The Ocean and Global Change

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 in Caribbean reef, sea grass, and mangrove ecosystems. Conduct field measurements for contribution to time-series datasets.

Instructor: Sea Education Association Oceanography Faculty

Locations: SEA campus in Woods Hole, MA, at a field station in the U.S. Virgin Islands, and at sea on SEA's sailing school vessel *Corwith Cramer*.

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, climate, tourism, and personal well-being, as well as many other necessary ecosystem services. This is certainly true of the coastal environments in the Caribbean, including reefs that provide 100s of millions of dollars worth of human-valued services. Ours is the first generation to truly appreciate that the global ocean ecosystem is not immutable but instead has undergone and continues to undergo rapid change caused by millennia of 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. A holistic viewpoint is required to understand the myriad impacts of the Anthropocene on Caribbean coastal ecosystems. Nestled between local drivers associated with human practices on land and global phenomenon mediated through changes in ocean conditions, Caribbean reefs sit at the center of Anthropocene change. Thus, our studies will employ an island ridge-top to ocean reef-crest approach, with a fair share to understanding historical drivers.

Global 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, as the global ocean continues to change it no longer provides the goods and services humanity requires and our livelihood is threatened.

It is important to note that human extraction from the ocean and corresponding negative environmental impacts are not shared equally among all socio-political, 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 (i.e. the Eastern Caribbean islands) that illustrate the following *interdisciplinary, program themes* and related oceanographic topics:

1) *Environmental Justice* – Eutrophication, Coastal Pollution and Tourism
2) *Economic Equity* – Fisheries and Ocean Resource Extraction
3) *Sense of Place* – Iconic Species and the Science of Marine Protected Areas
4) *The Anthropocene* – Climate Change and the Role of Science in Policy-making

When we move our classroom to the U.S. Virgin Islands we will meet with resident experts in the academic, scientific, government, and non-government fields whose job is to find solutions to the myriad challenges of marine conservation in the Caribbean.

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 on coral reefs? Will increased nutrient loading shift coral-algal-sponge 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 sustainable use of coastal ecosystem resources? How must human economic, political, and social structure respond to climate change through adaptation and/or mitigation?

This course consists of 17 lecture/discussion sessions (approx. 1.5 hours each), 1 exam based on 'fundamentals' lectures (4 hours), 4 global ocean case studies presented by students (4 hours) and corresponding discussion questions to be included in student journals (1 hour per topic = 4 hours), and greater than 36 hours of laboratory watch participation (active learning/laboratory) across about 18 underway days at sea. Some of the sessions are joint activities integrated with other *Caribbean Reef Expedition* courses, and the weekly contact hours given in the preliminary course calendar below reflects only the portion allocation to the *OGC* course.

Learning Outcomes:

1. Understand, from a scientific perspective, human value of ocean and coastal ecosystems.
2. Understand, from a scientific perspective, anthropogenic pressures on ocean and 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%
Caribbean Region Case Study • Presentations (10%) • Fact Sheets (10%)	20%
OGC Journal – onshore & the islands	20%

At Sea:

Lab Watch Participation	20%
OGC Journal – at Sea • Equipment Diagram (5%) • Creature Feature (5%)	10%
Oceanographic Data Reports	15%

Assignments on Shore:

Fundamentals Exam: A take-home exam, covering material from lectures, readings and discussions, will be given at the end of Week 2 on shore. Emphasis will be on application of concepts and identification of marine organisms introduced in class, not rote memorization of facts. Expect to spend approximately 4 hours on the exam.

Caribbean Region Case Study: The final weeks of the shore component will explore the four *Caribbean Reef Expedition* program themes from scientific/oceanographic perspectives through close examination of regional case studies. Formal lectures will introduce each program theme and relevant oceanographic concepts, while student-led presentations and class discussion will highlight the complex interaction of the-best-available-science with human enterprise and the unsustainable ocean policies that are often the result. Working in small teams, students will **research, present and lead discussion** of their chosen Caribbean region case study. Student presentations will provide a detailed view of each case study including relevant background material and highlight the challenges and implications arising from anthropogenic changes to coastal environments and resources of the Caribbean. Individually, each student will prepare a **two-page factsheet and resource list** that details a specific topic related to their chosen regional case study. The entire class is expected to do the required readings and engage in class discussion for each regional case study presentation.

OGC Journal onshore and the islands: Class notes, reflections, and formal responses to weekly discussion prompts, all neatly recorded and organized in a provided journal, will assess student understanding of, and engagement, with each *Caribbean Reef Expedition* theme and corresponding regional case study. Class notes include faculty lectures and student regional

case-study presentations. Reflections will include student's thoughts and consideration of each program theme based on assigned readings and their own exploration. Formal responses to discussion prompts will address potential solutions to regional problems identified in each case study. While in the U.S. Virgin Islands, we will experience firsthand our regional case studies in action through a series of discussions with local experts. These meetings will be followed by discussion prompts and reflection questions for each program theme that will be recorded in student journals.

Assignments at Sea:

Lab Watch Participation: 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 direction, 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 four weeks at sea students will progress through three phases of responsibility. In phase I students are actively learning lab skills, in phase II they 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, including at least these two entries in their journals:

- Oceanography Equipment Diagram – Choose a piece of scientific equipment of interest and write a technical summary. 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.
- Creature Feature – Choose a marine organism of interest and write a natural history summary. The selected creature must have been observed from the ship and/or collected in our nets. Each 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.

Oceanographic Data Reports: Caribbean reefs are imbedded in the global ocean and thus we must understand how the global ocean is changing in the Anthropocene. With a firm foundation in oceanography from the shore component, students will now be ready to explore the ocean as scientists. Student teams will select an oceanographic dataset of particular interest and document how this ocean characteristic has changed through time by comparing observations made during our cruise among the eastern Caribbean islands to SEA archived data collected on previous voyages. A concise written report and supporting analysis and graphics will set the oceanographic stage necessary for our interpretation of the coral reef, seagrass, and

mangrove research being conducted in the *Directed Oceanographic Research* (DOR) or *Practical Oceanographic Research* (POR) courses.

Readings:

Readings for the Foundations portion of the course will come from three texts:

Miller, C.B. 2004. Biological Oceanography. Blackwell Science, Oxford, UK.

Nybakken, J.M. and Bertness, M. 2005. Marine Biology, an Ecological Approach 6th ed. Benjamin Cummings, 592 pp.

Segar, D.A. 2013. Introduction to Ocean Sciences. Online text, http://www.reefimages.com/oceans/oceans.html

Readings for the Focal Program Themes portion of the course will be assigned from, but not limited to, the following sources:

Al-Abdulrazzak, D., and Trombulak, S. 2012. Classifying levels of protection in Marine Protected Areas. Marine Policy, 36: 576-582.

Cazenave, A. and Llovel, W. 2010. Contemporary sea level rise. Ann. Rev. Marine Science, 2: 145-173.

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

Emanuel, K., Sundararajan, R., and Williams, J. 2008. Hurricanes and global warming. Bull. Am. Met. Soc., March 2008: 347-367.

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

Law, K.L., et al. 2010. Plastic accumulation in the north Atlantic gyre. Science, 329: 1185-1188.

Mann, M.E., et al. 2009. Atlantic hurricanes and climate over the past 1500 years. Nature, 460: 880-885.

Moret-Ferguson, S., et al. 2010. The size, mass, and composition of plastic debris in the western North Atlantic. Mar. Poll. Bull., 60: 1873-1878.

Walther, G-R., et al. 2002. Ecological response to recent climate change. Nature, 416: 389-395.

Williams, R.G., and Follows, M.J. 2011. Ocean Dynamics and the Carbon Cycle. Cambridge University Press, Cambridge. 404pp.

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

Zettler, E., et al. 2013. Life in the 'plastisphere': microbial communities on plastic marine debris. Env. Sci. Tech., 47: 7137-7146.

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? (It's okay to use a biased source as long as you incorporate it knowingly and transparently into your own work.) Keep track of good sources that might be useful for subsequent assignments, and annotate in your bibliography any sites you cite. 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!

Course Calendar:

Topic	Readings/Assignments Due
Week 1 (8 hours) – on shore at SEA campus in Woods Hole	

Introduction to *Caribbean Reef Expedition* program and *The Ocean and Global Change (OGC)*; Overview of Course Goals & Assignments
 	
Lecture/Discussion Topics:
• Oceanographic Patterns of our Cruise Track; The Caribbean Landscape (with *MEH*)
• Foundations of Chemical & Physical Oceanography
  o Salinity, Temperature, Density
  o Heat Budget, Atmospheric Circulation
  o Ocean Surface Circulation
 	
MBL/WHOI Library and Woods Hole tour
	Readings:
	Segar, selected chapters
	Miller, selected chapters
	Cruise Prospectus
	SSV *Corwith Cramer* virtual tour
	
	Select Caribbean Region Case Study Topic

Week 2 (6 hours) – on shore at SEA campus in Woods Hole	
Lecture/Discussion Topics: • Foundations of Physical Oceanography (continued) o Thermohaline Circulation • Foundations of Biological Oceanography	***Readings:*** Segar, selected chapters Miller, selected chapters Nybakken & Bertness, selected

○ Nutrients and Light in the Ocean ○ Primary Production – phytoplankton ○ Secondary Production – microbes & zooplankton ○ From Nekton to Fisheries – open ocean ecology ○ Trophic Cascades; Shifting Baselines ○ Marine Biological Classification Explain Lab set-up and Take Home Exam	chapters ***Take-home Fundamentals Exam***
Week 3 (5 hours) – on shore at SEA campus in Woods Hole	
Marine Pollution Topics: Eutrophication, marine debris, ocean soundscape Caribbean Region Case Study Presentations: • *Environmental Justice* – Eutrophication, Coastal Pollution and Tourism	***Readings:*** Segar, selected readings Law et al. (2010) Moret-Ferguson et al. (2010) Zettler et al. (2013) Other discussion readings TBD ***Case Study Discussion Questions due in journals***
Week 4 (5 hours) – on shore at SEA campus in Woods Hole	
Fisheries Topics: Fisheries Ecology; Stock v. Production, Maximum Sustainable Yield, Global and Regional Fisheries Trends; Ecological Responses Caribbean Region Case Study Presentations: • *Economic Equity* – Fisheries and Ocean Resource Extraction	***Readings:*** Segar, selected readings Nybakken & Bertness, selected readings Hollowed et al. (2013) Worm et al. (2009) Other discussion readings TBD ***Case Study Discussion Questions due in journals***
Week 5 (5 hours) – on shore at SEA campus in Woods Hole	
Protecting the Marine Environment Topics: Single vs. Multi-species vs. Marine Area protection - Motivation, Science and Implementation Caribbean Region Case Study Presentations: • *Geographic Identity* - Iconic Species and the Science of Marine Protected Areas	***Readings:*** Al-Abdulrazzah et al. (2012) Other discussion readings TBD ***Case Study Discussion Questions due in journals***

Week 6 (6 hours) – on shore at SEA campus in Woods Hole	
Topic: Climate Change/Warming Oceans/Ecological Responses Caribbean Region Case Study Presentations: • *The Anthropocene* – Climate Change and the Role of Science in Policy-making Cruise Research Plan/Briefing (with *MEH*)	***Readings:*** Cazenave and Llovel (2010) Doney et al. (2012) Emanuel et al. (2008) Mann et al. (2009) Walther et al. (2002) Other discussion readings TBD ***Case Study Discussion Questions due in journals***
Week 7 (4 hours) – at field station in the U.S. Virgin Islands	
Visiting Speakers with Discussion: Virgin Islands Environmental Resource Station (VIERS), National Park Service (NPS), U.S. Geological Survey, University of the Virgin Islands, etc.	***Discussion questions due in journals***
Week 8 (4 hours) – at field station in the U.S. Virgin Islands	
Visiting Speakers with Discussion: U.S. Fish and Wildlife, St. Croix Environmental Association, The Nature Conservancy, dive/tour operators, etc.	***Discussion questions due in journals***
Week 9 (10 hours) – at sea	
Introduction to the Lab and Safety Protocols Science Lab Watch – Begin Data Collection	Phase I responsibilities (learn the skills)
Week 10 (10 hours) – at sea	
Science Lab Watch – Continued Data Collection	Phase I responsibilities continue ***Equipment Diagram in journal***
Week 11 (10 hours) – at sea	
Science Lab Watch – Continued Data Collection	Phase II responsibilities (apply the skills) ***Creature Feature in journal***
Week 12 (10 hours) – at sea	
Ship Mission Work	Phase III responsibilities (lead Lab Watch) ***Oceanography Reports due***