The Ocean and Global Change (OGC)

CAS NS 326 (4 credits)

Course Catalog Description:
Ocean ecosystem change in the anthropocene: warming, acidification, fisheries depletion, and pollution. Review principles of circulation, seawater chemistry, nutrient dynamics, and biological production to understand causes and consequences of change. Conduct field measurements for contribution to time-series datasets.

Instructors: Sea Education Association Oceanography Faculty

Locations: SEA campus in Woods Hole, MA, and aboard a SEA sailing school vessel at sea.

Prerequisites: Admission to Sea Semester. Sophomore standing or consent of instructor.

Course Philosophy and Approach:

Humanity depends upon, and extracts value from, the ocean for food, transport, climate, and personal well-being, as well as many other necessary ecosystem services. Ours is the first generation to truly appreciate that the global ocean ecosystem is not immutable but instead has and continues to undergo rapid change caused by unsustainable human practices. Collectively these anthropogenic changes to the ocean (as well as terrestrial and atmospheric ecosystems) have led to the designation of a new geologic time period – the Anthropocene. Warming, acidification, fisheries depletion, and pollution are but a few examples of human pressures on the oceans that influence natural patterns in the distribution, diversity and abundance of marine organisms. Unfortunately, human impact on the global ocean continues to cause rapid change that threatens the services and resources upon which human civilization depends.

It is important to note that human extraction from the ocean and corresponding negative environmental impacts are not shared equally among all socio-political or cultural groups. There are, in the most reductive of terms, winners and losers. This course examines the history and condition of the Anthropocene ocean with emphasis on observed pressures, ecological responses and potential solutions (management, adaptation, and mitigation) that are just and equitable for all humanity.

We build a foundation of global ocean principles by first reviewing ocean circulation, seawater chemistry, nutrient dynamics, and biological production. We will then examine the many ways humanity extracts value from the global ocean, highlighting the negative consequences of unsustainable practices. Human impacts on ocean ecosystems will be examined through regional case studies (e.g., the islands of New Zealand) that illustrate the following *interdisciplinary Global Ocean program themes* and related oceanographic topics:

1) The Anthropocene – Climate Change
2) Economic Equity – Fisheries and Ocean Resource Extraction
3) Environmental Justice – Eutrophication and Coastal Pollution
4) Geographic Identity – Iconic Marine Habitats and Species

Examples of questions this course will explore and try to answer on both regional and global scales include: Is ocean productivity diminishing as surface waters warm? Are oxygen-deprived waters becoming more widespread as the surface ocean becomes more stratified? Will open-ocean plankton communities change in response to the acidification of seawater? Does depletion of top predators impact lower food web structure and interactions? Will increased nutrient loading shift phytoplankton community composition? Can plastic marine debris serve as a substrate for biological production and vector for non-native introductions? How can the best available science inform and guide future human activity and use of marine resources? How must human economic, political, and social structure respond to climate change through adaptation and/or mitigation?

This course consists of 15 lecture/discussion sessions (approximately 1.5 hours each), 2 field trips (6 hours), 1 exam based on 'fundamentals' lectures (4 hours), 4 global ocean case studies presented by students (4 hours), 1 lab practical exam (1.5 hours at sea), and at least 50 hours of laboratory watch participation (active learning/laboratory) during ~25 underway days at sea.

Learning Outcomes:

1. Understand, from a scientific perspective, human value of ocean & coastal ecosystems.
2. Understand, from a scientific perspective, anthropogenic pressures on ocean & coastal ecosystems.
3. Foster ocean literacy, to encourage a commitment to securing ocean health.
4. Gain practical experience in oceanographic data collection, analysis, and reporting.

Evaluation:

On Shore	
Fundamentals Exam	15%
Anthropocene-Ocean Presentations	15%
Presentations (10%); Discussion Questions (5%)	
OGC Journal Onshore	10%
Ocean Change Project – Part I	5%
At Sea	
Lab Practical Skills	10%

Watch Participation	20%
OGC Journal at Sea	15%
Equipment Diagram (5%)	
Data Discussions (5%)	
Creature Feature (5%)	
Ocean Change Project – Part II	10%

Assignments Onshore:

Fundamentals Exam

A take-home exam, covering material from lectures, readings and discussions, will be given at the end of week four. Emphasis will be on application of concepts introduced in class, not rote memorization of facts. Expect to spend approximately 4 hours on the exam. This fundamentals exam is worth 15% of the final course grade.

New Zealand Anthropocene-Ocean Presentations

The final weeks of the shore component will explore four *Global Ocean* (GO) themes and related ocean topics (see above) through a close examination of regional case studies. Formal lectures will introduce each GO theme and relevant oceanographic concepts. Student teams will then research and present information on aspects of regional oceanography and Anthropocene-ocean parameters in New Zealand's coastal waters. These presentations will provide the entire class a detailed view of the challenges and implications arising from anthropogenic changes to marine environments and resources of New Zealand. Twenty-four hours prior to their presentation, each group will distribute a single discussion prompt on their topic for their classmates to ponder and discuss in class. Each student will present on topics within two of the four themes during the shore component. A rubric will be provided for additional details. The entire class is expected to do the required readings and engage in the discussion. The presentations and related discussion questions are worth 15% of the final course grade.

OGC Journal Onshore

Students will keep a journal both onshore and at sea. Journal assignments will include neatly recorded and organized formal responses to weekly discussion prompts. These responses will address potential solutions to regional and global problems facing marine ecosystems. They will be used to assess understanding of, and engagement with, each GO theme, with students reflecting on each theme based on assigned readings and their own exploration. Students are also encouraged to use their journal to record class notes, including faculty lectures and student presentations. Students should organize their journal with a Table of Contents so that it can be used as a reference and make it easier for faculty to evaluate at the end of the program. The shore component of the OGC journal is worth 10% of the final course grade.

Ocean Change Project (Parts I and II)
Each student will choose a scientific focus for assessment of ocean change along our cruise track as part of a small group (2-3 people) project. Each project will research historical changes in oceanographic variables over *time* using the scientific literature and historical SEA data. At sea, students will use data along our cruise track to explore changes in these ocean variables over *space* and assess factors that control these characteristics of the ocean system. Topics may include: physical structuring (temperature, salinity and density), seawater chemistry (nutrients and carbon), biomass, and biological diversity. A literature review will result in a bibliography of sources related to each topic. The entire class will be responsible for collection of these data, but each person will be responsible for analysis of data within their particular focus, as part of a small group. Students will complete Part I of this project ashore – the 'Bibliography' and 'Introduction' sections of their project report, together worth 5% of their final course grade. Part II of this project, analyzing the data and writing the 'Data' and 'Interpretation' sections of the final project report, will be completed at sea; this is worth 10% of the final course grade. Details of this assignment will be provided during the initial class meeting.

Assignments at Sea:

Lab Practical Exam
A 1.5-hour exam will be administered during the third week at sea to test practical knowledge of standard safety and operational procedures in the lab. This exam is worth 15% of the final course grade.

Lab Watch Participation
Science watch activities onboard ship will be assessed in on-watch evaluations by SEA Assistant Scientists. Each student is an essential crewmember of the ship at sea. Excellent watch-standers follow directions, work effectively as part of the team, show independence, demonstrate good judgment and leadership, and are a supportive, helpful, and reliable shipmate. Teamwork is particularly important in this course, so much so that a student's attitude and participation directly affects the physical progress and ultimate success of the voyage. Over the course of six weeks at sea students will progress through three phases of responsibility. In phase I students are actively learning lab skills, in phase II they are actively applying those skills to achieve our scientific mission, and in phase III they take the lead in running all lab watch activities.

OGC Journal at Sea
Students will document their scientific journey at sea in their journal. This will include at least three types of entries, with details guided by a rubric:

- Oceanography Equipment Diagram – Students will choose a piece of scientific equipment that appeals/interests them and write a technical summary in their journal. Each technical summary should include a diagram of working parts and illustrate its use. In a few paragraphs explain the importance of this equipment to our understanding of how the global oceans work. This diagram is worth 5% of the final course grade.

- Data Discussions and Interpretations – Students will make weekly journal entries that summarize what they learned in class and in the lab regarding data collected during the voyage. These notes should include, when appropriate, illustrations, maps, figures and graphs to help depict important concepts, as well as definitions of new terminology. Each week, a particular dataset will be introduced to the class as part of the Daily Science report and students will be asked to reflect upon and interpret these data in their journals. These data discussions are worth 5% of the final course grade.
- Creature Feature – Students will choose a marine organism that appeals/interests them and write a natural history summary in their journal. The selected creature must have been observed from the ship and/or collected in our nets. Each creature feature should include at least one illustration based on a sketch from memory or a photograph taken by the student or a shipmate – as opposed to copying an image from a textbook. In a few paragraphs explain the importance of each organism to the ocean ecosystem with relevant biological / ecological details and distinguishing features for identification. This creature feature is 5% of the final course grade.

Expectations and Requirements:

- Punctual attendance is required at every class meeting.
- Active participation in class discussion is expected.
- Late assignment submissions are not accepted.
- The policy on academic accuracy, quoted below, will be strictly followed in this class.

  The papers that you submit in this course are expected to be ***your original work.*** You must take care to distinguish your own ideas and knowledge from wording or substantive information that you derive from one of your sources. The term "sources" includes not only published primary and secondary material, but also information and opinions gained directly from other people and text that you cut and paste from any site on the Internet.

  The responsibility for learning the proper forms of citation lies with you. Quotations must be placed properly within quotation marks and must be cited fully. In addition, all paraphrased material must be acknowledged completely. Whenever ideas or facts are derived from your reading and research, the sources must be indicated. (Harvard *Handbook for Students,* 305)
- Considerations for use of internet sources:

  As you browse websites, assess their usefulness very critically. Who posted the information and why? Can you trust them to be correct? Authoritative? Unbiased? Your annotation should include the name of the author or organization originating any material that you reference. If you can't identify the source, don't use it!
- *Please consult information in the SEA Student Handbook on Academic Integrity and direct any questions to SEA Semester faculty.*

Readings:

Readings for the Ocean Essentials portion of the course will come mainly from two texts:

1. Segar D.A. 2013. Introduction to Ocean Sciences. Online text, http://www.reefimages.com/oceans/oceans.html
2. Nybakken J.M. 2005. Marine Biology, an Ecological Approach. 6th ed. Benjamin Cummings, 592 pp.

Readings and other materials for the Focal Program Themes portion of the course will be assigned from, but not limited to, the following sources. There will be additional region- and site-specific readings based on program destination.

Boyd, P.W., C.S. Law, and S.C. Doney. 2011. Commentary: A climate change atlas for the ocean. Oceanography 24(2): 13–16.

Branch, T.A., et al. 2010. The trophic fingerprint of marine fisheries. Nature, 468: 431-435.

Deep Water Currents, NASA simulation. https://pmm.nasa.gov/education/videos/thermohaline-circulation-great-ocean-conveyor-belt

Doney, S.C., et al. 2009. Ocean acidification: the other CO_2 problem. Ann. Rev. Marine Science, 1: 169-192.

Doney, S.C., et al. 2012. Climate change impacts on marine ecosystems. Ann. Rev. Marine Science, 4: 11–37.

Eriksen, M., et al. 2014. Plastic pollution in the world's oceans: more than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. PLoS ONE, 9(12).

Hollowed, A.B., et al. 2013. Projected impacts of climate change on marine fish and fisheries. ICES Jour. Mar. Sci., 70: 1023-1037.

Ivar do Sul, J.A. and M.F. Costa. 2014. The present and future of microplastic pollution in the marine environment. Environmental Pollution, 185: 352-364.

Jackson, J.B.C., et al. 2001. Historical Overfishing and the Recent Collapse of Coastal Ecosystems. Science, 293: 629-638.

Jambeck, J.R., et al. 2015. Plastic waste inputs from land into the ocean. Science, 347 (6223): 768-771.

Kroeker, K.J., et al. 2013. Impacts of ocean acidification on marine organisms: quantifying sensitivities and interaction with warming. Global Change Biology, 19: 1884-1896.

Law, K.L. and R.C. Thompson. 2014. Microplastics in the seas. Science, 345 (6193): 144-145.

Law, K.L. 2017. Plastics in the marine environment. Ann. Rev. Marine Science, 9: 205-229.

Murphy, R.J., et al. 2001. Phytoplankton distributions around New Zealand derived from SeaWiFS remotely-sensed ocean colour data. New Zealand Journal of Marine and Freshwater Research, 35(2): 343-362.

National Research Council (NRC), 2012. Climate Change: Evidence, Impacts, Choices.

Surface Currents, NASA simulation https://www.nasa.gov/topics/earth/features/perpetual-ocean.html

Whale fall animation. https://ocean.si.edu/ocean-life/marine-mammals/life-after-whale-whale-falls

Worm, B. et al. 2006. Impacts of biodiversity loss on ocean ecosystem services. Science, 314: 787-790.

Worm, B., et al. 2009. Rebuilding global fisheries. Science, 325: 578-585.

Course Calendar:

Topic	Readings/Assignments Due
Week 1 Ocean Essentials (7.5 hours) – on shore at SEA campus in Woods Hole	
Introduction to *The Global Ocean* program and *The Ocean and Global Change (OGC)*; Overview of Course Goals & Assignments Lecture/Discussion Topics: • Introduction to Oceanography • Foundations of Chemical & Physical Oceanography o Salinity, Temperature, Density o Heat Budget, Atmospheric Circulation o Ocean Circulation MBL/WHOI Library and Woods Hole tour	***Readings:*** Segar, selected chapters ***Watch:*** *Surface Currents*, NASA *Deep Water Currents,* NASA
Week 2 Ocean Essentials (4.5 hours) – on shore at SEA campus in Woods Hole	
Lecture/Discussion Topics: • Foundations of Biological Oceanography o Nutrients and Light in the Ocean o Productivity	***Readings:*** Segar, selected chapters Nybakken, selected chapters Murphy et al., 2001

◦ Carbon Cycling ◦ Marine Ecosystems & Food Webs • Science Along *Global Ocean* Cruise Track	Cruise Prospectus SSV *RC Seamans* virtual tour ***Watch:*** *Whalefall Animation* ***Due:*** *Select NZ Case Study and Ocean Change Project Topics*
Week 3 Climate Change (4 hours) – on shore at SEA campus in Woods Hole	
Lecture/Discussion Topics: • Climate Change and the Ocean • Trends & Ecological Responses • Ocean Acidification NZ Climate Change Presentations	***Readings:*** Doney et al., 2009 Boyd et al., 2011 Doney et al., 2012 NRC, 2012 Kroeker et al., 2013 Other discussion readings TBD
Week 4 Fisheries & Ocean Resource Extraction (4 hours) – on shore at SEA campus in Woods Hole	
Lecture/Discussion Topics: • Fisheries Ecology • Trends & Ecological Responses NZ Fisheries Presentations	***Readings:*** Segar, selected readings Nybakken, selected readings Jackson et al., 2001 Worm et al., 2006 Worm et al., 2009 Branch et al., 2010 Hollowed et al., 2013 Other discussion readings TBD ***Due:*** *GO Discussion Questions (Topic 1); Ocean Change Project Bibliography; Take-Home Exam*
Week 5 Eutrophication & Coastal Pollution (8.5 hours) – on shore at SEA campus in Woods Hole	

Lecture/Discussion Topics: • Sources of Pollution • Watersheds and Biological Impacts NZ Pollution Presentations Plankton Lab Blue Carbon Marsh Field Trip	***Readings:*** Segar, selected readings Eriksen et al., 2014 Law and Thompson, 2014 Ivar do Sul & Costa, 2014 Jambeck et al., 2015 Law, 2017 Other discussion readings TBD ***Due:*** *GO Discussion Questions (Topic 2); Ocean Change Project Introduction*
Week 6 Iconic Marine Habitats & Species (4 hours) – on shore at SEA campus in Woods Hole	
Lecture/Discussion Topics: • Higher Trophic Levels & Endangered Species NZ Marine Habitats & Species Presentations Cruise Research Plan/Briefing	***Readings:*** Endangered Species Act (ESA) Status Reviews Other discussion readings TBD ***Due:*** *GO Discussion Questions (Topics 3 & 4)*
Week 7 (9 hours) – at sea	
Training Phase I: Apprenticeship • Shipboard Orientation • Introduction to the Shipboard Laboratory & Safety Protocols • Learn Scientific Sampling and Data Collection Skills Begin collecting scientific data	**Due:** *Equipment diagram in journal*
Week 8 (9 hours) – at sea	
Training Phase I: Apprenticeship (continued) Continue collecting scientific data	***Due:*** *Data Discussion Response in journal (Comparative)*
Week 9 (10.5 hours) – at sea	
Training Phase II: Skill Development • Increased Responsibility for Lab Routines • Data analysis techniques	***Due:*** *Data Discussion response in journal (Trends & profiles)*

Continue collecting scientific data Practical Exam	
Week 10 (9 hours) – at sea	
Training Phase II: Skill Development (continued) Continue collecting scientific data	***Due:*** *Data Discussion response in journal (Relational)*
Week 11 (9 hours) – at sea	
Training Phase III: Leading the Science Watch • Apprentice Lab Manager Continue collecting scientific data Data analysis/mentoring sessions	***Due:*** *Creature Feature in journal*
Week 12 (9 hours) – at sea	
Training Phase III: Leading the Science Watch (continued) Multi-Watch Mission/Exercise	***Due:*** *Ocean Change Project Reports*