

## ZOOLOGY

<http://www.zoology.siu.edu/>  
zoology@zoology.siu.edu

## COLLEGE OF SCIENCE

Graduate Faculty:

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

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

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

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

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

**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, Ph.D., Oregon State University, 1977; 1984. Mammalogy, wildlife ecology.

**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.**, Associate Professor, Ph.D., College of William and Mary, 1994; 1998. Population genetics; conservation genetics; fishery management.

**Hellgren, Eric C.**, Professor, Ph.D., Virginia Tech, 1988; 2005. Wildlife Ecology.

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

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

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

**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.

**Lewis, William M.**, Professor, *Emeritus*, Ph.D., Iowa State University, 1949; 1949.

**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, Ph.D., Michigan State University, 1968; 1969. Entomology: insect ecology.

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

**Nielsen, Clay**, Adjunct Assistant 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, Ph.D., University of North Dakota, 1979; 2004. Wildlife ecology, contamination ecology.

**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.

**Trushenski, Jesse**, Assistant Professor, Ph.D., Southern Illinois University Carbondale, 2006; 2008. Fish physiology and aquaculture.

**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; 2995. Fish ecology and management.

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The Department of Zoology's 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 six disciplinary areas: conservation biology; ecology & ecosystem studies; environmental toxicology; evolutionary biology

& systematics; fisheries biology & aquaculture; and wildlife ecology & management. These research groups draw heavily upon the expertise of faculty members affiliated with SIUC's Fisheries and Illinois Aquaculture Center, Co-operative Wildlife Research Laboratory, and Center for Ecology. Graduate research in Zoology is facilitated by SIUC'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

(<http://www.science.siu.edu/zoology/applicationprocess2.html>). 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 program should be made to the Director of Graduate Studies in Zoology. More information is available on the department's website (<http://www.science.siu.edu/zoology/graduateprogram.html>). 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 or developmental biology); 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. 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 of 30 hours of graduate credit (15 hours at the 500 level) is required beyond the bachelor's degree, including 21 hours of graded coursework, 2 hours of ZOOL 589, 6 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 close 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 ZOO 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 Pre-

liminary 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 ZOO 600 Research and Dissertation (only 6 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.

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## Courses (ZOO)

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

**405-3 Systematic Zoology.** Theory and procedure of classification; population taxonomy; variation and its analysis; rules of zoological nomenclature; taxonomic publication. Three one-hour lecture-discussion meetings per week. Prerequisite: 220a,b or 220.

**407-4 Parasitology.** Principles, collection, identification, morphology, life histories, and control measures. Two lectures and two 2-hour laboratories per week. Prerequisite: ZOO 220. Laboratory/Field Trip Fee: \$15.

**408-3 Herpetology.** Taxonomic groups, identification, morphology, and natural history of amphibians and reptiles. One lecture and two 2-hour laboratories per week. Laboratory/field trip fee: \$15. Prerequisite: 220b or 220.

**409-4 Vertebrate Histology.** Microscopic structure of organs and tissues with emphasis on mammalian material. Two lectures and two 2-hour lab per week. Laboratory/field trip fee: \$15. Prerequisite: 220 A, B or 220.

**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. Prerequisite: Biology 307.

**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. The risk assessment process involves issues such as global climate change,

habitat loss, acid rain deposition, reduced biological diversity, and the ecological impacts of pesticides and toxic chemicals. It uses measurements, testing, and mathematical models to quantify relationship between the initiating event and the effects. This course will include an overview of the basic framework for conducting an ecological risk assessment, and a general discussion of individual case studies involving several important environmental issues. This is a good introductory class for a student interested in assessing the effects of various stressors on environmental health. Prerequisite: 220, Biology 307 and Chemistry 340 or equivalent, or instructor's permission.

**413-4 The Invertebrates.** Structure, phylogeny, distinguishing features and habitats of the invertebrates. Two lectures and two 2-hour laboratories per week. Laboratory/field trip fee: \$15. Prerequisite: 220a or 220.

**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. Laboratory/field trip fee: \$15. Prerequisite: 220a or 220.

**415-3 Limnology.** Lakes and inland waters; the organisms living in them, and the factors affecting these organisms. Two lectures per week and one four-hour laboratory alternate weeks. Laboratory/field trip fee: \$15. Prerequisite: 220a or 220.

**418-5 Comparative Vertebrate Anatomy.** The comparative structure and evolution of vertebrate organ systems. Two lectures and three 2-hour laboratories per week. Laboratory/field trip fee: \$30. Prerequisite: 220B or 220.

**421-4 Histological Techniques.** Methods of preparing animal tissue for microscopic study and learn theories of staining and histochemistry. One lecture and two three-hour laboratories per week. Offered Fall term. Prerequisite: ten semester hours of biological science.

**426-3 Comparative Endocrinology.** Comparison of mechanisms influencing hormone release, hormone biosynthesis and the effects of hormones on target tissues. Include ablation and histology of glands and chemical and bio-assays with vertebrates and invertebrates. Two lectures and one two-hour laboratory per week. Prerequisites: 220 A, B or 220. Laboratory/field trip fee: \$15

**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. Prerequisite: ZOOL 220.

**433-6 A, B (3,3) Comparative Physiology.** Variations of physiological processes in animal phyla, comparison with human physiology, and physiological adaptation to environmental variation. (a) Review of basic physiology principles and comparative aspects of mechanism and function. (b) Comparative physiology and environmental adaptation; mechanisms of coping with environmental variation. Prerequisites: (a) One year of biological science (b) ZOOL 433a, PHSL 433a, or equivalent.

**435-3 Plant-Insect Interaction.** 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, co-evolution/cospeciation, and chemical ecology. Prerequisite: Biology 200a, b or equivalent; Biology 307 or equivalent.

**438-3 Plant and Animal Molecular Genetics Laboratory.** (Same as PLB 438, PSAS 438, AGSE 438, AND PLSS 438) Arabidopsis and Drosophila model organisms, lab-based training in laboratory safety, reagent preparation, phenotype analysis, genetics, DNA and RNA analysis, PCR, cDNA construction, cloning and sequencing of genes. Includes plant and bacterial transformation, and a 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. Prerequisites: BIOL 305. Lab fee: \$30.

**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.

**441-3 Evolutionary Ecology.** An overview of how phenotypic variation in organisms is optimized and constrained

by ecological and evolutionary factors. Material drawn from perspectives of life history, behavioral ecology, and population and community ecology. Overview of the theoretical frameworks and case studies of major areas in evolutionary ecology. Prerequisites: BIOL 304, 307. Recommended: MATH 141.

**443-3 Restoration Ecology.** (Same as Plant Biology 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: Biology 307 or equivalent.

**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. Prerequisite: BIOL 307 or equivalent, or consent of instructor. Lab fee: \$15.

**445-4 Wetland Ecology and Management.** 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. Lab Fee: \$25. Prerequisite: either BIOL 200 or PLB 200; and BIOL 307; or consent of instructor. Two lectures and one 4-hour lab per week. Same as PLB 445.

**450-3 Genome Evolution.** 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: Consent of instructor or BIO 305 and ZOO 304.

**458-3 Issues in Aquatic Ecology.** With its primary focus on freshwater ecosystems, this course will cover important issues in aquatic ecology including: surface water and groundwater quality, global warming, use of fish hatcheries, exotic species, genetically manipulated organisms, stream habitat degradation, dams, diversions, the Great Lakes, local issues. Prerequisite: Biology 307 or consent of instructor.

**460-2 Upland Game Birds.** Biological overview and identification of upland and shoreline game birds plus raptors and selectively-managed species. One lecture and one two-hour laboratory per week; there will be up to two Saturday field trips. Laboratory/field trip fee: \$10. Prerequisite: 220B or 220 or consent of instructor.

**461-3 Mammalogy.** Taxonomic characteristics, identification, and natural history of mammals. Two one-hour lectures and one two-hour laboratory per week. Laboratory/field trip fee: \$10. Prerequisite: 220B or 220.

**462A-2 Waterfowl Ecology and Management.** 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, or consent of instructor.

**462B-1 Waterfowl Ecology and Management (laboratory).** This laboratory will meet one day/week for two 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. Laboratory/field trip fee: \$10. Prerequisites: none

**463-3 Game Mammals.** Natural history and management. Two lectures and one two-hour laboratory per week. Laboratory/field trip fee: \$10. Prerequisite: 220B or 220 or consent of instructor.

**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 lecture per week. Prerequisite: consent of instructor.

**465-3 Ichthyology.** Taxonomic groups, identification, and natural history of fishes. Two lectures and one two-hour laboratory per week. Laboratory/field trip fee: \$10. Prerequisite: 220B or 220.

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

**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. Laboratory/field trip fee: \$10. Prerequisite: 220B or 220.

**468-3 Wildlife Biology Principles.** Basic concepts of wildlife ecology and management. Includes lectures on ecological physiology, population dynamics and wildlife management strategies. Prerequisite: Biology 307 and seven other semester hours of biological science.

**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. Laboratory/field trip fee: \$30. Prerequisite: 220 A, B or 220.

**471-4 Entomology.** Structure, classification, and life histories of insects. Two lectures and two 2-hour laboratories per week. Laboratory/field trip fee: \$10. Prerequisite: 220a or 220.

**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.

**473-4 Aquatic Entomology.** Structure, classification and biology of aquatic insects. Two lectures and two 2-hour laboratories per week. Laboratory/field trip fee: \$10. Prerequisite: 220a or 220.

**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 alternate weeks. Prerequisite: BIOL 200A or ZOOL 118 or ANS 121 with grade of C or better.

**478-3 Animal Behavior.** Biological basis of the behavior of animals. Two lectures and one two-hour laboratory per week. Offered Fall semester. Prerequisite: one year of biological science or permission of instructor.

**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. Prerequisite: special approval needed of instructor.

**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 qualifying 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 landscaped processes. Prerequisite: BIOL 307 or consent of instructor.

**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: Biology 305 or equivalent.

**520-3 Advanced Invertebrates.** The nature and life of invertebrate animals with emphasis on comparative form, function, behavior and occurrence. Three two-hour meetings per week. Prerequisite: consent of instructor.

**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: 415 and consent of instructor.

**523-3 Watershed Science.** (Same as Plant Biology 523) This course is part the SIU IGERT program and will focus on ecological, geomorphic, and hydrological concepts related to watersheds including hydrograph generation, frequency analysis, erosional and depositional processes, channel geomorphology, water quality and biotic integrity, and structure and function of stream ecosystems. This course will include readings and discussions and will feature guest lecturers from on specific topics. Restricted to graduate students (masters and doctoral).

**530-3 Wildlife Diseases.** Introduction to the causes and nature of diseases of wildlife with emphasis on wild mam-

mals 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. Prerequisite: consent of instructor.

**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.

**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: Biology 307 and Chemistry 340 or equivalent, or instructor's permission.

**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. Prerequisite: consent of instructor.

**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.

**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.

**554-1 to 4 (1 per semester) Evolution Seminar.** (Same as Anthropology 554, Molecular Biology, Microbiology and Biochemistry 554, Plant Biology 554) Advanced topics in evolutionary biology including genetics & development, evolutionary ecology, phylogeny, paleontology, biogeography, population genetics, molecular ecology, speciation, molecular evolution, and macroevolution. Topics will vary each semester. Seminar format with group discussions and

student presentations. Graded *S/U*. Prerequisite: consent of instructor.

**556-3 Phylogenetics.** (Same as ANTH 556, MBMB 556, and PLB 554) 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. Prerequisite: consent of instructor.

**557-4 Biostatistics.** (Same as Plant Biology 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.

**558-4 Advanced Biostatistics.** (Same as Plant Biology 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: 557, Plant Biology 557 or equivalent.

**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.

**564-1 to 2 Aquaculture Techniques.** 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: 477 or consent of instructor.

**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: 465 or consent of instructor.

**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: 466 or consent of instructor.

**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 generat-

ing plants on fishes, and in-depth consideration of indices of community structure and current topics in fish management. Three lectures per week. Prerequisite: 466 or consent of instructor.

**570-3 Advanced Aquaculture.** Special topics in aquaculture and practical methods for the production of coldwater, coolwater, warmwater, and tropical aquatic species. Three lectures per week and one weekend field trip. Prerequisite: 477 or equivalent.

**573-3 Physiological Ecology.** The role of physiological, morphological, and behavioral adaptations and adjustment 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 and regulation. Prerequisites: BIOL 307 pr consent of instructor.

**578-3 Population Genetics.** (Same as Plant Biology 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.

**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. Prerequisite: consent of instructor.

**580-1 Current Topics in Evolution.** (Same as Anthropology 580, Molecular Biology, Microbiology and Biochemistry 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.

**581-2 Zoological Literature.** Diversity and functions of zoological literatures, scientific writing and the publication process. Two lectures per week. Prerequisite: graduate status in a biological science.

**582-1 to 4 (1,1,1,1) Graduate Zoology Seminars.** Special topics in zoology. Consult department for each semester's topic. One meeting per week. Prerequisite: consent of instructor and department.

**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.

**585-36 (3 per topic) Seminar.** Advanced study of special topics in zoology. (a) Seminar in animal behavior. (c) Seminar in ecosystems. (d) Seminar in wetland ecology. (e)

ments 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: Biology 307 or equivalent, and consent of instructor.

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

**577-2 Population Ecology.** Principles of population dynamics as related to animals, with application to Seminar in wildlife ecology: impact of land use. (f) Seminar in fish biology. Survey of fish biology and ecology dealing largely with topics not covered in 465. Life history strategies, physiology and other fundamental biological features of fishes will be covered in some depth. Prerequisite: 465. (g) Seminar in parasitology. (h) Seminar on the amphibia. (i) Seminar in developmental biology. Detailed coverage of current topics of interest in developmental biology; the course will emphasize interacting systems in the development of both vertebrates and invertebrates, from the molecular to the tissue levels. Prerequisite: 300, Biology 309, or equivalent. (z) Seminar in selected topics. Prerequisite: consent of instructor or department.

**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.

**587-3 Community Ecology.** This course focuses on a search for pattern in the structure, composition and dynamics of ecological communities. We will examine similarities and differences in composition or structure of ecological communities to try to establish what factors may determine or constrain their organization in time and space. This course complements material presented in 577. Prerequisite: Biology 307 or equivalent.

**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.

**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 students in Zoology.

**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.

**596-1 to 66 (1 to 12 per semester) Research.** Graded *S/U* only. Credit may not be used toward a degree in Zoology. Prerequisite: consent of instructor.

**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. Prerequisite: admission to Ph.D. degree program in Zoology and consent of major adviser.

**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. Prerequisite: consent of instructor.

**599-1 to 12 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. Prerequisite: consent of instructor.

**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. Prerequisite: consent of instructor.

**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.