

Global Change Biology

In the year 2000, atmospheric chemist Paul Crutzen suggested that humans had fundamentally changed Earth systems so much that it was time to declare a new geological epoch: the Anthropocene. While this proposal has yet to be formally accepted, the sentiment of the statement has given rise to a whole new scientific sub-discipline seeking to understand the impacts of these massive planetary alterations on living organisms: Global Change Biology. This course is roughly divided into three parts. In part one, we will discuss the drivers and physical effects of global change. In **part two**, we will focus on how these changes impact organisms and ecosystems. In **part three**, we will explore some of the anthropogenic responses aimed to mitigate the effects of global change on organisms.

Course Objective: The goals of this class are to broadly expose students to the drivers and effects of global change on life. Specifically, students should expect to:

- Obtain a broad foundation for the study of Earth Systems and drivers of global change, with an emphasis on terrestrial systems.
- Gain an understanding of the range of possible effects of global change on organisms, and the complexity of interacting drivers.
- Increase in comfort and competence reading primary literature, and learn to evaluate the current state of global change science with all of its limitations and promises.

Required Text: Because of the diversity of topics covered, we will approach our study of global change biology through the developing body of primary scientific literature rather than through a single text book. Many lectures will pair with suggested readings (italicized below) that will provide additional background to the lecture topic or other examples of the concepts being discussed.

Course structure: This course will meet twice per week for 75 minutes. This first half will consist of a lecture from the instructor, with the second half consisting of student facilitated discussions on relevant papers.

Prerequisites: A course in introductory biology or permission of instructor.

Topic	Reading(s)
1] Introduction to our changing climate system	IPCC 2014
2] Paleoclimate: the effects of rapid climate change in deep time	Knoll 2007
3] Predicting future climates	Bonan 2018, <i>Newman Ch.2 (Canvas)</i>
4] Feedbacks, sources and sinks	Cox 2000, <i>Kurz 2008</i>
5] Localized impacts: disturbance	Westerling 2006, <i>Logan 2001</i>
6] Land use change	Foley 2005, <i>Grimm 2008</i>
7] Nutrient cycling	Vitousek 1997, <i>Diaz 2008</i>
8] Marine effects	Kroecker 2013, <i>Cheung 2010</i>
9] Interacting drivers	Hoff 2011, <i>Newman Ch. 13 (Canvas)</i>
10] Plant physiology	Korner 2006
11] Terrestrial ecosystem productivity and sequestration	Norby 2011
12] Environmental tolerance	Kaliq 2014
13] Plasticity and phenological shifts	Cleland 2012, <i>Logan 2014</i>
14] Global change and evolution	Reusch 2007, <i>Gorton 2018</i>
15] Fragmentation and migration	Chen 2011, Hamman 2012
16] Invasion	Liu 2017, <i>Milbau 2003</i>
17] The 6th extinction	Plotnick 2016 <i>Pyron 2017</i>
18] Novel ecosystem and communities	Hobbs 2009, <i>Clavel 2010</i>
19] Conservation I: Who, what, where, why?	Chan 2006, <i>Duffy 2014</i>
20] Conservation II: How?	McGwire 2016, <i>Willis 2009</i>
21] Ecological restoration	Cannon 2018, <i>Harris 2006</i>
22] Conservation policy	Diaz et al. 2015
23] Spotlight on REDD+	Visseren-Hamakers 2012, <i>Lindenmayer 2012</i>
24] Communicating science in an era of global change	Knowlton 2017, <i>Godet 2018</i>

References

Bonan, G.B. & Doney, S.C. (2018) Climate, ecosystems, and planetary futures: The challenge to predict life in Earth system models. *Science* **359**, 533+.

Cannon, J.B., Barrett, K.J., Gannon, B.M., Addington, R.N., Battaglia, M.A., Fornwalt, P.J., Aplet, G.H., Cheng, A.S., Underhill, J.L., Briggs, J.S. & Brown, P.M. (2018) Col-

- laborative restoration effects on forest structure in ponderosa pine-dominated forests of colorado. *Forest Ecology and Management* **424**, 191 – 204.
- Chan, K.M.A., M., P.R., Ranganathan, J., Boggs, C.L., Chan, Y.L., Ehrlich, P.R., Haff, P.K., E., H.N., Karim, A.K. & P., M.D. (2006) When agendas collide: Human welfare and biological conservation. *Conservation Biology* **21**, 59–68.
- Chen, I.C., Hill, J.K., Ohlemueller, R., Roy, D.B. & Thomas, C.D. (2011) Rapid Range Shifts of Species Associated with High Levels of Climate Warming. *SCIENCE* **333**, 1024–1026.
- Cheung, W.W.L., Lam, V.W.Y., L., S.J., Kearney, K., Watson, R., Zeller, D. & Pauly, D. (2010) Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. *Global Change Biology* **16**, 24–35.
- Cleland, E.E., Allen, J.M., Crimmins, T.M., Dunne, J.A., Pau, S., Travers, S.E., Zavaleta, E.S. & Wolkovich, E.M. (2012) Phenological tracking enables positive species responses to climate change. *Ecology* **93**, 1765–1771.
- Cox, P.M., Betts, R.A., Jones, C.D., Spall, S.A. & Totterdell, I.J. (2000) Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model. *Nature* **408**, 184 EP –.
- Diaz, R.J. & Rosenberg, R. (2008) Spreading dead zones and consequences for marine ecosystems. *Science* **321**, 926–929.
- Diaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J.R., Arico, S., Baldi, A., Bartuska, A., Baste, I.A., Bilgin, A., Brondizio, E., Chan, K.M.A., Figueroa, V.E., Duraiappah, A., Fischer, M., Hill, R., Koetz, T., Leadley, P., Lyver, P., Mace, G.M., Martin-Lopez, B., Okumura, M., Pacheco, D., Pascual, U., Perez, E.S., Reyers, B., Roth, E., Saito, O., Scholes, R.J., Sharma, N., Tallis, H., Thaman, R., Watson, R., Yahara, T., Hamid, Z.A., Akosim, C., Al-Hafedh, Y., Allahverdiyev, R., Amankwah, E., Asah, S.T., Asfaw, Z., Bartus, G., Brooks, L.A., Caillaux, J., Dalle, G., Darnaedi, D., Driver, A., Erpul, G., Escobar-Eyzaguirre, P., Failler, P., Fouda, A.M.M., Fu, B., Gundimeda, H., Hashimoto, S., Homer, F., Lavorel, S., Lichtenstein, G., Mala, W.A., Mandivenyi, W., Matczak, P., Mbizvo, C., Mehrdadi, M., Metzger, J.P., Mikissa, J.B., Moller, H., Mooney, H.A., Mumby, P., Nagendra, H., Nesshover, C., Oteng-Yeboah, A.A.,

- Pataki, G., Roue, M., Rubis, J., Schultz, M., Smith, P., Sumaila, R., Takeuchi, K., Thomas, S., Verma, M., Yeo-Chang, Y. & Zlatanova, D. (2015) The IPBES Conceptual Framework - connecting nature and people. *Current Opinion in Environmental Sustainability* **14**, 1–16.
- Duffy, R. (2014) Waging a war to save biodiversity: the rise of militarized conservation. *International Affairs* **90**, 819+.
- Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A., Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, I.C., Ramankutty, N. & Snyder, P.K. (2005) Global consequences of land use. *Science* **309**, 570–574.
- Godet, L. & Devictor, V. (2018) What conservation does. *Trends in Ecology & Evolution* **33**, 720 – 730.
- Gorton, A.J., Moeller, D.A. & Tiffin, P. (2018) Little plant, big city: a test of adaptation to urban environments in common ragweed (*ambrosia artemisiifolia*). *Proceedings of the Royal Society of London B: Biological Sciences* **285**.
- Grimm, N.B., Faeth, S.H., Golubiewski, N.E., Redman, C.L., Wu, J., Bai, X. & Briggs, J.M. (2008) Global change and the ecology of cities. *Science* **319**, 756–760.
- Hamann, A. & Aitken, S.N. (2012) Conservation planning under climate change: accounting for adaptive potential and migration capacity in species distribution models. *Diversity and Distributions* **19**, 268–280.
- Harris, J.A., Hobbs, R.J., Higgs, E. & Aronson, J. (2006) Ecological restoration and global climate change. *Restoration Ecology* **14**, 170–176.
- Hobbs, R.J., Higgs, E. & Harris, J.A. (2009) Novel ecosystems: implications for conservation and restoration. *Trends in Ecology & Evolution* **24**, 599–605.
- Hof, C., Araújo, M.B., Jetz, W. & Rahbek, C. (2011) Additive threats from pathogens, climate and land-use change for global amphibian diversity. *Nature* **480**, 516–519.
- Joanne, C., Romain, J. & Vincent, D. (2011) Worldwide decline of specialist species: toward a global functional homogenization? *Frontiers in Ecology and the Environment* **9**, 222–228.

- Khaliq, I., Hof, C., Prinzing, R., Böhning-Gaese, K. & Pfenninger, M. (2014) Global variation in thermal tolerances and vulnerability of endotherms to climate change. *Proceedings of the Royal Society of London B: Biological Sciences* **281**.
- Knoll, A.H., Barnbach, R.K., Payne, J.L., Pruss, S. & Fischer, W.W. (2007) Paleophysiology and end-Permian mass extinction. *Earth and Planetary Science Letters* **256**, 295–313.
- Knowlton, N. (2017) Doom and gloom won't save the world. *Nature* **544**, 271.
- Körner, C. (2006) Plant co₂responses: an issue of definition, time and resource supply. *New Phytologist* **172**, 393–411.
- Kroeker, K.J., Kordas, R.L., Crim, R., Hendriks, I.E., Ramajo, L., Singh, G.S., Duarte, C.M. & Gattuso, J.P. (2013) Impacts of ocean acidification on marine organisms: quantifying sensitivities and interaction with warming. *Global Change Biology* **19**, 1884–1896.
- Lindenmayer, D.B., Hulvey, K.B., Hobbs, R.J., Colyvan, M., Felton, A., Possingham, H., Steffen, W., Wilson, K., Youngentob, K. & Gibbons, P. (2012) Avoiding bio-perversity from carbon sequestration solutions. *Conservation Letters* **5**, 28–36.
- Liu, Y., Oduor, A.M.O., Zhang, Z., Manea, A., Tooth, I.M., Leishman, M.R., Xu, X. & van Kleunen, M. (2017) Do invasive alien plants benefit more from global environmental change than native plants? *Global Change Biology* **23**, 3363–3370.
- Logan, J.A. & Powell, J.A. (2001) Ghost forests, global warming, and the mountain pine beetle (coleoptera: Scolytidae). *American Entomologist* **47**, 160–173.
- Logan, M.L., Cox, R.M. & Calsbeek, R. (2014) Natural selection on thermal performance in a novel thermal environment. *Proceedings of the National Academy of Sciences* **111**, 14165–14169.
- McGuire, J.L., Lawler, J.J., McRae, B.H., Nuñez, T.A. & Theobald, D.M. (2016) Achieving climate connectivity in a fragmented landscape. *Proceedings of the National Academy of Sciences* .
- Milbau, A., Nijs, I., Van Peer, L., Reheul, D. & De Cauwer, B. (2003) Disentangling invasiveness and invasibility during invasion in synthesized grassland communities. *New Phytologist* **159**, 657–667.

- Newman, J., Anand, M., Henry, H., Hunt, S. & Gedalof, Z. (2011) *Climate Change Biology*. CABI International.
- Norby, R.J. & Zak, D.R. (2011) Ecological Lessons from Free-Air CO₂ Enrichment (FACE) Experiments. *Annual Review of Ecology Evolution and Systematics* Vol. 42 (ed. Futuyma, DJ and Shaffer, HB and Simberloff, D), vol. 42 of *Annual Review of Ecology Evolution and Systematics*, pp. 181–203, Annual Reviews.
- Pachauri, R. & Meyer, L. (2014) Ipcc, 2014: Climate change 2014: Synthesis report. contribution of working groups i, ii and iii to the fifth assessment report of the intergovernmental panel on climate change. Tech. rep., IPCC, Geneva, Switzerland.
- Plotnick, R.E., Smith, F.A. & Lyons, S.K. (2016) The fossil record of the sixth extinction. *Ecology Letters* **19**, 546–553.
- Pyron, R. (2017) We don't need to save endangered species. extinction is part of evolution. *The Washington Post* .
- Reusch, T.B.H. & Wood, T.E. (2007) Molecular ecology of global change. *Molecular Ecology* **16**, 3973–3992.
- Visseren-Hamakers, I.J., McDermott, C., Vijge, M.J. & Cashore, B. (2012) Trade-offs, co-benefits and safeguards: current debates on the breadth of redd+. *Current Opinion in Environmental Sustainability* **4**, 646 – 653.
- Vitousek, P., Aber, J., Howarth, R., Likens, G., Matson, P., Schindler, D., Schlesinger, W. & Tilman, D. (1997) Human alteration of the global nitrogen cycle: Sources and consequences. *Ecological Applications* **7**, 737–750.
- Westerling, A.L., Hidalgo, H.G., Cayan, D.R. & Swetnam, T.W. (2006) Warming and earlier spring increase western u.s. forest wildfire activity. *Science* **313**, 940–943.
- Willis, S.G., Hill, J.K., Thomas, C.D., Roy, D.B., Fox, R., Blakeley, D.S. & Huntley, B. (2009) Assisted colonization in a changing climate: a test-study using two UK butterflies. *Conservation Letters* **2**, 45–51.