

Zoology

zoology.siu.edu
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COLLEGE OF SCIENCE

Graduate Faculty:

Anderson, Frank E., Associate Professor, Ph.D., University of California, Santa Cruz, 1998; 1999. Invertebrates; molecular systematics, molecular evolution.

Anthoney, Terence R., Associate Professor, *Emeritus*, M.D., University of Chicago, 1968; and Ph.D., University of Chicago, 1975; 1971.

Boyles, Justin G., Assistant Professor, Ph.D., Indiana State University, 2009; 2011. Conservation physiology.

Brandon, Ronald A., Professor, *Emeritus*, Ph.D., University of Illinois, 1962; 1963.

Brooks, Marjorie, Associate Professor, Ph.D., University of Wyoming, 2003; 2009. Limnology; biogeochemistry; toxicology.

Brown, Jason L., Assistant Professor, Ph.D., East Carolina University, 2009; 2016. Integrated ecological, evolutionary, genetic, and geospatial analysis.

Burr, Brooks M., Professor, *Emeritus*, Ph.D., University of Illinois, 1977; 1977.

Catenazzi, Alessandro, Assistant Professor, Ph.D., Florida International University, 2006; 2012. Amphibian conservation.

Chen, Da., Assistant Professor, Ph.D., College of William and Mary, 2009; 2011. Wildlife toxicology.

Eichholz, Michael W., Associate Professor, Ph.D., University of Alaska, 1998; 2002. Waterfowl, wetland ecology.

Englert, DuWayne C., Professor, *Emeritus*, Ph.D., Purdue University, 1964; 1963.

Feldhamer, George A., Professor, *Emeritus*, Ph.D., Oregon State University, 1977; 1984.

Garvey, James E., Professor, Ph.D., Ohio State University, 1997; 2000. Fisheries biology.

Halbrook, Richard S., Associate Professor, *Emeritus*, Ph.D., Virginia Polytechnic Institute and State University, 1990; 1993.

Heidinger, Roy C., Professor, *Emeritus*, Ph.D., Southern Illinois University Carbondale, 1970; 1970.

Heist, Edward J., Professor, Ph.D., College of William and Mary, 1994; 1998. Population genetics; conservation genetics; fishery management.

Ibrahim, Kamal, Associate Professor and *Director of Graduate Studies*, Ph.D., Cambridge University, 1989; 2001. Population genetics.

Jimenez-Ruiz, F. Agustin, Associate Professor, Ph.D., University of Nebraska-Lincoln, 2004; 2009. Parasitology.

King, David G., Associate Professor, *Emeritus*, Ph.D., University of California, San Diego, 1975; 1977.

Kohler, Christopher C., Professor, *Emeritus*, Ph.D., Virginia Polytechnic Institute, 1980; 1981.

Krajewski, Carey, Professor and *Chair*, Ph.D., University of Wisconsin-Madison, 1988; 1990. Vertebrate molecular systematics.

LeFebvre, Eugene A., Associate Professor, *Emeritus*, Ph.D., University of Minnesota, 1962; 1966.

Lovvorn, James R., Professor, Ph.D., University of Wisconsin-Madison, 1987; 2009. Waterbird ecology; food webs.

Lydy, Michael J., Professor, Ph.D., Ohio State University, 2001. Aquatic toxicology.

McPherson, John E., Jr., Professor, *Emeritus*, Ph.D., Michigan State University, 1968; 1969.

Muhlach, William L., Associate Professor *Emeritus*, Ph.D., University of Illinois at Chicago, 1986; 1987.

Nielsen, Clay, Adjunct Professor, Ph.D., Southern Illinois University Carbondale, 2001; 2003. Wildlife ecology and management.

Reeve, John, Associate Professor, Ph.D., University of California Santa Barbara, 1985; 2000. Quantitative ecology.

Schauber, Eric M., Associate Professor, Ph.D., University of Connecticut, 2000; 2002. Wildlife ecology.

Shepherd, Benjamin A., Professor, *Emeritus*, Ph.D., Kansas State University, 1970; 1969.

Sparling, Donald W., Associate Professor, *Emeritus*, Ph.D., University of North Dakota, 1979; 2004.

Stahl, John B., Associate Professor, *Emeritus*, Ph.D., Indiana University, 1958; 1966.

Thomas, Richard H., Associate Professor, Ph.D., University of Arizona, 1985; 2004. Molecular evolution.

Waring, George H., Professor, *Emeritus*, Ph.D., Colorado State University, 1966; 1966.

Warne, Robin W., Assistant Professor, Ph.D., University of New Mexico, 2008; 2011. Physiological ecology.

Whiles, Matt R., Professor, Ph.D., University of Georgia, 1995; 1999. Stream ecology; freshwater invertebrates; entomology.

Whitledge, Gregory, Associate Professor, Ph.D., University of Missouri, 2001; 2005. Fish ecology and management.

The Department of Zoology offers graduate programs leading to the Master of Science and Doctor of Philosophy degrees. These degrees are awarded on the basis of demonstrated scholarship, with an emphasis on the ability to organize, conduct, and report original research. The department's graduate program is organized around five disciplinary areas: ecology & ecosystem studies; environmental toxicology; evolution, genetics, and population biology; fisheries biology & aquaculture; and wildlife ecology & management. These research groups draw heavily upon the expertise of faculty members affiliated with SIU's Center for Fisheries, Aquaculture, and Aquatic Sciences, Cooperative Wildlife Research Laboratory, and Center for Ecology. Graduate research in Zoology is facilitated by SIU's geographic location, notably its proximity to extensive national forests, wildlife refuges, state parks, and other natural areas of diverse physiography.

Admission

Application forms can be obtained via the departmental webpage (zoology.siu.edu). A completed departmental application includes: the form, transcripts of all previous college credits, an official score report for the Graduate Record Examination (GRE) General Test, and three letters of evaluation that address the applicant's academic abilities. A nonrefundable application fee must be submitted with the departmental application form. Applicants pay this fee when applying electronically to the Graduate School. Students who wish to be considered for a University fellowship must have a complete application on file by December 1. There are no other application deadlines, but early contact with the department is encouraged.

Applicants for both M.S. and Ph.D. programs must fulfill

all admissions requirements of the Graduate School. Inquiries about Zoology graduate programs should be made to the Director of Graduate Studies in Zoology. More information is available on the department's website (zoology.siu.edu/graduate). Prospective applicants are strongly encouraged to make contact with faculty members in their area of research interest prior to submitting an application.

Applicants to the master's program must possess the following academic background: 24 semester hours (or equivalent) in courses covering the basic principles of zoology (including animal diversity, genetics, ecology, and evolution); one year of college chemistry (organic and biochemistry are also desirable); one year of college mathematics including college algebra and trigonometry (calculus and statistics are also desirable); an undergraduate grade point average of at least 2.70 ($A = 4.0$). Applicants with a GPA less than 2.70 will be considered on individual merit.

Applicants for the doctoral degree must have a solid background in biological science, hold a master's degree, and have a grade point average in graduate work of 3.25 or above. Applicants with a graduate GPA less than 3.25 will be considered on individual merit. Direct entry to the doctoral program for students with only a bachelor's degree, or accelerated entry from the master's program, is possible for students demonstrating exceptional potential.

Advisement and Progress Toward Degree

During the admission process and prior to registration, a student should consult with faculty members representing his or her area of interest to identify an advisor. Advisors will be assigned formally by the Director of Graduate Studies upon admission. A change in advisor later in the program must be coordinated and approved by the Director of Graduate Studies.

Each student, in consultation with the advisor, must assemble an advisory committee to be approved by the Director of Graduate Studies before the end of the first semester of enrollment. For the master's degree, the committee shall consist of at least three graduate faculty members, one of whom may be from outside the department, with the advisor serving as chair. For the doctoral degree, the advisory committee shall consist of five graduate faculty members, one of whom must be from outside the department, with the advisor serving as chair. Master's committees may have no more than one adjunct member; Ph.D. committees may have no more than two adjunct members. All adjunct members of graduate committees must have a Ph.D. A program of study must be approved by the advisory committee and submitted to the Director of Graduate Studies no later than second semester of enrollment. A research proposal must be approved by the advisory committee and submitted to the Director of Graduate Studies no later than the third semester. Students may not register for ZOOL 599 or 600 before their proposal is approved.

Master of Science Degree

All requirements of the Graduate School must be satisfied. At least 30 hours of graduate credit (15 hours at the 500-level) is required beyond the bachelor's degree, including 21 hours of graded coursework, two hours of ZOOL 589, six hours of ZOOL 599, and two or more courses in a specific area representing the research tool. A grade point average of 3.00 in graduate coursework must be maintained. Failure to meet this requirement will result in academic probation and loss of financial support from the department.

Thesis. Students must prepare and defend a thesis based on the results of original research. The nature of the research is developed by the student in consultation with the advisor and advisory committee. The thesis is evaluated by the advisory committee and must be successfully defended before graduation. The defense consists of a presentation of thesis results in public seminar, followed by a closed session of oral evaluation by the advisory committee. A final version of the thesis must be approved by the advisory committee, the Director of Graduate Studies, the Department Chair, and the Graduate School. M.S. candidates must follow all Graduate School procedures in applying for graduation and deposit one bound copy of their thesis with the department.

Doctor of Philosophy Degree

All requirements of the Graduate School must be satisfied. Students entering the doctoral program are expected to have taken courses in the broad areas of animal diversity & evolution, ecology, and cell biology & genetics. Admission to the Ph.D. program requires two courses in two of these areas and three courses in the third. Students may be admitted with deficiencies, but must acquire the necessary coursework as part of their doctoral studies.

There is no minimum credit-hour requirement beyond the Graduate School's residency and dissertation requirements. A student, in consultation with his or her advisory committee, prepares a program of study that includes courses (including two semesters of ZOOL 589), seminars, and research. A research tool, consisting of at least two courses in a specific subject area, is required. A 3.25 grade point average in graduate coursework must be maintained. Failure to meet this requirement will result in loss of financial support from the department.

Preliminary Examinations. Written and oral examinations are taken after the tool requirement and major portion of any other formal coursework are completed, usually at the end of the second year of graduate study. The examinations focus on the student's area of research expertise as defined by the student, the advisor, and the advisory committee, and approved by the Director of Graduate Studies and the Department Chair. Administration and evaluation of these examinations is governed by the department's Preliminary Examination Policy. Students must pass both preliminary examinations to advance to candidacy.

Dissertation. Students must prepare and defend a dissertation based on the results of original research. The nature of the research is developed by the student in consultation with the advisor and advisory committee. Students must register for at least 24 hours of ZOOL 600 Research and Dissertation (only six hours are permitted prior to candidacy). The dissertation is evaluated by the advisory committee.

Final Examination. With the approval of the advisory committee, the candidate requests the Director of Graduate Studies to schedule a dissertation defense. The defense consists of a presentation of dissertation results in a public seminar, followed by a closed session of oral evaluation of the student's dissertation research by the advisory committee. A final version of the dissertation must be approved by the advisory committee, the Director of Graduate Studies, the Department Chair, and the Graduate School.

Graduation. Ph.D. candidates must follow all Graduate School procedures in applying for graduation and deposit one bound copy of their dissertation with the department.

Concentration in Ecology. Students opting to declare Ecology as a concentration shall follow the same program as students in the Zoology Ph.D. degree program that do not declare a concentration subject to the following: The Seminar in Ecology (PLB 589A) or equivalent (equivalent agreed upon by the student's committee) must be taken once each year until a student achieves candidacy. The research tool shall be statistics. The student's advisory committee shall consist of at least two members from outside the Department of Zoology.

Courses (ZOOL)

Students enrolled in zoology courses may incur field trip or laboratory expenses of \$5 to \$25.

ZOOL 405-3 Systematic Zoology. Estimation, analysis, and interpretation of phylogenetic trees; concepts, delimitation, and description of species; biological taxonomy and systems of classification; application of phylogenetics to the study of evolution. Prerequisites: BIOL 304 and MATH 108 with grades of C or better.

ZOOL 407-4 Parasitology. Principles, collection, identification, morphology, life histories, and control measures. Two lectures and two 2-hour laboratories per week. Prerequisite: ZOOL 220 with a grade of C or better. Laboratory/Field Trip Fee: \$15.

ZOOL 408-3 Herpetology. Taxonomic groups, identification, morphology, and natural history of amphibians and reptiles. Two lectures and one 2-hour laboratory per week. Prerequisite: ZOOL 220 with a grade of C or better. Laboratory/Field Trip Fee: \$15.

ZOOL 409-4 Vertebrate Histology. Microscopic structure of organs and tissues with emphasis on mammalian material. Two lectures and two 2-hour labs per week. Prerequisite: ZOOL 220A,B or ZOOL 220. Laboratory/Field Trip Fee: \$15.

ZOOL 410-3 Conservation Biology. An introduction to patterns of global biodiversity and threats to that diversity. Course emphasizes how principles from numerous biological disciplines are involved in conserving and managing biodiversity, and how social, economic, and political factors affect conservation strategies. Prerequisites: BIOL 307 and MATH 108 with grades of C or better.

ZOOL 411-3 Environmental Risk Assessment. Risk assessment can be defined as the process of assigning magnitudes and probabilities to the adverse effects of human activities or natural catastrophes. Prerequisites: BIOL 307 and CHEM 340 with grades of C or better.

ZOOL 413-4 The Invertebrates. Structure, phylogeny, distinguishing features and habitats of the invertebrates. Two lectures and two 2-hour laboratories per week. Prerequisite: ZOOL 220A or ZOOL 220. Laboratory/Field Trip Fee: \$15.

ZOOL 414-4 Freshwater Invertebrates. Taxonomic groups, identification, distribution, and habitats of the North American freshwater invertebrate fauna. Two lectures, two 2-hour laboratories per week. Prerequisite: ZOOL 220A or ZOOL 220. Laboratory/Field Trip Fee: \$15.

ZOOL 415-3 Limnology. (Same as PLB 416) Lakes and inland waters; the organisms living in them, and the factors affecting these organisms. Two lectures and one 4-hour laboratory

alternate weeks. Prerequisite: BIOL 307 with a grade of C or better. Laboratory/Field Trip Fee: \$15.

ZOOL 418-3 Vertebrate Anatomy Laboratory. Comparative anatomy and dissection of representative vertebrate specimens. Three 2-hour laboratories per week. Prerequisite: ZOOL 220 with a grade of C or better. Prior or concurrent registration in ZOOL 320 recommended. Laboratory/field Trip Fee: \$30.

ZOOL 425-3 Invertebrate Paleontology and Paleoecology. (Same as GEOL 425) Concepts of paleontology and paleoecology. Emphasis on functional morphology, lifestyles and habitats of fossil invertebrates and algae. The nature and evolution of marine and coastal paleocommunities. The effects of extinction events on paleocommunities and biodiversity. Laboratory. Field trips required. Prerequisite: GEOL 325 or ZOOL 220 with grade of C or better. Expense will vary in proportion to distance traveled and locations visited and will be determined before each semester. Field trip fee not to exceed \$199.

ZOOL 426-3 Comparative Endocrinology. (Same as ANS 426, PHSL 426) Comparison of mechanisms influencing hormone release, hormone biosynthesis, and the effects of hormones on target tissues, including mechanisms of transport, receptor kinetics, and signal transduction. Prerequisites: ANS 331 or ZOOL 220 or PHSL 310 with a grade of C. Laboratory/Field Trip Fee: \$15.

ZOOL 432-3 Principles of Toxicology. This course will introduce students to the main topics in the field of toxicology. The emphasis will be on understanding physiological, biochemical, and molecular mechanisms of toxicity. Prerequisites: BIOL 200A and BIOL 200B; or BIOL 211, BIOL 212, and BIOL 213; with grades of C or better.

ZOOL 433-3 Comparative Animal Physiology. (Same as PHSL 433) Variations of physiological processes in animal phyla, comparison with human physiology, and physiological adaptation to environmental variation. Review of basic physiological principles and comparative aspects of mechanism and function. Prerequisites: BIOL 200A or BIOL 211; BIOL 200B or BIOL 213, or PHSL 310; with grades of C or better.

ZOOL 434-3 Environmental Physiology. Physiological adaptations to environmental conditions in animals and humans. Lab/lecture course explores molecular, hormonal, immunological, developmental, and phenotypic processes mediating responses to factors such as stress, disease, contaminants, nutrition, and life history trade-offs. Prerequisite: BIOL 307 or PHSL 310 or ZOOL 433 with a grade of C or better. Laboratory/field trip fee: \$20.

ZOOL 435-3 Plant-Insect Interaction. (Same as PLB 435) Plants and insects have played major roles in influencing each other's evolutionary diversification. This course will be an evolutionary and ecological examination of the interactions between plants and insects. Topics will include herbivory, pollination relationships, ant-plant mutualisms, host plant choice, specialized vs. generalized relationships, seed and fruit dispersal, coevolution/cospeciation, and chemical ecology. Prerequisite: BIOL 200A or BIOL 211 and BIOL 200B or BIOL 212 or equivalent; BIOL 307 or equivalent.

ZOOL 438-3 Plant and Animal Molecular Genetics Laboratory. (Same as PLB 438, PSAS 438, AGSE 438, CSEM 438) Arabidopsis and Drosophila model organisms, training in laboratory safety, reagent preparation, phenotype analysis, genetics, DNA and RNA analysis, PCR, cDNA construction, cloning and sequencing.

Includes plant and bacterial transformation, and population level analysis of genetic variation using RAPD markers in grasses and Alu insertion in humans. Two 2-hr labs and one 1-hr lecture per week. Prerequisite: BIOL 305 or equivalent or consent of instructor. Lab fee: \$30.

ZOOL 440-3 Wildlife Nutritional Ecology. This course will provide an understanding of basic nutritional principles (including foraging, digestion, absorption, metabolism, and requirements), demonstrate their application to ecological relationships of wild terrestrial vertebrates with their environment, and stimulate students to critically evaluate published literature in this field of study. Prerequisite: BIOL 307.

ZOOL 443-3 Restoration Ecology. (Same as PLB 443) Ecological restoration tests current understanding of ecosystem assembly and function. This course applies ecological theory to restoration, with an emphasis on factors influencing plant community assembly and evaluating restoration success. Two lectures a week and one four-hour lab alternate weeks. Prerequisite: BIOL 307 or equivalent.

ZOOL 444-4 Ecological Analysis of Communities. (Same as PLB 444) Includes concepts and methods pertaining to the analysis of ecological data. Approaches will include a variety of methods for analyzing multivariate ecology, diversity, pattern, and spatial data. Laboratory will include the computer application of these concepts and methods to field situations. Two lectures and one 4 hour lab per week. Prerequisite: PLB/ZOOL 360, BIOL 307. Lab fee: \$15.

ZOOL 445-3 Wetland Ecology and Management. (Same as PLB 445) This course provides students with experience in wetland ecology and management with an emphasis on wetland functioning, field sampling, and identification of common wetland plants. Prerequisite: either BIOL 200B or BIOL 213 or PLB 200; and BIOL 307; or consent of instructor. Two lectures and one 4-hour lab per week. Lab fee: \$25.

ZOOL 450-3 Genome Evolution. (Same as PLB 455) This course introduces the diversity of genomes and the evolutionary forces shaping them. Molecular evolution from the level of single nucleotides to whole genomes will be covered. Prerequisites: BIOL 304 and BIOL 305.

ZOOL 458-3 Multiple Stressors in Ecology. In this class, students will use a step-by-step approach to evaluate an environmental issue or human concern compounded by climate change. The evaluation will begin with a conceptual model of the problem, followed by planned management strategies based on collaborative decision making. The class is designed to foster quantitative reasoning, include that reasoning in research, and articulate findings in terms that foster collaborative management and outreach. Examples of potential projects include climate change impacts in concert with disease propagation, habitat quality and quantity, pollutant uptake in ectotherms, coral bleaching, changing human coastal communities, or fire incidence.

ZOOL 461-3 Mammalogy. Taxonomic characteristics, identification, and natural history of mammals. Two 1-hour lectures and one 2-hour laboratory per week. Prerequisite: ZOOL 220B or ZOOL 220. Laboratory/Field Trip Fee: \$10.

ZOOL 462A-2 Waterfowl Ecology and Management (Lecture). This class will explore the pertinence of basic life history theory and ecological principles to waterfowl management. Lecture topics include but are not limited to waterfowl life histories

(i.e., productivity and mortality), foraging ecology, nutrition, habitat use, habitat management, migration, and the influence of harvest. Prerequisites: ZOOL 220, BIOL 307 with minimum grades of C. Co-requisite: ZOOL 462B.

ZOOL 462B-1 Waterfowl Ecology and Management (Laboratory). This laboratory will meet 1 day/week for 2 hours. The primary objective will be waterfowl identification with a secondary emphasis on wetland plant identification and field techniques in waterfowl research and management. There will be 2-3 Saturday field trips. Prerequisites: none. Laboratory/field trip fee: \$20.

ZOOL 464-3 Wildlife Administration and Policy. Responsibilities of private, state, and federal natural resources management agencies. Legal and political processes in areas of wildlife and natural resources. Three lectures per week. Special approval needed from the instructor.

ZOOL 465-3 Ichthyology. Anatomy, physiology, sensory biology, behavior, taxonomy, evolution, zoogeography, and ecology of fishes. Two lectures and one 2-hour laboratory per week. Prerequisite: ZOOL 220 with a grade of C or better. Laboratory/Field Trip Fee: \$10.

ZOOL 466-3 Fish Management. Sampling, age and growth, dynamics, habitat improvement, manipulation of fish populations, and management of freshwater and marine fish stocks. Two lectures per week and one 4-hour laboratory alternate weeks. Offered Fall term. Prerequisite: 10 hours of biological science or consent of instructor.

ZOOL 467-3 Ornithology. Classification and recognition of birds and the study of their songs, nests, migratory habits, and other behavior. One lecture and one four-hour laboratory per week. Prerequisite: ZOOL 220B or ZOOL 220. Laboratory/Field Trip Fee: \$10.

ZOOL 468-3 Wildlife Biology Principles. Basic concepts of wildlife ecology and management. Includes lectures on ecological physiology, population dynamics, and wildlife management strategies. Prerequisite: ZOOL 220, BIOL 307.

ZOOL 469-3 Wildlife Techniques. Field-oriented course with instruction in techniques for management of wild species and their habitat. One 1 1/2-hour lecture and one 3-hour laboratory per week, two of which may be field trips on Saturdays. Prerequisite: ZOOL 220A,B or ZOOL 220. Laboratory/Field Trip Fee: \$30.

ZOOL 471-4 Entomology. Structure, classification, and life histories of insects. Two lectures and two 2-hour laboratories per week. Prerequisite: ZOOL 220A or ZOOL 220. Laboratory/Field Trip Fee: \$10.

ZOOL 472-3 Introduction to Systems Biology. (Same as PLB 471) The experimental and bioinformatics analysis of large genomic and post-genomic data sets. The goal is integration of gene regulation, protein interaction, metabolite and hormonal signaling molecules into an understanding of basic cellular circuitry networks. Examine redundancy, robustness and decision making in biological systems. Prerequisite: BIOL 305 or CS 330. Lab fee: \$15.

ZOOL 477-3 Aquaculture. (Same as ANS 477) Production of food, game, and bait fishes. Design of facilities, chemical and biological variables, spawning techniques, diseases and nutrition. Two lectures per week and one four-hour laboratory on alternate weeks. Prerequisites: BIOL 200A or BIOL 211 or ZOOL 118 or ANS 121 with grade of C or better.

ZOOL 478-3 Animal Behavior. Biological basis of the behavior of animals. Two lectures and one 2-hour laboratory per week. Prerequisite: One year of biological science or permission of instructor.

ZOOL 485-2 to 4 Special Topics in Zoology. Examination of topics of special interest not available in other departmental courses. Offered in response to student need and faculty availability. Special approval needed.

ZOOL 490-3 Energetics, Food Webs, and Ecosystems. (Same as PLB 490) This course places conservation of particular species into the context of community and ecosystem management. Approaches to quantifying energy needs of individual species will be extended to models of trophic networks among multiple species. Food web structure and function, species interactions, and resilience to species loss species invasions, and environmental changes will be examined in light of landscape processes. Prerequisite: BIOL 307 or consent of instructor.

ZOOL 496-1 to 3 Zoology Field Studies. Formal, individualized training in field zoology, including experiences that acquaint students with animals in various environments, methods of field study, specimen collection and preservation, management and conservation, or other relevant skills. A prospectus of the training experience must be approved by a Zoology faculty supervisor before registration. Credit hours may not be counted toward a minor or major in Zoology. Not for graduate credit. Mandatory Pass/Fail. Prerequisite: ZOOL 220 with a grade of C or better.

ZOOL 505-2 Wildlife Administration and Management Constituencies. This class will explore what motivates individuals to pursue outdoor activities, why individual user groups are often extremely passionate about their individual outdoor activity, how outdoor activities impact wildlife populations and habitat, outdoor ethics, how to safely interact with individuals who are often in possession of firearms or other potentially dangerous tools that are used for hunting, and how to resolve conflicts between user groups.

ZOOL 510-3 Evolutionary Biology. An introductory survey of evolutionary biology at the graduate level, emphasizing conceptual issues in evolutionary genetics, adaptation, systematics, and macroevolution. Prerequisite: BIOL 305 or equivalent.

ZOOL 521-3 Stream Ecology. The physical, chemical, and biological factors affecting organisms in streams. Two lectures per week and one four-hour laboratory alternate weeks. Prerequisite: ZOOL 415. Special approval needed from the instructor.

ZOOL 530-3 Wildlife Diseases. Introduction to the causes and nature of diseases of wildlife with emphasis on wild mammals and birds. The relationship of disease to the population ecology of species will be emphasized further. Two lectures and one two-hour laboratory per week. Offered Spring term. Special approval needed from the instructor.

ZOOL 532-3 Wildlife Toxicology. Fate and effects of environmental toxicants in wildlife. Review of descriptive and mechanistic toxicology for environmental contaminants. Investigation of the relationship between individual and community responses to toxicant exposure. Examination of current hazard assessment protocols and associated regulatory agencies. Prerequisite: ZOOL 468 or consent of instructor.

ZOOL 533-4 Aquatic Toxicology. This course will provide an overview of concepts and methodology for conducting tests in the

field of aquatic toxicology. Specific topics to be covered include: acute and chronic bioassays, bioaccumulation tests including biotransformation processes and toxicokinetics, and modeling techniques using Quantitative Structure Activity Relationships and fugacity modeling. This class is recommended for students interested in learning about the applied methodology used in the rapidly evolving field of aquatic toxicology. Prerequisite: BIOL 307 and CHEM 340 or equivalent, or instructor's permission.

ZOOL 534-3 Wildlife Habitat Analysis. Physical, biological and behavioral factors that influence habitat use and selection by wild vertebrate populations. Landscape level analysis of wildlife habitats. Modeling habitat suitability, environmental impact and wildlife population dynamics with habitat data. Application and use of remote sensing and geographic information systems in natural resource management and habitat evaluation. One two-hour lecture and one two-hour laboratory per week. Special approval needed from the instructor.

ZOOL 535-3 Quantitative Zoogeography. This course focuses on spatial analyses from the perspective of the organism (or a group of organisms) and the role of the environment in shaping its distribution. The course will cover topics associated with species distribution modeling, biodiversity quantification, landscape genetics, animal movement analyses, home range quantification, and landscape conservation prioritization from the perspective of conserving a single species. Prerequisite: familiarity with GIS and consent of instructor.

ZOOL 536-3 Spatial Analysis in Ecology. This course provides the ecological, GIS and statistical foundations needed to perform spatial analyses of ecological data at the landscape level. The course will cover the conceptual basis and practical application of GIS-based techniques for accounting for spatial autocorrelation, data reduction, batch processing of analyses (in Python, ArcGIS and R), spatial interpolation of spatial data, and building mixed predictive models aimed at assessing landscape level processes. Prerequisite: familiarity with GIS and consent of instructor.

ZOOL 540-3 Stable Isotopes in Ecology. This course will introduce students to fundamentals of stable isotope biogeochemistry, analytical techniques, and interpretation and analysis of stable isotope data. Students will become acquainted with a diverse array of applications of stable isotopes in ecological research in terrestrial and aquatic systems. Two lectures or discussions per week. Prerequisite: 6 hours of chemistry, 10 hours of biological science. Special approval needed from the instructor.

ZOOL 545-3 Ecosystem Ecology. (Same as PLB 545) Fundamentals of and human modification to atmospheric chemistry and cycling of major nutrients in terrestrial ecosystems are covered in the context of global change. Laboratory exercises provide methodology and analytical approaches to studying ecosystem structure and function. Two lectures a week and one four-hour lab alternate weeks.

ZOOL 550-3 Analysis of Vertebrate Populations. This course provides instruction in the estimation of demographic parameters including but not limited to occurrence, abundance, mortality, birth, growth, philopatry, emigration, and immigration. Students will be introduced to and provided detailed instruction in the use of Program MARK to analyze data from individually marked organisms. Prerequisite: a course in statistics.

ZOOL 556-3 Phylogenetics. (Same as ANTH 556, MBMB 556, and PLB 556) An advanced introduction to modern methods of

phylogenetic inference, emphasizing both theoretical background concepts and numerical approaches to data analysis. Topics include properties of morphological and molecular characters, models of character evolution, tree estimation procedures, and tree-based testing of evolutionary hypotheses. Special approval needed from the instructor.

ZOOL 557-4 Biostatistics. (Same as PLB 557) Basic biostatistics procedures used by researchers in life sciences and related fields. Topics include descriptive statistics, probability and distributions, statistical models, likelihood methods, experimental design, analysis of variance, regression, correlation, and the use of statistical software.

ZOOL 558-4 Advanced Biostatistics. (Same as PLB 558) Advanced biostatistical procedures used by researchers in life sciences and related fields. Topics include multiple and logistic regression, randomization tests, jackknife and bootstrap, Mantel tests, BACI designs, MANOVA, repeated measures analysis and the use of statistical software. Prerequisite: ZOOL 557, PLB 557 or equivalent.

ZOOL 559-4 Analytical Techniques in Toxicology. This is an advanced class for graduate students interested in the analytical tools used in the field of Environmental Toxicology. Prerequisite: CHEM 340 with C or better.

ZOOL 564-1 to 2 Aquaculture Techniques. (Same as ANS 564) Practical experience in aquaculture techniques. Course consists of modules which require student participation in hands-on experience, (e.g., spawning, induction of spawning, production of fry, operation and grading, diagnosis and treatment of parasites and diseases, and transporting of fish). One credit for completion of two modules. Register any semester, one year to complete elected number of modules. Written report and examination required for each module. Cost incurred by student varies with modules selected. Prerequisite: ZOOL 477 or ANS 477 or consent of instructor.

ZOOL 565-3 Environmental Physiology of Fish. Synthesis of effects of pollutants on physiological processes of fish. Course begins with an overview of fish physiology. Topics include: concepts, methods, and measurements in aquatic toxicology; histopathological, physiological, and behavioral responses to pollutants; and toxicity of heavy metals, organics, particulates and other pollutants. Three lectures per week. Prerequisite: ZOOL 465 or consent of instructor.

ZOOL 568-2 Fish Stock Assessment. Methods of characterizing fish populations including mortality rates, age growth analysis, population sampling, yield models, habitat evaluation procedures and creel survey techniques. Two one-hour meetings per week. Prerequisite: ZOOL 466 or consent of instructor.

ZOOL 569-3 Advanced Fisheries Management. Advanced topics related to the management of fisheries including urban fisheries, native American fisheries, freshwater commercial fisheries, Great Lakes fisheries, impact of power generating plants on fishes, and in-depth consideration of indices of community structure and current topics in fish management. Three lectures per week. Prerequisite: ZOOL 466 or consent of instructor.

ZOOL 570-3 Advanced Aquaculture. (Same as ANS 570) Special topics in aquaculture and practical methods for the production of coldwater, coolwater, warmwater, and tropical aquatic species. Prerequisite: ZOOL 477 or ANS 477 or equivalent with a grade of C or better.

ZOOL 571-3 Fish Reproduction and Breeding. (Same as ANS 571) Principles of finfish reproductive strategies, reproductive physiology and captive breeding. The role of genetics and the use of biotechnology and various breeding techniques in breeding programs will also be emphasized. The purpose of this course is to develop an understanding of fish reproduction and breeding techniques and to gain an appreciation of the complexity involved in managing a hatchery breeding program. Two lectures a week and one four-hour lab alternate weeks. Prerequisite: ZOOL 477 or ANS 477 or equivalent with a grade of C or better.

ZOOL 573-3 Physiological Ecology. The role of physiological, morphological, and behavioral adaptations and adjustments in the ecology of vertebrate organisms with special emphasis on examining the energy balance and environment as it influences vertebrate ecology. Two hours of lecture and one two-hour laboratory. Prerequisite: BIOL 307 or equivalent. Special approval needed from the instructor.

ZOOL 574-1 to 6 Internship in Wildlife Administration and Management. A minimum 2-month full-time internship will be conducted at a Fish and Wildlife Refuge, National Forest, State Wildlife Area, or other private or publicly held land trust. During the time of the internship, daily activities of the students will be supervised by agency personnel. In collaboration with agency personnel, students will be required to write and submit a land improvement proposal to an appropriate funding agency. Internships must be approved by the Director of the Professional Science Master's program in Zoology. Grading will be based on a rubric outlining student performance during the day to day activities internship and the final land improvement proposal.

ZOOL 575-3 Topics in Amphibian Biology. Readings, discussions, and student presentations on current research in the biology of amphibians.

ZOOL 576-1-12 hours; 1 per semester Seminar in Ecology. (Same as PLB 589A) Discussions of current and historical research and literature in various subject areas of ecology.

ZOOL 577-3 Population Ecology. Principles of population dynamics as related to animals, with application to management and conservation of animal populations. Areas of emphasis include (A) an introduction to mathematical models and graphical theory of population dynamics, (B) application of theory to population management & conservation, and (C) empirical approaches to studying population persistence and regulation. Prerequisite: BIOL 307 or consent of instructor.

ZOOL 578-3 Population Genetics. (Same as PLB 578) Genetic structure of populations, factors causing changes and principles governing rate and direction of change. Three lectures per week. Prerequisite: BIOL 304 or equivalent, and BIOL 305 or equivalent.

ZOOL 579-3 Molecular Genetics Techniques. Practical experience in molecular genetics techniques currently used in zoology for population genetic analysis and for molecular systematics. Emphasis will be on methods for allozyme, mtDNA and nuclear DNA analysis. Class projects will focus on experimental design, data collection and analysis. Special approval needed from the instructor.

ZOOL 580-1 Current Topics in Evolution. (Same as ANTH 580, MBMB 580) The Evolution Discussion Group meets weekly throughout the year to discuss current evolutionary literature and the research of participants. All students and faculty with

an interest in evolutionary biology are welcomed to participate. **ZOOL 581-2 Zoological Literature.** Diversity and functions of zoological literatures, scientific writing and the publication process. Two lectures per week. Restricted to graduate status in a biological science.

ZOOL 582-1 to 4 (1,1,1,1) Graduate Zoology Seminar. Special topics in zoology. Consult department for each semester's topic. One meeting per week. Special approval needed from the instructor and department.

ZOOL 584-3 Conservation Genetics. Application of principles from evolutionary and ecological genetics to conservation biology, fishery management, wildlife management, and aquaculture. Includes an overview of classical, molecular, population and quantitative genetics leading to an understanding of how managers can conserve genetic diversity and evolutionary potential of natural and captive populations. Prerequisite: BIOL 305 or consent of instructor.

ZOOL 585E-3 per topic Seminar: Reasoning in Ecology. Conceptual issues in ecology and ecological research.

ZOOL 585G-3 per topic Seminar in Parasitology. Advanced study of special topics in zoology.

ZOOL 585Z-3 per topic Seminar in Selected Topics. Advanced study of special topics in zoology. Special approval needed from the instructor or department.

ZOOL 586-1 Fisheries Seminar. Contemporary topics, literature, and oral and written communication in fisheries science. Enrollment required for zoology graduate students specializing in fisheries science for all fall and spring semesters until degree requirements are completed, unless exempted by the student's academic advisor. Only one 586 credit hour, however, may be used to satisfy degree requirements. One meeting per week.

ZOOL 588-1 to 4 (1, 1, 1, 1) Wildlife Seminar. Contemporary topics, literature, and oral and written communication in wildlife ecology. Enrollment required for zoology graduate students specializing in wildlife ecology for all Fall and Spring semesters until degree requirements are completed. Only four 588 credit hours, however, may be used to satisfy degree requirements. One meeting per week.

ZOOL 589-1 to 2 (1,1) Zoology Colloquium. Regularly scheduled presentations by invited seminar speakers on topics of current research interest in Zoology. Graded S/U. Only two credits of 589 may be used to satisfy degree requirements. Restricted to graduate status in Zoology.

ZOOL 593-1 to 12 Individual Research. Investigation in zoology other than those for theses. Only three hours may be credited toward a degree. Some costs may be borne by the student.

ZOOL 596-1 to 66 (1 to 12 per semester) Research. Graded S/U only. Credit may not be used toward a degree in Zoology. Special approval needed from the instructor.

ZOOL 597-1 to 12 Advanced Zoological Techniques. Individualized techniques or experimental procedures to prepare for dissertation research. May be taken at another university. Number of credits determined by committee. Graded on S/U basis following final report submitted to major adviser. Restricted to admission to Ph.D. degree program in Zoology. Special approval needed from the major adviser.

ZOOL 598-1 to 6 Research Paper. Research paper for Master of Science degree for Biological Sciences major. Some cost may be borne by the student. Graded S/U only. Special approval needed from the instructor.

ZOOL 599-1 to 36 (1 to 12 per semester) Research and Thesis. Thesis for Master of Science degree. Only six hours may count toward the degree. Some cost may be borne by student. Graded S/U only. Special approval needed from the instructor.

ZOOL 600-1 to 32 (1 to 16 per semester) Research and Dissertation. Research and dissertation for Doctor of Philosophy degree. Some cost may be borne by student. Graded S/U only. Special approval needed from the instructor.

ZOOL 601-1 per semester Continuing Enrollment. For those graduate students who have not finished their degree programs and who are in the process of working on their dissertation, thesis, or research paper. The student must have completed a minimum of 24 hours of dissertation research, or the minimum thesis, or research hours before being eligible to register for this course. Concurrent enrollment in any other course is not permitted. Graded S/U or DEF only.

ZOOL 699-1 Postdoctoral Research. Must be a Postdoctoral Fellow. Concurrent enrollment in any other course is not permitted.