Colin T. Kremer, PhD

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Appointments

2/2017 - present	**Postdoctoral Associate**	Michigan State University, Elena Litchman
9/2016 – 2/2017	**Postdoctoral Fellow**	Yale University, David Vasseur
9/2014 - 9/2016	**NSF Postdoctoral Fellow**	Yale University, David Vasseur Princeton University, Jorge Sarmiento

Education

2014	PhD	Plant Biology; Ecology, Evolutionary Biology & Behavior Advisor: Christopher A. Klausmeier	**Michigan State University**
2008	BS	Biology & Mathematics, *summa cum laude*	**SUNY College at Geneseo**
2005	AS	Math & Science, *summa cum laude*	**Jamestown Comm. College**

Research Grants, Fellowships, & Awards

2018	Outstanding Ecological Theory Paper. ESA Theory Section. (Kremer & Klausmeier 2017)
2018	NSF DEB proposal in review. '*Uncovering the population and community level consequences of phenotypic plasticity*'. PI: DA Vasseur, co-PIs **CT Kremer** & SB Fey.
2016-20	*NSF OCE/Dimensions of Biodiversity. '*Genetic, functional, and phylogenetic diversity determines marine phytoplankton community responses to changing temperature and nutrients*'. Co-author. ($640,989)
2016	NSF DEB full proposal invited, but not funded. '*Uncovering the population and community level consequences of phenotypic plasticity*'. PI: DA Vasseur, co-PIs **CT Kremer** & SB Fey
2014-16	NSF Postdoctoral Fellowship (Biology/Mathematics). ($138,000)
2014	Travel grant, Gordon Research Conference, Oceans Global Change Biol. ($500)
2012-14	Michigan State University Distinguished Fellowship. ($48,000)
2009-12	NSF Graduate Research Fellowship. ($90,000)
2011	Paul Taylor Travel Award, Dept. of Plant Biology, MSU. ($673)
2011	Travel grant, Envir. Sci. & Policy, MSU. ($500)
2009	Plant Sciences Summer Fellowship, MSU. ($6,000)
2007	Vito Volterra Award. Best theoretical ecology student talk, ESA.
2007	Student Research Poster Award, National MAA-AMS conference.
2005	Morris K. Udall Scholarship. ($5,000)
2005, 2008	SUNY Chancellor's Award for Excellence.

*I played a key role in developing/implementing this grant, but was not a PI due to my postdoc status.

Publications

Peer reviewed (19 papers) *Undergraduate co-author, [1]Equal contributors

In review Aranguren-Gassis, M, **CT Kremer**, CA Klausmeier, E Litchman. Nitrogen limitation inhibits marine diatom adaptation to high temperatures.

In review Lewington-Pearce, L, A Narwani, MK Thomas, **CT Kremer**, H Vogler, P Kratina. Temperature alters hierarchies of competitive ability among phytoplankton.

In review McInnes, AS, OF Laczka, KG Baker, ME Larsson, CM Robinson, JS Clark, L Laiolo, M Alvarez, B Laverock, **CT Kremer**, E van Sebille, MA Doblin. Live cell analysis at sea reveals divergent thermal performance between ocean microbial eukaryote populations.

2018 [1]**Kremer, CT**, [1]SB Fey, *A Arellano, DA Vasseur. Gradual plasticity alters population dynamics in variable environments: thermal acclimation in the green alga *Chlamydomonas reinhartdii*. *Proc. Roy. Soc. B* 285(1870): 20171942. doi:10.1098/rspb.2017.1942

2018 Edwards, KE, **CT Kremer**, ET Miller, MM Osmond, E Litchman, CA Klausmeier. Evolutionarily stable communities: a framework for understanding the role of trait evolution in the maintenance of diversity. *Ecology Letters. In Press.*

2018 O'Donnell, DR, *CR Hamman, *EC Johnson, **CT Kremer**, CA Klausmeier, E Litchman. Rapid thermal adaptation in a marine diatom reveals constraints and tradeoffs. *Global Change Biology* 24(10): 4554-4565. doi:10.1111/gcb.14360

2018 Yema, L, **CT Kremer**, I O'Farrell, P de Tezanos Pinto. Assessing patterns of morphological and physiological trait variation across heterocytous cyanobacteria at cellular and population levels. *Hydrobiologia* 823(1): 93-107. doi:10.1007/s10750-018-3698-5

2017 Bannar-Martin, KH, **CT Kremer,** et al. Integrating community assembly and biodiversity to better understand ecosystem function: the Community Assembly and the Functioning of Ecosystems (CAFE) approach. *Ecology Letters* 21(2): 167-180. doi:10.1111/ele.12895

2017 **Kremer, CT**, CA Klausmeier. Species packing in eco-evolutionary models of seasonally fluctuating environments. *Ecology Letters* 20(9): 1158-1168. doi:10.1111/ele.12813

2017 **Kremer, CT**, MK Thomas, E Litchman. Temperature- and size-scaling of phytoplankton population growth rates: Reconciling the Eppley curve and the metabolic theory of ecology. *Limnology & Oceanography* 62: 1658–1670. doi:10.1002/lno.10523

2017 Thomas, MK, M Aranguren-Gassis, **CT Kremer**, *MR Gould, *K Anderson, CA Klausmeier, E Litchman. Temperature-nutrient interactions exacerbate sensitivity to warming in phytoplankton. *Global Change Biology* 23: 3269–3280. doi:10.1111/gcb.13641

2017 Prunier, R, M Akman, **CT Kremer**, N Aitken, A Chuah, J Borevitz, KE Holsinger. Isolation by distance and isolation by environment contribute to population differentiation in *Protea repens* (Proteaceae L.), a widespread South African species. *Amer. J Botany* 104(5): 1–11. doi:10.3732/ajb.1600232

2016 **Kremer, CT**, A Shepard, M Finiguerra, A Fong, A Kellerman, S Paver, B Tolar, B Toscano. Realizing the potential of trait-based aquatic ecology: new tools and collaborative approaches. *Limnology & Oceanography* 62(1): 253-271. doi:10.1002/lno.10392

2016 Royer, AM, **CT Kremer**, *K George, S Pérez, DW Schemske, JK Conner. Incomplete loss of a conserved trait: function, latitudinal cline, and genetic constraints. *Evolution* 70(12): 2853-2864. doi:10.1111/evo.13096

2016 Coble, A, RG Asch, S Rivero-Calle, S Heerhartz, J Holding, **CT Kremer**, M Finiguerra, KE Strock. Climate is variable, but is our science? *Limnology & Oceanography Bulletin* 25: 71-76. doi:10.1002/lob.10115

2016 Thomas, MK, **CT Kremer**, E Litchman. Environment and evolutionary history determine the global biogeography of phytoplankton temperature traits. *Global Ecol. and Biogeography* 25(1): 71-86. doi:10.1111/geb.12387

2015 Litchman, E, P de Tezanos Pinto, KF Edwards, CA Klausmeier, **CT Kremer**, MK Thomas. Global biogeochemical impacts of phytoplankton in the past, present, and future: a trait-based perspective. *J Ecology* 103(6): 1384-1396. doi:10.1111/1365-2745.12438

2015 Seltzer, CE, **CT Kremer**, HJ Ndangalasi, NJ Cordeiro. Seed harvesting of a threatened African tree dispersed by rodents: Is enrichment planting a solution? *Global Ecol. and Consv.* 3: 645-653. doi:10.1016/j.gecco.2015.02.011

2014 **Kremer, CT**, JP Gillette, LG Rudstam, P Brettum, R Ptacnik. A compendium of cell and natural unit biovolumes for >1,200 phytoplankton species. *Ecology* 95(10): 2984.

2014 Vasseur, DA, JW Fox, A Gonzalez, R Adrian, BE Beisner, MR Helmus, C Johnson, P Kratina, **CT Kremer**, et al. Synchronous dynamics of zooplankton competitors prevail in temperate lake ecosystems. *Proc. Roy. Soc. B* 281: 1-9. doi: 10.1098/rspb.2014.0633

2013 **Kremer, CT,** CA Klausmeier. Coexistence in a variable environment: eco-evolutionary perspectives. *J Theoretical Biology* 339: 14-25. doi:10.1016/j/jtbi.2013.05.005

2012 [1]Thomas, MK, [1]**CT Kremer**, CA Klausmeier, E Litchman. A global pattern of thermal adaptation in marine phytoplankton. *Science* 338: 1083-1085. doi:10.1126/science.1224836. Featured in F1000.

Manuscripts in preparation (4+) **(available by request)**

Kremer, CT, KH Bannar-Martin, MA Leibold, SKM Ernest, et al. The environmental causes and functional consequences of biodiversity loss.

Kremer, CT, CA Stock, DA Vasseur, J Sarmiento. Evolution and trophic structure constrain marine ecosystems exposed to novel conditions.

Fitzpatrick, SW, **CT Kremer**, P Salerno, LM Angeloni, WC Funk. Demographic and evolutionary consequences of new gene flow into wild Trinidadian guppy populations.

Koffel, T, **CT Kremer**, KH Bannar-Martin, MA Leibold, et al. Modeling how community assembly alters the functioning of ecosystems.

Teaching Experience

Instructor of record

2012, 14-15, & 2017 Maximum Likelihood Analysis in Ecology, PLB 809, 1 credit, MSU.
Designed curriculum, presented lectures, and guided labs and student projects.

2012 Applying Algebra 2 Biology. Kellogg Biological Station, MSU.
Developed and presented curriculum for this program focused on aid incoming, at-risk, and minority freshmen by linking biology to mathematics.

2012 Meta-analysis: patterns of selection. MSU.

Planned and led computer activities on selection, as part of a high school summer program, for the BEACON Center for the study of Evolution in Action.

Guest lecturer

2017 Ecology, University of Connecticut at Waterbury, CT.

2016 Advanced Community Ecology, Yale University, CT.

2013 Statistical Methods in Ecology & Evolution, MSU.

2013 Methods in Applied Mathematics, Vassar College, NY.

2010, 2012 Theoretical Ecology Lab, MSU.

2012 Introduction to Statistics, REU Program, Kellogg Biological Station, MSU.

2011 Population & Community Ecology, MSU.

Teaching Assistant

2014, 2017 Program coordinator, 'Enhancing linkages between mathematics and ecology', MSU.

2011 Evolutionary Ecology & Adaptive Dynamics, MSU.

2009-10 Maximum Likelihood Analysis in Ecology, MSU.

2007 Biological Data Analysis, SUNY Geneseo.

Outreach & Workshops

2014-2018 Letters to a Pre-scientist. Pen-pal program designed to increase awareness of STEM fields in primary school classrooms.

2016-2017 NCSE Scientist in the Classroom program. Metropolitan Business Academy (Magnet High School), New Haven, CT

2008 Math day. Organized & led a workshop on mathematical biology for middle school students, SUNY Geneseo.

2003-2005 Tutored peers and lead workshops on writing, chemistry, and mathematics. Jamestown Community College, NY.

Mentoring Experience

2017-18 Udall Alumni Association Mentoring Program

Advised 3 students on preparing for and applying to graduate school, and post-PhD employment in ecology/environmental sciences; included a successful NSF GRFP.

2015-16 Brittany Labbadia. Senior, Yale University.

Supervised senior research thesis, 'Effects of temperature variation and thermal acclimation on the growth of *Chlamydomonas reinhardtii*'.

2015-16 Aldo Arellano. Junior, Dartmouth University.

Co-advised with Dr. Sam Fey. In his student research experience, Aldo studied interspecific variation in the thermal acclimation responses of phytoplankton.

2015 Steven Xu. Senior, Staples High School, CT, Advanced Science Research Program.

Advised student project on 'Effects of elevated CO_2 on algal biofuel production'.

2015 Megan Morrow. Western Connecticut State University.

Matrix modeling of deer tick population ecology.

2012 Lydia Auner*. Freshman, Carleton College.

During a summer at Kellogg Biological Station, MSU, Lydia studied the interactive effects of nutrients and temperature on phytoplankton growth, combining mathematical modeling and lab experiments. (*Recipient of NOAA Hollings Scholarship)

Invited Seminars

2018 Beakers to oceans, days to decades: evolution and plasticity mediate microbial ecology in a changing world.
Dept. of Ecology & Evolutionary Biology, UCLA, Los Angeles, CA.

2017 Evolutionary uncertainties, climate change, and the future of marine ecosystems.
Yale Institute for Biospheric Studies, Yale University, New Haven, CT.

2017 From beakers to oceans: Eco-evolutionary responses of phytoplankton to changing temperatures.
Dept. of Biology, Colby College, Waterville, ME.

2016 Adapting to an uncertain world: ecological & evolutionary responses to changing temperature.
Dept. of Biology, State University of New York College at Geneseo, Geneseo, NY.

2016 Adaptation as an optimization problem.
Nereus Program, University of British Columbia, BC, Canada.

2014 Uncovering the biogeography of phytoplankton thermal traits: insights from data & theory.
Dept. of Marine Sciences, University of Connecticut, Avery Point, CT.

2013 In hot water: Marine phytoplankton and climate change.
Dept. of Biology, Western Connecticut State University, CT.

Select Presentations

2018 **Kremer, CT**, M Aranguren-Gassis, CA Klausmeier, E Litchman. Experimental evolution, theory, and multiple stressors: nutrient limitation inhibits thermal adaptation. Gordon Research Conf: Oceans Global Change Biology. Waterville Valley, NH.

2017 **Kremer, CT**, MK Thomas, D Vasseur, JL Sarmiento, CA Stock, E Litchman. Anticipating the consequences of climate change: detecting and modeling evolutionary constraints to thermal adaptation. IMBeR Imbizo 5, Woods Hole, MA.

Kremer, CT, CA Klausmeier. Optimality assumptions in marine ecosystem models: when are they sub-optimal? Trait-based Approaches to Ocean Life, Os, Norway.

Kremer, CT, MA Leibold, KH Bannar-Martin, SKM Ernest. Diversity alone is not enough: Nitrogen enrichment and community assembly determine ecosystem response to drought. Ecological Soc. of America (ESA), Portland, OR.

2016 **Kremer, CT**, S Fey, DA Vasseur. Plastic physiological responses to hidden scales of variation alter population growth. Gordon Research Conf: Unifying Ecology Across Scales. Biddeford, ME.

Kremer, CT, CA Stock, DA Vasseur, JL Sarmiento. Variation in the adaptive capacity of plankton alters marine ecosystem responses to climate change. Ocean Sciences, New Orleans, LA.

2015 **Kremer, CT**, D Vasseur, C Stock. Changing climate & evolving ecosystems: Evolution and trophic interactions alter marine systems. ESA, Baltimore, MD.

Kremer, CT, MK Thomas, E Litchman, C Stock. Temperature and phytoplankton: disentangling empirical patterns and competing paradigms. OCB Trait-based Approaches to Ocean Life, Waterville Valley, NH.

Kremer, CT, CA Klausmeier. Temporal variation drives complex eco-evolutionary dynamics. Evolution, Guaruja, Brazil.

2014 **Kremer, CT**, MK Thomas, E Litchman, CA Klausmeier. Dissimilar thermal sensitivities may alter the response of phytoplankton functional groups to warming oceans. Gordon Research Conference: Oceans Global Change Biology. Waterville Valley, NH.

2013 **Kremer, CT**. Uncovering the role of temperature variation in the ecology and evolution of marine phytoplankton. Dept. of Ecology & Evolutionary Biology, Princeton, NJ.

	Kremer, CT, CA Klausmeier. Traveling between extremes: the shape of temporal variation alters competition and evolution in fluctuating environments. ESA, Minneapolis, MN.
2011	**Kremer, CT,** MK Thomas, E Litchman, CA Klausmeier. Adapting to variable thermal environments: A trait-based, eco-evolutionary approach. ESA, Austin, TX.
	Kremer, CT, CA Klausemeier, E Litchman. Detecting the role of resource competition in driving nitrogen fixing cyanobacteria blooms: a mechanistic approach. ASLO, San Juan, PR.
2010	**Kremer, CT**, E Litchman, P de Tezanos Pinto, I Dworkin, CA Klausmeier. Revisiting the causes of cyanobacteria blooms: a mixture model analysis of resource competition and abiotic factors. ESA, Pittsburgh, PA.
2009	**Kremer, CT,** CA Klausmeier. Examining the evolutionary stability of coexistence: competition in fluctuating resource environments. ESA, Albuquerque, NM.
2008	**Kremer, CT**, B Girdler. Detecting the driving forces of species diversity patterns: a modeling approach. Undergraduate Biomathematics Day. Buffalo, NY.
2007	**Kremer, CT**, C Leary, G Towsley, G Hartvigsen. Chaotic dynamics lost in small-world network metapopulations. ESA, San Jose, CA.
	Kremer, CT, C Leary, G Hartvigsen. Chaotic population dynamics in a small-world network model. MAA Undergrad. Student Poster Session, Joint AMS-MAA meeting, New Orleans.

Working Groups

2015-16	"Community assembly and the functioning of ecosystems in open systems", sDiv: German Centre for Integrative Biodiversity Research, Leipzig, Germany.
2010-11	"Predicting ecological change: multiscale analysis of plankton diversity and dynamics", Canadian Institute of Ecology and Evolution working group, Newmarket, ON.

Short Courses & Workshops

2014	ECO-DAS XI: Ecological dissertations in aquatic science	Univ. of Hawaii, Manoa, HI.
2013	Promises of big data across disciplines	Okinawa Inst. Sci. & Tech, Japan.
2011	Eco-evolutionary modeling of speciation	FroSpects, Abisko, Sweden.
2011	Managing ecological data	ESA workshop, Austin, TX.
2009	Adaptive Dynamics short course	Politecnico di Milano, Italy.
2009	Structural Equation Modeling workshop	ESA, Albuquerque, NM.

Research Experience

2009	Research Technician	Theoretical ecology & evolution. CA Klausmeier, MSU.
2008, fall	Field Technician	Seed dispersal. E Damschen, Savannah River Site, SC.
2007-08	ELME Fellow	Enhancing Linkages between Mathematics and Ecology (ELME) Summer program, Kellogg Biological Station, MSU. CA Klausmeier.
2005-08	Research Assistant	SUNY Geneseo. Biomath Career Initiative, NSF UBM Grant DMS-0436298. G Hartvigsen. Summer internship in 2006.

Professional Development

2017	How to be an ally to women in the sciences	Workshop organized by Women in Science at Yale University
2015	An Introduction to Evidence-Based Undergraduate STEM Teaching	Coursera MOOC, from the Center for the Integration of Research, Teaching, and Learning.

2012	Effective Mentoring	10-week summer course, KBS, MSU.
2009-10	Responsible Conduct of Research	MSU Graduate School workshop series.
2009	Effective Test Design	MSU Teaching Assistant Program.

Service

Professional service

2016-17 *Ad hoc* proposal review. NSF DEB, Population & Community Ecology Program.

2013 Ignite session moderator, ESA Meeting, Minneapolis, MN.
"Is the interaction of evolutionary and ecological dynamics widespread, or a special case?"

2010-13 Student liason, Theoretical Ecology Section, ESA.

2009-11 Secretary, Theoretical Ecology Section, ESA.

Committee service

2013-14 Academic Programing committee. Kellogg Biological Station, MSU

2012 Faculty Search committee (tenure-track): Integrative Plant Biology. MSU.

2008 Faculty Search committee (tenure-track): Ecology. SUNY Geneseo.

2010-11 Seminar committee. Kellogg Biological Station, MSU.

Society membership

Ecological Society of America
American Society of Naturalists
Association for the Study of Limnology & Oceanography
Phi Beta Kappa

Peer review

American Naturalist
Ecology
Ecology Letters
Ecology Research
Functional Ecology
Global Change Biology
Global Ecology & Biogeography
J Plankton Research
J Theoretical Biology
Limnology & Oceanography
Marine Biology
Nature Climate Change
Oikos
Oecologia
PLOS One
PNAS
Proc. Roy. Soc. B.

Dr. Christopher Klausmeier
Professor

PhD Advisor

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Dr. Elena Litchman
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Postdoctoral Advisor/PhD committee member

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Dr. David Vasseur
Associate Professor

Postdoctoral Advisor

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Yale University
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October 23, 2018

Dear Search Committee,

I am writing to apply for the position of Assistant Professor in Ecological/Evolutionary Theory at Florida State University. I have a PhD in Plant Biology and Ecology, Evolutionary Biology, and Behavior from Michigan State University (MSU). I completed an NSF Postdoctoral Fellowship at Yale/Princeton and I am currently a Postdoctoral Associate at MSU. My broad training in ecology and evolution, my unique combination of theoretical and empirical skills, my enthusiasm for collaborative research, and my funding and publication record will make me a strong addition to your institution.

As a quantitative ecologist, I am passionate about: (1) developing mathematical theory to distill and examine the essence of complex ecological systems, and (2) confronting theoretical predictions with empirical data, inciting the daring moments when ideas (…and often hopes) are dashed or upheld, and science advances. In particular, I study how dynamic changes in species' traits (driven by evolution and plasticity) affect ecology, from individual populations to entire ecosystems. The context for my work involves exploring how changing temperature and nutrient regimes affect phytoplankton (globally important photosynthetic microbes), over time scales from hours to centuries, and in habitats from beakers to oceans. This emphasis allows me to both advance abstract ecological theory and address applied questions, including predicting the effects of climate change on our biosphere.

In my dissertation (with Dr. Christopher Klausmeier) I studied how temporal environmental variation affects the evolution and coexistence of species, in turn influencing the diversity and functional composition of communities. One paper arising from this work received this year's Outstanding Ecological Theory award from the ESA Theory Section (Kremer & Klausmeier 2017). I also developed new eco-evolutionary theory revealing the mechanisms behind global patterns of thermal adaptation in phytoplankton. This allowed me to predict global shifts in species ranges, as changing ocean temperatures restructure communities.

As an NSF fellow my research program expanded to include: (1) incorporating evolutionary theory into global ocean models to explore the fate of ecosystems in novel warming environments (with Drs. David Vasseur and Jorge Sarmiento); (2) demonstrating that the dynamic effects of phenotypic plasticity, generally ignored by theorist and experimentalists, radically alter how populations respond to variable environments; and (3) developing new methods to study the direct and indirect effects of environmental change on ecosystem function, informed by community assembly theory (with Drs. Mathew Leibold & Morgan Ernest). Currently, I am studying how environmental fluctuations structure and maintain intra- and inter-specific trait diversity, providing essential raw material for communities to react to climate change. Supported by an NSF Dimensions grant that I helped write (PI: Dr. Elena Litchman), I am expanding on my dissertation, integrating new theory with long-term time series analyses and experimental results.

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While aquatic microbes typically supply the context for my work, I am broadly motivated by chances to answer fundamental ecological and evolutionary questions using quantitative techniques. In the past, this has led to collaborations on topics ranging from Tanzanian forest conservation, to floral structure evolution, and the population genomics of South African plants. I love engaging in interdisciplinary research, using cutting-edge mathematical and statistical methods to interrogate ecological and evolutionary systems. I see numerous opportunities for productive new collaborations at FSU, with faculty (or graduate students) interested in developing or expanding the theoretical component of their research.

I am strongly committed to teaching and mentoring students and early career scientists. I use evidence-based teaching practices to equip my students with critical scientific and quantitative reasoning skills. I have taught in a range of courses, including designing and leading a course on 'Maximum Likelihood Analysis in Ecology' at MSU on four occasions. I employ case studies and real data in my teaching, translating my research into classroom experiences, and use student-led projects to foster engagement and learning. I engage in outreach to help students interested in biology strengthen their quantitative skills, addressing a common impediment to increasing the diversity of STEM fields. I have also had the pleasure of mentoring undergraduate research projects on topics ranging from modeling deer tick population dynamics to thermal acclimation in algae. I am excited to build on these experiences, continuing to purse excellence in teaching and mentoring.

My interdisciplinary research, developing and testing theory in order to understand the dynamic effects environmental change on everything from populations to ecosystems, and my experience with teaching and mentoring, make me a strong candidate for this position at Florida State University. My background complements your department's existing strengths in evolutionary and marine ecology, while offering additional expertise in theoretical and statistical ecology. In addition to building my own externally funded lab, I am excited to serve your students, department, and university community, as a mentor, teacher, and researcher.

I have enclosed my CV and other materials. Thank you for your time and consideration.

Sincerely,

Colin T. Kremer

Colin T. Kremer

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Colin T. Kremer, Ph.D.

STATEMENT OF TEACHING PHILOSOPHY

Motivation. To become successful scientists, professionals, and citizens, students need scientific and quantitative reasoning skills and a fundamental knowledge of biology. I teach and mentor for two reasons: I want to help students develop these skills, and I enjoy guiding them to the thrilling moments that come with mastering difficult ideas. I love exploring the fascinating complexity of ecology and evolution with students through hands-on activities, field trips, and research.

Teaching Experience. My experiences range from one-on-one mentoring to formal classroom instruction. I developed my own intensive course on 'Maximum Likelihood Analysis in Ecology' (MLE), which I have taught for four years at Michigan State University. This course brings students – from undergraduates to postdocs – into the same classroom, where I teach them how to analyze non-normal and non-linear data in [R]. Over the years, I have worked with students from >20 schools (including former FSU student Erica Holdridge), studying topics from protists to prairies. Evaluations are strong (*"I learned more in a single week than in an entire semester of statistics"*). I also regularly guest lecture on topics including ecology, evolution, and mathematical biology. Through my teaching, I work with under-represented and disadvantaged students (from middle school through college). A lack of quantitative literacy is a common impediment to increasing the diversity represented in STEM fields, especially biology. I focus on helping students discover how math relates to biology, providing motivation for improving their quantitative skills. I also using diverse pedagogical techniques to engage and include all students. Collectively, these experiences have inspired me, shaping my goals and skills as an instructor.

Goals. I want my students to expand their knowledge and skills. If we represent this knowledge as K, my goal is to make K > 0, and ideally as large as possible. How do I accomplish this? It helps to examine a basic equation, or model, as I might do in class. For example, let:

$$K = I \times P \times A$$

where **I** = Information, **P** = Processing, **A** = Application. To make sense of this, I describe each variable in turn and provide examples, before showing how they work together in this equation.

Information: Knowledge begins with information; there are basic facts students need to know as educated citizens and biologists. I provide students with information through lectures and readings. I use interactive class wikis to provide additional online material (articles, websites, videos) and to enable students to share interesting things that they discover. I also ensure that students learn how to find information independently using electronic and library resources.

Processing: Unorganized information is confusing and easily forgotten. I help my students process information by: (i) identifying key content and revisiting core concepts across classes, (ii) presenting the same information in different ways, such as illustrating the mathematical relationships between probability distributions as a map on a chalkboard, and (iii) making my students communicate what they learn, which pushes them to organize their own ideas. My MLE students work on labs in pairs, answer questions on the board, and present their final projects. These approaches involve students in teaching and learning, helping them process information.

Application: Organized information is converted into usable knowledge when students apply it. Opportunities for application come from spending time in the lab or field, designing, performing, and interpreting experiments. Before learning about general linear models, I take my MLE students out to the field sites that provide the plant community data we study in lab. Abstract statistics become concrete when connected to a motivating ecological question (Is there a stability-productivity relationship?) and a tangible field experience. Minimizing lectures, I focus instead on extensive, open-ended [R] activities that I developed. The course ends with students using MLE to analyze real data (usually from their own research), cementing their knowledge.

Methods. To achieve my goals, I find it important to: Communicate expectations clearly. I tell my students what I expect of them and what to expect from me. I provide clear syllabi with detailed learning objectives and use online tools including course management software to communicate. Use diverse assessments. I expect my students to show their knowledge in multiple ways (papers, presentations, projects), helping me identify and reward the strengths of a diverse student body. I also survey my students regularly, from pre-course assessments to real-time, anonymous surveys during difficult lectures ("I get it" to "slow down!"). This helps me adapt and continually refine my teaching, providing effective instruction from year to year.

Mentoring. The research experiences I had as an undergraduate at a liberal arts college, and later in graduate school, changed my life. I want to create similarly transformative experiences, building an interactive lab group where students with different experience levels work together and learn from each other. This goal motivates my approach to mentoring.

Undergraduates: I have enjoyed mentoring several undergraduates, including: (i) Lydia Auner, who spent a summer investigating how temperature-nutrient interactions affect phytoplankton; and (ii) Brittany Labbadia and Aldo Arellano, who explored thermal acclimation in phytoplankton. Brittany's work culminated in her senior thesis, and Aldo is a co-author on our first manuscript on this project (Kremer et al. 2018). These projects all integrated mathematical modeling and experiments. I meet my students regularly, reviewing their goals, challenges, and successes, and continue mentoring them in applying for REUs, graduate school, and beyond.

Graduate students: As an adviser and committee member I am excited to work with students with diverse interests (not just phytoplankton), drawing on my quantitative skills. My 1st year students will: (i) read widely, to develop their interests, (ii) complete a project directly tied to my research, to gain skills and publish early, and (iii) apply for fellowships, to structure their reading and support their research. Senior students will focus increasingly on their own research, attending conferences, and publishing. I seek to develop independent, well-rounded students, prepared for careers both in and out of academia, depending on their personal goals.

Courses. I am excited to teach engaging, hands-on courses at FSU, using interactive [R] models to visualize tough concepts in introductory or quantitative classes, and leading regular observations in ecology classes, to amass data that students can use across years to address real ecological questions (e.g. Is plant phenology changing?). Depending on the department's needs, I would love to teach project-based courses at the undergraduate or graduate level. General courses I could lead include ecology, biostatistics, and aquatic/marine ecology. Advanced courses could include *Theoretical Ecology* (exploring the foundations of population, community, and ecosystem processes with analytical and numerical techniques) or *Quantitative Methods in Ecology & Evolution* (covering likelihood, Bayesian, and other modern computational approaches, with applications to students' own research data). Finally, I would be excited to develop seminars on eco-evolutionary theory or trait-based ecology.

Conclusion. Knowledge exceeds zero only if Information, Processing, and Application are positive; this informs how and what I teach. I strive to develop independent, confident students who can locate, organize, and apply critical information and quantitative tools to solve problems. 13

Colin T. Kremer, Ph.D.

RESEARCH STATEMENT

As a quantitative ecologist, I work across disciplines, using theory, large datasets, and targeted experiments to study the links between organismal physiology, evolution, and population, community, and ecosystem ecology. My research program focuses on: (1) exploring the ecological effects of trait evolution and plasticity in fluctuating environments, (2) linking theoretical and empirical trait-based ecology, and (3) studying how evolution and community assembly mediate the response of ecosystems to our changing world.

Evolution and plasticity in fluctuating environments.

Classic theory explores how variable environments enable species with static traits to coexist, sustaining biodiversity. Yet trait change is ubiquitous, driven by plastic and evolutionary mechanisms. These processes complicate efforts to predict the effects of variation on ecology. I study how trait change alters coexistence theory, using models (based on Adaptive Dynamics and quantitative genetics) and experiments. Previously, I showed that plasticity and rapid evolution undermine a coexistence mechanism based on resource fluctuations (Kremer & Klausmeier 2013). More recently, I examined how temperature fluctuations structure communities that are both ecologically and evolutionarily stable (**Fig. 1**; Kremer & Klausmeier 2017; Edwards, Kremer et al. 2018). This work revealed novel examples of alternative stable states in eco-evolutionary systems: identical fluctuations can support several distinct communities. It also shows that limiting similarity still applies to evolving communities.

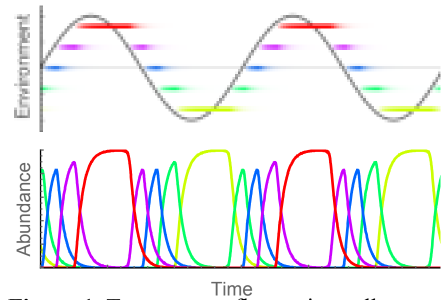

Figure 1. Temperature fluctuations allow five species with different thermal niches to stably coexist (Kremer & Klausmeier 2017).

Current research. Realizing that rapid evolution occurs and causes feedbacks between trait change and ecology shook long-held ecological paradigms. Plastic trait change on ecological time scales may be even more common, yet this mechanism receives far less attention and relevant theoretical frameworks are scarce. I am studying how plasticity affects ecology in variable environments, using thermal acclimation in phytoplankton as a model system (with David Vasseur/Yale and Samuel Fey/Reed College). Our experiments reveal large acclimation effects that vary among species. In particular, I have shown that conventional models that ignore plasticity fail to predict the population dynamics of *Chlamydomonas reinhartdii* exposed to variable experimental temperatures (Kremer et al. 2018). This result shows that existing theory is insufficient. It also challenges a host of biogeographic predictions that implicitly assume acclimation is faster than environmental change; new theories and mathematical frameworks are badly needed. Our project led to an invited NSF-DEB full proposal (2016), to study the mechanisms and ecological effects of acclimation; a revised version is currently under review.

Future research. My group will investigate interactions between ecology, evolution, plasticity, and environmental variability. This includes exploring a new theoretical framework I have developed, which illustrates that different acclimation patterns (lauded by opposing groups of biologists studying different taxa) are actually special cases of a general phenomenon. This theoretical work will be combined with short-term empirical studies of phytoplankton – organisms that are both simple (small, fast-growing, largely asexual) and socially relevant (fueling aquatic food webs and fixing ~50% of all CO_2, annually). We will also advance eco-evolutionary theory in fluctuating environments, considering: (i) how spatial and temporal variation jointly influence evolving communities across scales, and (ii) how evolution and plasticity mediate competitive/mutualistic interactions between species with different lifespans.

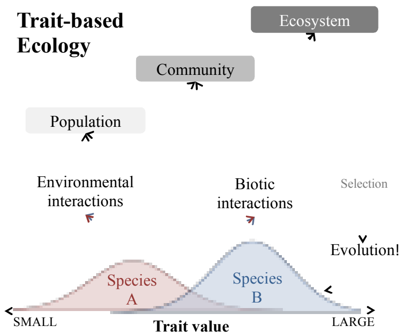

Figure 1 (left). Trait-based ecology uses variation in species traits to explain ecological processes across scales and to link evolution with ecology (Kremer et al. 2016).

Figure 2 (right). Predicted changes in phytoplankton community diversity by 2100 as oceans warm (figure remade from Thomas, Kremer et al. 2012).

<u>Linking theoretical and empirical trait-based ecology.</u>

Trait-based ecology examines how ecological patterns emerge from fundamental organismal properties, providing new ways to predict the occurrence and interaction of species (**Fig. 2**). However, the rapid growth of this field carries a significant risk: that empirical efforts may outpace the development of accompanying theoretical frameworks, slowing scientific progress. I work at the interface of theoretical and empirical trait ecology to confront this issue, and other challenges (reviewed in Kremer et al. 2016), including an under-appreciation of how variable traits are through space and time. I develop new theory to investigate empirical patterns and I capitalize on existing data to discriminate among theories. For example, I uncovered global relationships between (i) the traits that define the thermal niches of hundreds of phytoplankton species and (ii) the thermal environments where they occur (Thomas, Kremer, et al. 2012 & 2016). Using a novel eco-evolutionary model, I was then able to show that these patterns agree with our theoretical understanding of thermal ecology and local adaptation. Finally, with this framework, I was able to predict how climate change will affect future species distributions and community diversity, including declines in the tropics (**Fig. 3**; Thomas, Kremer, et al. 2012). Recently, I also reconciled competing theories describing the size- and temperature-dependence of phytoplankton growth, revealing that oceanographic models overestimate the sensitivity of primary production to rising temperatures (Kremer et al. 2017).

Current research. In my current position, I am exploring how trait diversity is partitioned within and across competing species in phytoplankton communities from two contrasting environments (Rhode Island and Bermuda). This collaborative work is supported by an NSF Dimensions grant that I helped write (PI: Elena Litchman/MSU). For the first time, new observational data will allow me to test predictions arising from my theoretical work (Kremer & Klausmeier 2017). I am also incorporating thermal adaptation into global ocean models (extending my NSF fellowship, see below), and developing new ways of modeling the joint effects of temperature and nutrients on species distributions (Thomas et al. 2017) and adaptation within evolutionary experiments (O'Donnell et al. 2018; Aranguren-Gassis et al., *in review*).

Future research. My research group will advance the conceptual foundation of trait-based ecology. We will develop new theory and test existing theory using new observations or existing resources. For example, the many eco-evolutionary models developed in recent decades are seldom used quantitatively, yet they have a powerful capacity to generate predictions of trait-environment relationships. Compared against empirical data, such predictions ultimately allow tests of underlying theory (as in Thomas, Kremer et al. 2012). My students and I will capitalize on this opportunity, developing and applying quantitative eco-evolutionary models to understand links between other phytoplankton traits (e.g., size, stoichiometry, plasticity), environmental factors (temperature, nutrients, light), and species interactions (predation, bacterial mutualisms).

Figure 4. By 2100, climate change will create novel high temperature environments (areas bounded by purple contours). When incorporated into current ecosystem models, evolutionary constraints lead to a predicted decline of 10-15% in mesozooplankton productivity in these regions, with negative consequences for tropical fisheries. (Kremer et al. *in prep*).

<u>Ecosystem consequences of evolution and community assembly in a changing world.</u>

Human actions have widespread environmental impacts, from eutrophication to climate change, which alter the diversity and composition of ecological communities. The first two areas of my research explore how trait dynamics mediate the effects of environmental change on populations and communities. I also study how environmental change affects ecosystems, incorporating concepts from evolutionary theory and community assembly.

Current research. Due to computational limits, contemporary global ecosystem models oversimplify ecological diversity and neglect evolution entirely. Yet evolutionary adaptation is critical to understanding the fate of communities and ecosystems in novel environments created by climate change. In my first position as an NSF Fellow, I integrated ecological and evolutionary theory with a global marine ecosystem model used to predict the effects of climate change (with Jorge Sarmiento/Princeton, Charles Stock/NOAA GFLD, and David Vasseur/Yale). I showed that adding realistic constraints to thermal adaptation in global ecosystem models alters the size distribution and productivity of tropical plankton communities facing climate change (**Fig. 4**; Kremer et al., *in prep*). I am currently exploring the conditions, locations, and time scales over which more costly and realistic models (which consider biodiversity and evolution) yield predictions that deviate importantly from simpler models grounded in theory.

I am also a key member of a working group focused on integrating community assembly theory with the study of biodiversity-ecosystem function relationships (sponsored by sDiv; organized by Mathew Leibold and Morgan Ernest). My contributions examine the direct and indirect effects of environmental changes on ecosystem function. I have developed new conceptual and statistical approaches based on the Price equation, deployed as an [R] package (Bannar-Martin, Kremer et al. 2017). I am applying this approach to terrestrial grasslands from Cedar Creek, MN (Kremer et al. *in prep*), to better understand the ties between diversity, composition, and ecosystem function outside of tightly controlled, randomized studies.

Future research. I will continue improving the coupling of ecological and evolutionary theory with global models that inform policy, seeking ways to tractably represent the behavior of functionally diverse communities. Additionally, the tools I develop open up new areas of research, creating abundant opportunities for my future students. For example, Price equation techniques have yet to be applied to marine systems, or to theoretical models of community dynamics, which could inform our interpretation of empirical patterns.

Summary. As a quantitative ecologist, I explore fundamental ideas in ecological and evolutionary theory, while striving to understand how natural and human induced environmental changes affect ecology across scales. My research program's breadth (including marine and freshwater systems) allows me to compete for funding from multiple NSF directorates and foundations to support my work. I am excited to mentor undergraduates, graduate students, and postdocs, cultivating their ability to ask and answer deep questions about the natural world. I am committed to building a diverse, interactive research group, where empiricists gain quantitative skills, mathematicians find inspiration in nature, and both groups work together to unravel the wonderful complexities of ecology and evolution.