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 & Maritime Studies/Ocean Policy Faculty

Locations: On shore in San Diego, CA, and aboard a SEA sailing school vessel at sea.

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

Course Philosophy and Approach:

The ocean ecosystem is undergoing rapid change caused by anthropogenic pressures spanning a range of scales. Warming, acidification, fisheries depletion, and pollution are but a few examples of the pressures impacting distribution, diversity and abundance of marine organisms. This course examines the condition of the Anthropocene ocean with emphasis on observed pressures and ecological responses.

We will begin by setting the necessary foundation with a review of the principles underlying ocean circulation, seawater chemistry, nutrient dynamics, and biological production. We will then proceed to examine the leading challenges to the marine ecosystems, on both regional and global scales. 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 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 changing marine ecosystems through adaptation and/or mitigation? Students will examine these challenges as they specifically relate to the nearshore region off the U.S. West Coast and in the North Pacific Gyre, gather oceanographic data for assessment of regional ocean health, and explore approaches for addressing management issues there.

The first two weeks of *The Ocean and Global Change* course are held onshore in San Diego, CA. This is followed by six weeks at sea aboard a SEA sail training vessel, where students embark as active members of the crew. This course consists of ~20 hours lecture/discussion sessions, 1

exam based on 'fundamentals' lectures, 4 global ocean case studies presented by students, 1 lab practical exam, and at least 45 hours of mentored laboratory watch participation (active learning/laboratory) during ~40 underway days at sea.

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%
OGC Journal Onshore	5%
Ocean Change Project – Part I	5%
At Sea	
Lab Practical Skills	10%
Watch Participation	20%
Anthropocene-Ocean Theme Presentations	15%
Presentations (10%)	
Discussion Questions (5%)	
OGC Journal at Sea	20%
OGC Themes (5%)	
Equipment Diagram (5%)	
Data Discussions (5%)	
Creature Feature (5%)	
Ocean Change Project – Part II	10%

Assignments Onshore:

Fundamentals Exam

An exam, covering material from lectures, readings and discussions, will be given at the end of the shore component. Emphasis will be on application of concepts introduced in class, not rote memorization of facts. This fundamentals exam is worth 15% of the 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. 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 5% of the 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 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 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.

Anthropocene-Ocean Presentations

Beginning during the shore component and continuing at sea, we will examine the ocean themes of warming, acidification, pollution, and overfishing, through a close examination of regional and global case studies. Themes will be assigned to student teams at the beginning of the program, and each team will research that theme during the shore component in the context of ocean parameters off California and the regional North Pacific. They will present this information at sea, providing the entire class a detailed view of the challenges and implications

arising from anthropogenic changes to regional marine environments and resources. 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. 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 course grade.

OGC Journal at Sea

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

- 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 global theme, with students reflecting on each theme based on assigned readings and their own exploration. These responses are worth 5% of the course grade.
- 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 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 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 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 Global Ocean Themes portion of the course will be assigned from, but not limited to, the following sources.

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.

Byrne, R.H., et al. 2009. Direct observations of basin-wide acidification of the North Pacific Ocean. Geophys. Res. Lett. 37: L02601.

Cazenave, A. and W. Llovel. 2010. Contemporary Sea Level Rise. Ann. Rev. Mar. Sci. 2:145-173.

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

Doney, S.C. 2006. The dangers of ocean acidification. Sci. Am. March: 58-65.

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.

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

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., et al. 2010. Plastic accumulation in the North Atlantic gyre. Science, 329: 1185-1188.

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

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

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

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

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

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.

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

Course Calendar:

Topic	Readings/Assignments Due
Week 1 Ocean Essentials (10 hours) – on shore in San Diego, CA	

Introduction to *The Ocean and Global Change (OGC)*; Overview of Course Goals & Assignments
 	
Lecture/Discussion Topics:
• Introduction to Oceanography
• Foundations of Chemical & Physical Oceanography
  ○ Salinity, Temperature, Density
  ○ Heat Budget, Atmospheric Circulation
  ○ Ocean Surface Circulation
  ○ Thermohaline Circulation
 	
Research Anthropocene-Ocean Themes
	Readings:
	Segar, selected chapters
	
	Watch:
	Surface Currents, NASA
	Deep Water Currents, NASA

Week 2 Ocean Essentials (10 hours) – on shore in San Diego, CA	

Lecture/Discussion Topics:
• Foundations of Biological Oceanography
  ○ Nutrients and Light in the Ocean
  ○ Stock v. Productivity
  ○ Primary Production – phytoplankton
  ○ Secondary Production – microbes & zooplankton
  ○ Global Carbon Budget & Cycle
  ○ Marine Ecosystems & Food Webs
• Science Along *SEA Summer Session* Cruise Track/Cruise Research Plan & Briefing
 	
Research Anthropocene-Ocean Themes, continued
 	
Fundamentals Exam
	Readings:
	Segar, selected chapters
	Nybakken, selected chapters
	Cruise Prospectus
	SSV *RC Seamans* virtual tour
	
	Watch:
	Whalefall Animation
	
	Due: *Ocean Change Project Introduction & Bibliography*
	Due: *Journal entries based on assigned topics*

Weeks 3 & 4 (20 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 Week 3 Theme: Warming • Thermal expansion v. Melt • Trends – Regional & Global • Ecological Responses • Warming and Catastrophic Storms Week 4 Theme: Acidification • Carbonate Chemistry of Seawater • Trends • Ecological Responses • Carbon Sequestration	***Week 3 Readings:*** Boyd et al., 2011 Cazenave and Llovel, 2010 Doney et al., 2012 Emanuel et al., 2008 Mann et al., 2009 NRC, 2012 Walther et al., 2002 ***Week 4 Readings:*** Byrne et al., 2009 Doney 2006 Doney et al., 2009 Kroeker et al., 2013 **On-watch evaluation** ***Due:*** *Equipment diagram and Theme Discussion & Data Discussion responses in journal*
Weeks 5 & 6 (20 hours) – at sea	
Training Phase II: Skill Development • Increased Responsibility for Lab Routines • Data analysis techniques Continue collecting scientific data Lab Practical Exam Week 5 Theme: Pollution • Status of marine debris research • Trends • Ecological Responses Week 6 Theme: Overfishing • State of our Fisheries (Regional & Global) • Trends • Ecological Responses • Fisheries Governance	***Week 5 Readings:*** Eriksen et al., 2014 Ivar do Sul & Costa, 2014 Jambeck et al., 2015 Law et al., 2010 Law and Thompson, 2014 Law, 2017 Zettler et al., 2013 ***Week 6 Readings:*** Branch et al., 2010 Hollowed et al., 2013 Jackson et al., 2001 Worm et al., 2006 Worm et al., 2009 **On-watch evaluation**

	Due: *Theme Discussion & Data Discussion responses in journal*
Weeks 7 and 8 (20 hours) – at sea	
Training Phase III: Leading the Science Watch • Apprentice Lab Manager Continue collecting scientific data Data analysis/mentoring sessions Multi-Watch Mission/Exercise	**On-watch evaluation** ***Due:*** *Creature Feature and Data Discussion responses in journal.* ***Due:*** *Ocean Change Project Reports*