D., Professor of Seismology and Professor of Civil and Environmental Engineering; B.S., Geophysics, Stanford University; M.S., Marine Geophysics, Stanford University; Ph.D., Seismology, Princeton University.  
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Dr. Malin joined the Department of Geology in 1991 after more than a decade as a research seismologist at the University of Southern California and the University of California. His interests include tectonics, seismic wave propagation, and earthquakes, with current focus on central California. Since seismic waves are inseparable from the geology in which they originate and travel, his research has become increasingly interdisciplinary, emphasizing the ap-
Current projects at Duke include the mechanics of the San Andreas fault at Parkfield, the seismotectonics of the Coso Geothermal area, and seismic exploration of the southern Sierra Nevada, Owens Valley, and San Joaquin regions. The Duke-associated downhole seismometer networks at Parkfield and Coso have revealed patterns in seismicity that suggest the interaction of aseismic and seismic fault slip. Along with several other universities, the Duke seismology group determined the location of crossed, 300 km long refraction profiles in the Sierra Nevada/Death Valley region in 1993. The seismic networks offer the chance for hands-on study of seismicity and earthquake mechanics. The active seismic profiling projects provide experience with seismic imaging of crustal structure.

Patricia D. McClellan-Green, Ph.D., Research Scientist; B.S., M.S., Biology, East Carolina University; Ph.D., Toxicology, North Carolina State University
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Dr. McClellan-Green studies gene regulation and expression by aquatic organisms in response to xenobiotic exposure. Research is under way to determine the mechanism of PAH and PCB mediated gene regulation in fish. Other areas of interest include the identification and characterization of various cytochrome P-450s in aquatic organisms and the genetic regulation of select P-450 genes.

She is in residence at the Marine Laboratory.

Margaret A. McKean, Ph.D., Associate Professor of Political Science and of Environment; B.A., Political Science and Asian Studies, University of California at Berkeley; M.A., Far Eastern Studies, Harvard University; Ph.D., Political Science, University of California at Berkeley
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Dr. McKean's initial interests in environmental issues focused on Japan's political response to serious pollution problems. She then turned to a consideration of environmental problems as collective action dilemmas and of environmental resources as common-pool goods subject to problems of underprovision and depletion. Her work on the Japanese experience at managing forest commons led to a broader interest in the relationship between property rights and environmental outcomes in both developing and developed worlds, in both past and present.

Her current research is aimed at learning when and where common property regimes may be used to enhance environmental efficiency and under what conditions governments become willing to devolve property rights onto communities and individual citizens.
Miguel A. Medina, Jr., Professor of Civil and Environmental Engineering and of Environment. B.S., M.S., Civil Engineering, University of Alabama; Ph.D., Water Resources and Environmental Engineering Sciences, University of Florida
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Dr. Medina’s research interests focus on water resources, hydrologic and water quality mathematical modeling, integration of contaminant transportation prediction models within a decision-analysis framework for risk assessment.

Marie Lynn Miranda, Ph.D., Dan and Bunny Gabel Associate Professor of the Practice of Environmental Ethics and Sustainable Development; A.B., Economics and Mathematics, Duke University; M.A., Ph.D., Economics, Harvard University
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Dr. Miranda’s primary research is in environmental health sciences, environmental justice, and resource and environmental economics, with an emphasis on interdisciplinary, policy-oriented perspectives. Dr. Miranda holds a deep interest in children’s special vulnerability to environmental toxicants. She has developed courses and conducted research on issues of environmental health with a particular emphasis on reproductive and developmental toxicants and childhood lead exposure. Her most recent work uses Geographic Information Systems technology to develop predictive risk exposure models for children’s environmental health, including lead-based paint, allergen and asthma triggers, and fire risks. Dr. Miranda has also conducted extensive research on the effectiveness of market-based incentives and pollution prevention policies on the management of domestic solid waste. She teaches courses on introductory environmental policy, United States environmental policy, and a senior capstone course titled “Endocrine Disruptors in the Environment.”

A. Bradshaw Murray, Ph.D., Assistant Professor of Geomorphology and Coastal Processes; B.A., Journalism, University of Minnesota; B.I.S., General Science, University of Minnesota; M.S., Physics, University of Minnesota; Ph.D., Geology, University of Minnesota
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Dr. Murray is interested in many surficial processes and patterns, including rivers and a range of desert, arctic, and alpine phenomena. His recent efforts have focused on coastal geomorphology and near-shore processes. The near-shore environment is a spatially extended system that exhibits complex, dynamic spatial patterns, including the arrangement of bars and channels, waves and often an array of along-shore and cross-shore currents. Dr. Murray approaches such systems with different perspectives and uses different techniques than have been employed traditionally. Drawing on lessons from nonlinear dynamics and the emergent phenomenon viewpoint, he looks for possibly simple, large-scale interactions that could explain complex behaviors. He uses relatively simple, cellular-automata-like models that incorporate only the interactions hypothesized to be important to determine if they are sufficient to produce the phenomena.

Another aspect of Dr. Murray’s research involves evaluating models of complex
systems, for which linear statistics concerning the system's behavior may not sensitively reflect the interactions that produced them. He applies and develops nonlinear data analysis techniques to sensitively test how realistic model interactions are. Dr. Murray is currently applying these methods to beach and surf zone problems, but plans to widen his focus onshore and offshore, to include studies of currents and sediment transport beyond the surf zone, as well as the formation and evolution of large-scale shoreline features.

**Michael K. Orbach**, Ph.D., Professor of the Practice of Marine Affairs and Policy; B.A., Economics, University of California, Irvine; M.A., Ph.D., Cultural Anthropology, University of California, San Diego  
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Dr. Orbach's research interests are in the application of social and policy sciences to coastal and ocean policy and management. His work uses a cultural, or human, ecology perspective to analyze human behavior in coastal and ocean environments. His current research projects include (1) the development and application of limited entry and effort management systems to marine fisheries; (2) the formation and socioeconomic impact of marine minerals policy; (3) marine mammal and endangered species-fisheries conflicts; and (4) citizen involvement in coastal and ocean policy.

Dr. Orbach specializes in the application of science to the policy and management process. He is in residence at the Marine Laboratory.

**Ram Oren**, Ph.D., Associate Professor of Ecology/Ecophysiology; B.S., Forest Resource Management, Humboldt State University; M.S., Ph.D., Forest Ecology, Oregon State University  
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Dr. Oren's research examines the effect of environmental and climatic conditions on individuals of many tree species. Depending on the sensitivity of species in each forest, forests respond to variation in the environment by changing water, carbon dioxide and energy flow between the biosphere and atmosphere. Using a local mass balance approach and detailed measurements of water flux and driving variables in the soil, plants and the atmosphere in forests from Brazil to Alaska, Dr. Oren's group evaluates the likely responses of different forest ecosystems to environmental change.

With his graduate students, Dr. Oren quantifies the components of water flux in forest ecosystems, and the influence of certain biotic and abiotic factors on these components. Climate variability, including variations in air temperature, vapor pressure deficit, incoming radiation and soil moisture, and environmental change, including elevated atmospheric carbon dioxide, affect intra and inter annual patterns and amounts of water used by forest ecosystems and their spatial distributions. These variations influence the temporal and spatial partitioning of incoming radiation between latent and sensible heat and the amounts of carbon dioxide taken from, or released to, the atmosphere.
J. Jeffrey Peirce, Ph.D. Associate Professor of Environmental Engineering and of Environment. B.E., Engineering Mechanics, The Johns Hopkins University; M.S., Ph.D., Civil and Environmental Engineering, University of Wisconsin at Madison
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Dr. Peirce has been a professor of environmental engineering at Duke for the past 20 years and has directed more than $2,200,000 in research sponsored by the National Science Foundation, the U. S. Environmental Protection Agency, the US. Department of Energy, the Governor's Office of the State of North Carolina, as well as selected industries. He has served as major professor for 60 graduate degrees at Duke with an emphasis on the design, construction and use of experimental devices to observe, measure and model the movement of fluids, non-water liquids and gases, through porous materials in natural and engineered systems. His current research focuses on the production and transformation of gases in soil and the transport to the lower troposphere. In 1984 Dr. Peirce was in the first group of researchers to receive the Presidential Young Investigator Award from the National Science Foundation.

Orrin H. Pilkey, Ph.D., Research Professor and James B. Duke Professor Emeritus of Geology. B.S., Geology, Washington State College; M.S., Geology, University of Montana; Ph.D., Geology, Florida State University
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Dr. Pilkey’s research centers on both basic and applied coastal geology, focusing primarily on barrier island coasts. Off Wrightsville Beach, NC, advantage is being taken of a petrographically distinct beach replenishment sand to determine paths of sand transport on the shoreface. Another ongoing project involves a detailed study of the evolution of salt marshes along various shoreline types in Pamlico and Albemarle Sounds. The goal is to understand how salt marshes in various geological settings will respond to a future rise in sea level and how this impacts on management strategies for salt marshes.

Recently, Dr. Pilkey’s group, along with INGEO-MINAS, carried out the first phase of a study of the Colombian Pacific Coast barrier island chain. Future studies will involve detailed coring of selected individual islands to determine how barrier islands evolve in tectonically active areas completely away from the influences of humans.

Applied studies are carried out under the auspices of the Program for the Study of Developed Shorelines (PSDS). Such studies have included a review of the national beach replenishment experience on all 3 U.S. coasts and analysis of the validity of replenished beach engineering design parameters. The PSDS group is currently exploring, from a geologic viewpoint, methods for mitigating hurricane damage on barrier islands. The PSDS is also analyzing the numerical models used by coastal geologists and engineers to predict the movement of beach sand, especially on beach replenishment projects.
Lincoln F. Pratson, Ph.D., Assistant Professor of Sedimentary Geology; B.S., Geology, Trinity University; M.S., Oceanography, University of Rhode Island; M.Ph., Ph.D., Geology, Columbia University  
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Dr. Pratson's research revolves around the role of sedimentary processes in shaping continental margins. Specific research interests include the dynamics of both current- and gravity-driven sediment transport, submarine canyon formation and seafloor evolution, the causes and consequences of submarine slope failure, and the interplay between marine sedimentation and tectonics. He conducts this research using a variety of methods. These range from seafloor mapping using multibeam bathymetry, side-scan sonar imagery, and shallow cores, to sequence stratigraphy based on seismic reflection and borehole data constrained in some instances by gravity measurements.

Dr. Pratson also develops numerical models of sedimentary processes for testing ideas about their dynamics and predicting their contribution to and imprint on the morphology and stratigraphy of continental margins. At present, he is working with researchers at the St. Anthony Falls Laboratory of the University of Minnesota using a new experimental tank to investigate the interplay between sediment supply, sea level change and subsidence in creating sedimentary sequences.

Joseph S. Ramus, Ph.D., Professor of Biological Oceanography; A.B., Ph.D., Botany, University of California, Berkeley  
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Dr. Ramus’s research includes the study of physical forcing of primary productivity in coastal plains estuaries. The research seeks a match between physiological response and the temporal frequency of physical drivers, the phasing of the organism with its environment. Another of Dr. Ramus's interests involves biotechnological research which includes extracellular polysaccharides produced by marine microphotoautotrophs. Two aspects are under investigation: (1) environmental regulation of carbon partitioning; i.e., the diversion of newly fixed carbon from growth (new photosynthetic machinery) to disposable heteropolysaccharides (viscoelastic biopolymers), and (2) drag reducing properties of the biopolymers in pipe flow. A third area under investigation is photoacclimation and photoinhibition in seaweeds and seagrasses. Of specific interest are macromolecular changes in the photosynthetic apparatus, the dynamic range of change and the effect of change on growth rate.

He is in residence at the Marine Laboratory.

Andrew J. Read, Ph.D., Rachel Carson Assistant Professor of Marine Conservation Biology; B.S., M.S., Ph.D., Zoology, University of Guelph  
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Dr. Read studies the ecology and conservation biology of marine mammals. His work focuses on how dolphins and porpoises obtain prey in a three-dimensional environment and how energy is partitioned among the competing demands of growth, maintenance and reproduction. This work involves field observation, experimentation and modeling. He is also interested in the impacts of human activities on populations of marine mammals.
and attempts to find solutions to such conflicts, particularly between marine mammals and commercial fisheries. This aspect of his work includes studies of animal behavior, modification of fishing practices to reduce mortality, and demographic analyses of the effects of removals. He is particularly interested in the development and application of new conservation tools to resolve such conflicts. He is in residence at the Marine Laboratory.

Kenneth H. Reckhow, Ph.D., Professor of Water Resources; B.S., Engineering Physics, Cornell University; M.S., Ph.D., Environmental Science and Engineering, Harvard University
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Dr. Reckhow's research activities have focused on the development, evaluation, and application of models for the management of water quality. In particular, he is interested in the effect of uncertainty on model specification, parameter estimation, and model applications. Recent work has expanded this theme to consider the effect of scientific uncertainties on water quality decision making.

Among the problems that Dr. Reckhow's research group has examined are lake eutrophication, toxic substances, and acid rain. Past work on eutrophication has centered on the development and evaluation of empirical models, estimation of prediction uncertainty using first order error analysis and Monte Carlo simulation, and a decision analytic approach to lake management. Current work by Dr. Reckhow and his students concerns probability (Bayes) networks and pattern recognition for eutrophication modeling.

Curtis J. Richardson, Ph.D., Professor of Resource Ecology; B.S., Biology, State University of New York at Cortland; Ph.D., Ecology, University of Tennessee
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Dr. Richardson's research interests in applied ecology center on long-term ecosystem response to large-scale perturbations such as acid rain, toxic materials, trace metals, flooding or nutrient additions. He has specific interests in wetland ecosystems, phosphorus nutrient dynamics in wetlands and the effects of environmental stress on plant metabolism and growth. Major research efforts have focused on wetlands as nutrient sinks and transformers. The central hypothesis being tested is that wetland ecosystems function as natural sinks (i.e., nutrient removal systems) for downstream ecosystems.

His current research activities include:
• Wetland restoration and its effects on regional water quality and nutrient biogeochemical cycles.
• The effects of agricultural runoff and hydrological alterations on Everglades nutrient cycling and storage.
• Development of ecosystem metrics as indices of wetland restoration success.
• The effects of highway construction on wetland functions.
• Wetland development trends in the southeastern United States.
• The effects of wetland land development on regional hydrologic flux and water quality.

The objectives of his field research are to test ecological principles and develop new approaches to environmental problem solving. The goal of these studies is to provide predictive models to aid in the management of ecosystems.
Daniel D. Richter, Ph.D., Professor of Soils and Forest Ecology; B.A., Philosophy, Lehigh University; Ph.D., Forest Soils, Duke University
E-mail: drichter@duke.edu
Dr. Richter's research objectives are centered on understanding and quantifying soil change that is affected by forest development and land use over time scales of decades and centuries. His work is directed at quantifying how ecosystem processes control the chemistry of soils, drainage waters and forest productivity. His scientific interests in these topics are motivated by a desire to improve the management of soil-plant-watershed systems. The responses of poorly buffered soils are of most interest, most particularly extremely weathered, acidic Ultisols that are common to the southeastern United States and to the humid tropics. His research objectives are pursued both individually and cooperatively with scientists from several disciplines. His primary educational objectives are to help students develop an understanding of and appreciation for ecological functions of soil and forest ecosystems through lectures, seminars, field trips, and indoor and outdoor laboratories.

Daniel Rittschof, Ph.D., Associate Professor of Zoology; B.S., Ph.D., Zoology, University of Michigan
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Dr. Rittschof's research interests involve chemical communication systems. His studies include external and internal molecular mediation of behavior (chemical ecology). At present, test systems are marine and include crustaceans (true crabs, hermit crabs and barnacles), molluscs and fish. Studies span the gamut from practical (nontoxic antifouling coatings, fish foods and fish feeding stimulants) to purely basic (larval release pheromones, designer peptides with biological activity, hermit crab shell attractant cues, hormonal control of feeding behavior, and enzymatic activities in crustacean and gastropod saliva). The driving theme of the work is the evolution of chemical communication systems and their components. He is in residence at the Marine Laboratory.

Stuart Rojstaczer, Ph.D., Associate Professor of Geology and Civil and Environmental Engineering; B.S., Geology, University of Wisconsin; M.S., Geology, University of Illinois; Ph.D., Applied Earth Sciences, Stanford University
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The broad aim of Dr. Rojstaczer's research is to understand better the role of subsurface fluid flow in geologic and human-induced hazards. A subsidiary interest is in the development of new techniques to determine elastic and fluid flow properties of the Earth in situ.
Dr. Rojstaczer and his students have recently examined many research topics including: land subsidence in the San Joaquin-Sacramento Delta (a region critical to water supply in California); groundwater flow induced by tectonic activity along the San Andreas Fault; the mechanics of geysers; measurement of air permeability in the field; rates of flow and residence times of fluids in karst; and interpolation of per-
meability structure in the presence of sparse data.

Central to the approach of examining these problems is the integration of field-derived data with theory. The research frequently requires the use of novel field collection techniques or the use of conventional techniques in novel settings. The field data is used to constrain quantitative models that describe the physical and chemical processes underlying the observations.

He is director of the Center for Hydrologic Science.

William H. Schlesinger, James B. Duke Professor of Biogeochemistry, and Dean of the Nicholas School of the Environment and Earth Sciences. A.B., Biology, Dartmouth College; Ph.D., Ecology and Systematics, Cornell University.
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Dr. Schlesinger focuses his research on the role of soils in the global carbon cycle. He is the co-principal investigator for the Free Air Carbon Dioxide Enrichment (FACE) Experiment in the Duke Forest—a project that aims to understand how an entire forest ecosystem (vegetation and soils) will respond to growth in elevated CO₂. He also has worked extensively in desert ecosystems and their response to global change—often leading to the degradation of soils and regional desertification. He served as Principal Investigator for the NSF-sponsored program of Long Term Ecological Research (LTER) at the Jornada Basin in southern New Mexico from 1991 to 2000. His past work has taken him to diverse habitats, ranging from Okefenokee Swamp in southern Georgia to the Mojave Desert of California. His research has been featured on NOVA, CNN, NPR, and on the pages of Discover, National Geographic, The New York Times, and Scientific American. Dr. Schlesinger has testified before U.S. House and Senate committees on a variety of environmental issues, including preservation of desert habitats and global climate change. He is a member of the Committee on Global Change Research of the National Academy of Sciences and the National Geographic Society's Committee on Research and Exploration. Dr. Schlesinger also serves as Vice President for Finance and Investments for the Ecological Society of America.

A member of Duke faculty since 1980, he is the author or coauthor of more than 130 scientific papers and the widely-adopted textbook, Biogeochemistry: An analysis of global change (Academic Press, 2nd ed. 1997). He was elected a member of the American Academy of Arts and Sciences in 1995.

Martin D. Smith, Ph.D., Assistant Professor of Environmental Economics; B.A., Public Policy, Stanford University; Ph.D., Agricultural and Resource Economics, University of California
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Dr. Smith’s research focuses on spatial issues in natural resource use and management, particularly in the marine environment. Dr. Smith specializes in applied econometrics and bioeconomic modeling. His current research projects include (1) evaluating marine reserves as a commercial fishery management tool, (2) studying the spatial and intertemporal behavior of renewable resource harvesters, (3) modeling the impacts of commercial fishing on endangered species through predator-prey interactions, (4) analyzing private agricultural land use decisions in federally managed wetlands, and (5) identifying transition dynamics in the organic farming industry.
Craig A. Stow, Ph.D., Visiting Assistant Professor of Water Resources; B.S., Environmental Technology, Cornell University; M.S., Marine Sciences, Louisiana State University; Ph.D., Environmental Modeling, Duke University
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Dr. Stow's research interests focus on the application of statistical modeling techniques to assist with management decisions in aquatic ecosystems. His work has included assessments of sediment-water nutrient interactions in lakes, patterns of contaminant bioaccumulation in Great Lakes fishes, and the effect of observation error on parameter estimation and model prediction. Dr. Stow's current research includes a study of food-web effects and fish growth rates on PCB bioaccumulation in Lake Michigan, a study of nutrient loading patterns in the Neuse River estuary, and an assessment of phosphorus levels in the Florida Everglades.

John W. Terborgh, Ph.D., James B. Duke Professor of Environmental Science; B.S., Biology, M.S., Ph.D., Plant Physiology, Harvard University
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Dr. Terborgh's interests lie in the fields of tropical ecology and conservation. At different times in his career he has studied birds, primates, herbs, and forest trees, and has directed student projects involving butterflies, lizards, amphibians, and crocodilians. The common denominator in all this work has been the goal of solving problems of general ecological interest using a comparative approach. Some typical comparisons have involved seasonal patterns in resource utilization by forest primates, habitat use by Amazonian birds, and latitudinal variation in the structure of mature forests.

Applications of ecology to conservation have increasingly become a central theme of his work. He regards as particularly important the need to understand the many consequences of habitat fragmentation, especially those related to the disruption of trophic level processes.

Dean L. Urban, Ph.D., Associate Professor; B.A., Botany and Zoology, M.A., Wildlife Ecology, Southern Illinois University; Ph.D., Ecology, University of Tennessee
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Dr. Urban's research interest is in landscape ecology: the development and implications of landscape pattern. He uses spatial simulation models and field studies to explore the interplay of abiotic environmental templates (temperature, moisture gradients), biotic processes (plant demography, competition, dispersal), and disturbances (including human land use) in governing forest pattern in montane landscapes. One current project uses a model as a framework for comparisons among forests in the Oregon Cascades, the Sierra Nevada of California, the White Mountains of New Hampshire, and the southern Appalachians of North Carolina. More recently, he has begun to explore the socioeconomic and environmental factors governing land use change in the Triangle region of North Carolina, centered on Durham and the Duke Forest.

Building on his work in forests, Dr. Urban is also interested in wildlife communities
in patchy landscape mosaics. His focus is on how landscape pattern and metapopulation processes interact to generate landscape-scale patterns in biodiversity. One emphasis of this research is to use models, interfaced with geographic information systems, to explore alternative conservation strategies.

Carel P. van Schaik, Ph.D., Professor of Biological Anthropology and Anatomy and of Environment; B.S., Biology, M.S., Ethology and Plant Ecology, Ph.D., Ethology, Utrecht University
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Dr. van Schaik is a tropical ecologist and ethologist with Duke’s Department of Biological Anthropology and Anatomy. His ecological research focuses on fungivores in tropical rain forests and their response to resource seasonality and disturbance. He is also interested in strategies of conserving biological diversity.

Dharni Vasudevan, Ph.D., Assistant Professor of Environmental Chemistry; B.S., Environmental Engineering Science, Massachusetts Institute of Technology; MSE, Environmental Engineering, Johns Hopkins University; Ph.D., Environmental Chemistry, Johns Hopkins University.
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Dr. Vasudevan is interested in the environmental chemistry of anthropogenic and naturally occurring organic and inorganic compounds at the solid-water interface, particularly the role of abiotic interfacial (surface) processes in the attenuation and mobilization of organic and inorganic compounds in subsurface environments (soil and subsoil systems) and surface waters (particle/water interface). This is an exciting and challenging area of research that serves to advance the understanding of fundamental principles and processes in environmental surface chemistry, while addressing societal and environmental concerns. The knowledge base developed from this research contributes to the characterization and prediction of chemical fate and transport and the evaluation of the role played by naturally occurring surfaces in biogeochemical cycling and site remediation.

Central research issues include the study of sorption, desorption and coordination chemistry; surface complexation theory; mineral precipitation, dissolution, and weathering; and surface-assisted chemical transformation processes. Dr. Vasudevan and her group use a combination of controlled laboratory experiments, molecular and surface complexation modeling, and statistical tools in their research. Completed and current projects have emphasized the study of iron oxide-rich soils (NC ultisols) and pure phase minerals (iron, aluminum and titanium oxides, silica, and kaolinite) and include: organic (pesticide/herbicide) and inorganic compound (phosphate and fluoride) sorption-desorption in soils; sorption of organic ligands with -OH, -COOH, -NH2, heterocyclic N groups at the metal-oxide water interface; influence of phosphate on organic compound retention in soils; use of approved tracers as surrogates for pesticide fate and transport; chemometric analysis of pesticide retention; and dissolved organic carbon characterization and retention in soils. See http://envchem.env.duke.edu.
Jonathan B. Wiener, J.D., Professor of Law and of Environmental Policy; A.B., Economics, Harvard College; J.D., Harvard Law School
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A member of the Duke Law School faculty, Mr. Wiener is interested in the interplay of science, economics, and law in addressing environmental and human health risks. Before coming to Duke, he worked in the area of environmental policy at the White House Council of Economic Advisers and Office of Science and Technology Policy, and at the United States Department of Justice. He also helped organize the environmental component of the AmeriCorps national service program. His policy work and writing have addressed topics including climate change, forests conservation, risk, biotechnology, mass torts, and incentives in regulation and litigation. He attended the Rio Earth Summit in 1992. In 1998, he served as president of the Society for Risk Analysis, Research Triangle Chapter. In 1999, he was a visiting professor at Harvard Law School.

Robert L. Wolpert, Ph.D., Associate Professor of Statistics and Decision Sciences and of Environment; A.B., Mathematics, Cornell University; Ph.D., Mathematics, Princeton University
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A member of Duke's Institute of Statistics and Decision Sciences, Dr. Wolpert is interested in the theory and foundations of statistical inference and in the application of advanced mathematical, numerical and statistical methods to the modeling and study of environmental and biological systems. His current research stresses the study of model selection, model validation, and uncertainty analysis for environmental simulation and risk-assessment models. Originally trained as a mathematician specializing in probability theory and stochastic processes, he was drawn to statistics by the interplay between theoretical and applied research.

Extended Faculty

S. Marshall Adams, Ph.D., Adjunct Professor; B.S., Wildlife Biology, M.S., Zoology, North Carolina State University; Ph.D., Marine Science, University of North Carolina at Chapel Hill
Dr. Adams is principal investigator of several large projects at Oak Ridge National Laboratory related to effects of environmental stress on aquatic ecosystems. His research interests are in the general areas of environmental impact assessment and biological indicators of aquatic ecosystem health.

Dianne Ahmann, Ph.D., Adjunct Assistant Professor; B.A., Biochemistry and Molecular Biology, Harvard College; Ph.D., Biology, Massachusetts Institute of Technology
Dr. Ahmann’s research focuses on the roles of microbial oxidation-reduction reactions in biogeochemistry and in environmental biotechnology. She is currently studying the effect of elevated atmospheric CO2 on microbial methane consumption in the Duke Forest FACTS-I facility, as well as the microbial production of alternative fuels in conjunction with researchers at the National Renewable Energy Laboratory. Dr. Ahmann is an assistant professor at the Colorado School of Mines, Golden, CO.

Steven Anderson, Ph.D., Adjunct Professor; B.A., Forest Management, Rutgers University; M.S., Forest Soils, University of Washington; Ph.D., Forest Economics, North Carolina State University.
Since mid-1997, Dr. Anderson has served as President and CEO of the Forest History Society which is based in Durham NC. He has broad experience in leading programs for extension forestry, wildlife, and aquaculture, and has provided leadership and vision in the identification and development of numerous educational programs.

**Marius Brouwer**, Ph.D., Adjunct Professor; B.S., Biology, M.S., Biochemistry and Microbiology, Ph.D., Biochemistry, University of Groningen, The Netherlands

Dr. Brouwer heads the toxicology section at the University of Southern Mississippi Institute for Marine Sciences/ Gulf Coast Research Laboratory. His research interests center around the study of the dual role of metals and oxygen as essential and toxic elements in biological systems, using marine organisms as experimental animals.

**Nora G. Bynum**, Ph.D., Adjunct Assistant Professor; B.A., Anthropology, Duke University; M.Phil., Ph.D., Anthropology/Forestry and Environmental Studies, Yale University.

Dr. Bynum is the Academic Director for the Organization for Tropical Studies at Duke University. She has taught at Duke University and the University of the South, and is currently Academic Director for the Organization for Tropical Studies located on the Duke campus.

**Russell C. Cattley**, Ph.D., Adjunct Assistant Professor; B.S., Rutgers University; M.S., Clemson University; V.M.D., University of Pennsylvania; Ph.D., University of North Carolina

Dr. Cattley’s areas of scientific interest are chemical carcinogenosis and toxicologic pathology. He serves as associate manager of the Cancer Program at the Chemical Industry Institute of Toxicology located in the Research Triangle Park.

**Fei Chai**, Ph.D., Adjunct Assistant Professor; B.S., Shandong College of Oceanology, P.R.China; M.A., Princeton University; Ph.D., Duke University

Dr. Chai is assistant professor of oceanography at the School of Marine Sciences, University of Maine. He is currently involved in research collaboration with Professor Barber of the Nicholas School.

**Yi Chao**, Ph.D., Adjunct Assistant Professor; B.S., Atmospheric Physics, University of Science and Technology of China; M.A., Geophysical Fluid Dynamics, Ph.D., Atmospheric and Ocean Sciences, Princeton University

Dr. Chao’s research interests seek to improve our understanding of the general circulation of the ocean and to determine its role in the Earth system and global climate. He is a member of the technical staff at the Jet Propulsion Laboratory of the California Institute of Technology.

**Sherri L. Cooper**, Ph.D., Adjunct Assistant Professor; B.S., Botany, Duke University; M.S., Marine Studies, University of Delaware; Ph.D., Physical Geography, Johns Hopkins University

Dr. Cooper’s interests include using paleoecological tools to re-create the history of water quality and vegetation changes in aquatic systems and watersheds, related to both climatic influences and anthropogenic effects. Her specialties include estuarine systems and diatom analysis. Current research is focused on the recent history of the Everglades, to recreate the vegetation, water quality, and fire history over the past 200 years for use in restoration plans.

**Humberto Díaz**, Ph.D., Adjunct Professor; B.S., Biology, Universidad Central de Venezuela; Ph.D., Zoology, Duke University

Dr. Díaz continues to conduct active research following a 30-year career in the administration of the Instituto Venezolano de Investigaciones Científicas (IVIC). His primary scientific interest is in the coastal benthic crustacean, and he works at the interface
Extended Faculty

Michael P. Dieter, Ph.D., Adjunct Professor; B.S., University of Notre Dame; M.A., Ph.D., Zoology, University of Missouri

Dr. Dieter is a physiologist and science editor for Environmental Health Perspectives at the National Institute of Environmental Health Sciences. His research interests lie in the area of environmental toxicology of metals, mammalian toxicology and carcinogenesis, and cellular biochemistry and physiology.

George R. Dubay, Ph.D., Adjunct Assistant Research Professor; B.S., Chemistry, Fairfield University; Ph.D., Physical Organic Chemistry, Duke University

Director of instrument operations in Duke's chemistry department, Dr. Dubay is interested in mass spectrometry methods to identify and quantify environmental contaminants and biochemically interesting compounds.

David S. Ellsworth, Ph.D., Adjunct Assistant Professor; B.S., Biological Sciences, Cornell University; Ph.D., Forestry, University of Wisconsin, Madison

Dr. Ellsworth currently participates in research in the Duke Forest concerning the physiological effects of carbon fluxes on pines under ambient and elevated inputs of carbon dioxide. He is a plant physiologist in the biosystems and process sciences division of Brookhaven National Laboratory.

David W. Engel, Ph.D., Adjunct Assistant Professor, B.A., Pre-Medicine, Ohio Wesleyan University, M.A., Zoology, Duke University, Ph.D., Zoology, North Carolina State University

Dr. Engel studies the metabolism and toxic effects of trace metals to marine organisms. In addition, he is involved in a study looking at the natural and physiological processes that control methyl mercury accumulation through the food webs to top predator marine and freshwater fish.

Dale A. Gillette, Ph.D., Adjunct Professor of Geology; B.A., Astronomy, M.S., Ph.D., Meteorology, University of Michigan, Ann Arbor

Dr. Gillette, physical scientist at the NOAA Air Resources Laboratories, is interested in eolian processes and has concentrated on mechanisms of wind erosion and applications to geology and ecology. He has provided information on many of the mechanisms of wind erosion.

Milton S. Heath, Jr., J.D., Adjunct Professor; A.B., Harvard University; LL.B., J.D., Columbia University

Dr. Heath specializes in environmental and natural resource law and administration, and the legislative and other governmental aspects of resource development. He is on the faculty of the Institute of Government at the University of North Carolina at Chapel Hill.

George R. Hendrey, Ph.D., Adjunct Professor; B.A., Zoology, M.S., Water and Air Resources, Ph.D., Limnology, University of Washington

Dr. Hendrey is head of the Biosystems and Process Sciences Division at Brookhaven National Laboratory and co-director of the Forest-Atmosphere Carbon Transfer and Storage (FACTS) project operating in the Duke Forest. His primary research interests are in ecology and the development of integrated field experiments for ecosystem analysis.

Thomas P. Holmes, Ph.D., Adjunct Professor; B.S., M.S., Agricultural Economics, University of Connecticut; Ph.D., Economics, Ohio Wesleyan University

Dr. Holmes is a research forester with the USDA Forest Service's Economics of Forest Protection and Management work unit at Research Triangle Park, N.C. His research focuses on the application of nonmarket valuation methods to problems of forest ecosystem protection and conservation in the United States and Brazil.

Extended Faculty 45
Peter A. Howd, Ph.D., Adjunct Assistant Professor; B.A., Geology and Economics, Williams College; M.S., Ph.D., Oceanography, Oregon State University

Dr. Howd’s studies focus on how waves and currents interact to determine the evolution of beach morphology, and how changing global weather patterns may alter the evolution of undeveloped shorelines. Having once served on the Nicholas School of the Environment’s faculty at the Duke Marine Laboratory, he is now on the faculty of the Department of Marine Science, University of South Florida.

Eric S. Kasischke, Ph.D., Adjunct Assistant Professor; B.S., Natural Resources, M.S., Remote Sensing, Ph.D., Remote Sensing and Forest Ecology, University of Michigan

Dr. Kasischke is a research engineer in the Earth Sciences division of the Environmental Research Institute of Michigan. His research revolves around two primary interests: utilization of airborne and satellite imagery to study characteristics and patterns of change in forested landscapes, and development of methods to monitor the location, areal extent and damage of fires in Alaskan boreal forests.

Gregory L. Kedderis, Ph.D., Adjunct Associate Professor; B.S., Chemistry, Worcester Polytechnic Institute; Ph.D., Biochemistry, Northwestern Medical and Dental School

Dr. Kedderis’ research interests include mechanisms of toxicity of drugs and xenobiotics; genotoxicity and chemical carcinogenesis; xenobiotic oxidation by cytochromes P450; biotransformations of chemicals; enzymology; and the relationship between chemical dosimetry and biological effects. He is a Scientist II at the Chemical Industry Institute of Toxicology, Research Triangle Park.

E. Ann LeFurgey, Ph.D., Adjunct Associate Research Professor; B.S., Biology, Chemistry, Maryville College; M.S., Ph.D., Marine Sciences, University of North Carolina, Chapel Hill

Director of the analytical electron microscopy facility in Duke University Medical Center’s Department of Cell Biology, Dr. LeFurgey is a cell physiologist with interest in the mechanisms of toxic injury in cells elicited by metals and organic pollutants. Her laboratory is one of few worldwide which focuses on the application of quantitative electron probe x-ray microanalysis and imaging to problems in environmental health and toxicology.

A. Dennis Lemly, Ph.D., Adjunct Assistant Professor; B.S., Biology, Western Carolina University; M.A., Science Education, Ph.D., Aquatic Ecology, Wake Forest University

Dr. Lemly is a senior research scientist with the US Forest Service Fisheries Research Unit at Virginia Tech University. His work is focused on the development and testing of fish/ macroinvertebrate bioindicators for wetland risk assessment.

Steven T. Lindley, Ph.D., Adjunct Assistant Professor; B.A., Aquatic Biology, University of California, Santa Barbara; Ph.D., Botany and Geology, Duke University

Dr. Lindley is an ecologist in NOAA’s National Marine Fisheries Service at the Southeast Fisheries Science Center, Tiburon Laboratory, California. His research interests focus on ecosystem and population ecology, numerical modeling, and application of stable isotopes as tracers of ecological processes.

Douglas J. Lober, Ph.D., Adjunct Assistant Professor; B.A., History, Yale University; M.B.A., Finance, Columbia University; M.F.S., Environmental Economics and Policy, and Ph.D., Forestry and Environmental Studies, Yale University

Dr. Lober is a research analyst for an investment firm in the Boston area. His research interests include the integration of business and the environment from a management perspective, pollution prevention, waste management, and environmental policy.

D. Evan Mercer, Ph.D., Adjunct Associate Professor; B.S., Biology, B.S., Zoology, University of Texas; M.S., Forest Ecology, University of Michigan; Ph.D., Natural Resource Economics, Duke University

46 Faculty
Dr. Mercer is a research economist with the USDA Forest Service’s Southern Research Station at Research Triangle Park, N.C. His current research interests are the economics of agroforestry; nonmarket valuation; rural development; and the effects of government policies, market factors, and societal values on the management and protection of tropical forest resources and properties of lake sediments.

Ellen M. Mihaiich, B.A., Biology, Wellesley College; M.S., Ph.D., Environmental Toxicology, Duke University

Dr. Mihaiich is a senior environmental toxicologist with Rhodia, Inc., an international chemical company. She is a diplomat of the American Board of Toxicology. Her research focuses on sound, scientific environmental risk assessment, identifying data needs and methods of interpretation of both exposure and effects data. Recently, she has been very involved in environmental endocrine issues and evaluating the process of risk assessment with chemicals that can mimic natural hormones.

Brian C. Murray, Ph.D., Adjunct Associate Professor; B.S., Economics and Finance, University of Delaware; M.S., Ph.D., Resource Economics and Policy, Duke University

Dr. Murray is a senior economist at the Research Triangle Institute’s Center for Economics Research. His areas of specialization include economic analysis of environmental policies and programs, analysis of industry structure and competition, and economic modeling of land use.

John Nagy, Ph.D., Visiting Research Scientist; B.S., Physics, Massachusetts Institute of Technology; Ph.D., Experimental High Energy Physics, University of Pennsylvania

Dr. Nagy’s research interests focus on environmental physics; effects of radiation and energy system effluents on human health and natural ecosystems; and hardware and software related to automated control, data acquisition, and diagnostics for scientific experiments.

Subhrendu Pattanayak, Ph.D., Adjunct Assistant Professor; B.A., Economics, University of Delhi; M.S., Econometrics, Purdue University; Ph.D., Environmental and Natural Resource Economics, Duke University

Dr. Pattanayak measures resource and environmental values and models economic behavior under environmental constraints for analysis of environmental policy. His recent research has focussed on non-industrial private forestry, urban land use dynamics, benefits of safe drinking water, and benefits transfer methodology. He models farm households’ passive or active use and valuation of forest resources, including ecosystem services, in national parks in Indonesia, Brazil, and Madagascar, and on agroforestry plots in the Philippines. His primary research interests are in the application of microeconometrics to economic evaluation of environmental and resource policies, and issues at the intersection of economic development and environmental protection.

Sam Pearsall, Ph.D., Assistant Adjunct Professor; B.S., Biology, University of Tennessee; M.P.S., Natural Resources Policy and Planning; Cornell University; Ph.D., Geography, University of Hawaii

Dr. Pearsall’s interests revolve around approaches to selecting, designing, and adaptively managing landscape-level sites for ecosystem conservation. His current research focuses mainly on modeling and managing the riverian and riparian ecosystems of the Roanoke River in North Carolina, but he is currently trying to open new projects on the Santee River in South Carolina and in the large Karst system of the Duck River watershed in Tennessee.

Song S. Qian, Ph.D., Adjunct Assistant Professor; B.S., Engineering, Tsinghua University; M.S., Environmental Systems Engineering, Nanjing University; M.S., Statistics, Ph.D., Environmental Sciences, Duke University
Dr. Qian is Visiting Scientist with The Cadmus Group and with Water Resources Research Institute of the University of North Carolina. His research involves Bayesian hierarchical modeling of toxic micro-organisms in the US drinking water supply, and modeling nutrient loading in the Neuse River Basin using SPARROW.

Narendra P. Sharma, Ph.D., Adjunct Professor; B.S., Agricultural Economics, University of Hawaii; M.S., Agricultural Economics, Rutgers University; M.E.M., Environmental Management, Duke University; Ph.D., Agricultural Economics and Economic Development, Virginia Polytechnic Institute and State University

Principal economist at the World Bank in Washington, D.C., Dr. Sharma is the primary author of the bank's forest policy. His research interests are in applied economics, project design and policy analysis. He has worked in developing countries on policy issues related to conservation and sustainable development, poverty, natural resource management, and policy dialogue. His current research focuses on quantification of environmental impacts and local participation.

Laura K. Snook, Ph.D., Adjunct Assistant Professor; B.A. History, Grinnell College; M.F.S., Tropical Forestry, Doctor of Forestry, Forest Ecology and Silviculture, Yale University

Dr. Snook is primarily interested in the application of ecological knowledge to the management and conservation of forests. Her research has focused on forest stand dynamics, disturbance ecology, and silviculture as well as social forestry and forest conservation. She has worked in highland (fir and pine), montane, and lowland tropical forests in Mexico, and has ongoing research projects in the mahogany forests of Mexico, Belize, and Brazil.

Arthur J. Spivack, Ph.D., Adjunct Associate Professor; B.S., Massachusetts Institute of Technology; Ph.D., Massachusetts Institute of Technology and Woods Hole Oceanographic Institution

Dr. Spivack's current research interests are the development and application of isotope geochemical methods. General areas of application include the reconstruction of mantle/ocean/atmospheric chemical evolution, atmospheric Cl chemistry, mid-ocean ridge hydrothermal systems and ocean margin pore fluid chemistry.

Harold Karl Steen, Ph.D., Adjunct Professor; B.S., Forestry, M.F., Ph.D., History of Conservation, University of Washington

Dr. Steen's research interests are the political and economic development of modern forestry concepts and policies, and the history of conservation and land use as related to current forest land issues. He is the former director of the Forest History Society at Duke University.

William G. Sunda, Ph.D., Adjunct Assistant Professor; B.A., Fundamental Science, Lehigh University; Ph. D., Chemical Oceanography, Massachusetts Institute of Technology/ Woods Hole Oceanographic Institution Joint Program

Dr. Sunda conducts research on the interactions between trace metal chemistry in marine systems and phytoplankton dynamics. He is interested in both the role of metals in controlling the productivity and species diversity of phytoplankton communities and the effect of algal communities on the biogeochemical cycling of metals. His interests cover limitation by essential micronutrient metals (Fe, Zn, Co, and Mn) and toxicity of heavy metals (e.g. by Cu and Cd). He also has had a long-standing interest in the role of chemical speciation of metals on their cellular uptake and utilization and toxicological effects.

Jerry J. Tulis, Ph.D., Adjunct Associate Professor; B.S., Bacteriology, University of Illinois; M.S., Medical Microbiology, Loyola University; Ph.D., Radiobiology, Catholic University of America
Dr. Tulis is primarily interested in the detection, amelioration, and prevention of adverse health effects in the occupational and environmental setting as a result of exposure to biohazardous agents and materials.

**John J. Vandenberg,** Ph.D., Adjunct Professor; B.A., Biology, The College of Wooster; M.S., Ph.D., Biophysical Ecology, Duke University

Dr. Vandenberg is director of EPA’s research program on airborne particulate matter. His interests include research on the health effects of air pollutants, atmospheric sciences, and the interface of science and air quality management.

**Brani Vidakovic,** Ph.D., Adjunct Associate Professor; B.S., M.S., Belgrade University; Ph.D., Statistics, Purdue University

Dr. Vidakovic’s research interests include wavelets, Bayesian decision theory, statistical theory of turbulence, T-Minimax complexity, and statistical education.

**David N. Wear,** Ph.D., Adjunct Professor; B.A., Botany, University of Montana; M.F., Resource Systems Science, Duke University; Ph.D., Forest Economics, University of Montana

Dr. Wear’s current research concerns the economics of ecosystem management, the design of forestry policies, and the regional assessment of forest production and investment. He is project leader for the economics of forest protection and management with the USDA Forest Service, Southeastern Forest Experiment Station, Research Triangle Park, NC.

**Reiner Zimmerman,** Ph.D., Adjunct Assistant Professor; B.S., Botany, M.S., Ecology and Biogeography, Ph.D., Physiological Plant Ecology, University of Bayreuth, Germany

Dr. Zimmermann is a member of the technical staff at the Jet Propulsion Laboratory/California Institute of Technology in Pasadena. His primary research interests are comparative studies of water use by vegetation along a latitudinal gradient from boreal to tropical forest types and the relationships between dielectric properties, tree water status, canopy structure, and its detection with synthetic aperture radar.

**Faculty Emeriti**

Roger F. Anderson, Ph.D., Professor Emeritus
Cazlyn G. Bookhout, Ph.D., Professor Emeritus
John D. Costlow, Ph.D., Professor Emeritus
George F. Dutrow, Ph.D., Professor Emeritus
John W. Gutknecht, Ph.D., Professor Emeritus
S. Duncan Heron, Ph.D., Professor Emeritus
Benjamin A. Jayne, Ph.D., Professor Emeritus
James Granville Osborne, B.S., Professor Emeritus
Ronald D. Perkins, Ph.D., Professor Emeritus
Orrin H. Pilkey, Ph.D., Professor Emeritus
William J. Stambaugh, Ph.D., Professor Emeritus
Degrees and Programs of Study
Duke University offers undergraduate, professional, and research programs in several areas of study related to natural resources and the environment. A Bachelor of Arts degree with a major in earth and ocean sciences or environmental sciences and policy is offered through Trinity College of Arts and Sciences. A Bachelor of Science Degree in earth and ocean sciences or environmental science is also offered through Trinity College. Master of Environmental Management (M.E.M.) and Master of Forestry (M.F.) degrees are offered by the Nicholas School of the Environment and Earth Sciences; and the Ph.D. degree is offered in both Earth and Ocean Sciences and the Department of the Environment of the Graduate School. The Master of Arts (A.M.) degree is available through the Graduate School for individuals wishing to pursue graduate study in the environment in conjunction with a J.D. degree in the School of Law. Students generally are not admitted to the Department of the Environment as candidates for a terminal Master of Science (M.S.) degree (except in the Division of Earth and Ocean Sciences); however, the M.S. may be awarded as part of a doctoral program.

The Master of Environmental Management degree is designed to develop expertise in planning and administering the management of the natural environment for maximum human benefit with minimum deterioration of ecosystem stability. M.E.M. degree candidates choose one of five programs of study: Coastal Environmental Management; Environmental Toxicology, Chemistry and Risk Assessment; Resource Ecology; Resource Economics and Policy; or Water and Air Resources.

The Master of Forestry degree concentrates on forest and associated resources, including timber, water, biodiversity, and recreation and their management from an ecological point of view. The graduate with a M.F. degree is qualified for administrative or staff positions with federal and state agencies, industries, consulting firms, and other organizations concerned with forest and land management. The Forest Resource Management program is offered under the M.F. degree. The Society of American Foresters accredits this program.

The Distinction Between Professional and Graduate Degrees. Professional graduate programs such as the M.E.M. and M.F. differ from traditional M.S./Ph.D. programs both in terms of the career goals of students and in terms of curricula. The M.E.M. and M.F. are considered "terminal" degrees, equipping graduates for lifelong advancement in their careers (although students who later choose to enter Ph.D. programs appear to suffer no disadvantage from taking a professional masters degree first). These careers span a wide variety of employment settings, including government agencies, private industry, nonprofit organizations, and international organizations. Most M.E.M./M.F. graduates hold management and staff positions where they are expected to compile, analyze and interpret natural and social science information and then use it to formulate a plan for action. They are rarely in positions where generating new scientific insights through original research is the main task. The M.E.M./M.F. curriculum reflects these employment goals. The emphasis is on coursework to provide a strong scientific and an-
alytical foundation for management-oriented decision making. A master's project supplements the coursework by allowing students to demonstrate their organizational and analytical skills in solving an environmental management problem in their areas of specialization.

Students planning careers primarily in university teaching and research are urged to follow a course of study in the Graduate School. The graduate degrees are appropriate for students desiring to concentrate their study and research within a well-defined subject area. Students usually pursue fewer and more advanced topics to a greater depth than do students in professional degree programs. Graduate School students emphasize research as a major part of their degree programs. An active research program is a vital component of the Nicholas School of the Environment and Earth Sciences, and most of the research projects in the school utilize Ph.D. candidates as research assistants. The prospective Ph.D. student should consult the Bulletin of the Graduate School (http://registrar.duke.edu/bulletins/Graduate) for more detailed information or visit the Graduate School website at http://www.gradschool.duke.edu.

Individually designed programs of study related to natural resources and the environment are possible under either the professional or graduate degrees, with faculty approval.

Requirements for the Professional Degrees

A total of 48 units are required for either the Master of Environmental Management (M.E.M.) or the Master of Forestry (M.F.) degree. At least 36 units and at least 3 semesters must be completed in residence at Duke. No more than 12 units may be completed through independent study off campus. All students must pay full tuition for four semesters, regardless of residency. Transfer credit is not accepted.

Students' programs consist of a combination of regular courses, independent projects, and seminars. A master's project of 4 to 6 units, consisting of both a written report and an oral presentation, is required of all students. Course work in other departments of the university and at nearby institutions is available to strengthen students' education in special areas.

A full semester load is 12 units, which should ordinarily consist of a combination of regular courses, independent projects, and the master's project. Many students take more. Permission of the student's advisor is required to take more than 15 or fewer than 9 units in a semester.

ONE-YEAR MASTER OF FORESTRY OPTION

Students who have an undergraduate degree in forestry may earn a Master of Forestry degree with only 30 units of credit. To be admitted to the one-year degree option, the student must have received a Bachelor of Science in Forestry degree from an accredited forestry school. The student must spend a minimum of two semesters in residence.

SPECIAL DEGREE TRACK FOR PRACTICING PROFESSIONALS

The Nicholas School of the Environment and Earth Sciences offers a special professional master's degree track, through the Senior Professional Program, that allows a reduced term of residency.

Candidates with at least five years of work experience in an environmental field may be admitted to the Nicholas School to complete a Master of Forestry or Master of Environmental Management degree with reduced credit and residency requirements. These professional degree candidates must spend one semester at Duke enrolled in regular, graduate level courses. Up to 15 units of credit are taken during this time. The remaining 15 or more units of credit required for a Master of Forestry or Master of Environmental Management degree may be earned through continuing education intensive courses, independent study, and a master's project. Candidates have five years from the date of acceptance to complete the credit requirements.
The student's advisor– upon evaluation of the individual's previous education, work experience, and career goals– establishes specific degree requirements for students in the Senior Professional Program, including required courses and the number of academic units necessary to complete the degree.

**Concurrent Degrees**

**Master of Environmental Management and Master of Forestry.** Students desiring to earn both the M.E.M. and the M.F. degrees can do so by planning their courses appropriately. The requirements for earning both degrees are as follows:

1. The student must qualify for either the M.E.M. or M.F. degree by earning 48 units of credit under the requirements set forth above.
2. For the second degree, the student must complete an additional 24 units of study that, in combination with courses taken for the first degree, meet the substance of the requirements for the second degree. Two additional semesters in residence are normally required, although, with careful planning, the student may complete both professional degrees in a total of five semesters.
3. The Master's project should combine the two areas of study.

Determination of eligibility for the degrees will be made on an individual basis and will consider the educational background and objectives of the student.

**Master of Business Administration.** The techniques of management science are applied with increasing frequency in the management of natural resources, and they are also now commonly used in the analysis of environmental problems. To integrate training in these management techniques more effectively into the curriculum, the Nicholas School of the Environment and Earth Sciences has developed a cooperative arrangement with Duke's Fuqua School of Business. Three years of study are required to earn the combined degrees of Master of Environmental Management/ Master of Business Administration or Master of Forestry/ Master of Business Administration. At least 36 units of credit within the school are required to receive the M.E.M. or M.F. degree; these include 4 to 6 units for the master's project. A typical program sequence would involve spending the first year in the Nicholas School of the Environment and Earth Sciences followed by a year in the Fuqua School of Business and concluding with the final year of combined work in both schools. There is, however, flexibility in which program the student commences study.

These concurrent degrees stress concepts, analytical reasoning, and the basic methodologies of management science, while providing the student with knowledge of current problems in the natural resource industries. Managerial economics, resource economics, organization theory and management, accounting, information and control, resource management, the legal environment, and public policy aspects of resource industries form a substantial component of each degree.

Because of the academic demands of these degrees, those entering without the necessary analytical skills or life science background may be required to take additional work beyond that specified.

Students who wish to undertake both the Master of Environmental Management or Master of Forestry and Master of Business Administration degrees must apply to and be accepted by each of the respective schools. For information on the Master of Business Administration degree, the prospective student should write to the Fuqua School of Business, Admissions Office, Duke University, Box 90104, Durham, N. C. 27708-0104 or visit the Fuqua website at http://www.fuqua.duke.edu.

**Master of Public Policy.** As issues concerning natural resources and the environment have become of increasing significance to the nation, there has developed a corresponding need for well-trained policy analysts who can provide timely and appropriate information and analysis to resource policy makers. To meet this need a unique concur-
Concurrent Degrees

Rent degree has been developed in cooperation with the Terry Sanford Institute of Public Policy. Students pursue a Master of Environmental Management or Master of Forestry degree and a Master of Public Policy. Doctoral candidates in forestry and the environmental sciences are also eligible to undertake the Master of Public Policy.

The concurrent degree takes two and one-half years to complete. The first year is typically devoted to study in the Terry Sanford Institute of Public Policy, and the second year and a half is typically spent in the Nicholas School of the Environment and Earth Sciences. At least 36 units of credit within the school are required to receive the M.E.M. or M.F. degree. A summer internship with a resource or environmental agency, or with a related legislative, judicial, or interest group, is required for the policy degree. Students in this joint degree program complete both a master's memo for the policy degree and a separate master's project for the M.E.M. or M.F. degree.

This degree provides training in the politics and economics of resource and environmental policy-making. Emphasis is placed on understanding the social and political forces involved, developing facility with quantitative and logical methods of forecasting, and evaluating policy consequences. Knowledge of the uses and limitations of policy analysis and an awareness of the ethical dimensions of policy choice are also stressed.

Students must apply to and be accepted by both the Nicholas School of the Environment and Earth Sciences and the Duke University Graduate School. For detailed information on the public policy degree, write to Director of Graduate Studies, Terry Sanford Institute of Public Policy, Duke University, Box 90243, Durham, N. C. 27708-0243 or visit their website at http://www.pubpol.duke.edu.

Juris Doctor in Environmental Law. Environmental and natural resource issues increasingly require legal and regulatory knowledge for resolution. There is a growing demand for resource managers and scientists who have legal credentials; similarly, attorneys are facing more situations in which knowledge of natural resources and the environmental sciences is critical to the resolution of disputes. To satisfy these demands, the Nicholas School of the Environment and Earth Sciences and the School of Law have developed a cooperative arrangement to allow pursuit of concurrent Master of Environmental Management or Master of Arts and Juris Doctor degrees.

For students in the concurrent M.E.M./J.D. program, the Nicholas School requires 36 units of credit, including a master's project. The School of Law requires 72 units of law credit and awards 12 units for work done in the Nicholas School.

Typically, a student will complete the first year of study in the School of Law and the second in the Nicholas School of the Environment and Earth Sciences. During the third and fourth years, the student will take a combination of courses in both schools. M.E.M./J.D. candidates must apply to and be accepted by both the Nicholas School of the Environment and Earth Sciences and the School of Law.

For students in the concurrent A.M./J.D. degree. 30 units of credit are required in the Department of the Environment of the Graduate School, of which 24 must be graded, and 72 units in the School of Law. Further information is available from the director of Graduate Studies. A.M. students are not required to write master's projects.

For information on the law degrees, prospective students should write to the School of Law, Admissions Office, Duke University, Box 90393, Durham, N.C. 27708-0393, http://www.law.duke.edu.

Master of Arts in Teaching. Over the last several decades, international concern for protecting our ecosystem has led to an increased understanding of the need to broadly educate citizens on the challenges facing our environment. This increased awareness is demonstrated through the development of numerous education programs aimed at K-12 students as well as to the general population. Environmental education is of increasing importance to those who prepare to teach, particularly in the sciences. Duke’s concurrent degree program between the Nicholas School of the Environment and Earth
Sciences and the Graduate School allows students to meet this need by earning a Master of Environmental Management (M.E.M.) and a Master of Arts in Teaching (M.A.T.) degree.

Students must complete 36 units of credit in the Nicholas School of the Environment and Earth Sciences, including a master's project. For the M.A.T. degree, students will complete 30 units of credit, including a full-year teaching internship.

For the M.A.T. degree, students will complete all requirements for the North Carolina teaching licensure in comprehensive science. Competencies required by the state will be met through undergraduate courses taken prior to admission to Duke, science courses taken as part of the M.A.T., or courses taken as part of the M.E.M.

Students will normally enroll in the M.A.T. program prior to enrolling in the M.E.M. program.

Students must apply to and be accepted by both the Nicholas School of the Environment and Earth Sciences and the Graduate School of Duke University, citing the Master of Arts in Teaching program. Students admitted to the M.A.T. program in comprehensive science must hold an undergraduate degree in one of the natural sciences with significant undergraduate preparation in biology and chemistry. Organic chemistry is required. The individual program of study will require additional preparation in the sciences and education in addition to a full-year teaching internship under the direction of a mentor.

Questions concerning the M.A.T. degree should be addressed to the Director of the Master of Arts in Teaching Program, Duke University, Box 90093, Durham, N.C. 27708-0093; telephone (919) 684-4353.

Other Concurrent Degrees. With the special permission of the education committee and the dean of the Nicholas School of the Environment and Earth Sciences, students are permitted, on an individual basis, to establish concurrent degree programs with certified graduate degree programs either within or outside of Duke University. In the past, students have designed such programs with law schools, business schools, and graduate engineering programs. As with the other concurrent degrees, the student must be enrolled in the Master of Environmental Management or Master of Forestry degree program for 36 units of credit and normally be in residence for three semesters.

To gain acceptance of a specially designed concurrent degree, the student must show an official acceptance from another certified graduate degree program. In order to receive the M.E.M. or M.F. degree, the student must have completed 36 units of credit, the master's project, all program area requirements, and all the degree requirements for the other degree program (with an official transcript of work completed). For additional information concerning special concurrent degrees, applicants should consult the Office of Enrollment Services.

Graduate Degrees

The Doctor of Philosophy (Ph.D.) degree in disciplines related to earth and ocean, environmental, and marine sciences is administered by the Graduate School of the university; however, the bulk of the instruction, research, and advising connected with it takes place in the Nicholas School of the Environment and Earth Sciences. Policy and procedures for admission, general requirements for degrees, registration, and academic regulations are given in detail in the bulletin of the Graduate School and are not repeated here.

Qualification of Students. Students seeking admission to the Graduate School must have received an A.B. or B.S. degree (or the equivalent in the case of foreign students) from an accredited institution. Usually the student should have majored in the area of intended graduate study or one closely related to it. Because research is such an integral part of graduate education and of the school's mission, the student's undergraduate record must evidence the capability and motivation to carry out independent research.
study and research at an advanced level.

**Admission.** Applicants for the Ph.D. degree are encouraged to use the Graduate School's electronic application. The address is http://www.gradschool.duke.edu. For those applicants who are not able to access the Internet, applications may be obtained from the Graduate School Admissions Office, Duke University, Box 90065, Durham, NC 27708-0065. It is important to emphasize that an individual faculty member must accept responsibility for advising an applicant before admission can be offered. Therefore, individuals considering application are encouraged to send inquiries about specific programs of study and research to the appropriate area of the Nicholas School in which their potential advisor resides. The brief summaries of individual faculty research interests at the beginning of this bulletin should help you decide where you should send your inquiry. Direct contact with individual faculty is also encouraged. To facilitate this, each faculty member's e-mail address is provided at the end of the statement of research interests.

Inquiries about programs and research in earth and ocean sciences should be sent to the Director of Graduate Studies, Division of Earth and Ocean Sciences, Nicholas School of the Environment and Earth Sciences, Box 90227, Duke University, Durham, NC 27708-0227 (E-mail: dgs@eos.duke.edu).

Inquiries about programs and research in environmental natural and social science on the Durham campus should be sent to the Director of Graduate Studies, Nicholas School of the Environment and Earth Sciences, Box 90328, Duke University, Durham, NC 27708-0328 (E-mail: gradadm@pinus.env.duke.edu).

Inquiries about programs and research in environmental natural and social science at the Marine Laboratory in Beaufort should be sent to the Director of Graduate Studies, Nicholas School of the Environment and Earth Sciences, Duke Marine Laboratory, 135 Duke Marine Lab Road, Beaufort, NC 28516-9721 (E-mail: ritt@duke.edu).

Any of the above three contact points can arrange to have application materials sent to the applicant. Information about the Nicholas School of the Environment and Earth Sciences, its various degree programs and the faculty research interests can also be found at the following three World Wide Web addresses: www.env.duke.edu, www.eos.duke.edu and www.env.duke.edu/marinelab. Applicants should refer to the current Bulletin of Duke University Graduate School (http://registrar.duke.edu/bulletins/Graduate/2000) for the requirements for the various degrees offered by the Graduate School.

The priority application deadline is December 31. However, applicants are encouraged to apply by December 1, if possible. Applications postmarked after this deadline will not be considered until all on-time applications have been processed. Applications received by December 1 require a $65 application fee, as opposed to $75 for those received after that date.

**Undergraduate Degrees**

The Nicholas School of the Environment and Earth Sciences collaborates with Trinity College of Arts and Sciences in awarding four undergraduate degrees: the Bachelor of Arts in Environmental Science and Policy, the Bachelor of Science in Environmental Sciences, the Bachelor of Arts in Earth and Ocean Sciences and the Bachelor of Science in Earth and Ocean Sciences. Courses for the majors are taught by more than 60 Duke professors in 20 cooperating departments and schools. Undergraduate directors and advisory committees representing the various areas and cooperating departments administer the degrees.

**Advising.** Faculty advisors in all undergraduate programs are assigned based on students' general areas of interest. Students present a proposed plan of study to their advisors that explains the rationale for their chosen area of concentration and emphasizes the connections among their courses. This approach encourages close relationships be-
between faculty and students with convergent interests.

**Study at the Marine Lab.** An option is available for one semester or summer of study at the Duke University Marine Laboratory in Beaufort, N.C. to fulfill elective requirements for the undergraduate degree programs. Many students choose to take advantage of this field-based approach to environmental sciences and policy.

**Bachelor of Arts in Environmental Sciences and Policy**

The undergraduate major in environmental sciences and policy is offered within the Bachelor of Arts degree to students interested in the interdisciplinary study of environmental issues. The major permits students to combine studies in the natural sciences and engineering with courses in the social sciences and humanities around general focus areas and themes. The major is specifically designed for students with career objectives such as environmental law, policy, science, management or planning that require in-depth understanding of environmental issues that cross traditional disciplinary boundaries. The prerequisites for the A.B. degree stress a firm foundation in basic natural and social science areas. An introductory core course focuses on local, regional and global case studies taught by interdisciplinary teams of faculty. Upper-level courses are selected in consultation with advisors to match a specific environmental theme or career objective. The upper-level curriculum includes a course in probability and statistics, an upper-level seminar, and an independent study, internship or field experience. At least two courses in the upper-level curriculum must be selected from approved lists in each of the social sciences/humanities and sciences/engineering areas.

Students interested in the Environmental Sciences and Policy Program should consult the Duke University Bulletin of Undergraduate Instruction, available from the Office of Undergraduate Admissions or on the web (http://www.registrar.duke.edu/bulletins) for further information or on the Nicholas School Web site at www.env.duke.edu/en/. The program is administered through Trinity College of Arts and Sciences; a member of the Nicholas School of the Environment and Earth Sciences faculty directs the program.

**Bachelor of Science in Environmental Sciences**

The undergraduate major in environmental sciences is offered within the Bachelor of Science degree to students interested in a cross-disciplinary scientific perspective on environmental issues. The major is designed to encourage breadth in the physical and life sciences and depth in a chosen area of scientific concentration. This major is designed for students with career objectives in environmental science, industry or management that require a strong scientific background, or for students intending to pursue graduate degrees in an environmental science. The prerequisites for the B.S. degree stress a firm foundation in the physical and lifesciences and mathematics. The major requirements include five core courses selected from six course (or course list) options that focus on the solid earth, the hydrosphere, the atmosphere, the biosphere, chemical cycling and the interface between humans and the environment. The major also includes a course in probability and statistics. The Focused Study consists of three upper-level natural science, engineering or mathematics courses proposed by the student in consultation with his or her advisor to form a concentration area.

Students interested in the Bachelor of Science in Environmental Sciences should consult the Duke University Bulletin of Undergraduate Instruction, available from the Office of Undergraduate Admissions or on the web (http://www.registrar.duke.edu/bulletins), for further information or the Nicholas School Web site at www.env.duke.edu/en/. The program is administered through Trinity College of Arts and Sciences; a member of the Nicholas School of the Environment and Earth Sciences faculty directs the program.
Undergraduate Degrees in Earth and Ocean Sciences

The Division of Earth and Ocean Sciences offers introductory and advanced courses in coastal geology, environmental geology, hydrology, geochemistry, geomorphology, geophysics, oceanography, paleontology, petrology, sedimentology and marine geology. A Bachelor of Science degree is offered for those students wishing to pursue further studies in the earth and ocean sciences, and for those who intend to work professionally in environmental sciences. A Bachelor of Arts degree is offered for those students who do not intend to pursue the earth sciences professionally, but wish to understand more fully local and global environmental issues.

Students interested in the Earth and Ocean Sciences Program should consult the Duke University Bulletin of Undergraduate Instruction, available from the Office of Undergraduate Admissions or on the web (http://www.registrar.duke.edu/bulletins), for further information or the divisional website (http://www.eos.duke.edu).

Nondegree, Special Status

Persons interested in pursuing graduate or professional studies in natural resources not leading to a degree may apply for nondegree, special status. Such students may take from 3 to 12 units of course work each semester; they are registered with the university as a student with appropriate privileges and they receive transcripts of work completed for each semester in residence. If the student later applies for admission into a regular degree program, some of the courses may count toward the degree. Students wishing to study for only one or two semesters or to do postdoctoral work should apply for nondegree, special status. Additional requirements are contained in a later section on admissions.
**Planning**

The responsibility for the specific content of the academic plan of study rests with the student. A thorough familiarity with and understanding of the regulations contained in this bulletin as well as other sources provided by the school are essential to sound planning.

During the first term of enrollment, each student is assigned a faculty advisor who should be consulted in planning a course of study. Other members of the faculty may also be consulted on an informal basis. Reassignment to another advisor is usually possible with approval of both the assigned advisor and the prospective advisor. A student may have a master's project advisor other than the assigned coursework advisor.

**Registration**

Entering students who enroll in the Master of Environmental Management or Master of Forestry degree program will receive instructions from the Nicholas School of the Environment and Earth Sciences about registering for courses. Registration should be completed during the orientation period. Students in residence register for succeeding semesters at times scheduled in the university calendar.

Registration is approved by the advisor and completed by the student using an online registration system. Registration is required in order to take courses for credit or audit. To establish eligibility for university and other loans, for the student health service, and for study and laboratory space, a student must be registered. All tuition and fee payments and any indebtedness must be settled before registration will be completed.

**Late Registration.** All students should register at the times specified by the university. The charge for late registration is $25.

**Change of Registration.** With approval of the advisor, the student can change registration for a period of ten days at the beginning of each semester.

**Refunds.** Tuition refunds are governed by the policy stated in the chapter on financial information.

**Graduate School Registration.** Students in Ph.D. degree programs initiate registration through the director of Graduate Studies of the Nicholas School and complete it through the online registration system. Registration requirements and procedures are described in the Bulletin of the Graduate School.

**Reciprocal Agreements.** Students enrolled full-time in the Nicholas School or in the Graduate School during the regular academic year may enroll for six hours of credit
per semester at the University of North Carolina in Chapel Hill, North Carolina State University in Raleigh, or North Carolina Central University in Durham provided that they are also registered for at least six hours of credit at Duke during the same semester. Similarly, graduate students in these schools may take up to six hours per semester at Duke. A student enrolled for two or more courses during a summer at Duke may take one of the courses at one of the neighboring institutions under the reciprocal agreement. This agreement does not apply to contract programs such as the American Dance Festival. The student must pay any special fees required of students at the host institution and provide his or her own transportation.

Immunization Requirement

The North Carolina immunization law requires students entering a college or university in the state to be immunized against the following diseases: measles, rubella, tetanus, diphtheria and, in some cases, polio. Each entering student is required to present proof of these immunizations in accordance with the instructions contained in the Student Health Services form provided with the student's matriculation material. This form should be completed and returned to Student Health Services prior to the student's first day of classes. Duke University cannot permit a student to attend classes unless the required immunizations have been obtained.

Courses

Course Descriptions. Courses offered by the school are described in the final section of this bulletin. However, courses are subject to change. A list of courses to be offered during a particular term, as well as schedules of courses offered in other departments at Duke and at neighboring universities, are available online and from the Office of Enrollment Services prior to registration for a given term.

Independent Study. All students are expected to place increasing emphasis on independent study as they near completion of residence. Independent study can involve many different topics and students register to take independent study credit under Environment 299. Several students can work together under the supervision of a faculty member by registering for Environment 200.

Master's Project. All students must complete a master's project of 4 to 6 credits. The project should be identified during the second term of study, initiated during the summer between academic years, and completed during the third and fourth terms. No student will be permitted to register for the fourth term of study until a project proposal has been approved by the student's advisor and has been received by the school's Office of Enrollment Services. During the final two terms major emphasis should be placed on the project. In completing the project, the student applies theoretical and analytical training acquired during the two years of study to actual natural resource or environmental problems. Students often use summer internships as the basis for master's projects and may consult closely with a supervisor outside the school, as well as with their faculty master project advisor, to complete their work. Students should maintain close contact with their advisors during the development and writing of the master's project. Projects should reach final stages of completion by mid-term of the final semester in residence. A complete draft of the project must be delivered to the advisor prior to October 1 for those graduating in December, prior to March 1 for those graduating in May, and prior to July 1 for those graduating in September. The advisor is responsible for critical assessment and grading.

Auditing. Students registered for a full course load may audit courses free of charge. Otherwise, the audit fee is $925 per course. In classes where enrollment is limited, students enrolled for credit will receive priority. Audited courses are recorded without grade on the student's permanent record. Regular attendance is expected. Changes from audit to credit are not permitted after the drop/add period.
D rop/Add. The period for dropping and adding courses ends on the tenth calendar day of the fall and spring semesters. During the summer dropping or adding of courses is limited to the first three days of the term. Students are advised to make all class changes on the first day of class if at all possible.

Intensive Courses. For the special intensive courses, students may register during the semester two weeks prior to the first day of the course. Students may not register for more than two intensives in a semester without permission of their advisor and the intensive course coordinator. Students who wish to drop an intensive must do so prior to the first day of the course.

Retaking Courses. Courses required as a part of the program elected by the student or required by the advisor must be retaken if failed. Courses prerequisite to more advanced courses the student wishes to elect must be retaken if failed. Elective courses may be retaken if the student wishes to do so. See the section on grades, below, for additional information.

Credit Hours

Candidates for the professional degrees are considered fully registered when they enroll full-time for the number of semesters required in their individual degree programs. The normal registration to reach the required minimum units of credit is 12 units per semester, although a variation from 9 to 15 units is common. Students must have the permission of their advisor to register for more than 15 units in a semester, and all students who wish to enroll for fewer than 9 units must make a formal request to the education committee to study part-time.

Summer Registration. Professional degree candidates are normally not required to register for summer courses. However, a student who wants to supplement his or her graduate work with courses during the summer should expect to do so through other departments in the university or at the Marine Lab in Beaufort. Students should consult with their advisors to make sure the courses are appropriate for their program of study. Tuition and fees for summer study depend on the applicable department. Summer registration does not affect the number of units, semesters in residence, or flat-fee tuition for the regular academic year.

Grades

The grading system used in the Nicholas School of the Environment and Earth Sciences is as follows: E (exceptional); G (good); S (satisfactory); F (failing); I (incomplete); Z (continuing).

The grades of P (pass) and F (fail) are used in the Nicholas School for seminars, master's projects, program area seminars and modular courses. At the instructor's option, the grades of P or F or regular letter grades are used for intensive courses and independent projects.

The grade of Z is assigned for an independent project or a master's project that extends over a period of more than one semester; a final grade is given upon completion of the project. Permission for the pass/fail option must be obtained in writing from the instructor upon registration for a course.

Incomplete Grades. A grade of I indicates that some portion of the student's work is lacking, for an acceptable reason, at the time grades are reported. Requirements of all courses in which an instructor assigns a grade of Incomplete must be fulfilled within one calendar year following the date of the assignment of the incomplete grade.

In exceptional circumstances, upon recommendation of the professor who assigned the grade of Incomplete, the dean of the Nicholas School may extend the time for completion of the course requirements. If, in the judgment of the professor and the student's advisor, completion of the requirements is not a reasonable alternative for the student, the student may petition the education committee to allow the grade of I to
stand permanently on his or her record. No student will be allowed to graduate with an incomplete unless permission has been granted for it to stand permanently on the record.

**Failure.** Failing a course may leave a student short of credits for graduation or lacking program curriculum requirements. If the failed course is not necessary to complete program curriculum requirements, the student may substitute another course to make up the lost credit, with the advisor’s approval. If the failed course is necessary to complete program curriculum requirements, the student must re-take either that course or an acceptable substitute, with the advisor’s approval. Both the original failing grade and the grade received for the retaken or substitute course will appear on the student’s transcript. Failure of a course also subjects the student to dismissal (see the sections on probation and dismissal).

**Probation and Dismissal.** Any of three situations will result in probationary status for the following semester:

1. failing one or more courses;
2. two or more S (S-, S, S+) grades in a semester;
3. failing to maintain a cumulative average of at least G- (=2.8).

A student on probation must meet jointly with his/her advisor and one additional faculty member selected by the Director of Professional Studies before the end of drop-add (preferably before the beginning of the semester) to discuss what is going wrong and how to remedy it. These faculty committees have the discretion to suggest that a student take a leave of absence for a semester if they judge that to be the best way for the student to improve academic performance. A student on probation must meet again with the advisor and second faculty member a month after the first meeting to review academic progress.

Any student who does not meet academic standards at the end of the probationary semester will be subject to dismissal from the Nicholas School. The Education Committee will make decisions on dismissal.

In addition, students must have at least 48 units of credit with a grade point average of G- (2.8) or better to graduate. Students who fail to meet that standard during their final semester must take additional Duke credits to meet the standard before they can graduate. Any exceptions are at the discretion of the Education Committee.

**Honor Code**

The Nicholas School advocates the highest standard of professional ethics and academic integrity. Students and faculty have developed an honor code for the school that is distributed to all students prior to matriculation and discussed during orientation.

**Academic Irregularities**

All cases falling outside the regular policies and procedures of the school are referred to the Education Committee for decision. The work of the committee includes review and decision regarding course requirements for graduation, student probation and withdrawal, student petitions for waivers of degree requirements, and all actions that deviate from established academic regulations.

A student who desires to petition the committee should do so by writing to the chair. A precise statement of the reason for the request is required. The student will be notified in writing of the decision of the committee by the chair.

**Transcripts of Credit**

A student who is registered for a course and who successfully completes the requirements as prescribed by the instructor receives credit on university records. A
transcript fee, charged to all students during their first semester in residence, covers all future transcript requests. Only the Office of the University Registrar, 103 Allen Building, issues transcripts of credit. Requests for transcripts, sent directly to the registrar, should state clearly the full name under which the work was taken, the dates of attendance, and to whom the transcripts are to be sent. The student must sign the request for release of a transcript. No transcripts will be issued for students who fail to clear all financial obligations to the university upon graduation.

**Length of Study**

For a full-time student, the normal time for completing a professional master’s degree is four semesters. Exceptions may be made for students who have an undergraduate degree in forestry and for students enrolled in the Senior Professional Program. No student, either full-time or part-time, is allowed more than five years to complete the requirements for the master’s degree.

**Leave of Absence or Withdrawal**

Occasionally, special circumstances require a student to leave the university for one or two semesters at a time. If the reason for the departure is considered an emergency, the student may request a leave of absence for a period not to exceed one year. If the reason is to study elsewhere in a combined degree program, a leave will be granted for the length of study. If the student plans to do field studies or an internship, he or she must maintain university enrollment by paying a registration fee each semester of the academic year until full-time study is resumed.

Under all circumstances, the student must request the leave for a specific length of time prior to departure from the university. Extensions must be requested if they are required. Failure to request a leave or an extension of leave may result in a penalty charge and/or dismissal from the university. A student is eligible to request a leave of absence only after having completed at least one semester of study.

A student who wishes to withdraw must make a written request to do so. For refunds upon withdrawal, see the chapter on financial information.

**Graduation**

Even if degree plans are tentative, a candidate for a degree must file a declaration of intention to receive the degree at the designated time for each semester. The intention to receive the degree is valid only for the semester in which it is filed. If the student does not receive the degree as expected, he or she must file a new intention.

All candidates are urged to attend the commencement exercises at which their degrees are to be awarded. A student who is unable to attend is required to file a notification with the dean, not later than four weeks prior to commencement, seeking permission to receive the degree in absentia.

**Debts**

Students are expected to meet all financial obligations to the university prior to completion of the degree. Failure to pay all university charges by the due dates specified by the university will bar the student from registration, class attendance, receipt of transcripts, certification of credits, leave of absence, or graduation until the account is settled in full. Further, an individual in default may be subject to withdrawal from the university.
Professional Programs
In the Nicholas School of the Environment and Earth Sciences, emphasis is placed on maintaining the highest standards of scholarship and on relevance to contemporary needs in natural resources study and research.

The school emphasizes three broad conceptual areas in its instruction and research: natural resource and environmental science, resource economics and policy, and quantitative methods of analysis and decision-making. Regular courses, intensive courses, seminars, and special studies are offered in each of the three areas. Preparation for professional employment requires a higher degree of specialization than is characterized by this framework, however. Hence, six programs of study have been designed by the faculty to assure professional competence in some aspect of natural resources while offering adequate breadth of educational experience. One of these programs, Forest Resource Management, is offered under the Master of Forestry degree. The remaining five: Coastal Environmental Management; Environmental Toxicology, Chemistry, and Risk Assessment; Resource Ecology; Resource Economics and Policy; and Water and Air Resources are offered under the Master of Environmental Management degree.

Ph.D. candidates may also use these programs as a foundation for their coursework.

Qualified students who have interests outside of the structured programs are permitted to design individual programs of study. Pursuit of an individual program requires preparation of a comprehensive statement of objectives and specification of each of the program components: major courses, quantitative courses, seminars, electives, and a master’s project. All individual programs of study are subject to approval by the education committee. Students who wish to pursue an individual program of study must request approval of their program by the end of their second semester of enrollment.

**Program Requirements**

Each of the school’s professional programs requires the completion of 48 units of graduate credit. These units are distributed among a set of core courses constituting the major, quantitative courses, electives, a master’s project, and seminars relevant to the program’s objectives. These broad categories are discussed briefly below, and major (core) courses are listed for each program. More specific information about requirements for any one of the programs may be obtained from the Office of Enrollment Services. With advisor approval, students may count up to 6 credits of coursework at the 100-level with a grade of at least C toward their degree requirements.

**Major (Core) Courses.** Each program requires a series of core courses in the major area of study. These courses are specified or, in some cases, elective within the limits of the program emphasis.

**Quantitative and Analytical Courses.** All programs require 6 to 12 units in quantitative and analytical methods.

**Elective Courses.** Elective courses are available to give the student flexibility in developing his or her course of study. These credits are used to add depth to the major area of study or to develop a second area of expertise. Students who select the Resource Economics and Policy program and who have not had previous training in a natural resource area must use at least three of their elective courses to meet this requirement.

**Master’s Project.** A master’s project constituting 4 to 6 units of credit is required. These projects take the form of individual or small group analysis efforts related to some area of natural resource management.
Seminars. All students are required to participate in seminars in their program area for 1 unit of credit. During their last semester in residence, students present the results of their master's project in a school-wide symposium.

Coastal Environmental Management

The Coastal Environmental Management (CEM) program provides a scientifically rigorous understanding of global, national, and local physical and biological coastal environments and processes and the human behaviors and policies that affect, and are affected by, those environments and processes. The specific aim of the program is to train scientifically informed professionals to fill coastal policy and management, research, or advocacy positions in federal and state agencies, industry, consulting firms, and non-profit organizations. The program also provides a firm foundation for future Ph.D. studies.

The first year of the program is usually spent on the Durham campus fulfilling the required courses in areas such as natural resource economics, general environmental policy, ecology, and methodological skills. The second year is usually spent in residence at the Marine Laboratory in Beaufort taking courses in the natural, social and policy sciences specific to the coastal and marine environment, and focusing on the production of the master's project. The Marine Laboratory provides an ideal setting for the study of natural and social scientific phenomena in the coastal and marine environment, and for interaction with coastal and marine constituencies and policy makers in the application of science to policy. Potentials for participation in the policy-making process are emphasized throughout the program.

The Coastal Environmental Management Program is offered under the Master of Environmental Management degree. The program provides an educational background in ocean science and coastal ecosystems and in natural resource and environmental policy as it applies to coastal and marine issues. Students may use electives and additional course work to accommodate a second emphasis in one of the other program concentrations offered within the school.

Core Courses. ENVIRON 276 Marine Policy; ENVIRON 270 Resource and Environmental Economics; one additional policy course; one ecology course; and two ocean science courses.

Environmental Toxicology, Chemistry, and Risk Assessment

The Environmental Toxicology, Chemistry, and Risk Assessment (ETCRA) program is concerned with the transport and fate, effects, and risks of pollutants to natural ecosystems and human users of those systems, as well as linkages between ecological and human health. ETCRA is a multidisciplinary program incorporating the concepts, information bases, and methodologies of ecology, toxicology, environmental chemistry, and risk assessment. The goal of the program is to produce scientists and environmental managers with a solid foundation in the principles underlying pollutant fates and impacts, as well as a firm grasp of state-of-the-art approaches for evaluating specific instances of environmental contamination and for making management decisions based upon quantitative analysis.

Duke offers exceptional opportunities for training in environmental toxicology, chemistry, and risk assessment. Environmental toxicology is a key component of the university-wide Integrated Toxicology Program. Additionally, the ETCRA curriculum is enhanced by resources of sister universities in the Research Triangle area (particularly the University of North Carolina at Chapel Hill and North Carolina State University) and institutions within the Research Triangle Park, such as the Environmental Protection Agency, the National Institutes of Environmental Health Sciences, and the Chemical Industries Institute of Toxicology.
Environmental toxicology, chemistry, and risk assessment is offered under the Master of Environmental Management degree. Students in the program are required to take a common core of courses that includes environmental toxicology and chemistry, ecology, environmental economics and policy, and statistics and risk assessment. Additionally, students are encouraged to develop a concentration in one of four specializations: environmental toxicology, environmental chemistry, environmental risk assessment, or occupational/environmental health and safety. A research track is available in this program.

**Core Courses.** ENVIRON 212 Environmental Toxicology; ENVIRON 240 Fate of Organic Chemicals in the Aquatic Environment; or ENVIRON 242 Environmental Aquatic Chemistry; ENVIRON 385 Environmental Decision Analysis, or an equivalent course; Human and Ecological Risk Assessment; one graduate course in ecology; and one course in environmental economics, policy or law.

### Forest Resource Management

The Forest Resource Management (FRM) program integrates forest ecology and management within an educational program that also emphasizes related environmental fields. The program builds knowledge in basic forest ecology and ecological management of forests for a variety of uses, including nontraditional forest products and conservation. This distinctive approach is brought about by coordinating a core set of forestry courses, in sampling, measurement, dendrology, silviculture, and ecology, with electives in resource-oriented courses such as soils, hydrology, air and water quality, biological conservation, and physiology; statistical analysis and modeling; and resource economics and policy. The Duke Forest serves as an outdoor laboratory in many of these courses.

The focus of the Forest Resource Management program is problem solving in complex ecological and management systems. Within the program, students may acquire skills that qualify them for positions in industry, conservation organizations, government agencies, nonprofit organizations, and other groups involved with the use and conservation of forests. Students can develop additional credentials for employment by jointly completing this program and also a Master of Environmental Management degree in the Nicholas School of the Environment and Earth Sciences, a Master of Business Administration degree in the Fuqua School of Business, a Master of Public Policy degree in the Terry Sanford Institute of Public Policy or a Juris Doctor degree in the Law School. The program also provides an excellent foundation for the Ph.D. and a career in research.

Forest Resource Management is offered under the Master of Forestry degree. Students may use electives and additional course work to accommodate a second emphasis or a second master's degree (MEM) in another program area within the school.

This program is accredited by the Society of American Foresters, which is recognized by the Council on Postsecondary Accreditation and the Department of Education as the accrediting body for forestry educational programs in the United States.

**Core Courses.** ENVIRON 201 Forest Resources Field Skills; ENVIRON 206 Forest Vegetation Sampling; ENVIRON 213 Forest Ecosystems; ENVIRON 205L Silviculture; forest ecosystem management; forest or resource economics; policy or administration; and professional ethics.

### Resource Ecology

Resource Ecology (RE) is the application of ecological science to the management of terrestrial and aquatic ecosystems. Ecosystem management produces goods for human consumption; manipulates ecosystem processes to provide environmental services, rec-
lamination, restoration and waste treatment; conserves species and habitats; and main-
tains and improves the integrity of ecosystems for long-term use and enjoyment. The
specific objective of the RE program is to train professionals for management or techni-
cal support positions with state or federal natural resource agencies, non-profit conserva-
tion and environmental organizations, regional planning bodies, resource
management companies, and consulting firms. Graduates of the program have practical
experience with the analysis of ecological problems such as species conservation, flood-
ing, habitat restoration, disturbance and mitigation of wetlands, soil conservation and
land use planning.

A strong background in quantitative methods is required of students in this
program, as it is for other programs offered by the school. Mathematical and conceptual
models are invaluable in clarifying and solving environmental problems. They are
essential to describe basic biophysical and biogeochemical processes, to test hypotheses,
and to predict and interpret the response of ecosystems to management and
disturbance.

To promote specialization within an otherwise broad field, the program has four
tracks: conservation, forest ecology and management, landscape ecology, and wetland
ecology and management. The track curricula include courses in fundamentals of
ecology, tools for measurement and analysis, elective areas in natural and social science,
and field skills.

Resource Ecology is offered under the Master of Environmental Management
degree. Students may use electives and additional course work to accommodate a
second emphasis in another program area within the school. Students can develop
additional credentials for employment by jointly completing this program and also a
Master of Forestry degree in the Nicholas School of the Environment and Earth Sciences,
a Master of Business Administration degree in the Fuqua School of Business, a Master
of Public Policy degree in the Terry Sanford Institute of Public Policy or a Juris Doctor
degree in the Law School. The program also provides an excellent foundation for the
Ph.D. and a career in research.

Resource Economics and Policy

Society long has had laws and institutions aimed at regulating the use of natural re-
sources such as forests, wetlands, wildlife, water, and minerals. During the past few de-
cades, new institutions have been developed to deal with problems of water and air
pollution, toxic substances, and related areas of environmental degradation. These insti-
tutions demand a professional who has the necessary expertise to staff both public and
private decision-making bodies.

The Resource Economics and Policy (REP) program is designed to train decision
makers and those who advise them. The program emphasizes the basic methods needed
by the professional for analyzing existing policy and for testing the possible outcome
of new environmental and resource policy being considered by public and private
agencies. The program is highly analytical and is oriented toward the analysis of
contemporary national and international environmental problems.

Decision making in natural resource and environmental policy requires mastery of
three broad areas of knowledge: the basic sciences pertaining to a natural resource or
an environmental phenomenon; the relevant disciplines in the social sciences; and the
quantitative methods required for using knowledge from the physical, biological, and
social sciences to arrive at a decision.

Courses relevant to renewable and nonrenewable natural resources may be part of
the student’s educational background or may be planned as part of the master’s degree.
For the natural resource or environmental policy analyst, the most important social
sciences are resource and environmental economics, political science, and legal analysis.
Economics includes environmental economics, the economics of public goods and
externalities, public finance, and the intertemporal allocation of natural resources.
Political science includes the behavior of administrative agencies, regulatory agencies, and legislative bodies. Legal analysis emphasizes the allocation of resources as reflected in property rights and environmental risks as reflected in torts. Quantitative methods, an essential component of this program, include statistical inference, benefit-cost analysis, and geographic information systems.

Resource economics and policy is offered under the Master of Environmental Management degree. Students may use electives and additional course work to accommodate a second emphasis in another program area within the school. Specializations are also available in international environmental policy, and marine and coastal zone management policy.

**Core Courses.** ENVI RON 270L Resource and Environmental Economics; ENVIRON 274 Resource and Environmental Policy; and one of the following: LAW 327 Environmental Law or ENVIRON 281 Resource and Environmental Law.

**Doctoral Program.** Students accepted for a doctoral program in resource economics and policy must have significant previous training in economics, political science or another social science. Doctoral candidates in resource and environmental economics must take substantial course work in Duke's Department of Economics and pass the department's qualifying examinations in economic theory. Doctoral candidates in resource and environmental policy must take substantial course work in political science, public policy or political economy in relevant departments at Duke or cooperating universities.

**Water and Air Resources**

The program in Water and Air Resources (WAR) enables students to obtain a scientific understanding of the basic physical, chemical and biological processes affecting these natural resources and trains students to apply this understanding, together with quantitative, analytical and statistical techniques, to the management of these resources. Emphasis is placed on understanding the following: effects of land resource management on water quality; water quantity and transport; water and atmospheric chemistry; air pollution; and the regulatory framework within which these resources are managed.

Course work and other training in the program cover basic physical and chemical processes relevant to hydrologic and atmospheric sciences, methods of quantitative and statistical analysis, and methods of management and decision-making. The basic processes emphasized are those concerned with watershed hydrology; stream and lake water quality; water and atmospheric chemistry; general meteorology and climatology; and the origins, transport, and fate of aquatic and atmospheric pollutants. Quantitative analysis techniques include statistical and numerical methods, probabilistic and deterministic models, and optimization and simulation methods. These courses are integrated with others in water and air resource management, and economic analysis.

Graduates of the program have the skills to become analysts or consultants for private industry and public agencies concerned with understanding the management and protection of water and air resources. These employers include government agencies, public utilities, consulting firms, and hydrologic, atmospheric, or environmental research centers.

Water and Air Resources is offered under the Master of Environmental Management degree. Majors in the program can select an area of concentration: water resources, air resources, or a combination of water and air resources. Students may use electives and additional course work to accommodate a second emphasis in another program area within the school. A research track is available in this program.

**Core Courses.** At least one course from among those approved in each of four areas: physical sciences, chemical sciences, biological or ecological sciences, and social sciences; plus three additional courses in the area of concentration.
Professional Versus Graduate Admissions

The student contemplating post-baccalaureate study at Duke in natural resources and the environment or geology enters either the Nicholas School of the Environment and Earth Sciences or the Graduate School depending on the choice of degrees. The professional degrees, consisting of the Master of Environmental Management (M.E.M.) and Master of Forestry (M.F.), are administered by the Nicholas School of the Environment and Earth Sciences. Students wishing to earn either of these professional degrees should apply directly to the school. Those wishing to earn a Doctor of Philosophy (Ph.D.) or Master of Arts (A.M.) degree should apply to the Graduate School. This chapter describes application to Nicholas School of the Environment and Earth Sciences professional degree programs.

Admission to the Nicholas School of the Environment and Earth Sciences

The Nicholas School of the Environment and Earth Sciences welcomes applications from men and women of all backgrounds who seek an intellectually challenging education designed to prepare them for leadership in a wide variety of natural resource and environmental careers. Admission is open to men and women who hold a bachelor's degree from an accredited college or university or who have completed at least three years of study in an institution participating in the Cooperative College Program. Admission as a special or nondegree student may also be granted under appropriate circumstances.

Prerequisites. All students admitted to the school are expected to have had the following:

1. Some previous training in the natural sciences or the social sciences related to their area of interest in natural resources;
2. At least one college semester of calculus;
3. A statistics course that includes descriptive statistics, probability distributions, hypothesis testing, confidence intervals, correlation, simple linear regression, and simple ANOVAs;
4. Experience using computer-based word processing, spreadsheets and databases. Web design software experience strongly encouraged.

Each program requires additional courses or recommends additional preparation, as follows:

- Coastal Environmental Management: microeconomics;
- Environmental Toxicology, Chemistry, and Risk Assessment: significant undergraduate education in biology and chemistry, with a course in organic chemistry required;
- Forest Resource Management: microeconomics, principles of ecology;
• Resource Ecology: microeconomics; principles of ecology;
• Resource Economics and Policy: microeconomics;
• Water and Air Resources: microeconomics; undergraduate training in chemistry recommended.

Although students without the level of preparation described above may be accepted for admission, deficiencies should be made up prior to enrollment in the Nicholas School. A limited number of deficiencies may be made up during the first year of residence; however, these courses will not count toward the 48 units of credit required for the M.E.M. or M.F. degree.

Admission Criteria. Admission to the Nicholas School of the Environment and Earth Sciences is highly selective. Academic performance as an undergraduate, scores on the Graduate Record Examination, and work experience are the primary factors considered in the application review process. Recommendations, the statement of educational goals, extracurricular activities, and other information requested on the application also provide a basis for selection.

The admissions committee considers each applicant as an individual. It attempts to evaluate each candidate for his or her academic potential, professional promise, and ability to benefit from and contribute to the goals of the school. Individuals with prior work experience are especially encouraged to apply.

Application Procedures. Application for admission to the Master of Environmental Management and the Master of Forestry degrees is made through the Office of Enrollment Services of the Nicholas School of the Environment and Earth Sciences by either submitting a paper application or an electronic application, which is available at http://www.env.duke.edu/degree-onlineapp.html. All correspondence should be addressed as follows: Office of Enrollment Services, Nicholas School of the Environment and Earth Sciences, Duke University, Box 90330, Durham, N.C. 27708-0330.

Students are admitted at the beginning of the fall term, and spring term, provided that space is available. For the fall, the application deadline is February 1 preceding the fall in which admission is desired. Because the school processes applications from more qualified students than it can admit, early submission of applications is recommended and no guarantee is made that applications received after the February 1 priority deadline will be considered.

Students who, because of unusual circumstances, wish to begin their studies in January should complete their application no later than October 15 prior to their matriculation.

Each applicant must submit the following before action can be taken. It is preferable that all materials be submitted together.

1. application form;
2. two copies of transcripts from each undergraduate and graduate school attended;
3. three letters of recommendation;
4. scores on the general (verbal, quantitative, and analytical) test of the Graduate Record Examination, taken within the last five years;
5. a nonrefundable application fee of $65 prior to January 1 and $75 after January 1.
6. certificate of financial responsibility and TOEFL scores, if the applicant is an international student;
7. undergraduate dean’s approval for students applying through the Cooperative College Program.

Application Forms. No applicant will be considered until the completed application form and all related documents are received by the Office of Enrollment Services.
The admissions committee attaches considerable weight to the statement of educational objectives submitted by the applicant. This statement should reflect well-defined motivation to pursue graduate study. The school is particularly interested in applicants who show leadership potential in the broad field of natural resources and the environment. Applicants are expected to demonstrate the maturity and sense of purpose essential to a demanding educational experience, including a concept of the value of professional education to the applicant's career plans and expectations.

Transcripts. Two copies of official transcripts of all undergraduate and graduate study should be sent to the Office of Enrollment Services in the application package in sealed envelopes that have been signed across the flap by the registrar of the institution attended.

Letters of Recommendation. Each applicant is required to submit three letters of recommendation, preferably on the form supplied with the application. These letters should be sent in the application package in sealed envelopes that have been signed across the flap by the writer. These recommendations provide the admissions committee with evaluations of the applicant's past performance in academic and employment related situations. Although recommendations from any source are acceptable, it is preferable that as many as possible come from college instructors.

Graduate Record Examinations. All applicants for degree programs must take the general test (verbal, quantitative, and analytical) of the Graduate Record Examination (GRE). Subject tests are not required. For scores to be considered, the GRE must have been taken within five years of the date of application. The GRE is administered by the Educational Testing Service at locations throughout the world. Applicants are urged to take the exam at the earliest convenient date. Scores on tests taken later than December may not reach the school until after the February 1 priority deadline. Scores should be reported to Duke University code number 5156. Registration forms may be obtained by writing to GRE, Educational Testing Service, Princeton, N.J. 08540. Applicants are requested to send copies of their reports to the Office of Enrollment Services, but official reports from the Educational Testing Service are required before admission decisions can be made.

Application Fee. A nonrefundable application fee of $65 prior to January 1 and $75 after January 1 is required of all applicants. A personal check, money order, or cashier's check made payable to Duke University is acceptable. Applicants who submit their applications electronically may pay the fee via credit card. Applications will not be officially received or processed until the required fee has been paid.

Additional Procedures for International Students. Each year the Nicholas School of the Environment and Earth Sciences welcomes a number of international students among its professional and graduate candidates. Applicants from other countries must meet the same criteria as applicants from the United States. All academic transcripts and other documents in support of admission must be accompanied by an official translation if the original document is not in English. The nonrefundable application fee must accompany the application. Applicants must have a fluent command of oral and written English. No allowance is made for language difficulty in arranging course schedules or in evaluating performance.

If the native language is not English, the applicant must submit scores on the Test of English as a Foreign Language (TOEFL) to be considered for admission. All arrangements for taking the TOEFL must be made directly with the Educational Testing Service, Box 6151, Princeton, N.J. 08540-6151; telephone 609-771-7100. In cases where an applicant's TOEFL score is low, the applicant may be accepted on the provision that he/she completes an intensive English language program. Students found to lack necessary competence should be prepared to assume all costs for being tutored in English and may need to reduce their course or research program while being tutored.
Nicholas School professional students will follow the same procedures as Graduate School students regarding assessments of English proficiency on their arrival at Duke. Proficiency exams in written and spoken English will be offered during orientation week. Students lacking the level of proficiency needed to do well at Duke will be able to enroll in additional English language instruction. These courses do not count toward the MEM/MF degrees.

The visa-granting authority in the student's country of origin, ordinarily the United States Embassy, requires proof that sufficient funds are available to the student to cover the expenses of all academic years of study before a visa can be granted. Foreign students are not eligible for federal and state loans, although they may qualify for certain educational loans through private United States agencies. Current immigration laws make it difficult for the foreign student to find summer employment and permanent employment in the United States after graduation. Merit-based financial assistance, if it is offered, is insufficient to cover the costs associated with studying at the Nicholas School. International students should expect to have other sources of support in order to obtain a visa.

Interviews. An interview with a member of the admissions committee is not required but may be helpful to the applicant as well as to the school. Consequently, those applicants who can visit the school are encouraged to do so. The visit presents an excellent opportunity for the applicant to ask questions, gain insight into the school, and bring items of concern to the attention of the admissions committee. Applicants are encouraged to allow sufficient time to visit classes, meet students and faculty, and tour the university.

In general, visits can be scheduled on weekdays throughout the academic year. Appointments should be made at least two weeks in advance. Although visits during the summer months are possible, they should be scheduled well in advance since no summer classes are taught and faculty are frequently away from campus. During the middle of the fall semester and near the beginning of the spring semester, formal visitation programs are hosted by the Office of Enrollment Services of the Nicholas School of the Environment and Earth Sciences. Interested individuals should contact that office at (919) 613-8070 for additional information.

Each year representatives of the school travel throughout the country to visit undergraduate schools. Applicants from the cooperative colleges should check with their program adviser for details of these visits. Applicants from other institutions interested in meeting with a representative of the school should write or call the Office of Enrollment Services. In addition, it is sometimes possible to arrange an interview with an alumnus, particularly where distance precludes travel to Durham. In all of these situations the emphasis is on exchanging information with the applicant.

For further information or to arrange a school visit, applicants may write to the Office of Enrollment Services, send an e-mail to envadm@duke.edu, or call (919) 613-8070.

Deferred Admission. Normally, applicants are admitted only to the class for which they have applied. However, a deferral of admission may be granted for the applicant to gain experience or to strengthen academic qualifications for graduate study or for other valid reasons. Except in unusual circumstances, a deferral of admission cannot be granted for more than one year. Deferral is granted on an individual basis. The size of each class frequently precludes open-ended guarantees of future admission; however, applicants with substantial reasons for deferring the start of graduate work are encouraged to send a request to the Office of Enrollment Services as soon as possible after receiving an offer of admission. Offers of financial assistance are cancelled upon deferral of admission and students must be reconsidered for financial aid.

Application Deadlines for the Professional Programs. Application forms and all other information required to complete the application and to allow a student to be con-
Admission with Nondegree Status

Persons wishing to enter the Nicholas School of the Environment and Earth Sciences as nondegree students must submit a special application form requesting nondegree status along with an application fee of $25. The applicant must have completed a bachelor’s degree from an accredited college or university and must submit an official transcript of all previous coursework. The Graduate Record Examination is not required although the GRE score is helpful in the admissions process. The student must have one letter of recommendation; this letter should indicate why the applicant should be allowed to undertake nondegree study at Duke. The application itself requires a brief statement of purpose in which the applicant should state his or her reasons for such study at Duke.

Admission as a Senior Professional Program Participant

Applicants for either the Master of Environmental Management or Master of Forestry degree through the Senior Professional Program follow the same application procedures as regular students in the school. Applications should be submitted by February 1 for the fall term and by October 15 for the spring term. Normally, degree candidates in the Senior Professional Program take the required semester in residence during the term following admission.

Degree candidates enrolled through the Senior Professional Program are not eligible for financial assistance from the Nicholas School of the Environment and Earth Sciences. They may, however, be eligible for federally funded student loans during semesters of full-time enrollment.

Admission to the Graduate School

Applications for Admission to Ph.D. degree programs should be obtained from and returned to the dean of the Graduate School, Duke University, Box 90065, Durham, N.C. 27708-0065, or e-mail grad-admissions@duke.edu. Applicants to these programs must follow the procedures and meet the deadlines specified by the Graduate School. Initial inquiries and questions concerning fields of study are best directed to the director of Graduate Studies, Nicholas School of the Environment and Earth Sciences. In addition, prospective students are urged to write directly to professors whose research interests match their own to discuss opportunities. Although the priority application deadline for the Graduate School is December 31, applicants are encouraged to apply by December 1.

Response to Offer of Admission

When admission is approved, the applicant will receive an offer of admission and an acceptance form. A nonrefundable tuition deposit is required with acceptance of the offer. The admission process is not complete until the acceptance form and the tuition deposit have been returned to the Office of Enrollment Services. Failure to respond by the stated deadline may result in cancellation of acceptance.
Tuition and Fees

Estimated Expenses for the Academic Year. The following approximate costs, applicable in 2001-2002, are indicative of costs that can be expected by M.E.M. and M.F. candidates; Ph.D. students should consult the Bulletin of the Graduate School.

Tuition ($10,275 per semester) $20,550
Student health fee ($239 per semester) $478
Student government fee ($10 per semester) $20
Recreation fee ($25 per semester) $50
Transcript fee (first semester only) $30
Housing $4,350
Food $3,550
Books and supplies $870
Transportation $1,066
Motor vehicle registration
   Automobile $80-198
   Motorcycle $45

In addition to these necessary expenses, the student will incur others, which will depend to a large extent upon individual tastes and habits. The average Duke student, however, can plan on a budget in the range of $29,000 to $35,000 for the academic year. Students with families naturally will have higher expenses.

Flat-fee Tuition. The flat-fee tuition allows Master of Environmental Management and Master of Forestry degree candidates to register for 9 or more units of credit for a fixed tuition payment per semester. The normal full-time enrollment is expected to be 12 units per semester, although units may vary from 9 to 15 depending upon the student's academic and assistantship requirements. Permission is required to register for fewer than 9 or more than 15 units in a semester.

Students in the two-year M.E.M. and M.F. programs will pay the flat-fee tuition for four semesters. Students in one of the concurrent degree programs will pay the flat fee

1 The figures contained in this section are projections and are subject to change.
for those semesters in which they are registered as full-time students in the Nicholas School of the Environment and Earth Sciences. Students in the concurrent M.E.M./M.F. program pay the flat-fee tuition for a minimum of five semesters. Students in the one-year M.F. degree option will pay the flat fee for two semesters.

If the student is permitted to be enrolled part time (fewer than 9 units), he or she will be charged per unit of credit ($925 per unit for the 2001-2002 academic year).

Students who wish to earn additional credits during the summer will be charged at the part-time rate per units of credit. Students who have completed the required semesters in residence and all course requirements except the master’s project will be charged a minimum registration fee ($350 for 2001-2002) each semester until the degree is completed.

All students are expected to be registered in residence, to be approved for a leave of absence, or to pay a minimum registration fee for each semester until their degree is completed.

Payment of Accounts. Invoices for tuition, fees, and other charges are sent by the Office of the Bursar and are payable by the invoice due date. As a part of the agreement of admission to Duke University, a student is required to pay all invoices as presented, unless other arrangements are made in advance. If full payment is not received, a late payment charge as described below will be assessed on the next invoice and certain restrictions as stated below will be applied. Students interested in arranging a payment plan should contact Tuition Management Services, 42 Valley Road, Newport, R.I. 02842-6376; telephone 800-722-4867.

Late Payment Charge. If the total amount due on the student invoice is not received by the invoice due date, a penalty charge will be accrued from the billing date. The penalty charge will be at a rate of 1.25 percent per month (15 percent per annum) applied to the past due balance. The past due balance is defined as the previous balance less any payments and credits received during the current month. Student loan payments, if delayed for reasons beyond the individual’s control, are treated as a credit on the student’s invoice until the loan payment is received.

Restrictions. An individual will be in default of this agreement if the total amount due is not paid by the due date. An individual who is in default will not be allowed to register for classes, receive a copy of the academic transcript, have academic credits certified, be granted a leave of absence, or receive a diploma at graduation. In addition, an individual in default may be subject to withdrawal from the university.

Tuition Refund Policy. In case of withdrawal from the university, Title IV federal financial aid received by students enrolled for the first time at Duke will be refunded on a pro rata basis. The pro rata formula is defined as the total school charges times the remaining portion of the enrollment period for which the student has been charged, rounded downward to the nearest 10 percent, less any unpaid charges owed by the student. The pro rata refund policy does not apply to any student whose withdrawal is after the 60 percent point in the period of enrollment. Sample refund calculations are available from the Enrollment Services Office.

If the student receives federal financial aid but is not attending the university for the first time or if the student does not receive federal financial aid, tuition will be refunded or carried forward as a credit for later study according to the following schedule:

<table>
<thead>
<tr>
<th>Withdrawal</th>
<th>Refund</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before classes begin</td>
<td>full amount</td>
</tr>
<tr>
<td>During first or second week</td>
<td>80 percent</td>
</tr>
<tr>
<td>During third, fourth or fifth week</td>
<td>60 percent</td>
</tr>
<tr>
<td>During sixth week</td>
<td>20 percent</td>
</tr>
<tr>
<td>After sixth week</td>
<td>none</td>
</tr>
</tbody>
</table>
This schedule also applies to housing charges of students moving from university housing to off-campus housing. The student health fee will not be refunded except when withdrawal occurs before classes begin. In the event of death, a full refund of tuition and fees will be granted.

**Late Registration.** Students who register at a date later than that prescribed by the university must pay a fee of $25 at the bursar’s office.

**Audit Fee.** Students registered for a full course load may audit courses without charge. Otherwise, audit fees are $925 per course.

**Transcripts.** Transcripts are available on request from the Duke University Office of the Registrar. During their first semester in residence, students are charged a $30 fee that covers the request of transcripts. Transcripts cannot be issued by the Nicholas School of the Environment and Earth Sciences.

**Housing Charges.** On-campus housing for professional and graduate students is available on a limited basis. Questions regarding costs should be addressed to the Office of Housing Administration, Duke University, Box 90451, Durham, N.C. 27708-0451.

**Motor Vehicles.** Motor vehicles parked on campus must be registered with the parking services office. Registration must be completed within five days after operation on campus begins. The proper registration decal should be displayed on the vehicle. The automobile registration fee is $80 in ungated lots and $198 in gated lots. Motorcycle registration is $45.

**Student Health Fee.** All students are assessed a fee for the Student Health Service. For the fall and spring, the fee is $478 ($239 per semester). For the summer, the fee is $77 per term.

**Medical Insurance.** All resident students are automatically billed for health insurance at the rate of $847 per year (single student cost). Family plans are more and are available through the university bursar’s office. A student who is covered under a family, group or individual major medical policy must sign a waiver form indicating that he/ she does not wish to be covered by the university student insurance policy. All foreign students are required to register for student insurance (and for the family plan if they have a spouse or children living in Durham) unless they have valid documentation indicating major medical coverage acceptable in the United States.

**Tuition and Fees for the Summer.** Very few course offerings are available on the Durham campus of the Nicholas School for the summer. M.E.M. and M.F. students, who wish to take additional credits during the summer, should expect to do so through other departments in the university or at the Duke University Marine Lab in Beaufort. Students should consult with their advisors to make sure the courses are appropriate for their program of study. Tuition and fees for summer study depend on the applicable department. Students who are interested in summer study in Beaufort should consult the Bulletin of the Nicholas School of the Environment and Earth Sciences, the Marine Laboratory Bulletin or the Marine Lab’s website, http://www.env.duke.edu/marineLab/. Information on fees, housing, policies and procedures related to the Duke University summer session is available from the Duke University website located at http://www.learnmore.duke.edu.

**Recreation Fee.** A mandatory fee of $50 per academic year ($25 per semester) will be charged to all registered students for usage of campus recreational facilities. Students’ spouses or domestic partners are eligible to use the facilities for a fee of $25 per semester, plus a $10 application fee.

**Athletic Events.** Students are admitted free of charge to all regularly scheduled university athletic events held on campus during the academic year, with the exception of basketball. Students who wish to attend home basketball games must enter the student ticket lottery and pay for tickets if selected.
Financial Assistance

Financial assistance in the form of scholarships, fellowships, or assistantships is available for qualified students pursuing either the professional degrees (M.E.M. or M.F.) or the graduate degrees (Ph.D.). Students enrolled through the Senior Professional Program are not eligible for school supported financial assistance but may be eligible for federally funded student loans.

All professional degree students must file the Free Application for Federal Student Aid (FAFSA) to be considered for student loans and work study. A separate application must be filed for each academic year.

Applicants may obtain a FAFSA from a college or university counseling and placement center or financial aid office. The form is also available on-line at http://www.fafsa.ed.gov. Professional degree applicants must also complete the financial aid section of the Application for Admission. Scholarships and assistantships are granted from school funds, which are in limited supply. Consequently, only well-qualified students can expect to receive awards. Scholarships and assistantships are awarded on the basis of demonstrated outstanding academic ability and a high degree of professional promise.

Fellowships are obtained from foundation grants, private industry, or individual donors. Donors of fellowship funds sometimes place restrictions on the use of the funds as well as on the amount of awards.

Research assistantships are obtained primarily from grant and contract funds awarded to various faculty in the school. University-funded assistantships are available for students who have sufficient experience to contribute to one or more ongoing research or academic programs.

Pursuant to the Tax Reform Act of 1986, students performing any services (whether degree related or not) required by their scholarship, fellowship or assistantship must have income taxes withheld. However, if the student anticipates no tax liability at the end of the calendar year, he or she can note "exempt" on the state and federal withholding forms and no taxes will be withheld. Income tax information is reported to the student by the university in January.

In all instances, admission to the school is a prerequisite for the award of assistance in any form. If offered financial assistance, professional students normally will receive the award for two years of study; it is expected that they will complete their degree within this period of time. For graduate students, it is the policy of the school to provide financial assistance through university funds for three years; it is expected that Ph.D. candidates will obtain research grants to fund their study past the third year. However, the school has the right to examine the progress of each student to determine eligibility for continuation of awards beyond the first year.

No student will receive financial aid while on probation unless an appeal is approved by the Admissions and Awards Committee.

Eligibility for Financial Assistance

A significant portion of the financial assistance for students in the Nicholas School of the Environment and Earth Sciences is provided by federal, Title IV funds. To qualify for such funding, usually in the form of loans, students must meet federal eligibility requirements including the maintenance of satisfactory academic progress. Professional degree students must complete at least 18 units of course work with at least 6 units of G and/or E grades during the first full year of study and may not receive a grade of F in any course to be eligible for federal financial aid for their second year.

Although professional degree students have five years from the first date of matriculation in the school to complete their degree requirements, they are eligible for federal financial assistance for the equivalent of four full-time semesters only. Students who fail to meet the satisfactory academic progress requirements or need federal
financial assistance for more than the equivalent of four semesters may appeal to the admissions and awards committee.

Graduate degree candidates should review the Bulletin of the Graduate School for details regarding satisfactory progress for their degree program.

**SCHOLARSHIPS**

University Scholarships. A limited number of scholarships are awarded each year to selected students who are pursuing either professional or graduate degrees. Awards are made on the basis of academic qualifications and professional or scientific promise. Amounts of awards vary.

**FELLOWSHIPS**

**C.G. Bookhout Scholarship Fund.** The Bookhout Scholarship provides financial assistance to juniors, seniors, or beginning graduate students with a professional interest in the natural sciences.

**Rachel Carson Graduate Fellowship.** A fellowship is awarded to a selected student who is conducting research related to some aspect of the Rachel Carson Estuarine Research Reserve.

**Timothy J. and Anne G. Creem Scholarship Fund.** Fellowships are awarded each year to selected students pursuing a Master of Forestry degree. The stipends are determined by the amount of endowment income each year.

**Cummings Family Fellowship.** Fellowships are awarded each year to selected students who are pursuing a Master of Environmental Management or Master of Forestry degree. The stipends are determined by the amount of endowment income each year.

**Barbara L. Dannenberg Fellowship.** A fellowship is awarded to a selected student, preferably in the field of ecology, who is involved in undergraduate education. The award ranges up to $9,000.

**Doris Duke Conservation Fellowships.** The Nicholas School of the Environment and Earth Sciences is one of a select group of schools to partner with the Doris Duke Charitable Foundation to identify students with professional promise for future leadership in conservation. Fellows are competitively selected during the first semester of study and are awarded a summer internship stipend, supplemental tuition support and partial educational loan repayment.

**Federal Paper Board Company Fellowship.** A fellowship is awarded each year to a selected student interested in a career in industrial forestry. The stipend ranges up to $3,000 per year.

**Virlis L. Fischer Fellowship.** A fellowship is awarded each year to a second-year Master of Environmental Management or Master of Forestry candidate with demonstrated financial need. The stipend is determined by the amount of endowment income each year.

**Forestry and Environmental Studies Endowment Fund Fellowships.** Made possible by a grant of the Cordelia S. May Charitable Trust, this fund currently provides multiple fellowships in the area of wetland research and restoration.

**Leroy B. George Fellowship.** A fellowship is awarded to a selected student from the Haywood or Buncombe counties or the Hendersonville, North Carolina, school systems. Second preference is given to a student from the southern Appalachian region. If a qualified student cannot be identified within the region the fellowship may be awarded to a student in the school who has demonstrated interest in resource and environmental education and planning. The amount of the fellowship is approximately $4,000 per year.

**Charlotte H. and Robert Hay Endowment Fellowship.** A fellowship is awarded annually to a selected student in forestry or environmental studies. The award ranges from $3,000 to $4,000.
Richard E. Hug Fellowship. A fellowship is awarded to a selected student who is pursuing a Master of Environmental Management or Master of Forestry degree. The stipend ranges up to $2,000 per year.

Melanie Elizabeth Lynn Memorial Scholarship. The Melanie Elizabeth Lynn Memorial Scholarship provides financial assistance to female graduate students for summer academic course work.

Mary Derrickson McCurdy Graduate Fellowship. A fellowship is awarded to a selected student who is conducting research at the Duke University Marine Laboratory.

Andrew W. Mellon Foundation Fellowship. Fellowships are awarded each year to selected students pursuing master's or Ph.D. degrees. Stipends range from $1,000 to $5,000 a year.

Muchnic Foundation Endowment Fellowship. A fellowship is awarded each year to a selected student who has demonstrated financial need. The award ranges up to $2,000.

Nicholas School of the Environment and Earth Sciences Alumni Association Fellowship. Fellowships are awarded each year to selected students who are pursuing a Master of Environmental Management or Master of Forestry degree. The students must have completed one year of study. The amount of the fellowships is set at $2,000 per year.

Nicholas School of the Environment Alumni Association Minority Fellowship. A fellowship is awarded each year to a selected minority applicant for the Master of Environmental Management or Master of Forestry degree. The amount of the award is determined by the endowment income each year.

Elizabeth Reid Endowment Fund. Income from this fund is currently used for a fellowship for a selected student. The award is in the $2,500 range.

Robert Safrit Graduate Fellowship. A fellowship is awarded to a selected student who is conducting research in some aspect of marine science at the Duke University Marine Laboratory.

Thomas and Anne L. Shepherd Endowment Fund. Income from this fund is currently used for multiple fellowships in the $3,000 to $11,000 range.

Harvey W. Smith Graduate Fellowship in Biological Oceanography. A fellowship is awarded to a selected student who is conducting research in biological oceanography at the Duke University Marine Laboratory.

John and Blake Sullivan Endowment Fund. Income from this fund may be used for fellowship support of a selected student. Awards range up to $1,300.

James F. West Endowment Fund. Income from this fund is currently used for fellowships in the $3,000 to $8,000 range.

Frederick K. Weyerhaeuser Forest History Fellowship. This fellowship is available campus-wide to graduate students who wish to study broadly in the area of forest and conservation history. The annual stipend is $11,000. Inquiries should be made to the Forest History Society, 701 Vickers Avenue, Durham, N.C. 27701.

Sara and Lewis Zirkle Fellowship. Fellowships are awarded to selected students pursuing master's or Ph.D. degrees. The stipend is determined by the amount of the endowment income each year.

INTERNSHIPS

David Brower Scholarship. Made possible by Dan and Bunny Gabel, the David Brower Scholarship provides a summer stipend for professional degree students so that they may serve as interns in grassroots environmental organizations that exemplify David Brower's uncompromising commitment to the environment.

Whitney Lawson Chamberlin Memorial Internship. Established by the family of Whitney Lawson Chamberlin, a first-year student at the Nicholas School of the Environ-
ment and Earth Sciences, the internship is awarded to a selected student to explore the interplay between business and the environment.

**Champion International Corporation Intern/Scholarship Program.** The Champion International Intern/Scholarship program includes both an internship and scholarship. It provides first year M.E.M students an opportunity to compete for a paid summer internship with Champion and $10,000 tuition support for second year study.

**Doris Duke Internships.** Made possible by the Doris Duke Charitable Foundation, these internships are awarded to ten Doris Duke Fellows for work with nonprofit conservation organizations or public sector agencies for 11 weeks each summer.

**Kuzmier-Lee-Nikitine Endowment Fund.** Established by family and friends in memory of Kerrie Hamilton Kuzmier, Stephen Farrow Lee, and Pavlik Andre Nikitine, the Kuzmier-Lee-Nikitine Endowment supports an international internship project each summer.

**Stanback Internships.** Made possible by Fred and Alice Stanback, the Stanback Internship program awards 30 or more conservation and policy internships each year for work with selected environmental organizations.

**ASSISTANTSHIPS**

Assistantships for the Professional Degree Candidate. Assistantships may be awarded to a select number of professional students during their first year of study to assist faculty and staff with teaching, research, professional and other projects. It is expected that students will work for ten hours a week on their assigned project. Assistantships require a regular schedule for work to be arranged between the student and the faculty or staff member to whom he or she is assigned. During the second year of study, professional students may fulfill the assistantship requirement by working independently on their master's project.

The hours of assistance may limit the number of credit hours for which a student may register. Normally, professional students who receive assistantships for ten hours per week are limited to 12 units of credit per semester. Exceptions require the permission of the student's adviser.

Most assistantships are paid by the school on the monthly payroll. For the 2001-2002 academic year, the award for ten hours of assistance was $2,800. Normally, assistantships are available only for the academic year and require full-time enrollment in the school. A few awards may be available during the summer, however, for faculty research, staff, and Duke Forest assistance. Summer stipends are paid on a biweekly or monthly basis.

**Teaching Assistantships for Ph.D. Candidates.** Each year a selected number of Ph.D. candidates may be offered a financial aid package consisting of full tuition plus a monthly stipend. The tuition is a scholarship from school funds and is tax exempt. The monthly stipend ($1,611 per month in 2001-2002) requires up to 15 hours of work per week during the nine-month academic year and is taxable. Students receiving these stipends are assigned by the director of graduate studies to serve as teaching assistants for various faculty.

Normally, students are supported on teaching assistantships for only the first three years of their graduate study. After that, they are usually supported on research assistantships for the remainder of their graduate program. Students supported on teaching assistantships may also receive support for the three summer months from research funding.

**Research Assistantships for Ph.D. Candidates.** Funded from grant and contract research under the direction of various members of the faculty, research assistantships provide support during the course of study of the Ph.D. candidate. Typically, the research assistant completes one or more phases of a research project under the direction of the principal investigator, a member of the faculty. Normally, the research completed
forms a substantial component of the requirements of the Ph.D. dissertation. However, in some instances this may not be the case and the students pursue dissertation research in a related area of study.

The academic year stipend is salary for research involving up to 20 hours per week. Some research assistantships require full-time service during the summer. A regular schedule of research under the direction of the principal investigator must be maintained.

**Work-Study.** Work-study funds are administered for student employment through the Office of Enrollment Services. At the beginning of the academic year, students are made aware of work-study opportunities and informed of the application procedures. Interested students should file the Free Application for Federal Student Aid (FAFSA).

**Application for Awards for the Entering Student**

Application for awards is made concurrently with the application for admission. Applicants should initiate the necessary action early to ensure that the required documents are filed with the school’s Office of Enrollment Services on or before February 1 prior to fall term enrollment.

**Notification and Acceptance of Awards.** Recipients of awards are notified in April. Completed applications received after the February 1 priority deadline will be considered if vacancies occur at a later date.

Scholarships, fellowships, and the various categories of assistantships provide the basis for professional/graduate student support. Once offered by the university or the school, funds are committed to one student and are therefore unavailable to others. As a consequence, it is the policy of the school that all awards offered can be declined prior to May 1 without prejudice. However, offers accepted and left in effect after May 1 are binding for both the student and the school.

**Loans**

In terms of a needy student being able to afford the graduate program of his or her choice, federally insured student loans are often necessary and useful. Students should consider the nature of the loan and the positive and negative aspects of future loan payments, as well as investigate all other forms of financial assistance.

Federal law requires all students to have completed a Free Application for Federal Student Aid (FAFSA) to determine financial need. The FAFSA form may be obtained online at www.fafsa.ed.gov or by contacting a college or university financial aid office. No loan application will be processed without the FAFSA form having been submitted to the central processor. In addition federal law requires, in some cases, verification of income and other information.

**Federal Stafford Loans.** Federal Stafford loans of up to $18,500 ($8,500 subsidized and $10,000 unsubsidized) are available for eligible graduate/professional students. For loans made to new borrowers, interest is calculated at a variable annual rate, not to exceed 8.25 percent. Students who have outstanding loans retain their current interest rate. If a student is eligible for a subsidized federal Stafford loan, interest is paid by the federal government while the student is enrolled in school. Interest on unsubsidized loans must be paid by the student during enrollment or capitalized to the principal at the borrower’s request.

Students may be eligible for a combination of subsidized and unsubsidized loans. Eligibility for the subsidized loan is determined by subtracting all financial aid awards and the student’s expected contribution from the Nicholas School’s student budget. The student’s contribution is computed from the income and asset information submitted on the FAFSA. Eligibility for the unsubsidized loan takes into consideration the other financial aid being received by the student, but the expected student contribution is not
considered. Students may borrow from the unsubsidized loan program the difference between the student budget and their other aid (including any subsidized Stafford loan), up to a maximum of $18,500 for an academic year.

To obtain a federal Stafford loan, students may apply either to a state agency or bank that participates in the program. A partial listing of lenders is available from the school’s Enrollment Services Office.

Students who borrow through the federal Stafford program will be given entrance and exit interviews concerning the projected and actual costs of their loans. They will also be provided with information on loan consolidation, should this repayment option be desired or needed.

Federal Perkins Loans. Loans through the federal Perkins program are administered through the university for students who qualify under federal guidelines. The student must qualify as needy by the FAFSA form and in need of additional assistance beyond the maximum federal Stafford allocation. The interest rate is 5 percent, with payment on interest and principal deferred until nine months following graduation.

Duke Signature Select Loans. For students who need more funds than are available through the federal Stafford loan and the federal Perkins loan programs, the University offers the Duke Signature Select loan program. Through this program, students can borrow up to the cost of education (minus other aid received). The interest rate on this loan is based on the 91-day Treasury Bill (approximately 5.9 percent currently) +2.5% while in school, and the T-bill +3.1 percent during repayment. Repayment begins 6 months after graduation or dropping to less than half-time enrollment. Applications can be obtained by contacting the Office of Enrollment Services in the Nicholas School at (919) 613-8070. Since this is a private loan, a credit check will be made by the lender.

Federal Grant Programs. Students with only three years of study at one of the institutions in the Cooperative College Program may be eligible for undergraduate state and federal grant programs. Such students should consult their undergraduate financial aid officers, state loan agencies, or federal granting agencies for applications, requirements, and restrictions.
General Information

The Duke Marine Laboratory is a campus of Duke University and a unit within the Nicholas School of the Environment and Earth Sciences. Its mission is education and research in basic ocean and coastal ecosystem processes, coastal environmental management and policy, marine biotechnology and marine biomedicine. The laboratory operates year-round to provide training, educational, and research opportunities to about 3,500 persons annually, including undergraduate, graduate and professional students enrolled in the university's academic programs; visiting student groups who use the laboratory’s facilities; and scientists who come from North America and abroad to conduct research. A seminar/lecture series features many distinguished scientific speakers from across the nation and abroad.

The resident faculty members represent the disciplines of oceanography, marine biology, marine biomedicine, marine biotechnology, and coastal marine management and policy.

Location and Natural Environment

The Duke Marine Laboratory is situated on Pivers Island within the Outer Banks of North Carolina, only 150 yards across the channel from the historic town of Beaufort. A bridge connects the island with US Highway 70, making the laboratory readily accessible by automobile. Other transportation to the area consists of airline service via regional airports (New Bern, Kinston, and Jacksonville).

Beaufort is the third oldest town in the state and is surrounded by fishing and agricultural communities. The area is well known for its historic and scenic attractions as well as being a seaside resort. Cape Lookout National Seashore Park and the Rachel Carson Estuarine Research Reserve are within easy boating distance.

The area is a system of barrier islands, sounds, and estuaries rich in flora and fauna, and other diverse habitats, including rivers, creeks, mud flats, sand beaches, dunes, marshes, peat bogs, cypress swamps, bird islands, and coastal forests, making the area a haven for both nature lovers and those interested in the pursuit of marine science.

The laboratory is within range of both the temperate and tropical species of biota. The edge of the Gulf Stream oscillates between 30 and 40 miles offshore, with reefs on the wide continental shelf. A great variety of phytoplankton, seaweeds, seagrasses, and marshgrasses may be found in the area. Common animals include the blue crab, squid, shrimps, snails, clams, ctenophores, jellyfish, hydroids, sponges, polychaetes, sea urchins, starfish, brittle stars, sand dollars, skimmers, terns, gulls, herons, sea turtles, dolphins, and many species of fish. All provide ample opportunity for study and research and are readily accessible on foot, by car, or by boat.

The Beaufort-Morehead City area provides location for five other laboratories that collectively house one of the higher concentrations of marine scientists in the nation. These are the University of North Carolina’s Institute of Marine Sciences, the North Carolina State University Seafood Laboratory, the North Carolina Aquarium at Bogue Banks, North Carolina Division of Marine Fisheries; and the National Oceanic and Atmospheric Administration’s National Marine Fisheries Service, Beaufort Laboratory. This concentration of marine scientists provides a critical mass for the pursuit of science and education.
The Beaufort Experience

The Duke Marine Laboratory is an academic community, and the self-sufficient nature of its residential life serves well those who wish to study or to conduct research. The academic programs are limited to eighty students per regular academic semester (spring or fall) and one hundred per summer term, offering an unparalleled small-group learning experience. Although recreational opportunities are ample, the distractions are limited, allowing both student and researcher to become totally involved in the pursuit of marine science. Both students and researchers alike find that the Marine Laboratory has an invitingly open, friendly, and relaxed atmosphere that draws many back year after year. This community feeling, the potential for total immersion in learning, and the beauty of the natural environment have contributed to what is called "The Beaufort Experience."

Teaching and Research Facilities

The Duke Marine Laboratory’s modern physical plant consists of twenty-three buildings, including four dormitories, a large dining hall, one residence, a student commons, a storehouse for ship’s gear, classroom laboratories, six research buildings, and a maintenance complex. The Marine Laboratory operates the R/V Susan Hudson, a 57-foot fully-equipped coastal oceans research vessel, and is the home port for the R/V Cape Hatteras, a 135-foot oceanographic research vessel operated for the National Science Foundation by the Duke/University of North Carolina Oceanographic Consortium.

The laboratory also maintains an electronics shop, workshop, stockroom, and purchasing department.

Each research laboratory building is air-conditioned and equipped with running seawater through a PVC system. There are tanks, water tables, aquaria, autoclaves, ovens, and outdoor continuous-flow growth facilities. In addition to commonly used
laboratory equipment, the following are available: refrigerated centrifuges, fluorometers, spectrophotometers, balances, pH meters, both compound and inverted microscopes equipped with cameras and Nomarski optics, both fume and laminar flow hoods, liquid scintillation counter, constant temperature equipment, and HPLC.

The Marine Laboratory houses a Sun Sparc station as well as two Duke University public access clusters, MAC and IBM-PC, all connected to the Internet. Available for use are 13 586-based workstations and two MACs with word processing and statistics programs. Color printing and scanning services are also available on the island.

Research and teaching facilities also include the I. E. Gray Library-Auditorium which houses the Pearse Memorial Library, a branch of the Duke library system providing access to print and electronic resources that support interdisciplinary education and research with a primary focus on the marine environment. Electronic resources include online full-text journals, and the Duke online catalog. The library currently subscribes to 60 research journals and maintains holdings of approximately 23,000 volumes. Two NT workstations with laser printing capability and a general access photocopier are provided for public use.

The library actively participates in interlibrary loan and document delivery arrangements with the triangle universities and other national and international academic institutions and research centers. Additional cooperative agreements exist with the National Ocean Service Center for Coastal Fisheries and Habitat Research, the University of North Carolina Institute of Marine Sciences, and the University of North Carolina at Wilmington.

**Opportunities for Students**

The resident faculty offer a wide variety of graduate courses in the marine sciences that are appropriate for students planning careers in basic or applied research and/or teaching, environmental management or policy sciences, or environmental health sciences. Courses are offered during both the academic year and the summer. Many Environment courses are cross-listed with the Graduate School Departments of Biology, Cell Biology, and Public Policy Studies. Graduate research or individual study courses are also offered. Most of the summer courses carry 4 or 6 units of credit and include laboratory and direct field or shipboard experience.

Students have access to all laboratory facilities and the opportunity to meet visiting scientists from around the world. Room and board are available, and summer tuition scholarships are offered on a competitive basis.

Further information and application materials may be obtained from the Admissions Office, Duke University Marine Laboratory, Nicholas School of the Environment and Earth Sciences, 135 Duke Marine Lab Road, Beaufort, N.C. 28516-9721; telephone (252) 504-7502.
Research Centers
Research centers in the Nicholas School of the Environment and Earth Sciences are by design and intent flexible, multidisciplinary units. A major aim is to bring together specialized groups of scholars and professionals from many disciplines to focus their attention on current natural resource and environmental problems. The centers are headed by a director and staffed by an interdisciplinary faculty from Duke, neighboring universities, and a variety of public and private research organizations. Depending upon the level of funding, the centers may also employ research assistants and other support staff. The centers do not offer courses or degrees; rather, they offer students, scientists and other professionals an opportunity to participate in research through collaboration with affiliated faculty.

**Center for Hydrologic Science**

Co-Directors: Dr. Gabriel Katul, Associate Professor Of Hydrology, Nicholas School Of The Environment and Earth Sciences; Dr. Miguel Medina, Professor Of Civil Engineering, Pratt School Of Engineering

From global climate change to flooding to hazardous waste storage, the science of hydrology plays a key role in many problems facing society. Hydrology is the study of the hydrologic cycle and its components on land. Rivers, lakes, plants, soils, rocks and snow and ice provide the storages for water on land. Hydrologists are concerned with the magnitude and chemistry of these storages over time and space and the rate of transfer of water from one storage to another. Key transfer processes include river flow, groundwater flow, evaporation, transpiration and soil moisture flow. Studies of these storages and transfer processes allow us to examine a variety of environmental problems and devise solutions for them.

The twentieth century and its associated environmental problems have brought about an explosion of studies in hydrology, particularly those studies that relate to environmental issues and water hazards. Hydrologists have their roots in and depend upon a variety of associated disciplines including civil engineering, ecology, environmental engineering, geology, geophysics, mathematics, meteorology and soil science. At Duke University, we have reached across school and departmental boundaries to organize a university-wide program in hydrology.

The Center for Hydrologic Science, established in 1996 with funds from the provost's Common Fund, serves as a integrating center for hydrology research and graduate level hydrology education at Duke University. The center’s interdisciplinary nature reflects the interdisciplinary nature of the field of hydrology. The center draws faculty and their associated students and post-doctoral researchers from three schools at Duke: Arts and Sciences, the Pratt School of Engineering and the Nicholas School of Environment and Earth Sciences. Many faculty hold joint professorships in two of the three schools.
Research specialties of the faculty include:

- Contaminant hydrology
- Environmental geophysics
- Forest hydrology
- Geomorphology
- Hydrogeology
- Mathematical models of multi-phase transport
- Nutrient cycling
- Pollutant transport
- Remediation strategies
- Sediment transport
- Soil physics
- Surface chemistry
- Watershed hydrology

The broad range of faculty expertise in hydrology allows graduate students to obtain well-balanced training in the classroom.

The center offers fellowships for graduate study in hydrology and organizes a lecture series that attracts speakers of international stature. Monthly colloquia are organized for student and faculty presentations from Duke as well as the nearby University of North Carolina at Chapel Hill and North Carolina State University in Raleigh. For students engaged in Ph.D. research the center offers a Certificate in Hydrology that is granted in addition to the Ph.D. degree in their host department.

The mailing address is Nicholas School of the Environment And Earth Sciences, BOX 90328, Levine Science Research Center, Durham, N.C. 27708-0230; phone (919) 613-8033, Internet http://www.hydro.duke.edu.

University Superfund Basic Research Center

Director: Richard Di Giulio, Professor of Environmental Toxicology, Nicholas School of the Environment and Earth Sciences

There is increasing recognition that early life stages of humans and other organisms are particularly sensitive to environmental stressors such as pollutants. The Superfund Basic Research Center unites researchers from the Nicholas School of the Environment and Earth Sciences, the Pratt School of Engineering, and the Duke University Medical Center in examining the reproductive and developmental effects of chemicals found at Superfund sites.

Goals of the center are to study the mechanisms of exposure and toxicity in humans and ecosystems to specific Superfund chemicals which are selected based upon their potential relevance to reproductive and developmental cycles; to facilitate the transfer of mechanistic information obtained across particular vertebrate models (mammal and fishes) relevant to human and/or ecological health; to develop highly sensitive and efficient markers for reproductive and developmental toxicities that can be incorporated into human health and ecological assessments; to elucidate chemical mechanisms controlling the transport and fate of selected chemicals in order to improve predictions of human and ecosystem exposures to emissions from Superfund sites; to develop transgenic zebrafish and Fundulus models that will contribute to the understanding of reproductive and developmental impacts in vertebrates; to establish a strategy for elucidating potential exposures in human populations to chemicals emanating from Superfund sites in North Carolina and concomitantly communicate this information to health professionals, community leaders and the public; to enhance interdisciplinary research, and graduate and post-graduate training in the biomedical and environmental sciences.

The center capitalizes on the close ties that exist between biomedical and environmental scientists at Duke University and its Medical Center and with other institutions in the Research Triangle including NIEHS, U.S. EPA, the Chemical
Duke University Wetland Center

Director: Curtis J. Richardson, Professor, Nicholas School of the Environment and Earth Sciences

The goal of the Duke University Wetland Center is to provide sound scientific knowledge that will lead to sustainable wetland functions and values for the nation and the world. The center works toward this goal by conducting, sponsoring, and coordinating research and teaching on critical wetland issues.

Perhaps no single environmental issue has so polarized public opinion as the protection of wetlands. Part land, part water, wetlands are ecosystems in which water level and low oxygen support a unique ecological habitat conducive to the development of specific plant and animal species. The hydrologic and biologic nature of wetlands generally is poorly understood by the people expected to comply with wetland regulations. Many people are unaware of the connections between surface water and groundwater, and the link between the two that wetlands often provide. Similarly, people often are not aware of the economic and ecological importance of wetlands in improving water quality, providing flood control, supplying habitat for commercial fisheries, supporting waterfowl and wading birds as well as the hunting and recreational values these ecosystems provide. Further complicating the issue of appropriate wetland resource management, people want both the unfettered right to use their own land and the right to use unpolluted waters.

By bringing together scientists and professionals, the Duke Wetland Center is able to focus attention on these and other wetland issues of regional, national, and international scale. Core researchers for the center are the director, faculty, visiting scholars and graduate students. As part of a professional school within a private university, the Duke Wetland Center works independently on wetland issues without the political pressures often brought to bear upon public institutions.

Selected current and proposed research activities are:

- The Duke Forest Wetland Restoration project to improve water quality while providing a working laboratory for researchers and students
- Working with the North Carolina State Wetlands Restoration Program, the Duke Wetland Center is developing procedures identifying the best restoration sites for maximum watershed-level water quality improvement
- Effects of agricultural runoff on Everglades nutrient cycling and storage
- Water management strategies to sustain ecological integrity of the Everglades
- Assessment of wetland ecosystem functional response to highways
- Integrating ecological wetland functions and human wetland values
- Functional assessment of constructed wetlands versus natural wetlands
- Role of sediment processes in regulating water quality of the Cape Fear River
- Wetland hydrology, paleohydrology and hydrologic evolution

The Wetland Center is housed in the Levine Science Research Center on the Duke campus. The mailing address is Nicholas School of the Environment and Earth Sciences, Duke University, Box 90333, Durham, N.C. 27708-0333; telephone (919) 613-8009; fax (919) 613-8101; Internet http://www.env.duke.edu/wetland/. The center also maintains an Everglades research laboratory near West Palm Beach, Florida.

Forest Resources Center

Director: Daniel D. Richter, Professor, Nicholas School of the Environment and Earth Sciences
The objective of the Center for Forest Resources is to promote and conduct research and education that increases the ability to understand, use, and conserve forest ecosystems. This research is conducted worldwide and is motivated by a broad number of issues, including the balance of use and conservation, ecosystem sustainability, species diversity, air pollution effects, water and carbon cycling, conflict resolution over management alternatives, policy analyses, and economic valuation of commodity and non-commodity goods and services.

Duke's location in the USA South provides researchers and students with a special perspective of forestry ecology and management. The region is the world's most productive for forest wood products. Sustaining this enormous economic and ecosystem productivity depends upon long-term ecosystem dynamics that are strongly governed by a past in which these ecosystems have been intensively used and frequently degraded by agricultural practices, and a future in which improved management is critical to develop. Improving the water quality, soil capability, wildlife habitat, and overall management of these forest ecosystems are subjects of various studies.

Duke research on the southern forest is internationally regarded and includes the Korstian-Christensen studies of forest succession in the Duke Forest, the four-decade study of forest-soil biogeochemical sustainability at the Calhoun Experimental Forest in South Carolina, and the large collaborative project with Brookhaven National Laboratory to investigate effects of carbon dioxide on pine ecosystems in the Duke Forest.

The center benefits the school's educational activities in forest ecology, general ecology, silviculture, soil sciences, hydrology, modeling, and environmental social sciences. Center activities include periodic discussions, guest speakers or forums. Ultimately, the center aims to fund student research, fellowships, and visiting professorships.

The Forest Resources Center is a founding organization of the Southern Center for Sustainable Forests, a collaborative organization that promotes technical analysis of controversial issues related to forest management. The Southern Center is composed of researchers from Duke University and North Carolina State University, and from the North Carolina Department of Forest Resources, and has worked on such controversial issues as the ecologic and economic evaluation of the wood chip industry and an evaluation of two leading forest certification systems.

**Marine/Freshwater Biomedical Center**

**Director:** Celia Bonaventura, Professor, Nicholas School of the Environment and Earth Sciences

The Marine/Freshwater Biomedical Center of Duke University is a problem-oriented center that is nationally and internationally recognized for its contributions to environmental health. It integrates unique facilities and faculty expertise available on the Beaufort and Durham campuses of Duke University and applies this powerful collective strength to challenging problems of human and environmental health significance, with a focus on the adverse effects associated with the toxicity of metals and free radicals. Research advances by center investigators increase the understanding of underlying toxic mechanisms, so that good human and environmental health choices can be made. The center is distinguished by its record in biotechnology, its interdisciplinary programs, and its effectiveness in advancing marine and freshwater model systems for mechanistic studies. It is unique in its intellectual setting, providing a bridge between Duke's nationally recognized School of Medicine, the Nicholas School of the Environment and Earth Sciences, and the Marine Laboratory. In its physical setting it draws effectively on the institutes and industries of the Research Triangle of North Carolina. Through its interactive workshops and outreach efforts the center communicates re-
search findings on marine and freshwater aspects of environmental health problems to
the clinical and research arms of the medical community, policy makers and the public
at large.

**The specific aims of the center are to:**

- Support and enhance the distinctive mechanistic research programs of center
  investigators, drawing on the physical and intellectual resources of the Beaufort and
  Durham campuses of Duke University and other North Carolina institutions.
- Provide a cohesive framework for interdisciplinary interactions, information
  exchange and innovative technological development for improved environmental
  health research.
- Aid in the development and use of marine and freshwater model systems for
  mechanistic human and environmental health studies, with a focus on metal and free-
  radical toxicity.
- Enhance the application of state-of-the-art facilities and methodologies to both
  individual and collective environmental-health research programs.
- Provide community outreach and education that informs scientists, policy makers
  and the public at large about environmental health issues and research advances.

Feasibility studies are conducted to explore the advantages of various experimental
approaches and to encourage innovative research.

Students interested in working with members of the center’s participating faculty
should direct their first inquiry to the Admissions Office, Duke University Marine
Laboratory, 135 Duke Marine Lab Rd., Beaufort, NC 28516-9721; telephone (252) 504-
7502. It should be noted, however, that the center does not grant degrees. Graduate
students are enrolled in the degree programs of the respective department or school of
their mentors.

Researchers may direct their inquiries to the office of the Marine/ Freshwater
Biomedical Center, telephone (252) 504-7508. Dr. Celia Bonaventura serves as center
director.

**Program for the Study of Developed Shorelines**

**Director:** Orrin Pilkey, *James B. Duke Professor Emeritus of Earth Sciences, Nicholas
School of the Environment and Earth Sciences*

The Duke University Program for the Study of Developed Shorelines was estab-
lished in 1985 within the Department of Geology. The program takes a worldwide view
of modern coastal processes and geologic hazards.

A wide variety of research projects are directed under the auspices of this program,
whose ultimate goal is the examination of the geologic basis for managing developed
shorelines in a time of rising sea-level.

**Present projects include:**

- The study of the basis for prediction of beach replenishment success.
- Hurricane property damage mitigation on barrier islands.
- Evaluation of numerical models used to predict sand movement.
- Shoreface processes.

Research assistantships and other forms of support are available through the
program.

The Program for Developed Shorelines is housed in the Old Chemistry Building
on the Duke campus. The mailing address is Nicholas School of the Environment and
Earth Sciences, Duke University, Box 90230, Durham, N.C. 27708-0230; telephone (919)
684-4238.
Alternative Educational Opportunities
The Center for Environmental Education

Business leaders, environmental professionals, educators, journalists and policymakers must be increasingly well-trained in current environmental issues to face the challenges of the 21st century. Using the unique interdisciplinary perspective of the Nicholas School of the Environment and Earth Sciences, the Center for Environmental Education strives to improve knowledge and understanding of environmental processes for audiences beyond higher education. The Center for Environmental Education serves as a bridge linking the resources of the Nicholas School with participants desiring cutting-edge content, hands-on experiences and quality instruction.

The Center for Environmental Education provides Nicholas School students access to intensive courses designed for environmental professionals, opportunities to network with practicing professionals, and the opportunity to get involved in the local community. For more information, visit the Web site at www.env.duke.edu/cee.

Executive Education

Through the Center for Environmental Education, the Nicholas School of the Environment and Earth Sciences offers a series of executive education courses that are appropriate for both practicing professionals and advanced full-time students who are pursuing careers in resource management, policy, economics and environmental science. The intensive courses are designed to allow regular students to blend theory with practical experience, as well as allow experienced professionals to update theory and methodology. Recognized subject matter specialists provide instruction that is not normally available to the university community. The result is an enriched educational experience through the exchange of ideas and information by participants of diverse backgrounds.

Based on available space, Nicholas School students (M.F. and M.E.M. degree candidates) may register for the intensive courses two weeks prior to the first day of the course on a first-come, first-served basis; students in their second year of study are given priority. One unit of credit may be earned for each week of an intensive course. Students may not register for more than two intensive courses in a semester without special permission from their advisor and the executive education program director.

Executive education intensive courses are listed in a special section in the chapter "Courses of Instruction" in this bulletin. For more information on upcoming courses, contact the Center for Environmental Education at 919-613-8082 or visit the Web site at www.env.duke.edu/cee/execed.html.

The Center for Environmental Education also offers one- to three-day customized seminars and workshops on issues in environmental science. Please contact the Center for Environmental Education at 919-613-8082 for further information.

Community Education

Graduate students can get involved with the Durham community through environmental education. Community outreach initiatives have partnered the Nicholas School with local schools to provide students with environmental education opportunities and to provide local schools with support. Additionally, graduate students will have access to the Compaq Resource Center, a storehouse of environmental education resources. The MAT/ M.E.M. Program provides pre-service teachers with the opportunity to have the same rigorous foundation for teaching environmental science that environmental professionals have for practicing.
Cooperative Colleges

The Cooperative College Program is designed to coordinate the education of students in selected undergraduate schools with graduate programs in the broad area of resources and environment offered at Duke. Students are accepted for either of two degrees, the Master of Forestry (M.F.) or Master of Environmental Management (M.E.M.). Although the program is designed to accommodate a wide range of undergraduate backgrounds, experience indicates that it is best suited to majors in one of the natural or social sciences, pre-engineering, business, natural resources, or environmental science.

The program accepts students after three years of undergraduate study. With appropriate guidance, highly qualified students can reach a satisfactory level of preparation for graduate work at Duke in three years of coordinated undergraduate study. The baccalaureate degree is awarded by the undergraduate school after the student has earned enough units at Duke to satisfy the requirements of the undergraduate institution. Minimum time required to complete the bachelor’s degree is two full-time semesters at Duke. After four semesters at Duke, in which a minimum of 48 units of credit is earned, students may qualify for one of the professional master’s degrees.

A student interested in entering the Cooperative College Program should apply to one of the participating schools, a list of which is available from the Nicholas School of the Environment and Earth Sciences Office of Enrollment Services. Students applying for admission to Duke after the third year of study should do so by February 1 of the third year. Applicants from the participating schools are considered regular applicants for admission and are judged by the same criteria; therefore, students should submit application forms, transcripts, letters of recommendation, and results of the Graduate Record Examination. If the student is applying for a 3-2 program, he or she must also submit a letter from the undergraduate dean approving the application.

Duke/University of North Carolina Oceanographic Consortium

The Duke/University of North Carolina Oceanographic Consortium operates a 135-foot oceanographic research vessel, the R/V Cape Hatteras. The ship operates both on the continental shelf and in the deep sea in the western North Atlantic, concentrating in the region between Nova Scotia and the Caribbean. The ship is a member of the academic research fleet supported by the National Science Foundation for the purpose of providing oceanographic research opportunities to investigators. R/V Cape Hatteras is used for training at sea by the universities that make up the Oceanographic Consortium (Duke, North Carolina State, UNC-Chapel Hill, UNC-Wilmington, UNC-Greensboro, and East Carolina). The consortium also manages the acquisition and maintenance of oceanographic instrumentation used aboard the R/V Cape Hatteras, and holds annual meetings of ocean sciences staff from member institutions at the Duke Marine Laboratory. Inquiries concerning the use of the research vessel should be directed to Quentin Lewis Jr. (252) 504-7580 or quentin@duke.edu.

Forest History Society

Founded in 1946, the Forest History Society is a nonprofit, nonadvocacy organization committed to balanced and objective investigations of human interaction with the forest environment through time. Although its major focus is North America, the society is involved with a network of forest historians worldwide. In 1984, it became affiliated with Duke University and moved its headquarters to Durham.

The society emphasizes the utility of history to decision making in both the public and private sectors. The society believes that most currently held opinions are strongly
influenced by perceptions of the past and that a clear understanding of what really happened, as today’s issues evolved, is a vital component in the process of making prudent choices. Five major emphases enable the society to achieve its goals: a quarterly journal, *Environmental History*, research and publication, archival collecting, library and reference, and education and outreach.

*Environmental History* is co-published quarterly with the American Society for Environmental History. Its refereed articles, book reviews, and bibliographic listings enable investigators to keep current with the field. Research and publications, supported largely by grants, focus on topics that are important today and are also significant historically. Among the current topics are the history of forest and wildlife science, sustainable forestry, international forestry, forest economics, forestry on Native American lands, wood as an energy source, forest taxation, and industrial forestry research.

The collection of archival materials has been a major effort since the Society was founded. Included in the archives are the records of the American Forestry Association, American Forest Institute, National Forest Products Association, and the society of American Foresters. The society’s library and reference staff provide convenient access to the extensive literature of the field. Students and faculty of the university are welcome to use these valuable resources. The president is available for teaching and advising assignments at the Nicholas School of the Environment and Earth Science. The society also provides the F.K. Weyerhaeuser Fellowship for a graduate student studying forest and conservation history. Inquiries regarding the facilities and services offered by the society may be addressed to: President, Forest History Society, 701 Vickers Ave., Durham, N.C. 27701; telephone (919) 682-9319; http://www.lib.duke.edu/forest/.

**Integrated Case Studies for Wetlands and Coastal Management**

The case study approach to graduate education affords the student an opportunity to develop analytical and management skills through a close look at problems in wetland and coastal resources. Case studies are used in class instruction in both traditional and intensive courses in several of the school’s study areas.

In addition to utilizing completed case studies as course materials, students also have the opportunity to participate in the research and preparation of new case studies. The process of case preparation brings one in contact with professionals, businessmen, and others and offers a bridge between the academic curriculum and practical experience. This experience and the contacts made in the process of case research are valuable assets in securing employment.

The case studies are termed “integrated” case studies in natural resource analysis because they result from the cooperative efforts of a team of investigators comprising resource-ecologists, -economists, and -planners, as well as political scientists, sociologists, and others. The team approach is used in recognition of the fact that the successful analysis and resolution of the nation’s complex resource and environmental problems requires a holistic perspective. Optimally, this results in an exploration of the full ramifications of utilizing natural resource systems.

Case study formats have varied. For example, projects have resulted in color and sound 16mm films, simulation games and workshop conferences, as well as written reports. Typical issues addressed by past case studies include highway wetland siting issues, hazardous waste disposal in wetlands, management of coastal wetlands, bottom land forest management, and the development and management of restored wetlands.

Financial assistance, in the form of research fellowships, is available to qualified students interested in case study analysis. Up to six units of academic credit may be earned for case study work. Proposals for case studies are developed in consultation with the student’s faculty adviser and the case studies director, Curtis J. Richardson.
Integrated Toxicology Program

The Nicholas School of the Environment and Earth Sciences participates in Duke University’s graduate program in toxicology. The Integrated Toxicology Program operates under a specific charter to develop holistic and innovative approaches to toxicology training for Ph.D. students and postdoctoral fellows.

Research in environmental toxicology within the Nicholas School focuses on molecular and biochemical aspects of pollutant metabolism, adaptation, and modes of toxic action. The majority of this work employs freshwater, marine, and terrestrial organisms as toxicological models. The goals of toxicological research in the school are to achieve a fundamental understanding of processes governing the fates and effects of contaminants in the environment, and to elucidate linkages between human and ecosystem health. In order to achieve this goal, the curriculum and research activities of the program are designed to teach students the principles and methodologies of environmental chemistry, biochemistry, molecular biology, pathology, toxicology, ecology, and quantitative analysis. Upon completion of studies, the student is experienced in the design, execution and interpretation of current research in environmental toxicology. Completion of this training program at the Ph.D. level provides career opportunities in academia, industry, and research laboratories.

Training in environmental toxicology is also available to professional students in the Nicholas School through the Master of Environmental Management program in environmental toxicology, chemistry, and risk assessment. M.E.M. students have access to courses in the Integrated Toxicology Program curriculum and receive training appropriate for careers in industry, consulting firms, and government agencies concerned with the understanding and management of hazardous substances.

Students seeking admission to the program as a Ph.D. candidate make initial application to the Graduate School for admission to participating departments, including the Department of the Environment. Fellowships are available to outstanding students.

Direct inquiries to Dr. Richard T. Di Giulio, Director, Integrated Toxicology Program, Box 90328, Nicholas School of the Environment and Earth Sciences, Duke University, Durham, NC 27708. Internet: http://www.duke.edu/web/toxicology.

Interaction with Professionals

Professionals from academic and nonacademic spheres visit the school to present seminars, lecture in courses, participate in conferences, and attend short courses. Students have opportunities to meet with these professionals to exchange ideas and learn about career and internship possibilities. Other activities that foster interaction with professionals include seminar series, field utilization field trips to industry facilities in the South, and a western field trip.

The school recognizes the importance of graduate and professional student participation in professional organizations and makes available a limited amount of discretionary funding for activities that enhance the student’s educational experience. Grants are available on a competitive basis for activities that enhance the student's educational experience.

International Studies

The Nicholas School of the Environment and Earth Sciences has a history of contribution to international education and research. Graduates of the school, many of them foreign nationals, hold significant positions in many countries in multinational corporations, United States government agencies, or resource and conservation organizations that have global responsibilities. Members of the faculty have served overseas in programs of teaching and research, in both the developed and developing parts of the world.
The contemporary need for greater attention to international studies has led the school to develop professional associations and curriculum options for students who wish to combine international interests with study of natural resources and the environment. Duke University is a member of the South Atlantic States Association for Asian and African Studies and the Organization for Tropical Studies. On campus, an active Center for International Studies, Center for Tropical Conservation, Center for International Development Research, and several area study centers, including Latin American Studies, North American studies and South Asian Studies, provide a rich array of educational and research opportunities with global emphasis. Duke also has area study centers covering most of the world. Within the Nicholas School there is an active student international environmental study group. The potential exists for student participation in international projects through competition for grants and fellowships. In addition, students in the school may elect area studies or languages to further their understanding of global issues and cultures.

The school welcomes foreign students and considers an international student body of value to the learning environment. Qualified foreign students in Trinity College and in graduate and professional schools of the university are admitted to courses in the school, subject to the approval of the student’s adviser and the course instructor.

Internship Opportunities

Practical experience is integral to our educational process and even more important to hiring employers. Internships provide students with opportunities to explore specific career fields, enhance or learn relevant professional skills, establish networks of practicing professionals, or gain perspective on environmental issues in various geographic regions or countries. The Class of 2002 has secured internships across the United States and around the world working with industry, government agencies, consulting firms, conservation organizations and international communities and NGOs. For more information see the following chapter on career services.

Professional Skills Development

In addition to regular courses and seminars, the Nicholas School of the Environment and Earth Sciences offers a series of optional professional development lectures and workshops to prepare students for professional employment. Topics for these modules include field and laboratory techniques, communications skills, project organization and management, and teamwork skills. The schedule and detailed information concerning the series is made available to students during the academic year by the director of professional studies. A modest amount of credit is available for participation in these modules. In addition, there is a modest matching fund to help students defray the cost of skills training offered outside the school.
Career Planning and Placement
Career Services

The Nicholas School of the Environment and Earth Sciences employs its own Career Services staff to assist all graduate and professional students with defining career paths, learning job search skills, and finding internship and permanent employment opportunities. The Career Services staff offers alumni of the school assistance with professional development strategies and career transitions.

Career Planning. Individual counseling and group workshops are provided by professional staff members to assist students in the development of job search strategies and skills, resume and cover letter preparation, networking, and interviewing techniques.

Internship Opportunities. The Nicholas School is committed to the value of internships and strongly encourages every student to secure a career-related position to complement academic training, enhance skill development and increase professional knowledge. The school has achieved a 98 percent internship placement rate each of the past 11 years. The Career Services staff works with natural resource/environmental professionals to develop paid internship positions and assists students in finding opportunities relevant to career interests and goals. The Nicholas School has established significant partnerships with a wide variety of organizations (list below) to provide internships or internship grant funding opportunities for our students.

Most students pursue internships during the summer between academic years of study, although internships may be taken at other times and for a longer duration. Many students use the internship experience as a basis for the master's project.

Doris Duke Conservation Fellowships - The Nicholas School partners with the Doris Duke Charitable Foundation to identify students with professional promise for future leadership in conservation. Fellows are competitively selected during the first semester of study and are awarded a summer internship stipend, supplemental tuition support and partial educational loan repayment.

Stanback Conservation Internship Program - This program supports more than 45 paid conservation internships each summer with 27 different non-profit organizations.

Nicholas School Internship Grants - In 2001, the Nicholas School distributed grant funding for 14 summer internship projects developed and proposed by students.

Industry Partnerships - Industry sponsored internship/scholarships provide for internship stipends and tuition support each year.

External Internship Funds - Career Services staff work closely with external funding sources and the Duke University community to identify "pockets of money" to support unpaid internship projects. More than $45,000 was secured in 2001.
Job Search Assistance

The Career Services Web site (www.env.duke.edu/career/) provides up-to-date environmental internship and employment opportunities, relevant fellowships, scholarships and research grants as well as career advice for a successful job search.

The Resume Book, which highlights and promotes the professional qualifications and experiences of our graduating class is published annually and distributed to more than 800 potential employers. A web-based resume book is available at www.env.duke.edu/resumes.

The Alumni Career Network database is an excellent networking tool for identifying professionals by area of specialization or geographic location, to help students with internship and employment information as well as valuable career advice.

Job fairs and on-campus recruiting events are scheduled throughout the academic year to allow students opportunities to meet employers and broaden their knowledge of the environmental marketplace.

Employment Offers. Graduates of the Nicholas School of the Environment and Earth Sciences have an excellent record of success in finding challenging and satisfying employment in their areas of interest after degree completion, confirming the marketability of a professional/graduate degree from Duke. The table below illustrates the diversity of career paths selected by recent graduates from the Nicholas School.

Following is a list of selected employers that have hired our recent graduates:

<table>
<thead>
<tr>
<th>Employer Distribution</th>
<th>Class of 2000</th>
<th>Class of 1999</th>
<th>Class of 1998</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government Agencies</td>
<td>22%</td>
<td>33%</td>
<td>24%</td>
</tr>
<tr>
<td>Consulting Firms</td>
<td>36%</td>
<td>24%</td>
<td>41%</td>
</tr>
<tr>
<td>Research Institutes/Universities</td>
<td>6%</td>
<td>7%</td>
<td>3%</td>
</tr>
<tr>
<td>Nonprofit Organizations</td>
<td>18%</td>
<td>17%</td>
<td>11%</td>
</tr>
<tr>
<td>Industry</td>
<td>7%</td>
<td>7%</td>
<td>11%</td>
</tr>
<tr>
<td>Pursuing Additional Education</td>
<td>8%</td>
<td>6%</td>
<td>4%</td>
</tr>
<tr>
<td>Other</td>
<td>3%</td>
<td>6%</td>
<td>6%</td>
</tr>
</tbody>
</table>

Consulting Firms
ABT Associates
A.D. Marble & Company
AEI-Brookings Joint Center for Regulatory Studies
ARCADIS/ Geraghty & Miller
Battelle
Blasland, Bouck & Lee
Eastern Research Group
Ecology & Environment
Engineering and Environment, Inc.
ERDAS, Inc.
ENVIIRON Corporation
Exponent
Forest Resource Consultants, Inc.
ICF Consulting
IT Group
Jellinek, Schwartz & Connolly
Mangi Environmental Group
Parsons Engineering Science, Inc.
PHB Hagler Bailly, Inc.
Project Performance Corporation
Radian International
Roy F. Weston
SAIC
Tetra Tech, Inc.
The BSC Group, Inc.
The Hart Partners, Inc.
URS Corporation
Versar, Inc.
Waste Management/ AETS

Federal Government
Federal Energy Regulatory Commission
National Marine Fisheries Service
National Park Service
NOAA
NOAA/ National Ocean Service
ORISE/ US Army Environmental Center
US Department of Interior
US Forest Service
US General Accounting Office
US Geological Survey
US EPA
US Fish & Wildlife Service
US Peace Corps
US Postal Service

Business/Industry
3M Company
Amerada Hess Corporation
Champion International Corporation
ENRON
Exxon Chemical Company
Fetzer Vineyards
Flying J, Inc.
IBM
Intel
International Paper Company
Pitney Bowes
Preferred Adventures, LTD
Solutia, Inc
Southern Natural Gas Company
The Home Depot
The Mead Corporation
Toyota Motor Sales USA, Inc.
Wisconsin Electric Power Company
Xerox

Not-for-profit Organizations
American Bear Association
American Zoo & aquarium Association
Appalachian Mountain Club
Atlanta Legal Aid Society
Atlantic States Marine Fisheries Commission
Center for Resource Solutions
Children's Environmental Trust Foundation
Conservation International
Council on Economic Priorities
Environmental Defense
Environmental Law Institute
Field Museum of Natural History
Japan Wildlife Research Center
Joseph W. Jones Ecological Research Center
Lake Michigan Federation
League of Conservation Voters
Massachusetts Fisherman's Partnership
New England Aquarium
Northeast-Midwest Institute
Odyssey, The Maritime Discovery Center
Research Triangle Institute
Teton Regional Land Trust
The Nature Conservancy
The Wildlands Project
Wildlife Habitat Council
Winrock International
World Resources Institute
World Wildlife Fund

State/Local Government
City of Cambridge Conservation District
City of Santa Monica
Dekalb County Soil & Water District
Denver Regional Council of Governments
Douglas County Open Space & Natural Resources
Florida Coastal Management Program
King County Department of Natural Resources
New England Fishery Management Council
New York City Parks
Metropolitan Water District
Mountains Conservation & Recreation Authority
North Carolina Department of Environment & Natural Resources
North Carolina Coastal Management Division
Orange County Marine Institute
Santa Ana Regional Water Quality Control Board
South Carolina Sea Grant Consortium
Texas Natural Resources Conservation Commission
Town of Hilton Head
Washington Department of Natural Resources

National Park Service
NOAA
NOAA/ National Ocean Service
ORISE/ US Army Environmental Center
US Department of Interior
US Forest Service
US General Accounting Office
US Geological Survey
US EPA
US Fish & Wildlife Service
US Peace Corps
US Postal Service
Business/Industry
3M Company
Amerada Hess Corporation
Champion International Corporation
ENRON
Exxon Chemical Company
Pitney Bowes
Preferred Adventures, LTD
Solutia, Inc
Southern Natural Gas Company
The Home Depot
The Mead Corporation
Toyota Motor Sales USA, Inc.
Wisconsin Electric Power Company
Xerox
Housing

While limited housing is available on campus, most students in the Nicholas School of the Environment and Earth Sciences join the annual scramble to find a place to live off campus. The university is very much a part of the urban environment that is Durham, but the campus is not an urban one. It is not traversed by streets with housing and businesses. Consequently, the perimeter of the West Campus is densely developed with apartment complexes, and the East Campus is adjacent to a neighborhood of large, early 20th century homes, some of which have been converted to apartments. Free bus service is available between the two campuses.

The Department of Housing Management operates an off-campus housing service that consists of a staff person who maintains listings of apartment openings, house rentals, and roommates wanted. The off-campus housing service does not rate the quality of apartments, houses, or landlords, nor arrange viewings. However, a student maintained web site at www.duke.edu/web/n-watch does provide this type of information. Similarly, the Office of Enrollment Services in the Nicholas School of the Environment and Earth Sciences maintains a listing of houses and apartments popular with students in the school as well as a list of entering students who are interested in finding roommates. These lists are mailed to students during the summer.

Services for Students

Communications. Upon entrance to the Nicholas School, students are issued an Email address. Email is recognized as an official means of communication within the University. Students are encouraged to check their Email frequently.

Medical Care. The main components of the student health service include the University Health Services Clinic, located in the Pickens Building on West Campus, and the student infirmary in Duke Hospital South. Emergency transportation, if required, can be obtained from the Duke campus police. The facilities of the university health services clinic are available during both regular and summer sessions. The facilities of the student infirmary are available only from the opening of the university in the fall until graduation day in the spring.

The student health fee is nonrefundable after the first day of classes. Students may be covered during the summer for an additional charge. Dependents and family members are not covered at any time.

The resources of the Medical Center are available to all students and their spouses and children. Charges for all services received from the Medical Center are the responsibility of the student.
The university has an Accident and Sickness Insurance Plan available for full-time students. Although participation in this plan is voluntary, the university expects all graduate students to be financially responsible for medical expenses above those covered by the student health service. Students who have medical insurance or wish to accept the financial responsibility for any medical expense may elect not to join the Accident and Sickness Insurance Plan by signing a statement to this effect. Each full-time student in residence must purchase this student health insurance or indicate the alternative arrangement.

The Student Accident and Sickness Insurance Plan provides protection twenty-four hours a day during the 12-month term of the policy. Students are covered on and off the campus, at home, while traveling, and during interim vacation periods. For additional fees, a student may obtain coverage for a spouse or spouse and children. Term of the policy is from opening day in the fall.

Coverage and services are subject to change as deemed necessary by the university.

**Counseling and Psychological Services.** CAPS provides a comprehensive range of counseling and psychological services to assist and promote the personal growth and development of Duke students. The professional staff is composed of clinical social workers, psychologists, and psychiatrists experienced in working with young adults. Among services provided are personal, social, and academic counseling. A number of short-term seminars or groups focusing on skill development and special interests such as coping with stress and tension, fostering assertiveness, enriching couples' communication, and dealing with separation and divorce are also offered. A policy of strict confidentiality is maintained concerning each student's contact with the CAPS staff. Student health fees cover individual evaluation and brief counseling/therapy as well as skill development seminars. There are no additional charges to the student for these services.

Appointments may be made by calling 660-1000 or visiting CAPS, 214 Page.

**Career Center.** The Career Center, located in 110 Page Building on West Campus, offers a number of integrated services that address a range of student needs from indecision about career choices to assistance with the post-graduate job search. Although many of the services are designed primarily for undergraduates, graduate and professional students are also encouraged to register with the center and use its resources as their career plans evolve.

Students who are unsure of their career plans can obtain confidential counseling to help them better understand themselves and clarify career goals. Individual appointments with counselors are available, as are group workshops, testing, and computerized career guidance programs.

The Career Resources Library, 217 Page, has resources to help students choose careers or further training and education, as well as self-help materials for improving study techniques, time management, test-taking, and reading comprehension.

The Career Center serves as a liaison between Duke students and potential employers. Services offered include placement seminars and workshops, on-campus interviewing opportunities with employers and graduate/professional schools, position vacancy notices, a library of employer resources, and individualized placement counseling. To participate in job interviews scheduled throughout the year, students must be registered with the office and have assembled a permanent file.

In addition, the school maintains its own Office of Career Services. For further information, see the Career Planning and Placement section in this bulletin.

**International Adviser.** The International Office handles governmental matters for students from abroad such as statements of attendance for home governments, issuance of United States immigration forms for re-entry into the country after a temporary absence, and required yearly extensions of time. Any new student who is not a citizen of the United States should report with passport to the international adviser soon after arrival. The International Office is located at 300 Alexander Avenue.
Other Services. The Bryan University Center houses an information desk, two drama theaters, a film theater, stores for books and supplies, meeting rooms, lounges, snack bars, and other facilities. A barbershop, hairdresser, post office, and bank are also located in the center and in the nearby West Campus Union.

Student Organizations and Activities

Sports. Students are welcome to use recreational facilities such as the swimming pools, tennis courts, golf course, track, jogging course, handball and squash courts, gymnasium, weight room, and playing fields. Intramural programs provide an opportunity to participate in informal and competitive physical activity. A variety of clubs for gymnastics, scuba diving, sailing, cycling, badminton, karate, rugby, soccer, and crew are also active.

FOREM Club. The FOREM Club is the student organization for coordination of the school’s social functions, community service, and intramural team participation. FOREM is an acronym for Forestry and Environmental Management. Annual functions of the club include a Christmas party, Christmas treesale, Field Day, and year-end banquet.

Student Advisory Committee. The Student Advisory Committee, an elected student group in the Nicholas School of the Environment and Earth Sciences, meets regularly with the dean and faculty representatives to discuss courses and curriculum, programs, and long-range goals of the school.

Graduate and Professional Student Council (GPSC). The Graduate and Professional Student Council is the university-wide representative body for students registered in the various professional schools and departments of the Graduate School. The council provides a means of communication among graduate students, presents gradu-
ate student concerns to the administration, and selects students for membership on university committees. Representatives from the Nicholas School of the Environment and Earth Sciences are elected annually by the student body.

**Professional and Scientific Societies.** Students are encouraged to participate in one or more professional or learned societies appropriate to their academic interest. Many of these societies are interested in participation by students and offer a lower fee to encourage student membership. Student chapters of the Society of American Foresters, International Society of Tropical Foresters, National Association of Environmental Professionals, the American Water Resources Association and the Society of Environmental Toxicology and Chemistry are active in the school.

**Religious Services.** Interdenominational services are conducted on Sunday mornings in Duke Chapel. Roman Catholic masses are offered daily on campus. Several Protestant denominations have student centers on campus. The Divinity School conducts other chapel services and religious and social activities. There is also a Hillel group that meets regularly and a new on-campus facility to house Jewish student life activities was completed recently.

**Cultural Activities.** Concerts, recitals, lectures, plays, films, and dance programs are presented frequently on campus. Information on major events is available at Page Box Office or the Bryan Center information desk. The University Museum of Art, which has some excellent permanent collections, is located on East Campus.

**Harassment Policy.** Harassment of any kind is not acceptable in the Nicholas School of the Environment and Earth Sciences or at Duke University. It is inconsistent with the University’s commitments to excellence and to respect for all individuals. Duke University is committed to the free and vigorous discussion of ideas and issues, which the university believes will be protected by its harassment policy.

Harassment is described by Duke University as the creation of a hostile or intimidating environment, in which verbal or physical conduct, because of its severity and/or persistence, is likely to interfere significantly with an individual’s work or education, or affect adversely an individual’s living conditions on campus. Sexual coercion is a form of harassment with specific distinguishing characteristics. It consists of unwelcome sexual advances, requests for sexual favors or other verbal or physical conduct of a sexual nature when submission to such conduct is made either implicitly or explicitly a term or condition of employment; or submission to or rejection of such conduct by an individual is used as the basis for employment or educational decisions affecting the individual.

Members of the Nicholas School of the Environment and Earth Sciences community who have questions about the policy or how to deal with a suspected violation can obtain a copy of the policy and options for resolution from the Office of the Vice-President for Institutional Equity, Trent Hall.
Course offerings are subject to change. The student should consult the current university course schedule for listings of courses to be offered each semester.

Information about ENVIRON courses below 200-level can be found in the Duke University Bulletin of Undergraduate Instruction.

Environment Graduate Courses Given in Durham

200. Integrated Case Studies. A group of two to four students may plan and conduct integrated research projects on a special topic, not normally covered by courses or seminars. A request to establish such a project should be addressed to the case studies director with an outline of the objectives and methods of study and a plan for presentation of the results to the school. Each participant's adviser will designate the units to be earned (up to six units) and evaluate and grade the work. Instructor: Staff. Variable credit.

201. Forest Resources Field Skills. Introduction to field techniques commonly used to quantify and sample forest resources: trees, soils, water, and animal resources. Dendrology, vegetation sampling, soil mapping, river flow estimation, field water quality sampling, surveying, and use of compass. Instructor: Richter. 2 units.

203. Conservation Biology: Theory and Practice. An overview of biological diversity, its patterns, and the current extinction crisis. Historical and theoretical foundations of conservation, from human values and law to criteria and frameworks for setting conservation priorities; island biogeography theory, landscape ecology, and socioeconomic considerations in reserve design; management of endangered species in the wild and in captivity; managing protected areas for long term viability of populations; the role of the landscape matrix around protected areas; and techniques for conserving biological diversity in semiwild productive ecosystems like forests. Three field trips. Prerequisite: one ecology course or consent of instructor. Instructor: Staff. 3 units.

205L. Ecological Management of Forest Systems (Silviculture). The aim of the course is to equip future resource managers and environmental consultants with knowledge allowing them to propose lower impact practices to individuals and organizations who need to balance wood production with maintenance of environmental quality. Underlying principles of growth, from seed to mature trees, and stand dynamics are explored. Various alternative methods of manipulating growth, stand structure and development, ranging from little to large perturbations of forest systems, are presented and assessed in terms of their effect on resource quality. Includes laboratory. Instructor: Oren. 4 units.

206. Forest Vegetation Sampling. Theory and application of forest vegetation sampling. Direct and indirect estimation methods that range from timber cruising and inventory to sampling for species composition. Laboratory applications in Duke Forest to include over- and understorey vegetation. Instructor: Doggett. 3 units.

207L. Forest Pest Management. Fundamentals of entomology and plant pathology as appropriate to understanding the impacts of insects and diseases on forest productiv-
ity and their assessment for integration into forest management. Regional case examples and complexes are evaluated in terms of pest-population, forest-stand dynamics; economic and societal constraints; treatment strategies; monitoring systems; and benefit-cost analysis. This approach seeks to develop predictive capabilities in long-range pest management and decision making. Instructor: Doggett. 4 units. Offered in fall, even-numbered years.

212. Environmental Toxicology. Study of environmental contaminants from a broad perspective encompassing biochemical, ecological, and toxicological principles and methodologies. Discussion of sources, environmental transport and transformation phenomena, accumulation in biota and ecosystems. Impacts at various levels of organization, particularly biochemical and physiological effects. Prerequisites: organic chemistry and vertebrate physiology or consent of instructor. Instructor: Di Giulio. 3 units.

213. Forest Ecosystems. Emphasis on the processes by which forests circulate, transform, and accumulate energy and materials through interactions of biologic organisms and the forest environment. Ecosystem productivity and cycling of carbon, water, and nutrients provide the basis for lecture and laboratory. Instructor: Richter. 3 units.

214. Landscape Ecology. Emphasis on the role of spatial heterogeneity in terrestrial systems: its detection and description, agents of pattern formation, landscape dynamics and models, and the implications of heterogeneity of populations, communities, and ecosystems. Prerequisites: an intermediate-level ecology course, introductory applied statistics, and Environment 351, or consent of instructor. Instructor: Urban. 3 units.

215. Environmental Plant Physiology. Examination of tolerance, limiting factors, nutrition, and other ecological physiology concepts used in evaluating plant responses to multiple environmental stresses. Discussion of procedures for and examples of monitoring physiological responses to environmental perturbations and resource manipulation. Instructor: Oren. 3 units. Offered on sufficient demand.

216. Applied Population Ecology. Population dynamics of managed and unmanaged populations. A quantitative approach to exploitation and conservation of animal and plant populations, including harvesting, population viability analysis, population genetics. Prerequisites: introductory statistics, calculus, and computer programming or consent of instructor. Instructor: Staff. 3 units. Offered fall, even-numbered years.

217. Tropical Ecology. Ecosystem, community, and population ecology of tropical plants and animals with application to conservation and sustainable development. Prerequisite: a course in general ecology. Instructor: Terborgh. 3 units. C-L: Biology 215

221. Soil Resources. Emphasis on soil resources as central components of terrestrial ecosystems, as rooting environments for plants, and as porous media for water. Soil physics and chemistry provide the basis for the special problems examined through the course. Laboratory emphasizes field and lab skills, interpretive and analytical. Instructor: Richter. 3 units.

230L. Weather and Climate. Overview of the science of meteorology and principles of climatology, especially as applied to problems in ecology and natural resource management. Emphasis on the processes and characteristics of weather phenomena and local and regional climates. General introduction to sources of climatic data and climatic data analysis. Includes laboratory. Instructor: Knoerr. 4 units.

231. Ecological Theory and Data. Goals and contributions of ecological theory. Formulation of models and applications to data. Topics include demography, population growth, community interactions, food webs, metapopulations, disturbance, structure, stochasticity, chaos, and patchiness. Model development, analysis, and interpretation. Discussions focus on classical and current primary literature. Analysis of data using SPlus, making use of likelihood models, bootstrapping, and Bayesian approaches. Prerequisites: one year each of calculus and statistics. Instructor: Clark. 3 units. C-L: Biology 268
231L. **Ecological Theory and Data.** Laboratory version of Biology 268/Environment 231. Prerequisites: one year each of calculus and statistics. Instructor: Clark. 3 units. C-L: Biology 268L

232. **Microclimatology.** Introduction to the micrometeorological processes. Discussion of the integration of these processes and the resulting microclimates in the rural (forest, field, and water surface) and urban environments. Methods for modification of the microclimate. Offered on demand. Instructor: Knoerr. 3 units. C-L: Biology 232

233. **Soil Chemistry and Contamination.** Composition, structure, and chemistry of inorganic and organic soil components. Includes study of sorption/desorption, mineral weathering, oxidation-reduction reactions, and kinetics of soil chemical processes as related to contamination evaluation and remediation. Standard and innovative techniques for soil and groundwater cleanup will be discussed. Prerequisite: Environment 221 or 240 or 242 or consent of instructor. Instructor: Vasudevan. 3 units.

234L. **Watershed Hydrology.** Introduction to the hydrologic cycle with emphasis on the influence of land use, vegetation, soil types, climate, and land forms on water quantity and quality and methods for control. Development of water balance models. Analysis of precipitation patterns, rainfall and runoff, and nonpoint source impacts. Statistical handling and preparation of hydrologic data, simulation and prediction models, introduction to groundwater flow, laboratory and field sampling methods. Instructor: Katul. 4 units.


237L. **Field Botany of North Carolina’s Wetlands.** A survey of the flora of North Carolina’s wetland habitats with emphasis on plant identification in the field. Field trips to mountain, piedmont, and coastal wetlands. Examination of all groups of plants including bryophytes, ferns, and seed plants. Wetland habitats include swamps, bogs, poecilids, and brackish sites. Information on the floristics of the southeastern United States botanical nomenclature, systematic relationships of wetland plants, and an overview of wetland vegetation. Prerequisite: one course in plant diversity or systematics, or consent of instructor. Instructors: Shaw and Wilbur. 3 units. C-L: Biology 242L

238. **Bryology and Peatland Ecology.** Ecology, morphology, and systematics of mosses, liverworts, and hornworts. Emphasis on the identification of dominant species and on their habitat relationships. Special attention to peatmosses and the ecology of Sphagnum-dominated ecosystems. Involves a field trip during Fall break. Instructor: Shaw. 3 units.

239. **Human Health and Ecological Risk Assessment.** Topics central to both health and ecological risk assessment are explored. Basic concepts of hazard identification, dose-response relationships, exposure assessment, and risk characterization and communication are discussed in the context of both human health and environmental assessment. The basis and rationale for using specific, as well as extrapolated, scientific information and expert judgment, and the strengths and weaknesses of alternative ap-
approaches, are evaluated. Applications emphasizing real cases are used to illustrate the interdisciplinary process and products of risk assessment, as well as the regulatory use of the information. Group projects emphasized. Instructors: Mihaich and McMasters. 3 units.

240. Chemical Fate of Organic Compounds. Equilibrium, kinetic, and analytical approaches applied to quantitative description of processes affecting the distribution and fate of anthropogenic and natural organic compounds in surface and groundwater, including chemical transfers between air, water, soils/ sediments, and biota; and thermochemical and photochemical transformations. The relationships between organic compound structure and environmental behavior will be emphasized. Sampling, detection, identification, and quantification of organic compounds in the environment. Prerequisites: university-level general chemistry and organic chemistry within last four years. Instructors: Dubay and Vasudevan. 3 units. C-L: see Civil Engineering 240

241. Statistical Analysis of Ecological Data. Methods of statistical analysis, including experimental design, ANOVA, regression, longitudinal data, intervention studies, survival analysis. Lectures supplemented by student projects that involve application of techniques to data. Prerequisite: 1 year of undergraduate statistics. Instructors: Clark and Lavine. 3 units. C-L: Biology 266


248. Solid Waste Engineering. Engineering design of material and energy recovery systems including traditional and advanced technologies. Sanitary landfills and incineration of solid wastes. Application of systems analysis to collection of municipal refuse. Major design project in solid waste management. Prerequisite: Civil Engineering 124L or consent of instructor. Instructor: Staff. 3 units. C-L: see Civil Engineering 248

249L. Environmental Molecular Biology. Introduction to molecular techniques and gene regulation as they apply to environmental issues. Topics include basic cloning and sequencing, DNA/DNA/RNA/ protein separation and hybridization, polymerase chain reaction, in vitro mutagenesis, and protein expression. Student presentations illustrate how molecular technologies such as the creation of genetically engineered organisms address environmental problems. Prerequisite: introductory biology. Instructor: Freedman. 4 units.

250L. Form, Function, and Adaptation of Plants. The structural and developmental basis for the major functions of the plant body including energy harvest, mechanical support, transport, and storage. Structural adaptations to important environmental stresses. Emphasis on underlying biomechanical/physical principles. Prerequisite: Biology 25L; suggested: either Biology 110L, 140L, 149, or 152. Instructor: Staff. 4 units.

255. Applied Regression Analysis. Linear regression using both graphical and numerical methods. Model construction, critique, and correction using graphical residual analysis. One-way and two-way analysis of variance; introduction to design of experiments. Use of a standard statistical software package. Applications and examples drawn from various sources, emphasizing the biological and environmental sciences. Prerequisite: introductory applied statistics or equivalent. Instructor: Staff. 3 units. C-L: Statistics and Decision Sciences 242
260. Western Field Trip. One-week trip to observe land management and utilization practices in the western United States. Exposure to ecological, economic, and policy issues, as well as watershed, wildlife, and land use questions. May be repeated for credit. Consent of instructor required. Instructor: Edeburn. 1 unit.

262. Forest Management Traveling Seminar. Covers current topics in the broad field of forest management. Taught as a set of coordinated field trips with expert contacts in sites in the Carolina piedmont, coastal plain, and mountains. Topics of past seminars include fiber utilization, best management practices, forest regeneration, the chip mill issue, forest-pest management, and forest preservation management. May be repeated for credit. Instructor: Richter. 1 unit.

264. Applied Differential Equations in Environmental Sciences. General calculus and analytic geometry review; numerical differentiation and integration; analytic and exact methods for first and second order ordinary differential equations (ODE); introduction to higher order linear ODE, numerical integration of ODEs and systems of ODEs; extension of Euler’s method to partial differential equations (PDE) with special emphasis on parabolic PDE. Example applications include population forecasting, soil-plant-atmosphere water flow models, ground water and heat flow in soils, and diffusion of gases from leaves into the atmosphere. Prerequisite: Mathematics 31 or equivalent or consent of instructor. Instructor: Katul. 2 units.

266. Ecology of Southern Appalachian Forests. Field trips to various forest ecosystems in the southern Appalachian Mountains. Species identification, major forest types, field sampling, and history of effects of human activities. Consent of instructor required. Instructor: Richter. 1 unit.

270. Resource and Environmental Economics. The application of economic concepts to private- and public-sector decision making concerning natural and environmental resources. Intertemporal resource allocation, benefit-cost analysis, valuation of environmental goods and policy concepts. Prerequisite: introductory course in microeconomics. Instructor: Smith. 3 units. C-L: Economics 270, Public Policy Studies 272

271. Economic Analysis of Resource and Environmental Policies. Case and applications oriented course examining current environmental and resource policy issues. Benefits and costs of policies related to sustaining resource productivity and maintaining environmental quality will be analyzed using economic and econometric methods. Topics include benefit-cost analysis, intergenerational equity, externalities, public goods, and property rights. Prerequisite: Environment 270 or equivalent; Economics 149 recommended. Instructor: Kramer. 3 units. C-L: Economics 272

272. Evaluation of Public Expenditures. Basic development of cost benefit analysis from alternative points of view, for example, equity debt, and economy as a whole. Techniques include: construction of cash flows, alternative investment rules, inflation adjustments, optimal timing and duration of projects, private and social pricing. Adjustments for economic distortions, foreign exchange adjustments, risk and income distribution examined in the context of present value rules. Examples and cases from both developed and developing countries. Instructor: Conrad. 3 units. C-L: Economics 272


275S. Protected Areas, Tourism, and Local Development. Investigates issues of establishing and managing national parks, biosphere reserves, and other protected areas.
in situations where local populations compete for the same resources. Tourism is considered as a possible source of negative impacts on the protected area and as a source of local economic development. Includes consideration of tourism policy, resource protection strategies, microenterprise development, sustainable agriculture, and forestry. Instructor: Healy. 3 units.

**279. Atmospheric Chemistry: Principles and Processes.** Provides a broad overview of the science of oxidant chemistry in the atmosphere. Basic physical and chemical concepts relevant to the understanding of atmospheric chemistry will be presented and several contemporary topics will be discussed from a process-level perspective. Topics include atmospheric structure and chemical composition; atomic structure and chemical bonds; chemical thermodynamics and kinetics; atmospheric radiation and photochemistry, tropospheric and stratospheric ozone chemistry; aqueous-phase atmospheric chemistry; atmospheric aerosols; and air quality modeling. Prerequisites: one college-level course each in chemistry and calculus. Instructor: Kasibhatla. 3 units.

**280. Social Science Surveys for Environmental Management.** Social science research methods for collecting data for environmental management and policy analysis. Sampling, survey design, focus groups, pretesting, survey implementation, coding, and data analysis. Team projects emphasize development and practice of survey skills. Prerequisite: introductory applied statistics or equivalent. Instructor: Kramer. 3 units.

**281. Environmental Law.** Examination of contemporary environmental law and its common law antecedents in the context of the American legal system. Objectives are to provide basic training in analyzing cases and statutes, applying knowledge in a classroom setting, and using a law library. Instructor: Heath. 3 units.

**284S. Seminar in Land Use Policy.** Selected topics in United States land policy. Content varies each offering, but may include regulatory innovations, management of public lands, urban growth management, and landscape protection. Term paper and class presentations required. Half or one course for undergraduates. 1 to 3 units for graduate students. Instructor: Healy. Variable credit.


**294. Water Quality Skills.** Introduction to field and laboratory techniques for monitoring water quality characteristics including heat properties, BOD, flow, dissolved oxygen, nutrients, benthic invertebrates, and coliform indicators. Emphasis on technical report writing. Prerequisite: Environment 236. Instructor: Stow. 3 units.

**296. Environmental Conflict Resolution.** Practical techniques and scholarly underpinnings of environmental conflict resolution, including interest-based negotiation, mediation, public disputes, science-intensive disputes, and negotiation analysis. In-class time will be spent conducting negotiation role plays of increasing complexity and then debriefing them. Outside of class, students will prepare for the role plays and read background material to aid in debriefing. Students will keep a journal of their experiences. Instructor: Maguire. 2 units.

**298. Special Topics.** Content to be determined each semester. May be repeated. Instructor: Staff. Variable credit.

**299. Independent Studies and Projects.** Directed readings or research at the graduate level to meet the needs of individual students. Consent of instructor required. Units to be arranged. Instructor: Staff. Variable credit.

**307. Ecophysiology of Productivity and Stress.** Exploration of principles governing stand growth and its response to a variety of stresses. Emphasis on climate, soil re-
sources, and competition. Stresses and their reliefs determined by pollution and the availability of resources as modifiers of the physiological properties of trees. Instructor: Oren. 3 units. Offered on sufficient demand.

309. Seminar on Key Wetland Ecology Issues. Wetland functions, hydrology, biogeochemistry, decomposition, community habitat, and productivity are discussed in an ecosystem context along with current management issues. Topics vary each semester and cover such areas as wetland restoration, constructed wetlands for wastewater treatment, and wetland delineation. Students will be expected to make oral presentations as well as critique advanced readings in class. May be repeated. Instructor: Richardson. 2 units.

312. Wetlands Ecology and Management. The study of bogs, fens, marshes, and swamps. Emphasis on processes within the ecosystem: biogeochemical cycling, decomposition, hydrology, and primary productivity. Ecosystem structure, the response of these systems to perturbations, and management strategies are discussed. A research project is required. Prerequisites: one course in ecology and chemistry. Instructor: Richardson. 3 units.

313. Advanced Topics in Environmental Toxicology. Discussion of current issues. Topics vary but may include chemical carcinogenesis in aquatic animals; biomarkers for exposure and sublethal stress in plants and animals; techniques for ecological hazard assessments; and means of determining population, community, and ecosystem level effects. Lectures and discussions led by instructor, guest speakers, and students. Prerequisite: Environment 212. Instructor: Di Giulio. 3 units.

314. Integrated Case Studies in Toxicology. Students are assigned topics relative to their chosen research discipline in toxicology and are asked to develop case studies to present at a roundtable workshop. Emphasis on review and analysis of toxicological problems from a holistic (multidisciplinary) viewpoint. Offered on demand. Instructor: Abou-Donia. 1 unit. C-L: Pharmacology 314

315. Focused Topics in Toxicology. A contemporary advanced toxicology research area covered with readings from the current primary literature. An integrative review of the topic prepared as a collaborative effort. Consent of instructor required. Prerequisites: Pharmacology 233 and 347. Instructor: Levin. 1 unit. C-L: Pharmacology 315

317. Topics in Tropical Ecology and Conservation. Discussion of current issues and ideas at the interface between basic and applied science. Lectures, seminars, and discussion with student participation. Prerequisite: Environment 217 or equivalent. Instructor: Terborgh. 2 units.

319. Mechanisms in Environmental Toxicology. Provides an in-depth examination of key molecular and biochemical mechanisms by which organisms defend themselves against environmental pollutants. Cellular mechanisms by which chemicals produce toxicity when the defense systems are overwhelmed will be addressed. Includes examinations of "state of the art" approaches for experimentally elucidating these phenomena. Course format will be that of a graduate seminar, with lectures given and discussions led by the instructors, guest speakers, and course participants. Prerequisites: one course in biochemistry and one course in toxicology. Instructors: Di Giulio and Freedman. 3 units.

321. Advanced Readings in Soil Science. An advanced discussion course based on readings that concern current critical topics in the soil sciences. Readings are selected from both basic and applied aspects of the field. Instructor: Richter. 1 unit.

330L. Environmental Monitoring and Instrumentation. Methods of measuring and monitoring the earth's physical environment with emphasis on water and air resources. Characteristics and uses of contemporary sensors, measurement and data ac-
acquisition systems. Methods of obtaining and processing computer compatible data records. Includes laboratory. Offered on demand. Instructor: Knoerr. 4 units.


351. Computer-Based Map Analysis with Geographic Information Systems. Introduction to computer-based map analysis systems (geographic information systems). Use of map algebra in computer analyses of spatially distributed map information. Applications in analyzing and solving natural resource management problems. Instructor: Halpin. 3 units.

352. Spatial Analysis in Ecology. Techniques of spatial analysis as applied to ecological data, including scaling techniques, pattern analysis, indices of patchiness (adjacency, contagion), and inferential methods (cross-correlation, permutation procedures). Emphasis on hands-on applications in computer lab. Prerequisite: Environment 214 or consent of instructor. Instructor: Urban. 3 units.

353. Advanced Topics in Landscape Ecology. Small groups of students working together to complete a project in landscape analysis integrating remote sensing, geographic information systems, spatial analysis, and simulation modeling. Expectation is that each student will have experience in at least one of these areas. Consent of instructor required. Offered on demand. Instructors: Halpin and Urban. Variable credit.

354. GIS Analysis for Conservation Management. This course explores applications of geographic and spatial analysis to conservation management issues such as habitat analysis, biodiversity protection assessments, and nature reserve design. The primary goals of the course are: (1) to critically assess the theoretical underpinnings of conservation analysis techniques; and (2) to develop a high level of proficiency in the application of geographic and spatial analysis techniques for conservation management problems. Prior experience with GIS systems and consent of instructor required. Instructors: Halpin and Urban. 3 units.

356. Environmental Fluid Mechanics. Introduction to turbulent fluid flow and Navier Stokes equations; basic concepts in statistical fluid mechanics; development of prognostic equations for turbulent fluxes, variances, and turbulent kinetic energy; Monin and Obukhov similarity theory for stratified turbulent boundary layer flows; applications to CO2, water vapor, and heat fluxes from uniform and nonuniform surfaces; the local structure of turbulence and Kolmogorov's theory; turbulent energy transfer and energy cascade between scales; turbulence measurements in the natural environment. Prerequisite: Civil Engineering 122L, Mathematics 111 or 135, or equivalent. Instructor: Katul. 3 units.

357. Satellite Remote Sensing for Environmental Analysis. Environmental analysis using satellite remote sensing. Theoretical and technical underpinnings of remote sensing (multi-spectral image analysis, classification, and georectification) coupled with practical applications (land cover mapping, change analysis, ground truth techniques). Strong emphasis on hands-on processing and analysis of satellite and digital photogrametric imagery in a UNIX workstation environment. Consent of instructor required. Instructor: Halpin. 3 units.

358. Multivariate Analysis in Community and Landscape Ecology. Assembly in a lab setting portfolios of strategies for interpreting multivariate ecological datasets such as those relating species abundance to environmental variables, focusing on techniques commonly used by vegetation scientists (for example, ordination, classification, etc.). Emphasis on using and interpreting UNIX and PC-based software. Consent of instructor required. Instructor: Urban. 3 units.
385. **Environmental Decision Analysis.** Quantitative methods for analyzing environmental problems involving uncertainty and multiple, conflicting objectives. Topics include subjective probability, utility, value of information, multiattribute methods. Students will apply these tools to an environmental policy decision in a group project. Prerequisite: introductory applied statistics or equivalent. Instructor: Maguire. 3 units.

388. **Seminar in Resource and Environmental Policy.** Discussion of the political, legal, and socioeconomic aspects of public and private action in environmental quality control and management. Consent of instructor required. Instructor: Staff. Variable credit.

394. **Professional and Field Skills.** A series of modules offered on a rotating basis over the four semesters of a professional master's program. Modules consist of one to twenty hours of instruction in a skill needed for professional development or competence in field sampling or laboratory techniques. Examples of topics include environmental negotiation; environmental safety; use of computer packages; preparing presentations and written reports; sampling design; field sampling of trees, herbaceous plants, streambottom organisms; toxicological testing using plankton. Instructor: Maguire. Variable credit.

398. **Program Area Symposium.** Required symposium in each program area. Students present master's project research. Pass/ fail grading only. Instructor: Staff. 1 unit.

399. **Master's Project.** An applied study of a forestry or environmental management problem or an original research effort. A seminar presentation of the objectives, methodology, and preliminary findings is required. A written (or other medium) report at the conclusion of the project is also required. Undertaken with the guidance of the student's adviser. Consent of instructor required. Pass/ fail grading only. Instructor: Staff. Variable credit.

**ENVIRONMENT COURSES CURRENTLY UNSCHEDULED**

134L. Biological Cycles in the Ocean
242. Environmental Aquatic Chemistry
245. Ecology of Microorganisms
252L. Statistics and Data Analysis in Earth and Ocean Science
268. Advanced Topics in Nearshore Processes
283. Corporate Environmental Management and Strategy
316. Case Studies in Environmental and Forest Management
340. Biohazard Science
341L. Methods in Biohazard Science
342. Bioaerosols
372. Advanced Theory of Environmental and Natural Resource Economics
389. Seminar in Conservation and Environmental History

**Environment Intensive Courses (ENVIRON)**

258. **Forest Appraisal.** Presentation of the principles of real estate appraisal as they apply to valuation problems in forestry. Consideration of appraisal theory, accounting and tax concepts in forest land management. Application of financial analysis techniques to forest land management through lectures and problem-solving sessions. Intensive. Instructor: Burak. Variable credit.

286. **Land Conservation Strategies.** Knowledge, information, and identification of available resources to enable a volunteer or experienced professional to complete a land
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386. Implementation of the National Environmental Policy Act on Federal Lands and Facilities. Overview of NEPA content, case law, and current issues. Discussion of methods of implementing regulations, conducting and processing an environmental impact analysis, determining the proper level of documentation to fully record and disclose results. Intensive. Instructor: Clark. 1 unit.


Earth and Ocean Sciences (EOS) Courses Given in Durham

Information about earth and ocean sciences (EOS) courses below 200-level can be found in the Duke University Bulletin of Undergraduate Instruction.

200. Beach and Coastal Processes. The study of sedimentary processes and geomorphology of nearshore environments with emphasis on both developed and undeveloped barrier island systems. Instructor: Staff. 3 units.

202. Beach and Island Geological Processes. Field seminar in the evolution of beaches and barrier islands with emphasis on the interaction of nearshore processes with the trappings of man. Consent of instructor required. (Given at coast on two weekends.) Instructor: Staff. 2 units.

203. Physical Oceanography. Introduction to the dynamic principles of ocean circulation with an emphasis on large temporal and spatial scales of motion. Topics include wind-driven and density-driven flow, western boundary intensification, mid-ocean, shelf, and tropical circulations. Also taught as Environment 290 and Mechanical Engineering 290. Prerequisites: Mathematics 31 and 32 or consent of instructor. Instructor: Lozier. 3 units.

206S. Principles of Geological Oceanography. Geological aspects of the ocean basins including coastal to deep water sediment types and sedimentation processes, sea floor physiography, and environmental problems. Not open to students who have taken Earth and Ocean Sciences 205. Consent of instructor required. Instructor: Baker. 3 units.

207S. Analysis of Coastal Engineering Models. A critical evaluation of the assumptions and principles underlying coastal engineering mathematical models used to predict the behavior of beaches. Involves classroom discussion of both the geology and
208S. Paleoceanography. Geology, paleoceanography, and evolution of the oceans, ocean basins, and marine biota based on analysis of deep-sea sedimentary sequences. Instructor: Corliss. 3 units.

209S. Climate Dynamics and the Paleoclimatic Record. Introductory readings and reviews of modern physical climatology followed by extensive readings covering the record of past climatic change, concentrating on last Quaternary and Holocene time. Topics include the global energy balance, the hydrologic cycle, general circulation of the atmosphere and oceans, climatemodeling, future climate change, and the known record of paleoclimate (from marine and lake sediments, corals, soils, ice cores, etc.). Some background in physical sciences recommended. Instructor: Baker. 3 units.

213. Modern and Ancient Oceanic Environments. Description of oceanic environments and geological processes that create or modify them through time. Reconstruction of paleoenvironmental/paleoceanographic conditions in the world’s oceans using sediments and fossils with emphasis on global climate change over a range of time scales. Inductive interpretations of geological data to construct paleoenvironmental models. Includes field trip. Research paper required. (Also given in Beaufort.) Instructors: Corliss, Klein, and staff. 3 units.

215. Introduction to Physical Coastal Processes. Nearshore physical processes responsible for the evolution of beaches and barrier islands. Various problems and possible solutions arising from human development of retreating shorelines. Involves a field trip and research paper. Consent of instructor required. Instructor: Murray. 3 units.

221. Hydrogeology. Theory of groundwater flow and solute transport with application to geologic processes, water resources, and water quality. Prerequisites: Chemistry 12L or 22L, Mathematics 103, and Physics 42L or consent of instructor. Instructor: Rojstaczer. 3 units.


230S. Advanced Structural Geology. Stress and strain emphasizing geometric, kinematic, and dynamic analysis of microstructures and mesoscopic structures. Prerequisite: Earth and Ocean Sciences 130L or consent of instructor. Instructor: Karson. 3 units.

233S. Oceanic Crust and Ophiolites. Structure, tectonics, petrology, and geochemistry of oceanic spreading environments and ophiolite complexes. Prerequisites: Earth and Ocean Sciences 106L and 130L or consent of instructor. Instructor: Karson. 3 units.

236S. Lithosphere Plate Boundaries. Plate tectonics and the geological and geophysical expression of orogenic belts, spreading centers, transform faults, subduction zones. Prerequisite: Earth and Ocean Sciences 130L or consent of instructor. Instructor: Karson. 3 units.

237S. Structure and Evolution of the Appalachian Orogen. Overview of sedimentation, deformation, and metamorphism responsible for the development of the Appalachian Mountain Belt from Newfoundland to Alabama in the context of plate tectonics. Prerequisites: Earth and Ocean Sciences 106L, 110L, and 130 or consent of instructor. Instructor: Karson. 3 units.

239S. Advanced Topics in Structural Geology and Tectonics. Selected topics related to deformation of rocks ranging from microstructure to plate tectonics. Prerequisite: Earth and Ocean Sciences 130L or consent of instructor. Instructor: Karson. 3 units.

241S. Coastal Processes and Geomorphology. Selected readings in nearshore processes and pattern formation, ranging from beach scales (for example, bars and channels) to shoreline scales (for example, barrier islands and capes), and ranging from coastal plain to rocky and arctic coasts. Optional field trip to study ocean island geomorphology in Hawaii after the semester. Consent of instructor required. Instructor: Murray. 3 units.

242S. New Perspectives and Methods in Surface Process Studies. Nonlinear dynamics and related approaches to understanding, modeling, and analyzing physical systems, with emphasis on applications in geomorphology. Consent of instructor required. Instructor: Murray. 3 units.


246S. Nearshore Hydrodynamics and Sediment Transport. Phenomena resulting from waves, wave momentum (radiation stress), and wave interactions. Includes oscillatory flow, long period (infragravity) motions, and mean currents. Nearshore sediment transport and possible origins of beach and nearshore topographic features. Consent of instructor required. Instructor: Murray. 3 units.

247S. Natural History of the Great Basin. Integrated study of the geomorphology, hydrology, climate, biology, and anthropology of the internally drained areas of Nevada, California, Utah, and Oregon. Comparison of Ice Age and modern features including lakes, soils, vegetation, animals, and humans. Consent of instructor required. Instructor: Haff. 3 units.

250. Applied Mathematics for the Environmental and Earth Sciences. Mathematical methods used in modeling and data analysis of environmental and geologic problems. Data sets or quantitative problems from the students used as original problems, to be completed as a final quantitative research product at the end of the semester. Different mathematical modeling approaches compared and evaluated. Focus depends on the research areas of class members. Instructor: Staff. 3 units.

252. Geophysics and Crustal Dynamics. A critical and mathematical evaluation of the earth's seismology, gravity, magnetism, heat flow, and internal dynamics. Derivation and evaluation of the basic equations of geophysics and geodynamics. The physics and computer methods of the locations and mechanics of earthquakes, seismotectonics and crustal dynamics, the earth's internal layers, the gravitational attraction of mountains, the magnetic properties of rocks, the cooling of the earth, and the basics of conti-
nal drift. Original research project required. Prerequisite: upper division or first-year graduate standing in science or engineering. Instructor: Malin. 3 units.

258S. Practical Experience in Modern Seismic Profiling II: Data Processing. Second of a three-course sequence in the application of seismic profiling in geological investigations for research, resource, and environmental purposes; signal processing step necessary to process portions of the 3D seismic reflection profiling from central Texas into interpretable images of the geology. Background topics include basic methods and theory of seismic data processing; focus on applying these methods to the field data. Prerequisite: Earth and Ocean Sciences 257S. Instructor: Malin. 3 units.

259S. Practical Experience in Modern Seismic Profiling III: Geological Interpretation. Third of a three-course sequence in the application of seismic profiling in geological investigations for research, resource, and environmental purposes; the geological meaning and significance of the processed 3D seismic reflection profiles collected in central Texas as part of Earth and Ocean Sciences 257S. Background topics including the basic methods of seismic data interpretation; focus on developing testable alternative hypotheses about the geology/hydrology/stratigraphy of the field site. Prerequisite: Earth and Ocean Sciences 258S. Instructor: Malin. 3 units.

269. Thermodynamics of Geological Systems. Introductory thermodynamics applied to geologic problems through understanding of phase equilibrium. Prerequisites: Earth and Ocean Sciences 105L (may be concurrent) and Mathematics 32. Instructor: Boudreau. 3 units.

270. Sedimentary Geochemistry. Chemistry of aqueous solutions and authigenic minerals in sedimentary systems. Prerequisite: Chemistry 12L or 22L, and Mathematics 32. Instructor: Baker. 3 units.

271. Stable and Radioactive Isotopes in Environmental Sciences. Theory and applications of stable and radioactive isotope distributions in nature (including oceanographic, geologic, hydrologic, and biological processes). Prerequisites: Chemistry 12L or 22L, and Mathematics 32. Instructor: Baker. 3 units.

272. Biogeochemistry. Processes controlling the circulation of carbon and biochemical elements in natural ecosystems and at the global level, with emphasis on soil and surficial processes. Topics include human impact on and social consequences of greenhouse gases, ozone, and heavy metals in the environment. Prerequisite: Chemistry 12L or 22L or equivalent. Instructor: Schlesinger. 3 units. C-L: Biology 272

273S. Analytic Techniques. An introduction to advanced analytic procedures used in the earth sciences: such as electron microbeam techniques (scanning electron microscopy, electron microprobe analysis) and plasma emission/absorption spectroscopy. Consent of instructor required. Instructors: Boudreau and Klein. 3 units.

275. Near-Surface Field Geophysics. Field oriented class in near-surface geophysical profiling for scientific and engineering uses. Covers the use of basic seismic and potential field methods for determining shallow geological structure and stratigraphy. Required data collection, analysis, and interpretation project. Consent of instructor required. Prerequisite: upper division or first-year graduate standing in science or engineering. Instructors: Boadu and Malin. 3 units.

285S. Layered Intrusions. Survey of layered igneous intrusions and current theories on crystallization and other processes occurring in mafic magmas. Quantitative methods related to magma crystallization including crystal size distribution theory, quantitative analysis of rock texture and its interpretation, crystal aging and numerical models of compaction, infiltration and reaction processes occurring in magma chambers. Offered alternate years. Research paper and presentation required. Prerequisites: Earth and Ocean Sciences 105L and 106L or consent of instructor. Instructor: Boudreau. 3 units.
291. Independent Study. Consent of instructor required. Instructor: Staff. 3 units.

293S. Frontiers of Geology I. Survey of the history, status, and trajectory of "hard-rock" petrology, structural geology, tectonics, and geophysics. Instructors: Karson and staff. 3 units.

294S. Frontiers of Geology II. Survey of the history, status, and trajectory of "soft-rock" petrology, stratigraphy, sedimentation, geochemistry, hydrology, and paleontology. Instructors: Karson and staff. 3 units.

295S. Advanced Topics in Geology. Topics, instructors, and credits to be arranged each semester. Instructor: Staff. Variable credit.

321L. Methods in Hydrogeology. Field and laboratory methods for investigation of applied hydrogeology problems. Must be taken concurrently with Earth and Ocean Sciences 221. Open to graduate students only. Instructor: Rojstaczer. 1 unit.

371. Advanced Topics in Geology. To meet the individual needs of graduate students for independent study. Instructor: Staff. Variable credit.

372. Advanced Topics in Geology. To meet the individual needs of graduate students for independent study. Instructor: Staff. Variable credit.

EARTH AND OCEAN SCIENCES COURSES CURRENTLY UNSCHEDULED

201. Physical Processes in Coastal Environments
208S. Paleoceanography
223. Computational Methods in the Hydrologic Sciences
230S. Advanced Structural Geology
237S. Structure and Evolution of the Appalachian Orogen
259S. Practical Experience in Modern Seismic Profiling III: Geological Interpretation
Courses Taught at the Marine Laboratory

Biology (BIOLOGY)

10L. Marine Biology. Physical and chemical aspects of estuarine and marine ecosystems and environments. Functional adaptations of marine organisms and the role of man and society on the ecosystems. Includes field trips to local environments with an emphasis on impacted environments and their relation to societal activity and policy. For students not majoring in natural sciences. (Given at Beaufort.) Instructor: Kenney. 1 unit.

109. Conservation Biology and Policy. Introduction to the key concepts of ecology and policy relevant to conservation issues at the population to ecosystems level. Focus on the origin and maintenance of biodiversity and conservation applications from both the biology and policy perspectives (for example, endangered species, captive breeding, reserve design, habitat fragmentation, ecosystem restoration/ rehabilitation). (Given at Beaufort.) Prerequisites: introductory biology; suggested: a policy and/or introductory ecology course. Instructors: Crowder (Beaufort) and Rubenstein (visiting summer faculty). 1 unit.

113L. Behavioral Ecology. How ecological factors shape foraging, mating, aggressive, and social behavior. Laboratory experiments and field observations from the Outer Banks environment. Independent projects and seminars. (Given at Beaufort in the summer.) Prerequisite: Biology 25L. Instructor: Rubenstein (visiting summer faculty). 1.5 units.

114L. Biological Oceanography. Physical, chemical, and biological processes of the oceans, emphasizing factors controlling distribution and abundances of organisms. The theory, methods, and limitations of biological oceanographic research. The laboratory teaches quantitative methods, experimental design, data acquisition, data processing, and data analysis and culminates in a research cruise where the students organize into a scientific party. One course (spring); one and one-half courses (summer). (Given at Beaufort and Bermuda.) Prerequisite: Biology 25L. Instructors: Ramus or staff (Beaufort); Nelson and Steinberg (Bermuda). Variable credit.

123. Analysis of Ocean Ecosystems. The history, utility, and heuristic value of the ecosystem; ocean systems in the context of Odum’s ecosystem concept; structure and function of the earth’s major ecosystems. (Given at Beaufort.) Prerequisite: one year of biology, one year of chemistry, or consent of instructor. Instructor: Barber. 1 unit.

125L. Biology and Conservation of Sea Turtles. Biology including the anatomy, physiology, behavior, life histories, and population dynamics of sea turtles linked to conservation issues and management. Focus on threatened and endangered sea turtle species, with special attention to science and policy issues in United States waters. Includes field experience with the animals and with their habitat requirements. Sea turtle assessment and recovery efforts, fishery-turtle interactions, population modeling and state/ national/ international management efforts. Students are encouraged to enroll for Biology 109 Conservation Biology and Policy concurrently. (Given at Beaufort.) Prerequisite: introductory biology. Instructor: Crowder, Wyneken (visiting summer faculty), or staff. 1 unit.
126. Marine Mammals. The biology of cetaceans, pinnipeds, sirenians, and sea otters. Topics covered include the diversity, evolution, ecology, and behavior of marine mammals and their interactions with humans. Detailed consideration given to the adaptations that allow these mammals to live in the sea. Evaluation of the scientific, ethical, and aesthetic factors influencing societal attitudes toward these animals and of their conservation management in light of domestic legislation and international treaties. (Given at Beaufort.) Prerequisite: introductory biology. Instructor: Read or staff. 1 unit.

126L. Marine Mammals. Laboratory version of Biology 126. Laboratory and field exercises consider social organization, behavior, ecology, communication, and anatomy of local bottlenose dolphins. (Given at Beaufort.) Prerequisite: introductory biology. Instructor: Read or staff. 1 unit.

127L. Marine Microbial Ecology. Microbial physiology and ecology within the context of biogeochemical processes. Quantitative modeling of microbial control of biogeochemical processes. Lectures, field trips, and laboratory exercises illustrating and employing the research techniques of microbial ecology to investigate microbial processes controlling nutrient cycling in the open ocean and coral reefs of Bermuda. (Given at Bermuda.) Prerequisites: introductory biology and chemistry. Instructors: Bates and Carlson (Bermuda). 1 unit.

128L. Estuarine Ecology. A study of the biological, physical, and chemical processes that structure estuarine communities. Field and laboratory techniques and data interpretation are considered. Not open to students who have taken Environment 208L. (Given at Beaufort.) Prerequisite: introductory biology and chemistry. Instructor: Kirby-Smith. 1 unit.

129L. Marine Ecology. Factors that influence the distribution, abundance, and diversity of marine organisms. Course structure integrates lectures and field excursions. Topics include characteristics of marine habitats, adaptation to environment, species interactions, biogeography, larval recruitment, and communities found in rocky shores, tidal flats, beaches, mangrove, coral reefs, and subtidal areas. Not open to students who have taken Zoology 203L. (Given at Beaufort fall and summer and at Bermuda, spring.) Prerequisite: introductory biology. Instructors: Crowder or Kirby-Smith (Beaufort); Lipschultz and Smith (Bermuda). 1 unit.

132S. Marine Biodiversity. Marine biodiversity in the context of theoretical ecology and environmental physiology. Topics include methods for quantifying and evaluating diversity and biological diversity in major marine habitats. Primary literature examples focus on quantifying human impacts and developing conservation measures. (Given at Bermuda.) Prerequisite: introductory biology. Instructors: Barnes and Coates (Bermuda). 0.5 units.

133S. Molecular Approaches to Questions of Physiology, Ecology, and Evolution in the Marine Environment. Techniques of molecular biology as they relate to physiological, ecological, and evolutionary questions. Examples from the subcellular to global scale taken from classic and contemporary readings from the primary scientific literature. Each participant in the course presents a critical analysis of the literature on a chosen subject. (Given at Bermuda.) Prerequisite: introductory biology. Instructor: Trapido-Rosenthal. 0.5 units. C-L: Environment 133S

150L. Physiology of Marine Animals. Comparative physiology of estuarine and marine animals. Physics and chemistry of estuarine and marine environments and physiological responses of animals to the major environmental drivers of temperature, salinity, oxygen, and light. Lectures and laboratories illustrating the approaches and methodology, analysis techniques, and written reporting of classical environmental physiology
research. One course (fall); one and one-half courses (summer). (Given at Beaufort.) Prerequisite: Biology 25L and Chemistry 12L. Instructor: Forward. Variable credit.

155L. Biochemistry of Marine Animals. The molecular basis of behavioral and physiological responses of organisms. Evolution of molecular endocrinology and signal transduction pathways. Focus on the theory and research methodology used to study the evolution of molecular signaling and control systems. Research projects using local invertebrates to study behavioral and physiological responses to environmental signals. Field trips include night walks in local environments and marine fossil expeditions to local strip mines involved with production of fertilizer, food additives, cement, and gravel. One course (fall and spring); one and one-half courses (summer). (Given at Beaufort.) Prerequisites: Biology 25L; and Chemistry 11L and 12L, or 21L and 22L. Instructor: Mc Clellan-Green (spring); Rittschof (fall and summer). Variable credit.

156L. Sensory Physiology and Behavior of Marine Animals. Sensory physiological principles with emphasis on visual and chemical cues. Laboratory will use behavior to measure physiological processes. (Given at Beaufort.) Prerequisites: Biology 25L and Chemistry 12L or 22L. Instructors: Forward and Rittschof. 1 unit.

176L. Marine Invertebrate Zoology. Structure, function, and development of invertebrates collected from estuarine and marine habitats. Not open to students who have taken Zoology 274L. One course (fall, spring, and Summer Term II); one and one-half courses (Summer Term I). (Given at Beaufort fall and summer or at Bermuda, spring.) Prerequisite: Biology 25L. Instructors: Dimock (Beaufort) or Kirby-Smith (Beaufort); Barnes and Coates (Bermuda). Variable credit.

190. Independent Study. Individual research and reading in a field of special interest, under the supervision of a faculty member, resulting in a substantive paper or written report containing significant analysis and interpretation of a previously approved topic. Open to all qualified students with consent of supervising instructor and director of undergraduate studies. A maximum of three courses of 190, 191, 192, 193T, 194T, and 197T may count toward the biology major. Instructor: Staff. 0.5 units.

191. Independent Study. Individual research and reading in a field of special interest, under the supervision of a faculty member, resulting in a substantive paper or written report containing significant analysis and interpretation of a previously approved topic. Open to all qualified students with consent of supervising instructor and director of undergraduate studies. A maximum of three courses of 191, 192, 193T, and 194T may count toward the biology major. Instructor: Staff. 1 unit.

192. Independent Study. Continuation of Biology 191. Open to all qualified students with consent of supervising instructor and director of undergraduate studies. A maximum of three courses of 191, 192, 193T, and 194T may count toward the biology major. Instructor: Staff. 1 unit.

193T. Tutorial. For junior and senior majors with consent of director of undergraduate studies and supervising instructor. Three courses of 191, 192, 193T, and 194T, maximum. Instructor: Staff. 1 unit.

197T. Tutorial. For junior and senior majors with consent of director of undergraduate studies and supervising instructor. A maximum of three courses of 190, 191, 192, 193T, 194T, and 197T may count toward the major. Instructor: Staff. 0.5 units.

213. Modern and Ancient Oceanic Environments. Description of oceanic environments and geological processes that create or modify them through time. Reconstruction of paleoenvironmental/ paleoceanographic conditions in the world’s oceans using sediments and fossils with emphasis on global climate change over a range of time scales. Inductive interpretations of geological data to construct paleoenvironmental models. Includes field trip. Research paper required. (Also given in Durham.) Instructors: Corliss, Klein, and staff. 3 units.
295S. Seminar. Instructor: Staff. Variable credit.

352. Tutorial. An approved academic exercise, such as writing an essay or learning a research skill, carried out under the direction of the appropriate staff members. Consent of instructor required. Hours and credit to be arranged. Instructor: Staff. Variable credit.

353. Research. To be carried on under the direction of the appropriate staff members. Consent of instructor required. Hours and credit to be arranged. Instructor: Staff. Variable credit.

354. Research. To be carried on under the direction of the appropriate staff members. Consent of instructor required. Hours and credit to be arranged. Instructor: Staff. Variable credit.

BIOLOGY COURSES CURRENTLY UNSCHEDULED

113L. Behavioral Ecology
164D. Developmental Biology
252L. Statistics and Data Analysis in Earth and Ocean Science

Cell Biology (CELLBIO)

210. Independent Study. Research resulting in a substantive paper or written report containing significant analysis and interpretation of a previously approved topic. Descriptions of specific areas may be obtained from the director of graduate studies. Consent of director of graduate studies required. 3 to 9 units. Instructor: Staff. Variable credit.

CELL BIOLOGY COURSES CURRENTLY UNSCHEDULED

205. Design and Analysis of Biological Experiments
213. Oxygen and Physiological Function
215. Seminar in the Physiology of Disease
217. Selected Membrane Transport
219. Molecular and Cellular Bases of Differentiation
232. Extracellular Matrix and Cell Adhesion
237. Analytical Imaging in Biomedical Research
305. Selected Topics in Cardiac Physiology

Earth and Ocean Sciences (EOS)

191. Independent Study. Individual research and reading in a field of special interest, under the supervision of a faculty member, resulting in a substantive paper or written report containing significant analysis and interpretation of a previously approved topic. Open only to qualified juniors and seniors by consent of director of undergraduate studies and supervising instructor. Instructor: Staff. 1 unit.

192. Independent Study. See Earth and Ocean Sciences 191. Open only to qualified juniors and seniors by consent of director of undergraduate studies and supervising instructor. Instructor: Staff. 1 unit.

195. Independent Study for Nonmajors. Individual research and reading in a field of special interest, under the supervision of a faculty member, resulting in a substantive paper or written report containing significant analysis and interpretation of a previously approved topic. Open to qualified juniors and seniors upon approval of the departmental faculty. Instructor: Staff. 1 unit.
Environment (ENVIRON)

121. Climate Change: A Global Perspective. Introduction to the scientific basis for prediction of global environmental change with emphasis on change in surface temperature, sea level, precipitation, and tropical cyclone activity. As an analytical exercise, students input temperature data sets from the Bermuda weather service and do basic analysis of Bermuda temperature anomalies over time. (Given at Bermuda.) Prerequisite: one year of chemistry. Instructors: Malmquist and Murnane (Bermuda). 1 unit.

122S. Climate-Related Hazards and Humanity. The roles of science, politics, and business in quantifying and managing risks associated with climate-related hazards such as hurricanes. (Given at Bermuda.) Instructor: Malmquist (Bermuda). 0.5 units.

125. Remote Sensing and Long-term Environmental Monitoring. Introduction to the theory and practice of environmental monitoring. Ocean biogeochemical cycles, tropical ecosystems, monitoring, and air and water pollution impact assessment and monitoring. Individual project required, the output of which is a grant proposal to do future monitoring work on a specific topic; project includes a review and reporting of the relevant literature, analysis of existing data sets on the topic, and the experimental plan for the project. (Given at Bermuda.) Instructor: Nelson. 1 unit.

132S. Current Topics in Oceanography and Marine Biology. Topics including the Iron Hypothesis, toxic algal blooms, and UV light considered through readings in the primary literature and student presentations. Emphasis on critical analysis of methodology, data analysis, and conclusions in primary peer-reviewed literature. (Given at Bermuda.) Prerequisite: introductory biology. Instructor: Staff (Bermuda). 0.5 units.

133S. Molecular Approaches to Questions of Physiology, Ecology, and Evolution in the Marine Environment. Techniques of molecular biology as they relate to physiological, ecological, and evolutionary questions. Examples from the subcellular to global scale taken from classic and contemporary readings from the primary scientific literature. Each participant in the course presents a critical analysis of the literature on a chosen subject. (Given at Bermuda.) Prerequisite: introductory biology. Instructor: Trapido-Rosenthal. 0.5 units. C-L: see Biology 133S


140. A Scientist’s Perspective on Environmental Principles, Policy, and Legislation. Bermuda’s ecological, economic, sociopolitical systems, and environmental legislation as both a case study and as a comparative microcosm. Topics include: ecosystem conservation, natural resource management, pollution and waste management, and energy conservation and management. (Given at Bermuda.) Instructors: Bates and Connelly (Bermuda). 1 unit.

191. Independent Study. Individual research and reading in a field of special interest, under the supervision of a faculty member, resulting in a substantive paper or written report containing significant analysis and interpretation of a previously approved topic. Open to qualified juniors and seniors with consent of instructor and director of undergraduate studies. Instructor: Staff. 1 unit.

191A. Independent Study. See Environment 191. Open to qualified juniors and seniors with consent of instructor and director of undergraduate studies. Instructor: Staff. 0.5 units.

192. Independent Study. See Environment 191. Open to qualified juniors and seniors with consent of instructor and director of undergraduate studies. Instructor: Staff. 1 unit.
192A. Independent Study. See Environment 191A. Open to qualified juniors and seniors with consent of instructor and director of undergraduate studies. Instructor: Staff. 0.5 units.

208. Estuarine Ecosystem Processes. A study of the physical, chemical, geological, and biological processes that control the structure of estuarine communities. Includes readings, oral presentations, and discussion of current literature from the journal Estuaries. Discussions focus on the management and policy implications of the science. Restricted to graduate students. Prerequisite: ecology, systematics, or field biology course or consent of instructor. Instructor: Kirby-Smith. 3 units.

209. Conservation Biology and Policy. Introduction to the key concepts of ecology and policy relevant to conservation issues at the population to ecosystems level. Focus on the origin and maintenance of biodiversity and conservation applications from both the biology and policy perspectives (for example, endangered species, captive breeding, reserve design, habitat fragmentation, ecosystem restoration/rehabilitation). Open to undergraduates only under Biology 109. (Given at Beaufort.) Prerequisite: introductory biology; suggested: a policy and/or introductory ecology course. Instructors: Crowder (Beaufort) and Rubenstein (visiting summer faculty). 3 units.

218L. Barrier Island Ecology. An integration of barrier island plant and animal ecology within the context of geomorphological change and human disturbance. Experimental evidence supporting the theory of barrier island formation and migration; plant and animal adaptations and their evolution, succession ecology, and conservation and restoration ecology. Strong emphasis in labs on independent use of quantitative field observation and research techniques. Prerequisite: Biology 25L or equivalent; suggested: course in botany or ecology. Instructors: Evans, Peterson, and Wells (visiting summer faculty). 4 units. C-L: Biology 218L

219L. Marine Ecology. Factors that influence the distribution, abundance, and diversity of marine organisms. Course structure integrates lectures and field excursions. Topics include characteristics of marine habitats, adaptation to environment, species interactions, biogeography, larval recruitment, and communities found in rocky shores, tidal flats, beaches, mangrove, coral reefs, and subtidal areas. Not open to students who have taken Biology 203L. Open to undergraduates only under Biology 129L. (Given at Beaufort fall and summer and at Bermuda, spring.) Prerequisite: introductory biology. Instructors: Crowder or Kirby-Smith (Beaufort); Lipschultz, McKenna, and Smith (Bermuda). 4 units. C-L: see Biology 203L

351. Tutorial. An approved academic exercise, such as writing an essay or learning a research skill, carried out under the direction of the appropriate staff members. Consent of instructor required. Hours and credit to be arranged. Instructor: Staff. Variable credit.

223L. Behavioral Ecology. How ecological factors shape foraging, mating, aggressive, and social behavior. Laboratory experiments and field observations from the Outer Banks environment. Independent projects and seminars. Not open to undergraduates. Prerequisite: introductory biology (Biology 25L). Instructor: Rubenstein (visiting summer faculty). 6 units. C-L: see Biology 213L

224L. Coastal Ecosystem Processes. Physical, chemical, and biological processes in the coastal zone of the Carolinas. A unifying theme will be the coupling of watersheds, river basins, estuaries, and the coastal ocean through the movement of ground and surface waters. Topics include hydrology, nutrient cycles, sediment-water column interactions, primary and secondary production, and food web dynamics. Sustaining coastal ecosystems in the face of land use change. Instructors: Ramus and staff. 4 units. C-L: Biology 219L

225L. Coastal Ecotoxicology and Pollution. Principles of transport, fates, food-web dynamics and biological effects of pollutants in the marine environment. Laboratory to
stress standard techniques for assessing pollutant levels and effects. Prerequisites: introductory chemistry and biology. Instructor: Kenney. 4 units.

226. Marine Mammals. Ecology, social organization, behavior, acoustic communication, and management issues. Focused on marine mammals in the southeastern United States (for example, bottlenose dolphin, right whale, West Indian manatee). Only open to undergraduates under Biology 126. Prerequisite: introductory biology. Instructor: Read or staff. 3 units.

226L. Marine Mammals. Laboratory version of Environment 226. Laboratory exercises consider social organization and acoustic communication in the local bottlenose dolphin population. Prerequisite: introductory biology. Instructor: Read or staff. 4 units.

227L. Biology and Conservation of Sea Turtles. Biology including the anatomy, physiology, behavior, life histories, and population dynamics of sea turtles linked to conservation issues and management. Focus on threatened and endangered sea turtle species, with special attention to science and policy issues in United States waters. Includes field experience with the animals and with their habitat requirements. Sea turtle assessment and recovery efforts, fishery-turtle interactions, population modeling and state/national/international management efforts. Only open to undergraduates under Biology 125L. Prerequisite: introductory biology. Instructor: Crowder, Wyneken (visiting summer faculty), or staff. 4 units.

228L. Physiology of Marine Animals. Environmental factors, biological rhythms, and behavioral adaptations in the comparative physiology of marine animals. Open to undergraduates only under Biology 150L. Four units (fall); six units (summer). Prerequisites: introductory biology and chemistry. Instructor: Forward. Variable credit. C-L: Biology 253L

229L. Biochemistry of Marine Animals. Functional, structural, and evolutionary relationships of biochemical processes of importance to marine organisms. Open to undergraduates only under Biology 155L. Four units (fall and spring); six units (summer). Prerequisites: Biology 25L; and Chemistry 11L, 12L. Instructor: McCllellan-Green (spring); Rittschof (fall and summer). Variable credit. C-L: Biology 255L


244L. Molecular and Cellular Processes in Marine Organisms. Joint research projects on the adverse effects of environmental pollutants on marine organisms at the cellular and molecular level. Research methodologies include: spectroscopy (UV/ VIS, fluorescence, and atomic absorption); subcellular fractionation; protein purification and characterization using chromatography and electrophoresis; analysis of pollutant-induced damage to proteins, membranes, and DNA; measurement of activity of enzymatic defense systems. Lectures cover molecular mechanisms of damage and damage control, and concepts that underlie the methods to be used. Prerequisite: organic chemistry. Instructors: C. Bonaventura and McCllellan-Green. 4 units. C-L: see Cell Biology 244L

253L. Sensory Physiology and Behavior of Marine Animals. Sensory physiological principles with emphasis on visual and chemical cues. Laboratories will use behavior to measure physiological processes. Only open to undergraduates under Biology 156L. Prerequisites: introductory biology and chemistry. Instructors: Forward and Rittschof. 4 units.
254. **Research Design in Marine Studies.** Fundamentals of research design with emphasis on linkage between theory, empirical statements, study objectives, study design, data collection, statistical analysis, and integration. Consideration of coastal and marine examples from both natural and social sciences. Enrollment limited to graduate students. Instructor: Johnson. 3 units.

256S. **Seminar in Ocean Sciences.** Biological, chemical, physical, and geological aspects of the ocean and their relation to environmental issues. Consent of instructor required. Instructor: Staff. 2 units.

267S. **Conservation Biology of Marine Mammals.** Examination of issues affecting the conservation of marine mammal populations, including: habitat loss and degradation, interactions with commercial fisheries, and direct harvests. Consent of instructor required. Instructor: Read. 2 units.

268. **Advanced Topics in Nearshore Processes.** Advanced treatment of fluid processes in the nearshore. Topics drawn from nonlinear wave theory, radiation stresses and their gradients, forced and free infragravity waves, and the origins of mean currents in the surf zone. Other topics following students' interests. Prerequisite: Environment 290, Mathematics 111 or 114, or consent of instructor. Instructor: Staff. 3 units.

269S. **Advanced Topics in Marine Ecology.** Theoretical concepts from population, community, and evolutionary ecology will be linked to observations and experiments to enhance understanding of the structure and function of marine systems. Current topics in marine ecology (for example, marine food web dynamics, species interactions, life history strategies, fisheries ecology, conservation biology). Discussions based on readings from the primary literature with emphasis on developing critical and synthetic skills. Each student will prepare a research proposal in NSF format. May be repeated. Instructor: Crowder. 2 units. C-L: Biology 264S

273. **Marine Fisheries Policy.** Principles, structure, and process of public policymaking for marine fisheries. Topics include local, regional, national, and international approaches to the management of marine fisheries. A social systems approach is used to analyze the biological, ecological, social, and economic aspects of the policy and management process. Instructor: Orbach. 3 units.

276. **Marine Policy.** Formal study of policy and policy-making concerning the coastal marine environment. History of specific marine-related organizations, legislation, and issues and their effects on local, regional, national, and international arenas. Topics explored through use of theoretical and methodological perspectives, including political science, sociology, and economics. Consent of instructor required. Instructor: Orbach. 3 units. C-L: Public Policy Studies 197

291. **Geological Oceanography.** The geology of ocean basins, including origin, bottom physiography, sediment distribution, and sedimentary processes. Not open to students who have taken Earth and Ocean Sciences 206S. (Given at Beaufort.) Instructor: Staff. 3 units. C-L: Earth and Ocean Sciences 205

292L. **Biological Oceanography.** Physical, chemical, and biological processes of the oceans, emphasizing special adaptations for life in the sea and factors controlling distribution and abundance of organisms. Only open to undergraduates under Biology 114L. Four units (spring); six units (summer). (Given at Beaufort and Bermuda.) Prerequisite: introductory biology. Instructors: Ramus or staff (Beaufort); Nelson and Steinberg (Bermuda). Variable credit.

293. **Analysis of Ocean Ecosystems.** The history, utility, and heuristic value of the ecosystem; ocean systems in the context of Odum's ecosystem concept; structure and function of the earth's major ecosystems. Open to undergraduates only under Biology 123. Prerequisite: one year of biology, one year of chemistry, or consent of instructor. Instructor: Barber. 3 units.
295L. Marine Invertebrate Zoology. Structure, function, and development of invertebrates collected from estuarine and marine habitats. Not open to students who have taken Biology 176L, Biology 274L, or Zoology 274L. Open to undergraduates only under Biology 176L. Four units (fall, spring, and Summer Term II); six units (Summer Term I). (Given at Beaufort fall and summer or at Bermuda, spring.) Prerequisite: Biology 25L. Instructors: Dimock (Beaufort) or Kirby-Smith (Beaufort); Barnes and Coates (Bermuda). Variable credit. C-L: Biology 274L.

ENVIRONMENT COURSES CURRENTLY UNSCHEDULED

252L. Statistics and Data Analysis in Earth and Ocean Science