EARTH SYSTEMS


Mission of the Undergraduate Program in Earth Systems

The Earth Systems Program is an interdisciplinary environmental science major. Students learn about and independently investigate complex environmental problems caused by human activities in conjunction with natural changes in the Earth system. Earth Systems majors become skilled in those areas of science, economics, and policy needed to tackle the world’s most pressing social-environmental problems, becoming part of a generation of scientists, professionals, and citizens who approach and solve problems in a systematic, interdisciplinary way.

For students to be effective contributors to solutions for such problems, their training and understanding must be both broad and deep. To this end, Earth Systems students take fundamental courses in ecology, calculus, chemistry, geology, and physics, as well as economics, policy, and statistics. After completing breadth training, they concentrate on advanced work in one of six focus areas: biology, energy, environmental economics and policy, land systems, sustainable food and agriculture, or oceanography and climate. Tracks are designed to support focus and rigor but include flexibility for specialization. Examples of specialized foci have included but are not limited to environment and human health, sustainable agriculture, energy economics, sustainable development, business and the environment, and marine policy. Along with formal course requirements, Earth Systems students complete a 1-unit (270-hour) internship. The internship provides a hands-on academic experience working on a supervised field, laboratory, government, or private sector project.

The Earth Systems Program provides an advising network that includes faculty, staff, and student peer advisers.

The following is an outline of the sequential topics covered and skills developed in this major.

1. **Fundamentals**: The Earth Systems Program includes courses that describe the natural functioning of the physical and biological components of the Earth and human activities that interact with these components. Training in fundamentals includes introductory course work in geology, biology, chemistry, physics, and economics. Additional training in course work in single and multivariable calculus, linear algebra, and statistics provides students with skills needed for quantifying environmental problems. Training in statistics is specific to the area of focus: geostatistics, biostatistics, econometrics.

2. **System Interactions**: Focus in these courses is on the fundamental interactions among the physical, biological, and human components of the Earth system. Understanding the dynamics between natural variation in and human-imposed influences on the Earth system informs the development of effective solutions to social-environmental challenges.

   a. Earth Systems courses that introduce students to the dynamic and multiple interactions that characterize social-environmental challenges include:

3. **Skills Development**: Students take skills courses that help them to recognize, quantify, describe, communicate, and help solve complex problems that face society. For example, field and laboratory methods can help students to recognize the scope and nature of environmental change. Training in satellite remote sensing and geographic information systems allows students to monitor and analyze large-scale spatial patterns of change. This training is either required or recommended for all tracks.

4. **Communication**: Success in building workable solutions to environmental problems is linked to the ability to effectively communicate ideas, data, and results. Writing intensive courses (WIM) help students to communicate complex concepts to expert and non-expert audiences. Other Earth Systems courses also focus on effective written and oral communication and are recommended. All Stanford students must complete one WIM course in their major. Earth Systems students can fulfill the WIM requirement by successfully completing one of the following courses:

   a. Competence in understanding system-level interactions is critical to development as an Earth Systems thinker, so additional classes that meet this objective are excellent choices as electives.

3. **Track-Specific Requirements**: After completing a core designed to introduce students to different functional components of the Earth system, undergraduate students focus their studies through one of six tracks: Human Environmental Systems (formerly Anthroposphere), Biosphere, Energy, Science and Technology, Oceans and Climate (formerly Oceans), Land Systems, or Sustainable Food and Agriculture.

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5. **Communication**: Success in building workable solutions to environmental problems is linked to the ability to effectively communicate ideas, data, and results. Writing intensive courses (WIM) help students to communicate complex concepts to expert and non-expert audiences. Other Earth Systems courses also focus on effective written and oral communication and are recommended. All Stanford students must complete one WIM course in their major. Earth Systems students can fulfill the WIM requirement by successfully completing one of the following courses:

6. **Finding solutions**: Effective solutions to environmental problems take into consideration natural processes as well as human needs. Earth Systems emphasizes the importance of interdisciplinary analysis and implementation of workable solutions through:

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A comprehensive list of environmental courses (p. 12) is available on the "Related Courses" tab. This list as well as advice on courses that focus on problem solving are available in the program office.

**Learning Outcomes (Undergraduate)**

The program expects majors to be able to demonstrate the following learning outcomes. These learning outcomes serve as benchmarks for evaluating students and the program's undergraduate degree. Students are expected to:

1. demonstrate knowledge of foundational skills and concepts in order to advance the interdisciplinary study of the environment.
2. demonstrate the ability to analyze, integrate and apply relevant science and policy perspectives to social-environmental problems.
3. demonstrate the ability to communicate complex concepts and data relevant to social-environmental problems and questions to expert and non-expert audiences.

**Learning Outcomes (Graduate)**
The coterminal master’s degree in Earth Systems provides the student with enhanced analytical tools to evaluate the disciplines most closely associated with the student’s focus area. Specialization is gained through course work and independent research work supervised by the master’s faculty adviser.

**Bachelor of Science in Earth Systems**
The B.S. in Earth Systems (EARTHSYS) requires the completion of courses divided into three categories:
1. Core
2. Foundation and Breadth
3. Track-specific Requirements.

The student must fulfill the internship requirement, participate in the Senior Capstone and Reflection course (EARTHSYS 210A or EARTHSYS 210B), complete the Earth Systems Capstone Project (EARTHSYS 210P)/(or Honors Thesis), and complete the Writing in the Major (WIM) requirement.

Core courses, track courses, and electives must be taken for a letter grade. The WIM course may not also count towards the track or electives, if counted as a WIM.

**Required Core Courses**

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EARTHSYS 10</td>
<td>Introduction to Earth Systems</td>
<td>4</td>
</tr>
<tr>
<td>EARTHSYS 111</td>
<td>Biology and Global Change</td>
<td>4</td>
</tr>
<tr>
<td>EARTHSYS 112</td>
<td>Human Society and Environmental Change</td>
<td>4</td>
</tr>
<tr>
<td>Select one of the following:</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>EARTHSYS 210A</td>
<td>Senior Capstone and Reflection</td>
<td>3</td>
</tr>
<tr>
<td>or EARTHSYS 210B</td>
<td>Senior Capstone and Reflection</td>
<td>3</td>
</tr>
<tr>
<td>EARTHSYS 210P</td>
<td>Earth Systems Capstone Project (or HONORS THESIS)</td>
<td>2</td>
</tr>
<tr>
<td>EARTHSYS 260</td>
<td>Internship</td>
<td>1</td>
</tr>
<tr>
<td>Select one of the following (WIM):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EARTHSYS 191</td>
<td>Concepts in Environmental Communication</td>
<td>3</td>
</tr>
<tr>
<td>EARTHSYS 177C</td>
<td>Specialized Writing and Reporting: Environmental and Food System Journalism</td>
<td>4-5</td>
</tr>
<tr>
<td>EARTHSYS 149</td>
<td>Wild Writing</td>
<td>3</td>
</tr>
<tr>
<td>BIOHOPK 47</td>
<td>Introduction to Research in Ecology and Ecological Physiology</td>
<td>5</td>
</tr>
</tbody>
</table>

**Tracks**
See each track’s tab for the required Foundation and Breadth and Track-Specific Courses. All Earth Systems Majors must select a track from one of the following:

**Biospheres Track (p. 3)**
Explores biological systems and how human activities affect biological, ecological, and biogeochemical cycles. Coursework investigates ecosystems and society, conservation biology, ecology, and biogeochemistry.

**Energy, Science and Technology (p. 4)**
Investigates renewable and depletable energy resources, technology options for improved efficiency, and policy solutions to energy challenges.

**Environmental Geoscience (p. 5)**
Understand and articulate the ways in which Earth’s interior and surface operate, and how these systems are connected to one another and inextricably bound to the evolution of life and current human activities. Apply understanding of earth and human systems to develop workable, scientifically based, human-centered solutions to building resilience to natural hazards, and our planet’s most pressing environmental challenges.

**Human Environmental Systems (p. 5)**
Focuses on human interaction with and impact on the environment. Coursework in environmental policy and economics, sustainable development, natural and human-driven change, and social entrepreneurship.

**Land Systems (p. 5)**
Examines terrestrial ecology, land use, and land change driven by human activities and addressed by governmental policy. Students develop expertise in a focus area of land, water, or urban planning.

**Oceans, Atmosphere, and Climate (p. 8)**
Builds understanding of ocean systems through a focus on ocean physics, marine biology and chemistry, and remote sensing. A required and seminal track experience is a quarter away at Hopkins Marine Station, Stanford in Australia, or Stanford@SEA.

**Sustainable Food and Agriculture Track (p. 8)**
Focuses on local and global food and agricultural systems. Students gain a breadth of knowledge on these issues through study in food and society, climate and agriculture, the science of soils, world food economy, and principles and practices of sustainable agriculture.

**Honors Program**
The Earth Systems honors program provides students with an opportunity to pursue interdisciplinary research. It consists of a year-long research project that is mentored by one or more Earth Systems-affiliated faculty members, and culminates in a written thesis.

To qualify for the honors program, students must have and maintain a minimum overall GPA of 3.4. Potential honors students should complete the EARTHSYS 111 Biology and Global Change and EARTHSYS 112 Human Society and Environmental Change sequence by the end of the junior year. Qualified students can apply in Spring Quarter of the junior year, or the fourth quarter before graduation (check with program for specific application deadlines) by submitting a detailed research proposal and a brief statement of support from a faculty research adviser. Students who elect to do an honors thesis should begin planning no later than Winter Quarter of the junior year.

A maximum of 9 units is awarded for thesis research through EARTHSYS 199 Honors Program in Earth Systems. Those 9 units may not substitute for any other required parts of the Earth Systems curriculum. All theses are evaluated for acceptance by the thesis faculty adviser, one additional faculty member (who is the second reader), and the Director of Earth Systems. Both the adviser and second reader must be members of the Academic Council. Acceptance into the Honors program is not a guarantee of graduating with the honors designation.

Honors students are required to present their research publicly, preferably through the School of Earth, Energy, and Environmental Sciences’ Annual Thesis Symposium, which highlights undergraduate and graduate research in the school. Faculty advisers are encouraged to
sponsor presentation of student research results at professional society meetings.

More extensive work in mathematics and physics may be valuable for those planning graduate study. Graduate study in ecology and evolutionary biology and in economics requires familiarity with differential equations, linear algebra, and stochastic processes. Graduate study in geology, oceanography, and geophysics may require more physics and chemistry. Students should consult their adviser for recommendations beyond the requirements specified above.

1 The Geological Sciences requirement can be fulfilled by completing GEOLSCI 1, GEOLSCI 4, or EARTHSYS 117. GEOLSCI 1A, 1B, and 1C are no longer offered. If taken in previous years, these will still fulfill the Earth Systems’ Geological Sciences requirement.

**Biosphere**

**Learning Objectives:**

1. Articulate the interplay of ecology, evolution, and biogeochemistry and understand their connections to the functioning of ecosystems on multiple spatial and temporal scales.

2. Recognize how human activity alters ecological processes, and how ecological changes can interact with human societies at multiple scales.

3. Apply knowledge of natural sciences and human-mediated environmental change to conservation challenges, while considering implications for environmental justice.

**Requirements**

All students must complete the Required Core Courses (p. 2) listed under the “Bachelor’s (p. 2)” tab in addition to the required courses listed below.

**Additional foundation and breadth courses**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIO 81</td>
<td>Introduction to Ecology</td>
<td>4</td>
</tr>
<tr>
<td>BIO 82</td>
<td>Genetics</td>
<td>4</td>
</tr>
<tr>
<td>ECON 1</td>
<td>Principles of Economics</td>
<td>5</td>
</tr>
<tr>
<td>GEOLSCI 1</td>
<td>Introduction to Geology</td>
<td>5</td>
</tr>
<tr>
<td>MATH 19</td>
<td>Calculus</td>
<td>9</td>
</tr>
<tr>
<td>MATH 20</td>
<td>Calculus</td>
<td>9</td>
</tr>
<tr>
<td>MATH 21</td>
<td>Calculus</td>
<td>9</td>
</tr>
<tr>
<td>CHEM 33</td>
<td>Structure and Reactivity of Organic Molecules</td>
<td>5</td>
</tr>
<tr>
<td>PHYSICS 41</td>
<td>Mechanics</td>
<td>4</td>
</tr>
<tr>
<td>PHYSICS 45</td>
<td>Light and Heat</td>
<td>4</td>
</tr>
<tr>
<td>GEOPHYS 11</td>
<td>Introduction to the foundations of contemporary geophysics</td>
<td>4</td>
</tr>
<tr>
<td>BIOHOPK 174H</td>
<td>Experimental Design and Probability</td>
<td>3</td>
</tr>
<tr>
<td>ECON 102A</td>
<td>Introduction to Statistical Methods (Postcalculus) for Social Scientists</td>
<td>3</td>
</tr>
<tr>
<td>STATS 101</td>
<td>Data Science</td>
<td>3</td>
</tr>
<tr>
<td>STATS 110</td>
<td>Statistical Methods in Engineering and the Physical Sciences</td>
<td>3</td>
</tr>
<tr>
<td>STATS 116</td>
<td>Theory of Probability</td>
<td>3</td>
</tr>
<tr>
<td>STATS 141</td>
<td>Biostatistics</td>
<td>3</td>
</tr>
<tr>
<td>CME 106</td>
<td>Introduction to Probability and Statistics for Engineers</td>
<td>3</td>
</tr>
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</table>

Choose two courses from Ecology and Conservation Biology, and one course from each of the remaining sub-categories below, total six required:

**Biogeochemistry**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEE 177</td>
<td>Aquatic Chemistry and Biology</td>
<td>4</td>
</tr>
<tr>
<td>CEE 274A</td>
<td>Environmental Microbiology I</td>
<td>3</td>
</tr>
<tr>
<td>EARTSYS 132</td>
<td>Evolution of Earth Systems</td>
<td>4</td>
</tr>
<tr>
<td>EARTSYS 143</td>
<td>Molecular Geomicrobiology Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>EARTSYS 151</td>
<td>Biological Oceanography</td>
<td>3-4</td>
</tr>
<tr>
<td>EARTSYS 152</td>
<td>Marine Chemistry</td>
<td>3-4</td>
</tr>
<tr>
<td>EARTSYS 155</td>
<td>Science of Soils</td>
<td>3-4</td>
</tr>
<tr>
<td>EARTSYS 158</td>
<td>Geomicrobiology</td>
<td>3</td>
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</table>

**Ecology and Conservation Biology**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEO 130</td>
<td>The Hidden Kingdom - Evolution, Ecology and Diversity of Fungi</td>
<td>4</td>
</tr>
<tr>
<td>BIO 144</td>
<td>Conservation Biology: A Latin American Perspective</td>
<td>3</td>
</tr>
<tr>
<td>BIOHOPK 172H</td>
<td>Marine Ecology: From Organisms to Ecosystems</td>
<td>5</td>
</tr>
<tr>
<td>BIOHOPK 173H</td>
<td>Marine Conservation Biology</td>
<td>4</td>
</tr>
<tr>
<td>BIOHOPK 177H</td>
<td>Dynamics and Management of Marine Populations</td>
<td>4</td>
</tr>
<tr>
<td>BIOHOPK 185H</td>
<td>Ecology and Conservation of Kelp Forest Communities</td>
<td>5</td>
</tr>
<tr>
<td>EARTSYS 116</td>
<td>Ecology of the Hawaiian Islands</td>
<td>4</td>
</tr>
<tr>
<td>EARTSYS 185</td>
<td>Ecology and Natural History of Jasper Ridge &amp; Biological Preserve</td>
<td>4</td>
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**Ecology of the Hawaiian Islands**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>GEOLSCI 123</td>
<td>Evolution of Marine Ecosystems</td>
<td>4</td>
</tr>
<tr>
<td>OSPAUSTL 10</td>
<td>Coral Reef Ecosystems</td>
<td>3</td>
</tr>
<tr>
<td>OSPAUSTL 30</td>
<td>Coastal Forest Ecosystems</td>
<td>3</td>
</tr>
<tr>
<td>OSPSANTG 58</td>
<td>Living Chile: A Land of Extremes</td>
<td>5</td>
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<tr>
<td>OSPSANTG 85</td>
<td>(OSPSANTG 85)</td>
<td>3</td>
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</table>

**Ecosystems and Society**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>ANTHRO 118</td>
<td>Heritage, Environment, and Sovereignty in Hawaii</td>
<td>4</td>
</tr>
<tr>
<td>ANTHRO 166</td>
<td>Political Ecology of Tropical Land Use: Conservation, Natural Resource Extraction, and Agribusiness</td>
<td>3-5</td>
</tr>
<tr>
<td>ANTHRO 177</td>
<td>Environmental Change and Emerging Infectious Diseases</td>
<td>3-5</td>
</tr>
<tr>
<td>BIOHOPK 168H</td>
<td>Disease Ecology: from parasites evolution to the socio-economic impacts of pathogens on nations</td>
<td>3</td>
</tr>
<tr>
<td>EARTSYS 107</td>
<td>Control of Nature</td>
<td>3</td>
</tr>
<tr>
<td>EARTSYS 136</td>
<td>The Ethics of Stewardship</td>
<td>2-3</td>
</tr>
<tr>
<td>EARTSYS 139</td>
<td>Ecosystem Services: Frontiers in the Science of Valuing Nature</td>
<td>3</td>
</tr>
<tr>
<td>EARTSYS 159</td>
<td>Economic, Legal, and Political Analysis of Climate-Change Policy</td>
<td>5</td>
</tr>
<tr>
<td>EARTSYS 185</td>
<td>Feeding Nine Billion</td>
<td>4-5</td>
</tr>
<tr>
<td>EARTSYS 185</td>
<td>Feeding Nine Billion</td>
<td>4-5</td>
</tr>
<tr>
<td>HUMBIO 118</td>
<td>Theory of Ecological and Environmental Anthropology</td>
<td>5</td>
</tr>
<tr>
<td>LAW 2515</td>
<td>Environmental Justice</td>
<td>3</td>
</tr>
</tbody>
</table>
Energy, Science, and Technology

Learning Objectives:

1. Apply fundamental engineering principles to assess how transformation of systems of energy production, distribution, and consumption can contribute to achieving greater energy sustainability.

2. Use fundamental engineering principles—together with knowledge of economics, human behavior, energy infrastructure, and earth systems science—to assess and critique policy- and market-based solutions proposed to achieve greater energy sustainability.

3. Apply written, visual, and oral presentation skills to communicate scientific, technological, and policy knowledge to expert and non-expert audiences.

Requirements

All students must complete the Required Core Courses (p. 2) listed under the "Bachelor's (p. 2)" tab in addition to the required courses listed below.

Additional Foundation and Breadth Courses

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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<tbody>
<tr>
<td>BIO 81</td>
<td>Introduction to Ecology</td>
<td>4</td>
</tr>
<tr>
<td>or BIOHOPK 81</td>
<td>Introduction to Ecology</td>
<td>4</td>
</tr>
<tr>
<td>or BIO 83</td>
<td>Biochemistry &amp; Molecular Biology</td>
<td>4</td>
</tr>
<tr>
<td>or HUMBIO 2A</td>
<td>Genetics, Evolution, and Ecology</td>
<td>4</td>
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<tr>
<td>&amp; HUMBIO 2B</td>
<td>and Culture, Evolution, and Society</td>
<td>4</td>
</tr>
<tr>
<td>or EARTHSYS 1</td>
<td>Ecology of the Hawaiian Islands</td>
<td>4</td>
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<tr>
<td>CHEM 31A</td>
<td>Chemical Principles I</td>
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<tr>
<td>&amp; CHEM 31B</td>
<td>and Chemical Principles II</td>
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<tr>
<td>or CHEM 31X</td>
<td>Chemical Principles Accelerated</td>
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<tr>
<td>ECON 1</td>
<td>Principles of Economics</td>
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<tr>
<td>GEOLSCI 1</td>
<td>Introduction to Geology</td>
<td>4-5</td>
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<tr>
<td>or GEOLSCI 4</td>
<td>Coevolution of Earth and Life</td>
<td>4-5</td>
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<tr>
<td>or EARTHSYS 1</td>
<td>Earth Sciences of the Hawaiian Islands</td>
<td>4-5</td>
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<tr>
<td>or EARTHSYS 1</td>
<td>Evolution of Terrestrial Ecosystems</td>
<td>4-5</td>
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Biogeochemistry

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<td>Marine Chemistry</td>
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</tr>
<tr>
<td>EARTHSYS 155</td>
<td>Science of Soils</td>
<td>3-4</td>
</tr>
<tr>
<td>EARTHSYS 158</td>
<td>Geomicrobiology</td>
<td>3</td>
</tr>
<tr>
<td>ESS 256</td>
<td>Soil and Water Chemistry</td>
<td>3</td>
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</tbody>
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Methods

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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
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<tbody>
<tr>
<td>EARTHSYS 144</td>
<td>Fundamentals of Geographic Information Science (GIS) (REQUIRED)</td>
<td>3-4</td>
</tr>
<tr>
<td>Earthys 124</td>
<td>Earth Systems 124</td>
<td>4</td>
</tr>
<tr>
<td>EARTHSYS 142</td>
<td>Remote Sensing of Land</td>
<td>4</td>
</tr>
<tr>
<td>EARTHSY 211</td>
<td>Fundamentals of Modeling</td>
<td>3-5</td>
</tr>
<tr>
<td>ESS 124</td>
<td>Advanced Geographic Information Systems</td>
<td>4</td>
</tr>
<tr>
<td>ESS 165</td>
<td>Physical Hydrogeology</td>
<td>4</td>
</tr>
<tr>
<td>ESS 220</td>
<td>Geosystems</td>
<td>4</td>
</tr>
<tr>
<td>GEOLSCI 240</td>
<td>Data science for geoscience</td>
<td>3</td>
</tr>
</tbody>
</table>

Elective Requirement

Two additional courses at the 100-level or above are required. Each must be a minimum of 3 units.

Energy Fundamentals (required for all)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 19</td>
<td>Calculus</td>
<td>9</td>
</tr>
<tr>
<td>&amp; MATH 20 &amp; MATH 21</td>
<td>Calculus</td>
<td>9</td>
</tr>
<tr>
<td>CME 100</td>
<td>Vector Calculus for Engineers (preferred)</td>
<td>5</td>
</tr>
<tr>
<td>or MATH 51</td>
<td>Linear Algebra, Multivariable Calculus, and Modern Applications</td>
<td>5</td>
</tr>
<tr>
<td>PHYSICS 43</td>
<td>Electricity and Magnetism</td>
<td>4</td>
</tr>
<tr>
<td>PHYSICS 45</td>
<td>Light and Heat</td>
<td>4</td>
</tr>
<tr>
<td>BIOHOPK 174H</td>
<td>Experimental Design and Probability</td>
<td>3</td>
</tr>
<tr>
<td>or ECON 102A</td>
<td>Introduction to Statistical Methods (Postcalculus) for Scientists</td>
<td>3</td>
</tr>
<tr>
<td>or STATS 101</td>
<td>Data Science 101</td>
<td>3</td>
</tr>
<tr>
<td>or STATS 110</td>
<td>Statistical Methods in Engineering and the Physical Sciences</td>
<td>3</td>
</tr>
<tr>
<td>or STATS 116</td>
<td>Theory of Probability</td>
<td>3</td>
</tr>
<tr>
<td>or STATS 141</td>
<td>Biostatistics</td>
<td>3</td>
</tr>
<tr>
<td>or CME 106</td>
<td>Introduction to Probability and Statistics for Engineers</td>
<td>3</td>
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</table>

Energy Resources & Technology

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EARTHSYS 101</td>
<td>Energy and the Environment</td>
<td>3</td>
</tr>
<tr>
<td>EARTHSYS 102</td>
<td>Fundamentals of Renewable Power</td>
<td>3</td>
</tr>
<tr>
<td>EARTHSYS 103</td>
<td>Understanding Energy</td>
<td>4-5</td>
</tr>
</tbody>
</table>

Choose at least one course in each of the three sub-categories, total five required. Note that many of these have prerequisite work.

Energy Policy, Economics & Entrepreneurship

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY 110</td>
<td>Engineering Economics</td>
<td>3</td>
</tr>
</tbody>
</table>

Units
**Environmental Geoscience**

**Learning Objectives:**

1. Understand and articulate the ways in which Earth's interior and surface operate, and how these systems are connected to one another and inextricably bound to the evolution of life and current human activities.
2. Understand and view the current state of, and expected changes within, the earth system in the context of past changes experienced by our planet.
3. Apply understanding of earth and human systems to develop workable, scientifically based, human-centered solutions to building resilience to natural hazards, and our planet's most pressing environmental challenges.

**Requirements**

All students must complete the Required Core Courses (p. 2) listed under the "Bachelor's (p. 2)" tab in addition to the required courses listed below.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY 171</td>
<td>Energy Infrastructure, Technology and Economics</td>
<td>3</td>
</tr>
<tr>
<td>ENERGY 191</td>
<td>Optimization of Energy Systems</td>
<td>3-4</td>
</tr>
<tr>
<td>GSBGEN 336</td>
<td>Energy Markets and Policy</td>
<td>3</td>
</tr>
<tr>
<td>MS&amp;E 243</td>
<td>Energy and Environmental Policy Analysis</td>
<td>3</td>
</tr>
<tr>
<td>LAW 2503</td>
<td>Energy Law</td>
<td>3</td>
</tr>
<tr>
<td>MS&amp;E 294</td>
<td>Systems Modeling for Climate Policy Analysis</td>
<td>3</td>
</tr>
<tr>
<td>MS&amp;E 295</td>
<td>Energy Policy Analysis</td>
<td>3</td>
</tr>
</tbody>
</table>

**Elective Requirement**

One additional course at the 100-level or above is required. This course must be a minimum of 3 units. 3 units of approved energy seminars may count as one elective. See Earth Systems staff for the approved seminar list.

**Human Environmental Systems**

**Learning Objectives:**

1. Apply knowledge of fundamental physical and biological Earth system processes to analyze how human decisions shape environmental outcomes.
2. Apply fundamental principles and frameworks from the social sciences to analyze and understand (a) how humans make environmentally relevant decisions, and (b) how environmental changes shape human outcomes.

All students must complete the Required Core Courses (p. 2) listed under the "Bachelor's (p. 2)" Tab in addition to the required courses listed below.
or HUMBIO 2A Genetics, Evolution, and Ecology & HUMBIO 2B and Culture, Evolution, and Society or EARTHSYS 2Biology of the Hawaiian Islands

Chemistry

<table>
<thead>
<tr>
<th>Units</th>
<th>Courses</th>
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</thead>
<tbody>
<tr>
<td>5-10</td>
<td>CHEM 31X Chemical Principles Accelerated</td>
</tr>
<tr>
<td></td>
<td>CHEM 31A Chemical Principles I</td>
</tr>
<tr>
<td></td>
<td>&amp; CHEM 31B Chemical Principles II</td>
</tr>
</tbody>
</table>

Economics

<table>
<thead>
<tr>
<th>Units</th>
<th>Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>ECON 1 Principles of Economics</td>
</tr>
<tr>
<td></td>
<td>ECON 50 Economic Analysis I</td>
</tr>
<tr>
<td></td>
<td>ECON 155 Environmental Economics and Policy</td>
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</table>

Geological Sciences

<table>
<thead>
<tr>
<th>Units</th>
<th>Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-5</td>
<td>EARTHSYS 117 Earth Sciences of the Hawaiian Islands</td>
</tr>
<tr>
<td></td>
<td>GEOLSCI 1 Introduction to Geology</td>
</tr>
<tr>
<td></td>
<td>GEOLSCI 4 Coevolution of Earth and Life</td>
</tr>
<tr>
<td></td>
<td>EARTHSYS 128 Evolution of Terrestrial Ecosystems</td>
</tr>
</tbody>
</table>

Mathematics

<table>
<thead>
<tr>
<th>Units</th>
<th>Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-15</td>
<td>MATH 19 Calculus &amp; MATH 20 and Calculus</td>
</tr>
<tr>
<td></td>
<td>&amp; MATH 21 and Calculus</td>
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<td></td>
<td>MATH 20 Calculus</td>
</tr>
<tr>
<td></td>
<td>MATH 21 Calculus</td>
</tr>
<tr>
<td></td>
<td>MATH 51 Linear Algebra, Multivariable Calculus, and Modern Applications</td>
</tr>
<tr>
<td></td>
<td>or CME 100 Vector Calculus for Engineers</td>
</tr>
<tr>
<td></td>
<td>ECON 102A Introduction to Statistical Methods (Postcalculus) for Social Scientists</td>
</tr>
<tr>
<td></td>
<td>or BIO 141 Biostatistics</td>
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<tr>
<td></td>
<td>CS 106A Programming Methodology</td>
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</table>

Probability and Statistics

<table>
<thead>
<tr>
<th>Units</th>
<th>Courses</th>
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</thead>
<tbody>
<tr>
<td>3-5</td>
<td>BIOHOPK 174H Experimental Design and Probability</td>
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<tr>
<td></td>
<td>BIO 141 Biostatistics</td>
</tr>
<tr>
<td></td>
<td>ECON 102A Introduction to Statistical Methods (Postcalculus) for Social Scientists</td>
</tr>
<tr>
<td></td>
<td>STATS 101 Data Science 101</td>
</tr>
<tr>
<td></td>
<td>STATS 110 Statistical Methods in Engineering and the Physical Sciences</td>
</tr>
<tr>
<td></td>
<td>STATS 116 Theory of Probability</td>
</tr>
<tr>
<td></td>
<td>CME 106 Introduction to Probability and Statistics for Engineers</td>
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</tbody>
</table>

Choose one course in each of the three following sub-categories, with a total of six required. At least one of the six must be a skills/methods course marked with an asterisk (*):

**Economics, Policy, and Sustainable Development**

<table>
<thead>
<tr>
<th>Units</th>
<th>Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-5</td>
<td>EARTHSYS 136 The Ethics of Stewardship</td>
</tr>
<tr>
<td></td>
<td>CEE 175A California Coast: Science, Policy, and Law</td>
</tr>
<tr>
<td></td>
<td>ECON 51 Economic Analysis II</td>
</tr>
<tr>
<td></td>
<td>ECON 102B Applied Econometrics (*)</td>
</tr>
<tr>
<td></td>
<td>ECON 106 World Food Economy (*)</td>
</tr>
<tr>
<td></td>
<td>CEE 175A California Coast: Science, Policy, and Law</td>
</tr>
<tr>
<td></td>
<td>ECON 118 Development Economics</td>
</tr>
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</table>

**Mathematics**

<table>
<thead>
<tr>
<th>Units</th>
<th>Courses</th>
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<tbody>
<tr>
<td>4</td>
<td>MATH 19 Calculus</td>
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<tr>
<td></td>
<td>&amp; MATH 20 and Calculus</td>
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<td></td>
<td>&amp; MATH 21 and Calculus</td>
</tr>
<tr>
<td></td>
<td>MATH 20 Calculus</td>
</tr>
<tr>
<td></td>
<td>MATH 21 Calculus</td>
</tr>
<tr>
<td></td>
<td>MATH 51 Linear Algebra, Multivariable Calculus, and Modern Applications</td>
</tr>
<tr>
<td></td>
<td>or CME 100 Vector Calculus for Engineers</td>
</tr>
<tr>
<td></td>
<td>ECON 102A Introduction to Statistical Methods (Postcalculus) for Social Scientists</td>
</tr>
<tr>
<td></td>
<td>or BIO 141 Biostatistics</td>
</tr>
<tr>
<td></td>
<td>CS 106A Programming Methodology</td>
</tr>
</tbody>
</table>

**Units**

Choose one course in each of the three following sub-categories, with a total of six required. At least one of the six must be a skills/methods course marked with an asterisk (*):

**Economics, Policy, and Sustainable Development**

<table>
<thead>
<tr>
<th>Units</th>
<th>Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-5</td>
<td>ECON 121 (Not offered 18-19)</td>
</tr>
<tr>
<td></td>
<td>ECON 150 Economic Policy Analysis</td>
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<tr>
<td></td>
<td>ECON 159 Economic, Legal, and Political Analysis of Climate-Change Policy</td>
</tr>
<tr>
<td></td>
<td>ECON 51 Economic Analysis II</td>
</tr>
<tr>
<td></td>
<td>INTNLREL 135A International Environmental Law and Policy</td>
</tr>
<tr>
<td></td>
<td>IPS 270</td>
</tr>
<tr>
<td></td>
<td>LAW 2504 Environmental Law and Policy</td>
</tr>
<tr>
<td></td>
<td>MS&amp;E 243 Energy and Environmental Policy Analysis</td>
</tr>
<tr>
<td></td>
<td>GSBGEN 336 Energy Markets and Policy</td>
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<tr>
<td></td>
<td>MS&amp;E 299 Systems Modeling for Climate Policy Analysis</td>
</tr>
<tr>
<td></td>
<td>MS&amp;E 295 Energy Policy Analysis</td>
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</table>

**Human Behavior and Adaptation**

<table>
<thead>
<tr>
<th>Units</th>
<th>Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-5</td>
<td>CEE 151 Negotiation</td>
</tr>
<tr>
<td></td>
<td>ANTHRO 116B Anthropology of the Environment</td>
</tr>
<tr>
<td></td>
<td>ANTHRO 166 Political Ecology of Tropical Land Use: Conservation, Natural Resource Extraction, and Agribusiness</td>
</tr>
<tr>
<td></td>
<td>CEE 124 Sustainable Development Studio</td>
</tr>
<tr>
<td></td>
<td>CEE 126A (Not offered 18-19)</td>
</tr>
<tr>
<td></td>
<td>CEE 126B (Not offered 18-19)</td>
</tr>
<tr>
<td></td>
<td>EARTHYS 138 International Urbanization Seminar: Cross-Cultural Collaboration for Sustainable Urban Development</td>
</tr>
</tbody>
</table>

**Data Science and Analysis**

<table>
<thead>
<tr>
<th>Units</th>
<th>Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-5</td>
<td>CS 102 Big Data - Tools and Techniques</td>
</tr>
<tr>
<td></td>
<td>CS 106B Programming Abstractions</td>
</tr>
<tr>
<td></td>
<td>CS 124 From Languages to Information</td>
</tr>
<tr>
<td></td>
<td>ECON 102B Applied Econometrics (*)</td>
</tr>
<tr>
<td></td>
<td>EARTHYS 141 Remote Sensing of the Oceans (*)</td>
</tr>
<tr>
<td></td>
<td>EARTHYS 142 Remote Sensing of Land (*)</td>
</tr>
<tr>
<td></td>
<td>EARTHYS 144 Fundamentals of Geographic Information Science (GIS) (*)</td>
</tr>
<tr>
<td></td>
<td>EARTHYS 162 Data for Sustainable Development</td>
</tr>
<tr>
<td></td>
<td>ENERGY 240 Data science for geoscience</td>
</tr>
<tr>
<td></td>
<td>ESS 165 Advanced Geographic Information Systems (*)</td>
</tr>
<tr>
<td></td>
<td>ESS 214 Introduction to geostatistics and modeling of spatial uncertainty (*)</td>
</tr>
<tr>
<td></td>
<td>ESS 268 Empirical Methods in Sustainable Development (*)</td>
</tr>
</tbody>
</table>
Learning Objectives:

1. Design strategies for using multi-source and multi-scale observations of land surface processes that integrate field, geospatial, and human survey data to describe biophysical and socio-economic impacts of land systems changes.
2. Integrate biophysical and socioeconomic data related to land use and land cover change using geospatial tools to analyze and model complex, multi-scalar human-environmental interactions that determine land use dynamics.
3. Determine remedies to address negative impacts of land changes on human-environmental systems using land-use management tools and interventions.

Requirements

All students must complete the Required Core Courses (p. 2) listed under the "Bachelor's (p. 2)" tab in addition to the required courses listed below.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS&amp;E 231</td>
<td>Introduction to Computational Social Science</td>
<td>3</td>
</tr>
<tr>
<td>STATS 216</td>
<td>Introduction to Statistical Learning</td>
<td>3</td>
</tr>
</tbody>
</table>

**Elective Requirement**

Two additional courses at the 100-level or above are required. Each must be a minimum of 3 units.

A total of 7 courses are required from the 4 Land Systems Focus Areas. Concentrating courses in a single focus area below will allow students to deepen their understanding of the chosen system. For breadth considerations, students are required to take a minimum of 1 course from each focus area. In addition, two electives are required for this track. All track courses and electives must be taken for a letter grade (9 courses total).

**Land Ecosystems:**

- **EARTHSYS 155** Science of Soils (recommended) 3-4
- **EARTHSYS 180** Principles and Practices of Sustainable Agriculture (recommended) 3-4
- **BIO 144** Conservation Biology: A Latin American Perspective 3
- **EARTHSYS 105A & EARTHSYS 105B** Biological Preserve and Ecology and Natural History of Jasper Ridge Biological Preserve 8
- **EARTHSYS 116** Ecology of the Hawaiian Islands 4
- **EARTHSYS 128** Evolution of Terrestrial Ecosystems 4
- **ESS 256** Soil and Water Chemistry 3
- **ESS 223** Ecophysiology and Land Surface Processes 4
- **OSPSANTG 58** Living Chile: A Land of Extremes 5

**Water:**

- **CEE 166A** Watersheds and Wetlands (recommended) 4
- **CEE 101B** Mechanics of Fluids 4
- **CEE 162E** Rivers, Streams, and Canals 3-4
- **CEE 165C** Water Resources Management 3
- **CEE 166B** Floods and Droughts, Dams and Aqueducts 4
- **CEE 177** Aquatic Chemistry and Biology 4
- **EARTHSYS 104** The Water Course 3
- **GEOPHYS 190** Near-Surface Geophysics 3
- **OSPAUSTL 25** Freshwater Systems 3
- **OSPSANTG 79** Earth and Water Resources' Sustainability in Spain 3-4

**Land Use:**

- **ESS 270** Analyzing land use in a globalized world (recommended) 3
- **ANTHR 166** Political Ecology of Tropical Land Use: Conservation, Natural Resource Extraction, and Agribusiness 3-5
- **CEE 124** Sustainable Development Studio 1-5
- **CEE 175A** California Coast: Science, Policy, and Law 3-4
- **CEE 176A** Energy Efficient Buildings 3-4
- **EARTHSYS 118** Heritage, Environment, and Sovereignty in Hawaii 4
- **EARTHSYS 185** Feeding Nine Billion 4-5
- **EARTHSYS 238** Land Use Law 3
- **ECON 106** World Food Economy 4
- **ENERGY 101** Energy and the Environment 3
- **ENERGY 102** Fundamentals of Renewable Power 3
- **ENERGY 104** Sustainable Energy for 9 Billion 3
- **ENVRES 250** Environmental Governance 3
- **OSPSANTG 29** Sustainable Cities: Comparative Transportation Systems in Latin America 5
- **SIW 144** Energy, Environment, Climate and Conservation Policy: A Washington, D.C. Perspective 5
- **URBANST 110** Introduction to Urban Studies 4
- **ECON 106** World Food Economy 4
- **URBANST 113** Introduction to Urban Design: Contemporary Urban Design in Theory and Practice 5
- **EARTHSYS 185** Feeding Nine Billion 4-5
URBANST 164 Sustainable Cities 4-5
Methods:
EARTHSYS 144 Fundamentals of Geographic Information Science (GIS) (required)
Biogeophysical Dimensions (3 required):
EARTHSYS 124 Measurements in Earth Systems 3-4
EARTHSYS 142 Remote Sensing of Land 4
EARTHSYS 211 Fundamentals of Modeling 3-5
ESS 165 Advanced Geographic Information Systems 4
ESS 220 Physical Hydrogeology 4
GEOLSCI 240 Data science for geoscience 3

Two additional courses at the 100-level or above are required. Each must be a minimum of 3 units. See Earth Systems staff for a list of possible electives.

Oceans, Atmosphere, and Climate
Learning Objectives:
1. Apply fundamental physical, chemical, and biological principles toward understanding the behavior of the oceans, atmosphere, and climate and the interrelationships of these systems with human society.
2. Apply fundamental principles of ocean, atmospheric, and climate science through field, laboratory, and computer-based research experiences.

Requirements
All students must complete the Required Core Courses (p. 2) listed under the "Bachelor's (p. 2)" tab in addition to the required courses listed below.

Additional Foundation and Breadth Courses
BIO 81 Introduction to Ecology 4-10
or BIOHOPK 81 Introduction to Ecology
or HUMBIO 2A Genetics, Evolution, and Ecology
or HUMBIO 2B and Culture, Evolution, and Society
or EARTHSYS 1 Ecology of the Hawaiian Islands
CHEM 31A Chemical Principles I 5
& CHEM 31B and Chemical Principles II
or CHEM 31X Chemical Principles Accelerated
MATH 19 Calculus 3
& MATH 20 and Calculus
& MATH 21 and Calculus
MATH 51 Linear Algebra, Multivariable Calculus, and Modern Applications 3
& MATH 52 and Integral Calculus of Several Variables
(CME 100 preferred over MATH 51 and MATH 52)
or CME 100 Vector Calculus for Engineers
Physics (select one of the following): 3-4
PHYSICS 41 Mechanics
& PHYSICS 45 and Light and Heat
or GEOPHYS 1 Introduction to the foundations of contemporary geophysics
BIOHOPK 174H Experimental Design and Probability
or ECON 102A Introduction to Statistical Methods (Postcalculus) for Social Scientists
or STATS 101 Data Science 101
or STATS 110 Statistical Methods in Engineering and the Physical Sciences
or STATS 116 Theory of Probability

Sustainable Food and Agriculture
Learning Objectives:
1. Describe the main biophysical and socioeconomic constraints in food systems at global and local scales.
2. Apply knowledge of agricultural soils and plant growth to solve problems related to crop production, soil conservation, and natural resource management.
3. Identify the links between food systems and other aspects of the Earth system, including water, energy, and climate systems.
4. Assess and critique proposed policy or technological solutions that claim to make food systems more sustainable.

Requirements
All students must complete the Required Core Courses (p. 2) listed under the "Bachelor's (p. 2)" tab in addition to the required courses listed below.

Additional Foundation and Breadth Courses
BIO 81 Introduction to Ecology 4
or BIOHOPK 81 Introduction to Ecology
or HUMBIO 2A Genetics, Evolution, and Ecology
or HUMBIO 2B and Culture, Evolution, and Society
or EARTHSYS 1 Ecology of the Hawaiian Islands
CHEM 31A Chemical Principles I 5-10
& CHEM 31B and Chemical Principles II
or CHEM 31X Chemical Principles Accelerated
CHEM 31A Chemical Principles I 5-10
& CHEM 31B and Chemical Principles II
or CHEM 31X Chemical Principles Accelerated
ECON 1 Principles of Economics 5
ECON 155 Environmental Economics and Policy 5
GEOLSCI 1 Introduction to Geology 4-5
or GEOLSCI 4 Coevolution of Earth and Life
or EARTHSYS 1 Earth Sciences of the Hawaiian Islands
or EARTHSYS 1 Evolution of Terrestrial Ecosystems

MATH 19 Calculus 9
&MATH 20 and Calculus
&MATH 21 and Calculus

MATH 51 Linear Algebra, Multivariable Calculus, and Modern Applications 5
or CME 100 Vector Calculus for Engineers

PHYSICS 41 Mechanics 4
or PHYSICS 45 Light and Heat
or GEOPHYS 11 Introduction to the foundations of contemporary geophysics

A total of 7 courses are required from the Food and Agriculture Focus Areas. In addition, two electives are required for this track. All track courses and electives must be taken for a letter grade (nine courses total).

Fundamentals of Agriculture Production and Economics (both required):
ECON 106 World Food Economy 4
EARTHSYS 185 Feeding Nine Billion 4-5

Biogeophysical Dimensions (3 required):
EARTHSYS 155 Science of Soils 3-4
BIO 115 The Hidden Kingdom - Evolution, Ecology and Diversity of Fungi 4
EARTHSYS 142 Remote Sensing of Land 4
EARTHSYS 256 Soil and Water Chemistry 3
BIO 137 (Not given this year)
HUMBIO 113 The Human-Plant Connection 3
HUMBIO 130 Human Nutrition 4

Social Dimensions (choose 1):
ARCHLGY 124 Archaeology of Food: production, consumption and ritual 3-5
BIO 144 Conservation Biology: A Latin American Perspective 3
EARTHSYS 136 The Ethics of Stewardship 2-3
EARTHSYS 187 FEED the Change: Redesigning Food Systems 2-3
ECON 118 Development Economics 5
HUMBIO 113S Healthy/Sustainable Food Systems: Maximum Sustainability across Health, Economics, and Environment 4
HUMBIO 166 Food and Society: Exploring Eating Behaviors in Social, Environmental, and Policy Context 4
OSPMADRD 79 Earth and Water Resources’ Sustainability in Spain 3-4

Minor in Earth Systems, Sustainability Subplan

The minor in Earth Systems, Sustainability subplan, provides students with foundational knowledge, skills, and frameworks needed to understand social-environmental systems and address intergenerational sustainability challenges. Students declaring the minor in Earth Systems must also declare the Sustainability subplan.

To minor in Earth Systems, students must take the core courses listed below and approved electives for a minimum of 35 units. Courses that count toward the fulfillment of major requirements may not be counted toward the minor, and all courses must be taken for a letter grade.

Students declaring a minor in Earth Systems must do so no later than two quarters prior to their intended quarter of degree conferral; for example, a student must declare a minor before the end of Autumn Quarter to graduate the following Spring Quarter. The Sustainability subplan must also be declared in Axess when declaring the minor.

In addition, students pursuing the minor must complete the Multiple Major/Minor Form (http://studentaffairs.stanford.edu/sites/default/files/registrar/files/MajMin_MultMaj.pdf) and have it reviewed by all applicable departments/programs. This form must be submitted to the Student Services Center (https://studentservicescenter.stanford.edu/%22%20%5Ct%20%22_blank) by the application to graduate deadline for the term in which the student intends to graduate.

Required Course Work

Core

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EARTHSYS 10</td>
<td>4</td>
</tr>
<tr>
<td>EARTHSYS 111</td>
<td>4</td>
</tr>
<tr>
<td>EARTHSYS 112</td>
<td>4</td>
</tr>
</tbody>
</table>

(ECON 1 recommended as a pre- or co-requisite to EARTHSYS 112.)

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EARTHSYS 131</td>
<td>1</td>
</tr>
<tr>
<td>SUST 210</td>
<td>3</td>
</tr>
</tbody>
</table>

Electives

Students must take a minimum of 19 units of electives at the 100-level or above that address dimensions of environmental systems and social-environmental systems in theory or practice, with at least one course taken in each of the following four categories: Earth Systems Science/Engineering; Environmental Justice; Applied Problem Solving; and Skills.

Students may double-count courses in these categories (i.e. if a course fulfills both the Environmental Justice and Applied Problem Solving requirements, it can be applied to both categories).

A list of approved electives is available on the Earth Systems website and in the Earth Systems Program office (Y2E2 131). Students may petition to count one relevant freshman or sophomore seminar toward the minor.

Coterminal Master’s Degrees in Earth Systems

The Earth Systems Program offers current Stanford University undergraduates the opportunity to apply to a one-year coterminal master’s program. Earth Systems offers a coterminal Master of Science (M.S.) degree in Earth Systems and a coterminal Master of Arts (M.A.) degree in Earth Systems, Environmental Communication. The Environmental Communication subplan prints on both the transcript and the diploma.
Application and Admission

The Earth Systems Program has quarterly coterminal degree application deadlines: November 6, 2018; February 19, 2019; and May 14, 2019. Seniors must apply by Winter Quarter deadline. To apply, students should submit an online application. The application includes the following:

- The Stanford coterminal application (https://www.applyweb.com/stanterm)
- A statement of purpose
- A resume
- A current Stanford unofficial transcript
- Two letters of recommendation, one of which must be from the master's adviser (who must be an Academic Council member; each coterminal M.A. student has two advisers: Thomas Hayden and Kevin Arrigo, or another approved faculty adviser who is an Academic Council member)
- Master's Program Proposal (https://earth.stanford.edu/esys/program-forms): A list of courses that fulfill degree requirements signed by the master's adviser

1. Applications must be submitted no later than the quarter prior to the expected completion of the B.S. degree (and within quarterly application deadlines). An application fee is assessed by the Registrar's Office for coterminal applications, once students are matriculated into the program.

2. Students applying to the coterminal master's program must have completed a minimum of 120 units toward graduation with a minimum overall Stanford GPA of 3.4.

3. All applicants must devise a program of study that shows a level of specialization appropriate to the master's level, as determined in consultation with the master's adviser and the Director of Earth Systems. (See also following sections, Master of Science and Master of Arts in Earth Systems Degree Requirements).

4. Students applying from an undergraduate major other than Earth Systems should review their undergraduate course list with Deana Fabbro-Johnston, Richard Nevle, or Thomas Hayden (M.A. only).

5. The student has the option of receiving the B.S. degree after completing that degree's requirements or receiving the B.S. and M.A./M.S. degrees concurrently at the completion of the master's program.

6. Students must submit a new application to change from the M.S. to the M.A. in Earth Systems, or from the M.A. to the M.S. in Earth Systems. If accepted, the student must submit a Graduate Authorization Petition through Axess; a $125 fee applies to a successful Graduate Authorization Petition.

University Coterminal Requirements

Coterminal master's degree candidates are expected to complete all master's degree requirements as described in this bulletin. University requirements for the coterminal master's degree are described in the "Coterminal Master's Program (http://exploredegrees.stanford.edu/cotermdegrees)" section. University requirements for the master's degree are described in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/#masterstext)" section of this bulletin.

After accepting admission to this coterminal master's degree program, students may request transfer of courses from the undergraduate to the graduate career to satisfy requirements for the master's degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

In this master's program, courses taken during or after the first quarter of the sophomore year are eligible for consideration for transfer to the graduate career; the timing of the first graduate quarter is not a factor. No courses taken prior to the first quarter of the sophomore year may be used to meet master's degree requirements.

Course transfers are not possible after the bachelor's degree has been conferred.

The University requires that the graduate adviser be assigned in the student's first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master's Degree Program Proposal be completed by the student and approved by the department by the end of the student's first graduate quarter.

Coterminal Master of Science in Earth Systems Degree Requirements

The master of science degree in Earth Systems allows specialization through graduate-level course work that may include up to 9 units of research with the master's adviser. This may culminate in the preparation of a M.S. thesis; however, a thesis is not required for the degree. The process of building mastery in the field is enriched through steady communication with a faculty adviser.

The following are required of all M.S. students:

- A minimum of 45 units of course work and/or research credit (upon approval).
- At least 34 units of the student's course work for the master's program must be at the 200-level or above.
- All remaining course work must be at the 100-level or above.
- All courses for the master's program must be taken for a letter grade; courses not taken for a letter grade must be approved by the master's adviser and Director of Earth Systems.
- A minimum overall GPA of 3.4 must be maintained.
- All coterminal master's students are required to take the capstone course, EARTHSYS 290 Master's Seminar.

For the Master of Science degree in Earth Systems, the following courses must be taken if not completed in the undergraduate degree program. These courses do not have to be completed before applying to the coterm program. These may not be counted as part of the 45-unit master's degree:

<table>
<thead>
<tr>
<th>Units</th>
<th>Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>EARTHSYS 111 Biology and Global Change</td>
</tr>
<tr>
<td></td>
<td>EARTHSYS 112 Human Society and Environmental Change</td>
</tr>
<tr>
<td>4-10</td>
<td>Biology: One Biology Foundations/Core course pre-approved by Master's adviser, OR select from the following:</td>
</tr>
<tr>
<td></td>
<td>HUMBIO 2A Genetics, Evolution, and Ecology</td>
</tr>
<tr>
<td></td>
<td>HUMBIO 2B and Culture, Evolution, and Society</td>
</tr>
<tr>
<td></td>
<td>BIOHOPK 47 Introduction to Research in Ecology and Ecological Physiology</td>
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<tr>
<td></td>
<td>EARTHSYS 116 Ecology of the Hawaiian Islands</td>
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<tr>
<td>5-10</td>
<td>Chemistry (select one of the following):</td>
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<tr>
<td></td>
<td>CHEM 31X Chemical Principles Accelerated</td>
</tr>
<tr>
<td></td>
<td>CHEM 31A Chemical Principles I and Chemical Principles II</td>
</tr>
<tr>
<td>3-4</td>
<td>Physics (select one of the following):</td>
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<tr>
<td></td>
<td>One physics class from the PHYSICS 20 or 40 series or GEOPHYS 110</td>
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<tr>
<td>5</td>
<td>Mathematics (select one of the following):</td>
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<tr>
<td></td>
<td>MATH 51 Linear Algebra, Multivariable Calculus, and Modern Applications</td>
</tr>
<tr>
<td></td>
<td>CME 100 Vector Calculus for Engineers</td>
</tr>
<tr>
<td>3-5</td>
<td>Statistics (select one of the following):</td>
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<tr>
<td></td>
<td>BIOHOPK 174H Experimental Design and Probability</td>
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<tr>
<td></td>
<td>BIO 141 Biostatistics</td>
</tr>
</tbody>
</table>
Coterminal Master of Arts in Earth Systems, Environmental Communication

Degree Requirements

The Earth Systems Program offers current Stanford University undergraduates the opportunity to apply for admission to a 45-unit coterminal Master of Arts (MA) program in Earth Systems, Environmental Communication. The Earth Systems Master of Arts degree provides an overview of the theory, techniques, and challenges of communicating environmental science and policy concepts to diverse audiences and includes hands-on experience with different modalities of communication including writing, journalism, multimedia production, and informal education. The degree program is built on a set of required Core courses including a weekly seminar, a practicum placement, and a capstone project, enhanced with a range of individually selected Focus courses chosen either to emphasize a particular topic or modality or to provide greater breadth and diversity of study topics within environmental communication. Focus courses are selected in close consultation with the MA Director and a faculty co-adviser.

All Earth Systems Master of Arts students are also required to complete the Earth Systems Core, namely EARTHSYS 10 Introduction to Earth Systems (may be audited), EARTHSYS 111 Biology and Global Change, and EARTHSYS 112 Human Society and Environmental Change. These courses may be taken concurrently with the MA degree but may not be counted toward the 45 units required for the MA degree. Rarely, additional prerequisites or foundational courses may be required depending on the academic background and intended focus of each student.

The following are required of all M.A. students:

- All M.A. students must declare the Environmental Communication subplan in Axess.
- A minimum of 45 units of course work and/or research credit (upon approval).
- At least 34 units of the student's course work for the master's program must be at the 200-level or above.
- All remaining course work must be at the 100-level or above.
- All courses for the master's program must be taken for a letter grade; courses not taken for a letter grade must be approved by the master's adviser and Director of Earth Systems.
- A minimum overall GPA of 3.4 must be maintained.
- All coterminal master's students are required to take the capstone course, EARTHSYS 290 Master's Seminar.

Graduate Advising Expectations

The Earth Systems Program is committed to providing academic advising in support of graduate student scholarly and professional development. When most effective, this advising relationship entails collaborative and sustained engagement by both the adviser and the advisee. As a best practice, advising expectations should be periodically discussed and reviewed to ensure mutual understanding. Both the adviser and the advisee are expected to maintain professionalism and integrity.

Faculty advisers guide students in key areas such as selecting courses, designing and conducting research, developing of teaching pedagogy, navigating policies and degree requirements, and exploring academic opportunities and professional pathways.

Graduate students are active contributors to the advising relationship, proactively seeking academic and professional guidance and taking responsibility for informing themselves of policies and degree requirements for their graduate program.

For a statement of University policy on graduate advising, see the "Graduate Advising (http://exploredegrees.stanford.edu/graduatedegrees/#advisingandcredentialstext)" section of this bulletin.

**Director:** Kevin Arrigo

**Deputy Director:** Richard Nevle

**Associate Director:** Deana Fabbro-Johnston

emeritus, Woods Institute for the Environment), Rosamond Naylor (Earth System Science, Freeman Spogli Institute for International Studies, Woods Institute for the Environment), Richard Neve (Earth Systems), Julia Novy-Hildesley (Sustainability Science and Practice), Michael Osborne (Earth Systems), Stephen Palumbi (Biology, Hopkins Marine Station, Woods Institute for the Environment), Jonathan Payne (Geological Sciences), Kabir Peay (Biology), Emily Polk (Program in Writing and Rhetoric), Thomas Robinson (Medicine), Matt Rothe (Earth Systems, Hasso Plattner Institute of Design, Graduate School of Business), Jennifer Saltzman (Geological Sciences), Dustin Schroeder (Geophysics), Paul Segall (Geophysics), Deborah Sivas (Law), George Somero (Biology, Hopkins Marine Station), Jenny Suckale (Geophysics), James Sweeney (Management Science and Engineering, Woods Institute for the Environment), Leif Thomas (Earth System Science), Barton Thompson, Junior (Law, Woods Institute for the Environment), Sarah Truebe (Earth Systems), Tiziana Vanorio (Geophysics), Peter Vitousek (Biology, Emmett Interdisciplinary Program in Environment and Resources, Woods Institute for the Environment), Virginia Walbot (Biology), Paula Welander (Earth System Science), Cindy Wilber (Jasper Ridge), Michael Wilcox (Anthropology), Mikael Wolfe (History), Jane Woodward (Atmosphere and Energy Operations), Mark Zoback (Geophysics)

**Overseas Studies Courses in Earth Systems**

The Bing Overseas Studies Program (http://bosp.stanford.edu) manages Stanford study abroad programs for Stanford undergraduates. Students should consult their department or program’s student services office for applicability of Overseas Studies courses to a major or minor program.

The Bing Overseas Studies course search site (https://undergrad.stanford.edu/programs/bosp/explore/search-courses) displays courses, locations, and quarters relevant to specific majors.

For course descriptions and additional offerings, see the listings in the Stanford Bulletin’s ExploreCourses (http://explorecourses.stanford.edu) or Bing Overseas Studies (http://bosp.stanford.edu).

### Environmental Courses List

<table>
<thead>
<tr>
<th>Units</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Coral Reef Ecosystems</td>
</tr>
<tr>
<td>3</td>
<td>Freshwater Systems</td>
</tr>
<tr>
<td>3</td>
<td>Coastal Forest Ecosystems</td>
</tr>
<tr>
<td>3</td>
<td>Socio-Ecological Systems</td>
</tr>
<tr>
<td>3-4</td>
<td>Earth and Water Resources’ Sustainability in Spain</td>
</tr>
<tr>
<td>3-5</td>
<td>Environmental Economics and Policy</td>
</tr>
<tr>
<td>5</td>
<td>Living Chile: A Land of Extremes</td>
</tr>
</tbody>
</table>

### Environmental Courses List (Continued)

<table>
<thead>
<tr>
<th>Units</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>The Global Positioning System: Where on Earth are We, and What Time is it?</td>
</tr>
<tr>
<td>3</td>
<td>Electric Automobiles and Aircraft</td>
</tr>
<tr>
<td>2</td>
<td>Global Positioning Systems</td>
</tr>
<tr>
<td>3</td>
<td>History of South Africa</td>
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<tr>
<td>3</td>
<td>History of South Africa</td>
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<tr>
<td>3</td>
<td>Running While Others Walk: African Perspectives on Development</td>
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<tr>
<td>3</td>
<td>AIDS, Literacy, and Land: Foreign Aid and Development in Africa</td>
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<tr>
<td>3</td>
<td>Running While Others Walk: African Perspectives on Development</td>
</tr>
<tr>
<td>2</td>
<td>Media, Culture, and Society</td>
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<td>2</td>
<td>The American West</td>
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**Anthropology Courses**

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<tr>
<th>Units</th>
<th>Description</th>
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<tbody>
<tr>
<td>3</td>
<td>Peopling of the Globe: Changing Patterns of Land Use and Consumption Over the Last 50,000 Years</td>
</tr>
<tr>
<td>3</td>
<td>Animals and Us</td>
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<tr>
<td>3</td>
<td>Theory of Ecological and Environmental Anthropology</td>
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<tr>
<td>3</td>
<td>Incas and their Ancestors: Peruvian Archaeology</td>
</tr>
<tr>
<td>3</td>
<td>Thinking Through Animals</td>
</tr>
<tr>
<td>3</td>
<td>Heritage, Environment, and Sovereignty in Hawaii</td>
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<tr>
<td>3</td>
<td>Zoologia: An Introduction to Faunal Remains</td>
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<tr>
<td>3</td>
<td>Language and the Environment</td>
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<tr>
<td>3</td>
<td>The Politics of Humanitarianism</td>
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<tr>
<td>3</td>
<td>Mobilizing Nature</td>
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<tr>
<td>3</td>
<td>Science, Technology, and Medicine in Africa</td>
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<tr>
<td>3</td>
<td>Nature, Culture, Heritage</td>
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<tr>
<td>3</td>
<td>Research Methods in Ecological Anthropology</td>
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<tr>
<td>3</td>
<td>Environment, Nature and Race</td>
</tr>
<tr>
<td>3</td>
<td>Social and Environmental Sustainability: The Costa Rican Case</td>
</tr>
<tr>
<td>3</td>
<td>Indigenous Peoples and Environmental Problems</td>
</tr>
<tr>
<td>3</td>
<td>Political Ecology of Tropical Land Use: Conservation, Natural Resource Extraction, and Agribusiness</td>
</tr>
<tr>
<td>3</td>
<td>Everest: Extreme Anthropology</td>
</tr>
<tr>
<td>3</td>
<td>Australian Ecosystems: Human Dimensions and Environmental Dynamics</td>
</tr>
<tr>
<td>3</td>
<td>Environmental Change and Emerging Infectious Diseases</td>
</tr>
<tr>
<td>3</td>
<td>Evolution and Conservation in Galapagos</td>
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<tr>
<td>3</td>
<td>Social and Environmental Sustainability: The Costa Rican Case</td>
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<td>3</td>
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<td>3</td>
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<td>3</td>
<td>Environmental Change and Emerging Infectious Diseases</td>
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<tr>
<td>3</td>
<td>Evolution and Conservation in Galapagos</td>
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<tr>
<td>3</td>
<td>History of Anthropological Theory, Ecology and Environment</td>
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<td>3</td>
<td>Anthropology of Environmental Conservation</td>
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<tr>
<td>3</td>
<td>EcoGroup: Current Topics in Ecological, Evolutionary, and Environmental Anthropology</td>
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<tr>
<td>3</td>
<td>Dynamics of Coupled Human-Natural Systems</td>
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<tr>
<td>BIOE 44</td>
<td>Fundamentals for Engineering Biology Lab</td>
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<tr>
<td>BIOE 80</td>
<td>Introduction to Bioengineering (Engineering Living Matter)</td>
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<tr>
<td>BIOE 191</td>
<td>Bioengineering Problems and Experimental Investigation</td>
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<tr>
<td>BIOE 459</td>
<td>Frontiers in Interdisciplinary Biosciences</td>
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<tr>
<td>BIOHOPK 43</td>
<td>Plant Biology, Evolution, and Ecology</td>
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<tr>
<td>BIOHOPK 150H</td>
<td>Ecological Mechanics</td>
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<tr>
<td>BIOHOPK 152H</td>
<td>Physiology of Global Change</td>
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<tr>
<td>BIOHOPK 153H</td>
<td>Current Topics and Concepts in Quantitative Fish Dynamics and Fisheries Management</td>
</tr>
<tr>
<td>BIOHOPK 155H</td>
<td>Developmental Biology and Evolution</td>
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<tr>
<td>BIOHOPK 160H</td>
<td>Developmental Biology in the Ocean: Diverse Embryonic &amp; Larval Strategies of marine invertebrates</td>
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<tr>
<td>BIOHOPK 161H</td>
<td>Invertebrate Zoology</td>
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<tr>
<td>BIOHOPK 162H</td>
<td>Comparative Animal Physiology</td>
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<tr>
<td>BIOHOPK 163H</td>
<td>Oceanic Biology</td>
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<tr>
<td>BIOHOPK 166H</td>
<td>Molecular Ecology</td>
</tr>
<tr>
<td>BIOHOPK 167H</td>
<td>Nerve, Muscle, and Synapse</td>
</tr>
<tr>
<td>BIOHOPK 168H</td>
<td>Disease Ecology: from parasites evolution to the socio-economic impacts of pathogens on nations</td>
</tr>
<tr>
<td>BIOHOPK 172H</td>
<td>Marine Ecology: From Organisms to Ecosystems</td>
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<tr>
<td>BIOHOPK 173H</td>
<td>Marine Conservation Biology</td>
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<tr>
<td>BIOHOPK 174H</td>
<td>Experimental Design and Probability</td>
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<tr>
<td>BIOHOPK 177H</td>
<td>Dynamics and Management of Marine Populations</td>
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<tr>
<td>BIOHOPK 179H</td>
<td>Physiological Ecology of Marine Megafauna</td>
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<tr>
<td>BIOHOPK 181H</td>
<td>Physiology of Global Change</td>
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<tr>
<td>BIOHOPK 182H</td>
<td>Stanford at Sea</td>
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<tr>
<td>BIOHOPK 185H</td>
<td>Ecology and Conservation of Kelp Forest Communities</td>
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<td>BIOHOPK 187H</td>
<td>Sensory Ecology</td>
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<td>BIOHOPK 189H</td>
<td>Sustainability and Marine Ecosystems</td>
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<td>BIOHOPK 198H</td>
<td>Directed Instruction or Reading</td>
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<td>BIOHOPK 199H</td>
<td>Undergraduate Research</td>
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<td>BIOHOPK 250H</td>
<td>Ecological Mechanics</td>
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<td>BIOHOPK 252H</td>
<td>Physiology of Global Change</td>
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<td>BIOHOPK 253H</td>
<td>Current Topics and Concepts in Quantitative Fish Dynamics and Fisheries Management</td>
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<td>BIOHOPK 255H</td>
<td>Developmental Biology and Evolution</td>
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<tr>
<td>BIOHOPK 260H</td>
<td>Developmental Biology in the Ocean: Diverse Embryonic &amp; Larval Strategies of marine invertebrates</td>
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<tr>
<td>BIOHOPK 261H</td>
<td>Invertebrate Zoology</td>
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<tr>
<td>BIOHOPK 262H</td>
<td>Comparative Animal Physiology</td>
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<td>BIOHOPK 263H</td>
<td>Oceanic Biology</td>
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<td>BIOHOPK 266H</td>
<td>Molecular Ecology</td>
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<td>BIOHOPK 267H</td>
<td>Nerve, Muscle, and Synapse</td>
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<tr>
<td>BIOHOPK 268H</td>
<td>Disease Ecology: from parasites evolution to the socio-economic impacts of pathogens on nations</td>
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<tr>
<td>BIOHOPK 272H</td>
<td>Marine Ecology: From Organisms to Ecosystems</td>
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<tr>
<td>BIOHOPK 273H</td>
<td>Marine Conservation Biology</td>
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<tr>
<td>BIOHOPK 274</td>
<td>Hopkins Microbiology Course</td>
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<td>BIOHOPK 274H</td>
<td>Experimental Design and Probability</td>
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<td>BIOHOPK 275H</td>
<td>Synthesis in Ecology</td>
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<td>BIOHOPK 276H</td>
<td>Estimates and Errors: The Theory of Scientific Measurement</td>
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<td>BIOHOPK 277H</td>
<td>Dynamics and Management of Marine Populations</td>
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<tr>
<td>BIOHOPK 280</td>
<td>Short Course on Ocean Policy</td>
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<tr>
<td>BIOHOPK 285</td>
<td>Ecology and Conservation of Kelp Forest Communities</td>
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<td>BIOHOPK 287</td>
<td>Sensory Ecology</td>
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<td>BIOHOPK 289</td>
<td>Sustainability and Marine Ecosystems</td>
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<td>BIOHOPK 300</td>
<td>Research</td>
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<td>Physical Biology</td>
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<td>BIOHOPK 323</td>
<td>Stanford at Sea</td>
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POLISCI 136R Introduction to Global Justice
POLISCI 241S Spatial Approaches to Social Science
PSYCH 459 Frontiers in Interdisciplinary Biosciences
PUBLPOL 101 Politics and Public Policy
PUBLPOL 103D Ethics and Politics of Public Service
PUBLPOL 104 Economic Policy Analysis
PWR 1MS Writing & Rhetoric 1: Seeing Nature: The Power of Environmental Visual Rhetoric
PWR 1SI Writing & Rhetoric 1: Super-Storms, Polar Bears, and Droughts: The Rhetoric of Climate Change
PWR 2CR Writing & Rhetoric 2: Communicating Science to the Public
PWR 2JS Writing & Rhetoric 2: In Science We Trust
PWR 2KM Writing & Rhetoric 2: A Planet on the Edge: The Rhetoric of Sustainable Energy
PWR 2RL Writing & Rhetoric 2: The Rhetoric of the Natural and Beyond
PWR 2SB Writing & Rhetoric 2: Writing 'Science': Fact, Fiction, and Everything Between
PWR 91CL Intermediate Writing: Self & Science
PWR 91EP Intermediate Writing: Communicating Climate Change: Navigating the Stories from the Frontlines
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