Bios 4417/6417 Syllabus

**[Marine Ecology, 3 Credits]**

**[Tu Th, 0930-1045h, Cherry Emerson 320 – safe Covid-seating = 17 students]**

**Instructor Information**

|  |  |  |
| --- | --- | --- |
| Instructor | Email | Office Hours & Location |
| Mark Hay | mark.hay@biology.gatech.edu | EST 2102, 1300-1400h, Wed; and by appointment |

**General Information**

**Description**

Compared to terrestrial systems, marine ecosystems are larger, older, have a huge impact on global climate and biogeochemical cycles, and support nearly twice as many phyla of animals as do terrestrial systems. This course provides an overview of the biotic interactions and physical forces structuring marine communities, the function and ecosystem services provided by marine communities, and the major threats to their continued function and value.

## Pre- &/or Co-Requisites

BIOS 2335 or 2337 are pre-requisites, but in the past a number of students, primarily engineering students, with strong interests in marine biology but without these pre-requisites have petitioned me to waive the pre-requisites and have done well in the course. If you are interested, discuss your interests and background and I’ll likely make an exception.

## Course Goals and Learning Outcomes

[Goals include:

* Learn the state of modern ocean ecosystems, the ecosystem services they have traditionally provided, and the present threats to these ecosystems and services.
* Understand the complex biotic interactions that underlie marine ecosystem function and how these interactions may be leveraged to more wisely manage, conserve, and potentially restore marine communities.
* Learn the fundamentals of how good science is conducted by using strong inference and multiple working hypotheses.
* Become comfortable and proficient at reading, evaluating, and challenging the primary literature (i.e., we will not use a book, but will read and evaluate the primary literature related to each lecture topic).

**Course Requirements & Grading**

|  |  |  |
| --- | --- | --- |
| Assignment | Date | Weight (Percentage, points, etc) |
| Pop Quiz | Throughout the course | 5% |
| Exam 1 | 16 Feb | 20% |
| Exam 2 | 18 March | 20% |
| Exam 3 | 22 April | 20% |
| summary paper and presentation | Varies by student | 10% |
| Research proposal  /Career Summary | Self-scheduled, but before 2359 h on 18 April | 25% |
| Class participation/ discussion |  | 3% extra credit |

**Extra Credit Opportunities**

There will be considerable class discussion about the strengths and weaknesses of the assigned papers, major issues in the field of marine ecology, etc. At the end of the semester I’ll add 0 to 3 points to each person’s grade based on their contributions in class. Did you participate fully? Did you come with challenging questions or have insightful comments? Were you prepared by having read the paper assigned, etc.?

**Description of Graded Components**

There is no book for the class. We will read primary literature papers (i.e., real science or scientific summaries of real experiments or topics). Lectures and discussions will cover aspects of the papers, but will be broader in scope so as to better cover the general concepts and studies that the assigned papers represent one aspect of. YOU NEED TO BE IN CLASS AND TO TAKE NOTES – NOT ALL INFORMATION WILL BE IN THE READINGS OR ON THE POWERPOINTS. I’ll devote some time in each class period to discussions – some of the test material will come from these discussions – if you are not in class, you won’t know of the issues raised and discussed. I do not post powerpoints before the lecture. I will post the powerpoints before a test.

**Three tests:**

Tests will consist of a mix of multiple choice and short answer (a few sentences to a paragraph) questions mandating that you understand and be able to work with the concepts we covered. There are three exams (each covers only the material presented since the previous test). I am not reluctant to ask questions on the tests that have been addressed directly by the papers, but little, if at all, in class. I will ask questions about topics that come up in class discussions and were not in the reading or in the lecture – thus, you need to be in class. READ the assigned papers and understand them – if you don’t understand them, bring that up for discussion.

**Pop quizzes:**

I EXPECT YOU TO READ THE ASSIGNED PAPERS **BEFORE** COMING TO EACH CLASS. I will give pop quizzes designed to see if you read the papers as assigned (i.e., to punish you for not reading the papers and not being prepared to participate – there will be no make-ups for missed pop-quizzes, but you can drop ONE. Thus, don’t miss class and don’t be late). As you read the papers, make notes on what you question about them and bring that up in discussions in class. A LOT of learning occurs via these discussions. Don’t be hesitant to ask questions – If you have that question, others probably do as well.

**Short summary paper and presentation:**

You are to find, read, and summarize in no more than one page (12 pt font, single spaced, 1 inch margins all round) a primary research paper about a topic on our schedule (a good way to look for these is to look at the papers cited [in recent papers] or at papers that have cited the paper I assign [for older papers]). Find something that interests **you**. If there are special topics that interest you and that we are not covering, ask me if you can do a summary on a paper on that topic. I commonly OK these requests. Sources for good papers are *Science, Nature, PNAS, Ecology Letters, Ecology, Marine Ecology Progress Series, Oecologia, Ecological Applications, Trends in Ecology and Evolution*….). Include the following in each summary:

1) the reference for the paper,

2) a quick summary of the hypotheses, methods, and findings,

3) strengths of the study (what makes it interesting, novel, substantial and rigorous, etc.),

4) limitations of the study (are the methods suitable for the questions addressed? Do the author’s conclusions exceed the foundations of their data? etc. Explain your conclusions about these issues), and

5) a short statement on the overall value of the paper given its relative strengths and limitations.

SUBMIT THESE VIA EMAIL – PUT YOUR NAME ON THEM… somehow the need for this repeatedly escapes some.

**After turning this in and getting feedback from me, prepare a 10 minute powerpoint on this paper**. **THUS, BE SURE TO TURN YOUR SUMMARY PAPER IN SEVERAL DAYS BEFORE YOU ARE SCHEDULED TO PRESENT!** You will then present that powerpoint to the class at the end of one of the classes starting on 26 January (i.e., I’ll give you a couple of weeks to get prepared – **I’ve “volunteered” some of the graduate students to go first on this effort, so they will be the initial guinea pigs**). After the grad students, I’ve randomly assigned the rest of you to presentation dates. If a scheduled date is problematic for you, trade with someone and let me know of that. I’ll then change it on the schedule.

**Larger research paper:**

**There are two options for undergraduates – only one for grad students – see below.**

Option 1 for undergrads and the only option for grad students:

During the course, we will repeatedly discuss issues of experimental design, rigor, confounding factors in experiments, ways to control for, or lessen the influence of these, etc. By mid-way through the course, I expect you to have a good idea of how to pose and answer a novel question, how to conduct an experiment, how to be sure of appropriate controls, etc. Thus, this final assignment is for you to write a short proposal proposing an experiment in marine ecology. You need to include: a title, a short abstract of the question, an introduction providing background and justifying the importance of the question, and finally, a detailed experimental design on how you will address the question posed. The paper can be no more than 5 pages (10 pages for graduate students) single spaced (12 point font, 1 inch margins, - literature cited does not count in the 5 pages). You will be graded on the depth and understanding you show of the topic, of experimental design, and on the novelty and importance of the question you ask. As you progress through the semester reading papers, be on the look-out for what you see as unanswered questions you have after reading some of your favorite papers – these make good topics for a proposal. In numerous cases, students have used this proposal as a first draft for their M.S. or Ph.D. research. For those of you considering grad school, view this as an opportunity that may provide more than simply a grade in this class.   
Option 2 for Undergrads:

Instead of the above research proposal, you can overview the career publications of a productive/prominent marine ecologist and produce a 5-page paper (format limitations as described above): i) summarizing the main contributions of that scientist (i.e., of their many publications, what are their most impactful findings, how did they demonstrate those, why are these findings so impactful, etc.?) and ii) providing a quick summary of what “should be addressed next” given the new findings that this scientist has produced. In general, I’m expecting item (i) to take 4 - 4.5 pages and item (ii) to take 0.5 - 1.0 page of your text. To find prominent scientists to consider, you can search google scholar using “label:marine\_ecology” and select any of the first 100 listed scientists. However, not all excellent marine scientists have set-up a google scholar page and some exceptional scientists are younger and don’t yet have the “mileage” to make it into that top 100, so you can also choose someone from the list of assigned or suggested readings for this course or others you know of or see interesting readings from – however, you will have to OK that selection with me before selecting that person (I can also provide a list of others that will be fine, or that cover a topic you find especially interesting). I’m expecting that a good job on this option will require scanning over most of the abstracts produced by that author and then fully reading and interpreting the 10-15 most prominent or most interrelated papers for which that author is primarily responsible. Realize that being the 1st author on a paper indicates primary responsibility for the study, BUT also being the last author (or corresponding author) indicates a primary responsibility (i.e., among more established scientists, graduate students and post-docs are often first authors, but doing work initiated and supported by the last or corresponding author).

YOU CAN SELF-SCHEDULE THIS EFFORT AND TURN IT IN ANY TIME BEFORE APRIL 18.

**Job Opportunities, Summer courses, etc.** - Some of you will be interested in summer jobs involving marine ecology, summer classes, going on to grad-school, etc. Information I get regarding these will be sent to you via email, or possibly announced in class. Doing well, preferably very well, in this class enhances my ability to promote you for such opportunities. I also may hire assistants for the summer, and I work in Fiji, the Solomon Islands, French Polynesia (Tahiti, Moorea), etc. so…..

**Grading Scale**

I grade rigorously and expect you to do well. Your final grade will be assigned as a letter grade according to **roughly** the following scale. However, given that I’m a rigorous grader, it is not uncommon for there to be few students with 90%+ grades. **I curve the grades and it is not unusual for 86%+ to be in the A group.** As we progress through the tests, I’ll show you the class distribution on each and you can see your placement within the class distribution

A 90-100%

B 80-89%

C 70-79%

D 60-69%

F 0-59%

**Course Materials**

**Course Text**

We will read the primary literature (i.e., real scientific papers) for each lecture. There is no textbook. Papers for each lecture are listed below and will be available on Canvas or the equivalent (Tech periodically changes this, but you will know by the time class starts).

## Additional Materials/Resources

## If you are interested in specific topics within marine ecology and want additional information, discuss this with me and I can lead you to specific texts or suggest searches focused on especially impactful researchers, etc.

## Course Website and Other Classroom Management Tools

Readings, schedules, etc. will be posted on Canvas (or the equivalent)

**Course Expectations & Guidelines**

## Academic Integrity

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit http://www.catalog.gatech.edu/policies/honor-code/ or <http://www.catalog.gatech.edu/rules/18/>.

Any student suspected of cheating or plagiarizing on a quiz, exam, or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.

## Accommodations for Students with Disabilities

If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at (404)894-2563 or <http://disabilityservices.gatech.edu/>, as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter. See me or e-mail me to discuss your learning needs and we will find a way that is fair and works.

## Attendance and/or Participation

## Lectures and discussions will cover aspects of the papers, but will be broader in scope so as to better cover the general concepts and studies that the assigned papers represent one aspect of. YOU NEED TO BE IN CLASS AND TO TAKE NOTES – NOT ALL INFORMATION WILL BE IN THE READINGS OR ON THE POWERPOINTS. I’ll devote some time in each class period to discussions – some of the test material will come from these discussions – if you are not in class, you won’t know of the issues raised and discussed.

## Collaboration & Group Work

## Science is often a collaborative, interactive effort. During discussions in and out of class it is fine to share ideas, build and learn based on group discussions and interactions, etc. but for your presentation, research proposal, tests, etc. I expect all work to be your independent effort.

## Extensions, Late Assignments, & Re-Scheduled/Missed Exams

If you have an excused absence for missing an exam, I’ll give you a make-up exam, but it may be oral instead of written, may be a research paper on topics covered instead of a standard test, etc. Your proposal and presentation can be self-scheduled (but I’ll “help” with this if I don’t see you doing so). I expect all of these to be done on time. If you are late with assignments, come discuss this with me. If you have a very good reason (you were hospitalized, etc.), we will work out a way to give you additional time. If your reason for being late is less persuasive, I’ll deduct 5% of that grade’s value for each day it continues to be late.

## Student-Faculty Expectations Agreement

At Georgia Tech we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. See <http://www.catalog.gatech.edu/rules/22/> for an articulation of some basic expectation that you can have of me and that I have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, I encourage you to remain committed to the ideals of Georgia Tech while in this class.

## Student Use of Mobile Devices in the Classroom

No mobile phone use. You can use your computer for notes, for looking at the specifics of the papers we are discussing, etc, but usage needs to be for academic activities.

**Campus Resources for Students**

Georgia Tech has a range of services to help support your mental, emotional, and physical well-being. Click [here](http://ctl.gatech.edu/sites/default/files/documents/campus_resources_students.pdf) for a list of these relevant campus resources.

**Course Schedule**

**Schedule of Topics and Readings**

**A note on visiting lecturers**: Pre-covid, I usually left a couple of lecture slots open to take advantage of prominent marine ecologists that might visit my lab during the semester and that I could get to speak to the class. Given covid-related travel restrictions, and also that everyone is now used to virtual presentations, I realized that instead of relying on random “drop-ins,” I could just invite some of those I consider the-best-of-the-best. Thus, you will see three guest lectures listed below. These are three of the world’s most prominent marine ecologists, doing some of the most exciting work, and were also selected due to being excellent speakers and excellent humans in general (i.e., scientists that you would like to know). A rare advantage of covid is that we can allow these scientists to visit us from their homes. Visitors will be Professors i) Robert (Bob) Steneck from the U. of Maine discussing kelp bed ecology, ii) James (Jim) Estes from UC Santa Cruz discussing sea otters as keystone species, and iii) Doug McCauley from UC Santa Barbara discussing global-scale losses of marine vs terrestrial species.

**THE STATE OF, AND STRESSES ON, MARINE ECOSYSTEMS**

**January:**

**14** - **Introduction to the course – This is about marine ecology, but also about SCIENCE** –Read the one-page essay I posted and get comfortable with asking “stupid” questions. If we don’t ask these questions, we stay stupid – so speak up; doing so also will help those around you, and the “stupid” questions are often some of the most critical ones….

**What is “Science”?**

**Why MARINE Ecology**?

**The value of discussion instead of just lectures**: (real science is questioning/discussion/testing hypotheses – not defending them. Science is not listening, remembering, and taking tests – it is instead a “way of knowing” that allows you to find new truths)

**GLOBAL CHANGE AND OTHER LARGE-SCALE STRESSORS AND PROCESSES**

**19 - Overview of the ecological state of the ocean**

READ – Jackson JBC. 2008. Ecological extinction and evolution in a brave new ocean. Proceedings of the National Academy of Sciences. 105: 11458-11465.

**21 - Multiple working hypotheses, Strong Inference, and Pseudoreplication: A general discussion of experimental basics** – **controls, replicates, interspersion (i.e., what are the mechanics of a “good” experiment?)**

READ – Chamberlin, T.C. 1965. The method of multiple working hypotheses. *Science* 148: 754-759.

**SUGGESTED ONLY- THIS ONE IS LONG – HOWEVER, GRAD STUDENTS SHOULD READ IT -** Hurlbert, S.H. 1984. Pseudoreplication and the design of ecological field experiments. *Ecological Monographs* 54:187-211.

**26 - Animal movement, behavior, and the surprising “connectedness” of separated ecosystems – Rats and coral reefs, fish in the forest, mid-western farmers killing-off Gulf of Mexico fisheries, and the whale-pump of deep nutrients to shallow seas.**

Read – Graham et al. 2018. Seabirds enhance coral reef productivity and functioning in the absence of invasive rats. Nature 559: 250-253.

and

Roman J, et al. 2014. Whales as marine ecosystem engineers. *Front Ecol Environ* 12:377-385.

Presenters: 1) Noam Altman-Kurosaki 2) Nolan Barrett

Optional Reading if you choose to add some:

Polis, G. A., Anderson, W. B. & Holt, R. D. 1997. Toward an integration of landscape and food web ecology: the dynamics of spatially subsidized food webs. Annu. Rev. Ecol. Syst. 28, 289–316

Young, H. S., McCauley, D. J., Dunbar, R. B. & Dirzo, R. 2010. Plants cause ecosystem nutrient depletion via the interruption of bird-derived spatial subsidies. Proceedings of the National Academy of Sciences 107, 2072–2077

Hocking, M. D. & Reynolds, J. D. 2011. Impacts of salmon on riparian plant diversity. Science 331, 1609–1612

McCauley, D. J. et al. 2012. From wing to wing: the persistence of long ecological

interaction chains in less-disturbed ecosystems. Sci. Rep. 2, 409.

**28 - Climate change, global warming, and effects on marine systems**

READ - Hugues et al. 2018. Spatial and temporal patterns of mass bleaching of corals in the Anthropocene. Science 359: 80-83.

and

Hughes et al. 2018. Global warming transforms coral reef assemblages. Nature 556: 492-496

Presenters: 1) Cameron Perry 2) Sarah Roney

Optional Reading if you choose to add some:

Hoegh-Guldberg, O and JF Bruno 2010. The impact of climate change on the world’s marine ecosystems. *Science* 328: 1523-1528

Hughes et al. 2017. Global warming and recurrent mass bleaching of corals. Nature 543: 373-377.

Chase TJ, Pratchett MS, Frank GE, Hoogenboom MO (2018) Coral-dwelling fish moderate bleaching susceptibility of coral hosts. PLoS ONE 13(12): e0208545. https://doi.org/ 10.1371/journal.pone.0208545

**February:**

**2 - Tropicalization of marine communities**

READ – Vergés et al. 2014. The tropicalization of temperate marine ecosystems: Climate- mediated changes in herbivory cause community phase shifts. Proceedings of the Royal Society B 281: 20140846. <http://dx.doi.org/10.1098/rspb.2014.0846>

Presenters: 1) Virginia Pan 2) Andrew Sharkey

Optional Reading if you choose to add some:

Verges et al. 2016. Long-term empirical evidence of ocean warming leading to tropicalization of fish communities, increased herbivory and loss of kelp. Proceedings of the National Academy of Sciences 113: 13791–13796

Pacl et al. 2017. Biodiversity redistribution under climate change: impacts on ecosystems and human well-being. Science 355: eaai9214 (2017)

**4 - Ocean acidification: effects on marine ecosystems**

READ – Kroeker et al. 2010. Meta-analysis reveals negative yet variable effects

of ocean acidification on marine organisms. Ecology Letters, (2010) 13: 1419–1434 doi: 10.1111/j.1461-0248.2010.01518.x

Presenters: 1) Gabriella Chebli 2) Mary Mulcahy

Optional Reading if you choose to add some:

Kroeker KJ, et al. 2013. Impacts of ocean acidification on marine organisms: quantifying sensitivities and interaction with warming. *Global Change Biology* 19: 1884 – 1896, doi: 10.1111/gcb.12179

Nagelkerken and Munday 2016. Animal behaviour shapes the ecological effects of ocean acidification and warming: moving from individual to community-level responses. Global Change Biology (2016) 22, 974–989, doi: 10.1111/gcb.13167

Barner et al. 2018. Generality in multispecies responses to ocean acidification revealed through multiple hypothesis testing. Glob Change Biol. 2018;24:4464– 4477.

**9**  **- Effects of Disease on the structure and function of marine communities**:

READ Harvell et al. 2019. Disease epidemic and a marine heat wave are associated with the continental-scale collapse of a pivotal predator (*Pycnopodia helianthoides*). Science Advances 5 (1):eaau7042

Presenters: 1) available 2) Shannon Salter

Optional Reading if you choose to add some:

Harvell et al. 2002. Ecology- climate warming and disease risks for terrestrial and marine biota. Science 296: 2158-2162.

Keesing et al. 2010. Impacts of biodiversity on the emergence and transmission of infectious diseases. Nature 468: 647-652.

Lafferty et al. 2015. Infectious diseases affect marine fisheries and aquaculture economics. Annu Rev Mar Sci 7: 471-496.

Lessios HA. 2016. The great *Diadema antillarum* die-off: 30 years later. Annu Rev Mar Sci 8: 267-283.

Lamb et al. 2017. Seagrass ecosystems reduce exposure to bacterial pathogens of humans, fishes, and invertebrates. Science. 355: 731-733.

Lamb et al. 2018. Plastic waste associated with disease on coral reefs. Science 359: 460-462.

**11 Effects of fishing on marine ecosystems**:

READ – Erlandson JM and Ricks TC. 2010. Archeology meets marine ecology: the antiquity of maritime cultures and human impacts on marine fisheries and ecosystems. *Annual Review of Marine Science* 2: 231-251.

Presenters: 1) Michael Southard 2) available

Optional Reading if you choose to add some:

Conover DO, Munch SB. 2002. Sustaining fisheries yields over evolutionary time scales. Science 297: 94-96

Clark et al. 2017. Rising temperatures may drive fishing-induced selection of low- performance phenotypes. Scientific Reports | 7:40571 | DOI: 10.1038/srep40571

Silliman et al. 2018. Are the ghosts of nature's past haunting ecology today? Current Biology 28: R533-R536.

**16 -- EXAM #1**

**PROCESSES STRUCTURING MARINE COMMUNITIES**

**18**  - **GUEST LECTURE – Professor Robert Steneck (University of Maine) Ecosystem flips, locks, and feedbacks: the lasting effects of fisheries on Maine’s kelp forest ecosystem**.

READ – Steneck RS et al. 2013. Ecosystem flips, locks, and feedbacks: the lasting effects of fisheries on Maine’s kelp forest ecosystem. Bull Mar Sci 89: http://dx.doi.org/10.5343/bms.2011.1148

Optional Reading if you choose to add some:

Dayton PK. 1985. Ecology of kelp communities. Annu Rev Ecol Evol 16: 215-245.

Steneck RS, et al. 2002. Kelp forest ecosystems: biodiversity, stability, resilience and future. Environmental Conservation 29: 436–459.

Steneck RS and Johnson CR. 2013. Kelp forests: Dynamic patterns, processes, and feedbacks. Pages 315-336, In: Bertness M, Bruno J, Silliman B, and Stachowicz J (Editors) Marine Community Ecology and Conservation. Sinhauser Associates of Oxford University Press.

Do a Google Scholar search or a Web-of-Science search on “Steneck RS” – you will find a LOT of wonderful papers that are excellent options.

**23 - Disturbance, succession, and the maintenance of diversity**

READ – Sousa WP. 1979. Disturbance in marine intertidal boulder fields – the non-equilibrium maintenance of species diversity. Ecology 60: 1225-1239

Presenters: 1) Huy Tran 2) available

Optional Reading if you choose to add some:

Sousa WP. 1984. The role of disturbance in natural communities. Annu Rev of Ecol Syst 15: 353-391.

Stachowicz JJ. 2001. Mutualism, facilitation and the structure of ecological communities. BioScience 51:235-246.

Wernberg T et al. 2011. Impacts of climate change in a global hotspot for temperate marine biodiversity and ocean warming. J Exp Mar Biol Ecol 400: (special Issue) 7-16

Menge BA, Menge DNL. 2013. Dynamics of coastal meta-ecosystems: the intermittent upwelling hypothesis and a test in rocky intertidal regions. Ecol Monogr 83: 283-310

**25** - **Top-down versus bottom-up effects on marine communities**

READ Burkepile, DE and Hay ME. 2006. Herbivore versus nutrient control of marine primary producers: Context-dependent effects. **Ecology** 87: 3128-3139.

Presenters: 1) Jordan Baxter 2) Henry Crossley

Optional Reading if you choose to add some:

Casini et al. 2009. Trophic cascades promote threshold-like shifts in pelagic marine ecosystems. Proceedings of the National Academy of Sciences 106: 197–202

Holbrook et al. 2016. Coral reef resilience, tipping points, and the strength of herbivory. Scientific Reports 6: 10.1038/srep35817

He, Q, Silliman BR. 2016. Consumer control as a common driver of coastal vegetation worldwide. Ecol Monogr 86: 278-294

Zaneveld et al. 2016. Overfishing and nutrient pollution interact with temperature to disrupt coral reefs down to microbial scales. Nat Comm 7: 10.1038/ncomms11833

Allgeier et al. 2017. Animal pee in the sea: consumer-mediated nutrient dynamics in the world's changing oceans. Global Change Biology 23: 2166-2178.

Campbell et al. 2018. Herbivore community determines the magnitude and mechanism of nutrient effects on subtropical and tropical seagrasses. J Ecol 106: 401-412.

**March:**

**2 - Keystone consumers, trophic cascades, and multiple stable states(?)**

READ – Myers RA, et al. 2007. Cascading effects of the loss of apex predatory sharks from a coastal ocean. *Science* 315:1846-1850.

**AND**

Springer AM, et al. 2003. Sequential megafaunal collapse in the North Pacific Ocean: an ongoing legacy of industrial whaling? *Proceedings of the National Academy of Sciences* 100: 12223-12228.

Presenters: 1) Sara Delawalla 2) Tempel Dingman

Optional Reading if you choose to add some:

Jackson JBC, et al. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293: 629-638.

Frank KT, et al. 2005. Trophic cascades in a formerly cod-dominated ecosystem. Science 308: 1621-1623.

Heithaus MR, et al. 2008. Predicting ecological consequences of marine top predator declines. Trends in Ecology and Evolution 23: 202-210.

Casini M, et al. 2009. Trophic cascades promote threshold-like shifts in pelagic marine ecosystems. PNAS 106: 197-202.

Schmitz O. et al. 2018. Animals and the zoogeochemistry of the carbon cycle. Science 362: 1127- (eaar3213 (2018)

Haggerty MB, et al. 2018. Fish predators reduce kelp frond loss via a trait-mediated trophic cascade. Ecology 99: 1574-1583.

Kolla J, et al. 2018. Novel crab predator causes marine ecosystem shift. Scientific Reports 8: Article Number: 4956

**4 - Consumer-Prey interactions I (Effects of consumers on prey and community structure)**

READ – Estes JA et al. 2011. Trophic downgrading of planet Earth. *Science* 333: 301-306.

Presenters: 1) Audrey Dods 2) James Madigan

Optional Reading if you choose to add some:

Paine RT. 1966. Food web complexity and species diversity. American Naturalist 100: 65- 75.

Estes JA, et al. 1998. Killer whale predation on sea otters: linking oceanic and nearshore ecosystems. Science 282: 473-476.

Estes JA, Burdin A, Doak DF. 2016. Sea otters, kelp forests, and the extinction of Stellar's sea cow. Proceedings of the National Academy of Sciences 113: 880-885.

Rasher DB, Hoey AS, Hay ME. 2017. Cascading predator effects in a Fijian coral reef ecosystem. Scientific Reports 7:15684 DOI:10.1038/s41598-017-15679-w

Longo GO, Hay ME, Ferreira CLO, Floeter SR. 2018. Trophic interactions across 61 degrees of latitude in the Western Atlantic. Global Ecology and Biogeographyhttps://doi.org/10.1111/geb.12806

**9 - Consumer-Prey interactions II (Prey defenses – escape, deter, tolerate)**

READ – Duffy, J.E. and M.E. Hay. 2001. Ecology and evolution of marine consumer-prey interactions.  Pages 131-157, In Bertness, M, M.E. Hay and S.D. Gaines (eds.) Marine CommErik

Presenters: 1) Erik Heitshusen 2) Sanaya Kriplini

Optional Reading if you choose to add some:

Lubchenco J, Gaines SD. 1981. A unified approach to marine plant-herbivore interactions. 1. Populations and communities. Annual Review of Ecology and Systematics 12: 405-437.

Hay ME. 2009. Marine chemical ecology: Chemical signals and cues structure marine populations, communities, and ecosystems. Annual Review of Marine Sciences 1: 193-212.

Rasher DB, Stout EP, Engel S, Shearer TL, Kubanek J, Hay ME. 2015. Marine and terrestrial herbivores display convergent chemical ecology despite 400 million years of independent evolution. Proceedings of the National Academy of Sciences 112:12110-12115

Steneck RS, Bellwood DR, Hay ME. 2017. Herbivory in the marine realm: shaping ecosystems and colliding with the Anthropocene. Current Biology 27: R484-489

**11 - GUEST LECTURE – Prof James (Jim) Estes (UC Santa Cruz) – Historical ecology of sea otters and kelp forests in the Aleutian archipelago.**

READ: Rasher DB, et al. 2020. Keystone predators govern the pathway and pace of climate impacts in a subarctic marine ecosystem. **Science** 369: 1351-1354.

Optional Reading if you choose to add some:

Do a Google Scholar search or a Web-of-Science search on “Estes JA” – you will find a LOT of wonderful papers that are excellent options.

**16 - HOLIDAY!!**

**18 – Exam #2**

**23 - Competition: A general overview**

READ: Connell JH. 1978. Diversity in tropical rainforests and coral reefs - high diversity of trees and corals is maintained only in a non-equilibrium state. Science 199: 1302-1310.

Presenters: 1) Erin McCaskey 2) Kristie Yoo

Optional Reading if you choose to add some:

Buss LW and Jackson JBC. 1979. Competitive networks - non-transitive competitive relationships in cryptic coral reef environments. American Naturalist 113:223-234.

Grosberg RK. 1981. Competitive ability influences habitat choice in marine invertebrates. Nature 290: 700-702.

Burkepile, DE, JD Parker, CB Woodson, HJ Mills, J Kubanek, PA Sobecky, and ME Hay. 2006. Chemically-mediated competition between microbes and animals: microbes as consumers in food webs. *Ecology* 87:2821-2831

Rasher DB and ME Hay. 2010. Chemically rich seaweeds poison corals when not controlled by herbivores. Proceedings of the National Academy of Sciences. 107: 9683-9688.

Easson CG, et al. 2014. Complex ecological associations: competition and facilitation in a sponge-algal interaction. Marine Ecology Progress Series 507:153-167.

Elliott J, et al. 2016. How does the proliferation of the coral-killing sponge *Terpios hoshinota* affect benthic community structure on coral reefs? Coral Reefs 35: 1083-1095.

Bell, JJ, et al. 2018. Climate change alterations to ecosystem dominance: how might sponge dominated reefs function? Ecology 99:1920-1931

Chaves-Fonnegra, A, et al. 2018. Bleaching events regulate shifts from corals to excavating sponges in algal-dominated reefs. Global Climate Change 24:773-785.

**25 - Facilitation, positive interactions and the limitations of species-by-species interactions instead of imbedding these in the natural complexity of communities.**

READ – Bruno JF, Stachowicz JJ, and Bertness MD. 2003. Inclusion of facilitation into ecological theory. *Trends in Ecology and Evolution* 18: 119-125

Presenters: 1) Sungwon Park 2) Anais Paterno

Optional Reading if you choose to add some:

Hay, M. E. 1986. Associational plant defenses and the maintenance of species diversity: turning competitors into accomplices. AmericanNaturalist 128: 617-641.

Gil-Turnes, M. S., M. E. Hay, and W. Fenical. 1989. Symbiotic marine bacteria chemically defend crustacean embryos from a pathogenic fungus. Science 246:116-118.

He Q, Bertness MD. Altieri AH. 2013. Global shifts towards positive species interactions with increasing environmental stress. Ecology Letters 16: 695-706.

He Q, Bertness MD. 2014. Extreme stresses, niches, and positive species interactions along stress gradients. Ecology 95: 1437-1443.

Crotty SM, Bertness MD. 2015. Positive interactions expand habitat use and the realized niches of sympatric species. Ecology 96:2575-2582.

Clements CS and Hay ME. 2019 Biodiversity enhances coral growth, survivorship, and resistance to competitors. Nature Ecology and Evolution **10.1038/s41559-018-0752-7**

**30 - Mutualism, specialization, and what drives such relationships.**

READ - Feeney WE, et al. 2018. Predation drives recurrent convergence of an interspecies mutualism. Ecology Letters doi: 10.1111/ele.13184

Presenters: 1) Nabelle Abusharkh 2) Brooke Sciandra

Optional Reading if you choose to add some:

Hay, M. E., J. E. Duffy, and W. Fenical. 1990. Host-plant specialization decreases predation on a marine amphipod: an herbivore in plant's clothing. Ecology 71:733-743.

Trowbridge CD. 1991. Diet specialization limits herbivorous sea slugs capacity to switch among food sources. Ecology 72:1880-1888.

Hay, M. E. 1992. The role of seaweed chemical defenses in the evolution of feeding specialization and in the mediation of complex interactions. pages 93-118 in V. J. Paul (ed.), *Ecological Roles for Marine Natural Products*. Comstock Press, Ithaca, NY, USA

Duffy, J. E. and M. E. Hay. 1994. Herbivore resistance to seaweed chemical defense: the roles of herbivore mobility and predation risk. Ecology 75:1304-1319.

Stachowicz, J.J. and M.E. Hay 2000. Geographic variation in camouflaging behavior by a decorator crab: southern populations specialize on chemically noxious decorations. AmericanNaturalist 156: 59-71

Sotka EE, Hay ME. 2002. Geographic variation among herbivore populations in tolerance for a chemically rich seaweed. Ecology 83:2721-2735.

**APRIL**

**1 - Trait mediated interactions: The ecology of fear.**

READ –Maden EMP, Gaines SD, Warner RR. 2010. Field evidence for pervasive indirect effects of fishing on prey foraging behavior. Ecology 91: 3563-3571.

AND

Reynolds PL, Sotka EE. 2011. Non-consumptive predator effects indirectly influence marine plant biomass and palatability. Ecology 99: 1272-1281.

Presenters: 1) Jadyn Sethna 2) Ollie Shinn

Optional Reading if you choose to add some:

Weissburg M, Smee DL, Ferner MC. 2014. the sensory ecology of nonconsumptive predator effects. American Naturalist 184: 141-157.

Gravem SA, Morgan SG. 2016. Prey state alters trait-mediated indirect interactions in rocky tide pools. Functional Ecology 30: 1574-1582.

Gil MA, Zill J, Ponciano M. 2017. Context-dependent landscape of fear: algal density elicits risky herbivory in a coral reef. Ecology 98: 435-544.

Breed GA, et al. 2017. Sustained disruption of narwahl habitat use and behavior in the presence of Arctic killer whales. Proceedings of the National Academy of Sciences 114: 2628-2633.

Barner et al. 2018. Fundamental contradictions among observational and experimental estimates of non-trophic species interactions. Ecology 99: 557-566

**FUNDAMENTALS OF MARINE POPULATIONS**

**6 - Sex in the sea I: fertilization**

READ - Jensen et al. 2014. Adaptive maternal and paternal effects: gamete plasticity in response to parental stress. *Functional Ecology* 28:724-733.

Presenters: 1) Ireland Stackhouse 2) Logan Stuchtemeyer

Optional Reading if you choose to add some:

Donelson et al. 2018. transgenerational plasticity and climate change experiments: where do we go from here? Global Change Biology 24: 13-34.

Burgess SC, Marshall DJ. 2014. Adaptive parental effects: the importance of estimating environmental predictability and offspring fitness appropriately. Oikos 123: 769-776.

**8**  **- Sex in the sea II: Sex change**

READ – Munday et al. 2006. Diversity and flexibility of sex-change strategies in animals. *Trends in Ecology and Evolution* 21:89-95.

Presenters: 1) Hannah Strudwick 2) Jessica Winkler

Optional Reading if you choose to add some:

Hamilton SL, et al. 2007. Size-selective harvesting alters life histories of a temperate sex- changing fish. Ecological Applications 17: 2268-2280.

Scharer L, Rowe L, Arngvist G. 2012. Anisogamy, chance and the evolution of sex roles. Trends in Ecology and Evolution 27: 260-264.

Taylor BM. 2014. Drivers of protogynous sex change differ across spatial scales, Proceedings of the royal Society B-Biological Sciences 281: 10.1098/rspb.2013.2423

Hixson MA, Darren W, Sogard SM. 2014. BOFFFFs: on the importance of conserving old- growth age structure in fishery populations. ICES Journal of Marine Science 71:2171-2185.

**13**  **- Zygote/Larval behavior (now what do the babies do?)**

READ - Doropoulos et al. 2012. Ocean acidification reduces recruitment by disrupting intimate larval-algal settlement interactions. *Ecology Letters* 15: 338-346.

and

Munday PL, et al. 2010. Replenishment of fish populations is threatened by ocean acidification. Proceedings of the National Academy of Sciences 107: 12930-12934.

Presenters: 1) Nicholas Wong 2) Jessica Zhang

Optional Reading if you choose to add some:

Berkeley SA, Chapman C, Sogard SM. 2004. Maternal age as a determinant of larval growth and survival in a marine fish. Ecology: 85:1258-1264.

Harrington L, et al. 2004. Recognition and selection of settlement substrata determine post- settlement survival in corals. Ecology 85: 3428-3437.

Albright R, et al. 2010. Ocean acidification compromises recruitment success of the threatened Caribbean coral *Acropora palmata*. Proceedings of the National Academy of Sciences 107: 20400-20404.

Tebban J et al. 2015. Chemical mediation of coral larval settlement by crustose coralline algae. Scientific Reports 5: Article Number: 10803 

Lillis A, Apprill A, Suca JJ, Becker C, Llopiz JK, Mooney TA. 2018 Soundscapes influence the settlement of the common Caribbean coral *Porites astreoides* irrespective of light conditions. R. Soc. Open Sci. 5: 181358. http://dx.doi.org/10.1098/rsos.181358

**15**  **- Dispersal and open vs closed populations: Local recruitment despite pelagic dispersal – Larval behavior, adaptability, and effects on ecosystem resilience and recovery.**

READ – Almay GR, Berumen ML, Thorrold SR, Planes S, and Jones GP. 2007. Local replenishment of coral reef fish populations in a marine reserve. *Science* 316: 742-744.

and

Marshall, DJ, K Monro, M Bode, MJ Keough, and S Swearer. 2010. Phenotype-environment mismatches reduce connectivity in the sea. *Ecology Letters* 13:128-140

Presenters: 1) Cailyn Zicker 2) Katie Zong

Optional Reading if you choose to add some:

Taylor MS, Hellberg ME. 2003. Genetic evidence for local retention of pelagic larvae in a Caribbean reef fish. Science 299: 107-109.

Cowen RK, Paris CB, Srinvasan A. 2006. Scaling of connectivity in marine populations. Science 311:522-527.

Shanks AL. 2009. Pelagic larval durations and dispersal distance revisited. Biol Bull 216:373-385.

Harrison HB, et al. 2012. Larval export from marine reserves and the recruitment benefit for fish and fisheries. Current Biology 22: 1023-1028.

Pinsky ML, et al. 2012. Open and closed seascapes: where does habitat patchiness create populations with high fractions of self-recruitment? Ecological Applications 22: 1257-1267

Kough AS, Paris CB, Butler MJ. 2013. Larval connectivity and the international management of fisheries. PLOS ONE 8: 10.1371/journal.pone.0064970

Figueiredo J, et al. 2014. Increased local retention of coral reef larvae as a result of ocean warming. Nature Climate Change 4: 498-502.

Krueck NC, et al. 2017. incorporating larval dispersal into MPA design for both conservation and fisheries. Ecological Applications 27: 925-941.

Almany GR, et al. 2017. larval fish dispersal in a coral-reef seascape. Nature Ecology and Evolution 1: Article Number: UNSP 0148

**YOUR RESEARCH PAPER IS DUE TODAY (15 April) – FINISHING IT BEFORE TODAY IS A VERY GOOD IDEA (WELL before today is an even better idea!). I WILL ACCEPT PAPERS W/O PENALTY UNTIL MIDNIGHT ON 18 APRIL, BUT AFTER THAT, YOU LOSE 5 POINTS/DAY.**

**20 - GUEST LECTURE – Prof Douglas McCauley (UC Santa Barbara) Marine Defaunation -** how patterns of species loss differ in marine and terrestrial ecosystems; how and why the history of human influence differs in these two domains, and how that has shaped biodiversity and functioning of these respective domains?

READ - McCauley D, et al. 2015. Marine defaunation: animal loss in the global ocean. Science 347: Article Number: 1255641

Optional Reading if you choose to add some:

Do a Google Scholar search or a Web-of-Science search on “McCauley D” – you will find a LOT of wonderful papers that are excellent options.

**22 - Exam 3**

**27 - The remaining student presentations and a discussion and overview of the state of marine ecology**

**May**

**6 - FINAL EXAM (scheduled for 0800-1050 h – There is no final – your research paper counts as your final)**