University of California
NATURAL RESERVE SYSTEM

Mildred E. Mathias
Graduate Student Research Grants
2014-15

APPLICANT INFORMATION	First applicant	Second applicant (Joint application only)
First / given name	William	
Middle name (if used)		
Last / family name	Petry	
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Daytime phone number(s)	636 489 9884 / 949 824 6140	
Campus	Irvine	Select from drop-down list
Department	Ecology & Evolutionary Biology	
Advisor(s)	Kailen Mooney	
Year in program	5 - fifth year	Select from drop-down list

RESEARCH PROJECT	
Title	Scaling up demography – How climate and species interactions shape the population dynamics and management of the invasive herb Plantago lanceolata
Time schedule	Baseline data & application of treatment -- April-May 2015 Final demographic rate data collection -- April-May 2016 Model construction & analysis -- May-July 2016 Writing & publication -- August-September 2016
Other funding sources	None

Select each reserve where you intend to conduct your research

- [x] Angelo Coast Range Reserve
- [ ] Año Nuevo Island Reserve
- [ ] Blue Oak Ranch Reserve
- [ ] Bodega Marine Reserve
- [ ] Box Springs Reserve
- [ ] Boyd Deep Canyon DRC
- [ ] Burns Piñon Ridge Reserve
- [ ] Carpinteria Salt Marsh Reserve
- [x] Chickering American River Reserve
- [ ] Coal Oil Point Natural Reserve
- [ ] Dawson Los Monos Reserve
- [ ] Elliott Chaparral Reserve
- [ ] Emerson Oaks Reserve
- [ ] Fort Ord Natural Reserve
- [x] Hastings Natural History Reservation
- [x] James San Jacinto Mountains Reserve
- [ ] Jenny Pygmy Forest Reserve
- [ ] Jepson Prairie Reserve
- [ ] Kendall-Frost Mission Bay Marsh Res.
- [ ] Landels-Hill Big Creek Reserve
- [ ] McLaughlin Natural Reserve
- [ ] Merced Vernal Pools & Grassland Res.
- [ ] Motte Rimrock Reserve
- [x] Kenneth S. Norris Rancho Marino Res.
- [ ] Quail Ridge Reserve
- [ ] Sagehen Creek Field Station
- [ ] San Joaquin Marsh Reserve
- [x] Santa Cruz Island Reserve
- [ ] Scripps Coastal Reserve
- [ ] Sedgwick Reserve
- [ ] SNRS – Yosemite Field Station
- [ ] Stebbins Cold Canyon Reserve
- [ ] Steele/Burnand Anza-Borrego DRC
- [ ] Stunt Ranch Santa Monica Mntns. Res.
- [ ] Sweeney Granite Mountains DRC
- [ ] VESR – Sierra Nevada Aquatics Res Lab
- [ ] VESR – Valentine Camp
- [ ] White Mountain Research Center
- [ ] Younger Lagoon Reserve

How is the use of NRS reserve(s) important to your project?

The goal of my project is to understand how variation in climate and interactions with symbiotic species affect the population dynamics and invasion success of the plant Plantago lanceolata. Critical to the success of this project are populations well distributed across the climatic range of Plantago in California and their protection from outside influences that could otherwise alter population dynamics (e.g. grazing, mowing, and chemical applications). The risk of unforseen interference is only magnified with distance away from my home campus (UC Irvine), where populations will by necessity be visited only a handful of times during the project. The Natural Reserve System provides a network of sites that meet these requirements and for which there is no feasible substitute. Moreover, Reserve managers provide both a close connection to the natural history of the area that puts the data into context and the logistical support for coordinating across a state-wide spatial scale.

BUDGET **Funding may be requested for**: necessary supplies and minor equipment; reserve user fees; actual cost of food and travel to, from and at the reserve; special logistical costs; computer support; access to special analytical equipment, etc. **Non-allowable categories include**: travel to scholarly meetings; preparation of thesis copy; salaries and stipends; publication costs; purchase of classroom books; and purchase of computers or printers.			
	Description	Amount	Total
Supplies & minor equipment	Plant marking supplies: (9 control sites + 6 fungicide sites) x (100 tags + 2 transect end markers)	40	125
	Treatment supplies: 500g iprodione fungicide & personal protective equipment (Tyvek suit, face mask)	85	
Fees charged by the reserve	2 trips x 2 nights x [Angelo Coast -- $12, Hastings -- $15, James -- $10, Rancho Marino -- $10, Santa Cruz -- $10]	228	228
	2 trips x day use only at Anza Borrego & Chickering ($0/day; camping off-site)	0	
Travel (please put actual cost items and mileage @ $.50/mi on separate lines)	Mileage -- $0.50 x 1600 miles x 2 trips (set up and final)	1600	1758
	Ferry transit to Santa Cruz Island (2 roundtrips x $79)	158	
Subsistence			0
Other			0
	Total request (cannot exceed $3,000)		2111

Scaling up demography – How climate and species interactions shape the population dynamics and management of the invasive herb *Plantago lanceolata*

1. Conceptual background

Understanding population processes is critical to predicting the distribution and abundance of organisms in space and time. Recent increases in anthropogenic impacts on natural systems – encompassing global climate change, disturbance, and the introduction of exotic species – have altered population processes in many species, pushing some to extinction while facilitating explosive growth in others. Key to understanding population- and species-level changes is their dependence on the aggregation of individual responses; put another way, our ability to predict future changes rests on our understanding of the processes that alter individual performance and how these individual responses scale up to higher levels of biological organization.

Although tools to predict population growth rate (λ) from measurements of individual-level population processes have developed considerably since the 18th century (*1*), *we understand little about how spatial or temporal variation in population processes affect population dynamics*. Individual performance – and by extension population dynamics – depends heavily on environmental conditions that vary over both space and time, especially in sessile organisms, as they do not have the ability to migrate to more benign regions. Such variation is the rule rather than the exception in natural settings, and can manifest in complex ways when abiotic and biotic drivers of performance interact (*2*). Most studies of population dynamics fail to capture the full range of conditions an organism experiences; population studies in a database encompassing 932 plant species (COMPADRE 3.0) are typically short in duration (median=4.5, >90% are less than 12 years) and are poorly replicated in space (median=3.5, max=15 populations). Failure to sample demographic processes across the range of abiotic and biotic environments a species experiences not only hinders our ability to predict biological responses to ongoing anthropogenic change, but also confounds the widespread use of population models for conserving rare species (*3*) and managing invasives (*4*).

Adequate spatial and temporal replication is a colossal task for a single researcher to attempt, especially for wide-ranging invasive species. A growing movement in ecology resolves this barrier by establishing a network of globally-distributed collaborators, each contributing funding and data to meet the larger project objectives (see the International Tundra Experiment (*5*) and Nutrient Network (*6*) as examples). The distributed design also encourages both collaboration between junior and senior scientsts and participant-developed add-on projects that leverage the existing design and collaborative network to answer other important ecological questions. PlantPopNet (http://plantpopnet.wordpress.com) is a budding globally-distributed experiment that seeks to bridge gaps in our understanding of how climatic variation alters species traits and population dynamics using a widespread invasive plant as a model system. This proposal seeks to answer two questions:

1) **How does spatially variable climate affect individual performance and population dynamics?**
2) **Do interactions with symbiotic species modulate the impacts of climate?**

2. Study system

Plantago lanceolata (Plantaginaceae) is a short-lived perennial herb native to northern Europe that now occurs in 76 countries across every continent (*7*). Within California, *Plantago* has invaded 49 of 58 counties (*8*) and 13 of 39 UC Reserves (*9*). The worldwide invasion of *Plantago* places it as a model system for understanding invasion and naturalization processes.

Stymied efforts to control its spread are likely in part due to its rapid maturation, prodigious seed production and dispersal, and resilience to disturbance (*10*).

Plantago grows across a large range of climate regimes, making it an ideal candidate species to address questions involving spatial heterogeneity. Within California, it grows over a 4.6-fold gradient in mean annual temperature and a 36.4-fold gradient in mean annual precipitation (Fig. 1). This wide range of climate regimes provides an unparalleled opportunity to test the hypothesis that spatial variation in climate alters population processes and dynamics, and to understand which processes may be the best regional targets for invasive management.

Plantago frequently interacts with root-associated arbuscular mycorrhizal fungi (AMF), a pervasive symbiosis common to >80% of all plant species and many important invasives (*11*). AMF symbionts generally improve host plant performance in stressful environments by provisioning nutrients and water in exchange for carbon from the host; however, the benefits of the interaction for host plants may not outweigh costs in response to other stressors or in benign environments (*11*). Specifically for *Plantago*, plants hosting AMF grow better in poor soil and have higher concentrations of anti-herbivore compounds (*12*), but carbon allocation to AMF slows plant regrowth after grazing (*13*). As such, the effect of species interactions on individual performance and population dynamics may be contingent on environmental context.

3. Proposed methodology

The methodology outlined here will allow for data collection at 9 *Plantago* populations across their invasive range in California and provides an avenue for my collaboration with the global PlantPopNet network. I will add to this project an experimental design – replicable anywhere – that contrasts abiotic and biotic environmental drivers of *Plantago* population dynamics. I will use a coordinated set of UC-NRS Reserves (see letters of support) and nearby (<50km) public lands to advance these scientific and professional goals.

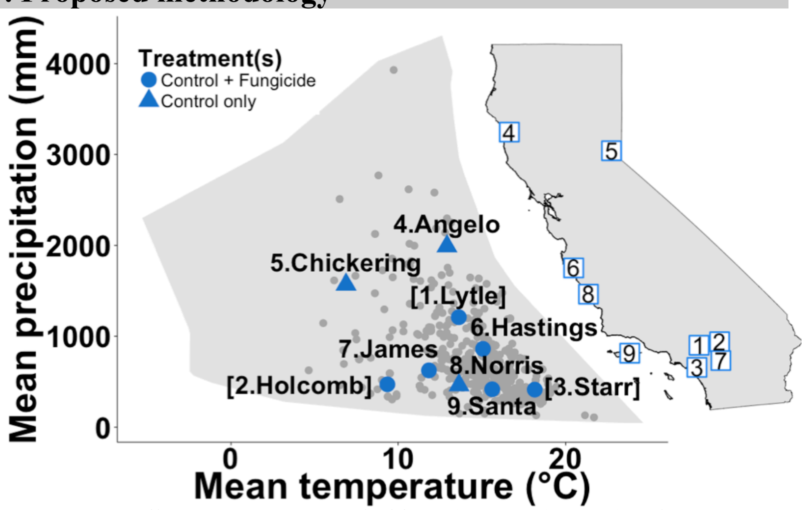

Fig. 1 (L) "Climate space" occupied by *Plantago lanceolata* in California expressed in mean annual temperature (°C) and precipitation (mm). Proposed study populations are shown in blue by treatment (see text for details; brackets indicate sites not requiring use of a Reserve). *Plantago* collection records (dark gray points) span more than 50% of the climate space of California (light gray polygon). Data sources: Climate – PRISM Climate Group; *Plantago* collections – Consortium of California Herbaria. **(R)** Proposed sites are shown in geographic space with numbers corresponding to L figure.

3.1 Demographic modeling (core PlantPopNet objective)

At each study population, I will mark 100 individual *Plantago* plants using small tags along a ca. 10 m long, 1 m wide transect. Where plant density is low, I will extend or replicate this transect design. I will mark transect ends using wood stakes and georeference them for precise relocation. I will measure annual rates of growth, survival, reproductive effort, and recruitment on these individuals and build integral projection models (IPMs) parameterized with the field data (*14*). I will use Life Table Response Experiment (LTRE) analyses – analogous to ANOVA – to understand how differences in plant performance among populations scale up to drive differences in population dynamics and link these to climatic differences among sites derived from nearby weather stations (*15*).

3.2 Experimental manipulation of species interactions (novel add-on)

Interactions with other species – in addition to the abiotic environment – can have profound impacts on individual performance, and by extension, population dynamics. I will explore the consequences of the close association of *Plantago* with symbiotic AMF contrasted against climatic variation by experimentally manipulating AMF colonization at a subset of study sites (Fig. 1). This component represents a novel contribution to the broader PlantPopNet collaboration that will be offered to project participants as a means to extend the inference of my research beyond California. At this early stage, one participant has already agreed to replicate this protocol at several populations near Brisbane, Australia (R. Salguero-Gómez, pers. comm.).

I will reduce AMF colonization by applying slow-release beads containing the fungicide iprodione at 2 $g \cdot m^{-2}$ to plants in a replicate transect every 60 days during the *Plantago* growing season (at most late March-early August; 10 m x 1 m transect treated = 20 $g \cdot application^{-1}$). This dose and application frequency effectively reduces AMF colonization (*12*). Moreover, iprodione has been shown to have low soil mobility and groundwater penetration (*16*), low toxicity to other organisms (*17*), and a short half-life in soil (14-30 days; *18*). Given its low impact, iprodione is registered in California for a wide variety of anti-fungal applications in landscape-scale commercial settings as well as residential use.

I will measure AMF colonization on both treated and control plants to ensure treatment efficacy. Finally, I will assess the demographic impact of interactions with AMF by building population models for fungicide-treated plants and comparing them to controls using the same methods used to build and compare population models across study sites.

4. Literature Cited

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4. E. R. Buhle, M. Margolis, J. L. Ruesink, Bang for buck: cost-effective control of invasive species with different life histories. *Ecol Econ* **52**, 355–366 (2005).
5. S. C. Elmendorf *et al.*, Global assessment of experimental climate warming on tundra vegetation: heterogeneity over space and time. *Ecol Lett* **15**, 164–175 (2012).
6. E. T. Borer *et al.*, Finding generality in ecology: a model for globally distributed experiments. *Meth Ecol Evol* **5**, 65–73 (2014).
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8. USDA, NRCS, The PLANTS Database (2014) (available at http://plants.usda.gov).
9. B. P. Haggerty, S. J. Mazer, *Flora of the University of California Natural Reserve System* (University of California Natural Reserve System, 2014).
10. Cal-IPC, *California Invasive Plant Inventory* (California Invasive Plant Council, 2006; http://www.cal-ipc.org).
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12. A. C. Gange, A. G. West, Interactions between arbuscular mycorrhizal fungi and foliar-feeding insects in *Plantago lanceolata* L. *New Phytol* **128**, 79–87 (1994).
13. G. B. De Deyn, A. Biere, W. H. van der Putten, R. Wagenaar, J. N. Klironomos, Chemical defense, mycorrhizal colonization and growth responses in Plantago lanceolata L. *Oecologia* **160**, 433–442 (2009).
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16. R. D. Wauchope, T. M. Buttler, A. G. Hornsby, P. W. M. Augustijn-Beckers, J. P. Burt, in *Reviews of Environmental Contamination and Toxicology*, Reviews of Environmental Contamination and Toxicology. G. W. Ware, Ed. (Springer New York, New York, NY, 1992), vol. 123, pp. 1–155.
17. C. MacBean, *The Pesticide Manual* (British Crop Protection, 2012).
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October 2014

Education

2010-	Ph.D. candidate, University of California at Irvine, Ecology & Evolutionary Biology (Advisor: Kailen Mooney; *advanced to candidacy November 2012*)
2006-2010	B.Sc. Biology (with minor in Mathematical Biology), *summa cum laude*, Truman State University, Kirksville, Missouri

Research Appointments

2013-	Graduate Affiliate, Center for Global Peace & Conflict Studies, University of California at Irvine
2007-2010	Undergraduate researcher, Truman State University
2009	NSF-REU Fellow, Rocky Mountain Biological Laboratory
2007	Resource Science field technician, Missouri Department of Conservation
2005	Fisheries field technician, Missouri Department of Conservation

Publications (*undergraduate coauthor, n = 7)

5. Moriera, X., K.A. Mooney, S. Rasmann, **W.K. Petry**, A. Carrillo-Gavilán, R. Zas, & L. Sampedro. 2014. Trade-offs between constitutive and induced defences drive geographical and climatic clines in pine chemical defences. Ecology Letters 17:537-546
4. **Petry, W.K.**, K.I. Perry*, A. Fremgen*, S.K. Rudeen*, M. Lopez*, J. Dryburgh*, & K.A. Mooney (2013) Mechanisms underlying plant sexual dimorphism in multi-trophic arthropod communities. Ecology 94: 2055-2065.
3. Mooney, K.A., A. Fremgen*, & **W.K. Petry** (2012) Plant sex and induced responses independently influence herbivore performance, natural enemies and aphid-tending ants. Arthropod-Plant Interactions 6: 553-560.
2. **Petry, W.K.**, K.I. Perry*, & K.A. Mooney (2012) Influence of macronutrient imbalance on native ant interactions with aphids, aphid enemies, and host plant flowers in the field. Ecological Entomology 37: 175-183.
1. **Petry, W.K.**, S.A. Foré, L.J. Fielden, & H-J. Kim (2010) A quantitative comparison of two sample methods for collecting *Amblyomma americanum* and *Dermacentor variabilis* (Acari: Ixodidae) in Missouri. Experimental and Applied Acarology 52: 427-438.

Fellowships & Grants

2014	Doctoral Dissertation Improvement Grant (DDIG), National Science Foundation
2011-2014	Graduate Research Fellowship (GRFP), National Science Foundation (*awarded 2010*)
2014	Research Grant, American Alpine Club
2014	Grant in Aid of Research (GIAR), Sigma Xi
2014	Graduate Student Grant, Rocky Mountain Biological Laboratory
2013	Travel Grant, Ecological Society of America Plant Population Ecology section

2013	School of Biological Sciences Graduate Fellowship, University of California Irvine
2013	John W. Marr Fund Research Grant, Colorado Native Plant Society
2013	Graduate Student Grant, Rocky Mountain Biological Laboratory
2012	Travel Grant, Ecological Society of America Plant Population Ecology section
2012	Research Grant, American Alpine Club
2012	Graduate Student Grant, Rocky Mountain Biological Laboratory
2011	Kingsdale Graduate Grant, Rocky Mountain Biological Laboratory
2011	Hendry Bequest, Alpine Garden Society
2010	Graduate Dean Recruitment Award, University of California Irvine
2010	NSF-IGERT Comparative Genomics Fellowship, University of Arizona (*award declined*)
2009	NSF-REU fellowship, Rocky Mountain Biological Laboratory

Conference Presentations

2014	Evolutionary Demography Society Meeting (Palo Alto, CA) – Sexually dimorphic responses to climate variation: Demographic causes and consequences of climate-skewed sex ratios
2013	Ecological Society of America (Minneapolis, MN), oral paper – Historical demography along a climatic gradient: Generating predictions of population responses to climate change in the montane dioecious herb *Valeriana edulis*
2013	Gordon Research Conference – Plant Herbivore Interaction (Ventura, CA), poster – *Valeriana edulis*, a system for studying the mechanisms of plant genetic effects on arthropod communities in the context of climate change
2012	Ecological Society of America (Portland, OR), oral paper – Warming up to changing trait frequencies: Rapid, climate change-induced shifts in population sex ratios along an elevation gradient
2011	Ecological Society of America (Austin, TX), oral paper – Sex-biased and variable herbivory parallel clinal variation in plant sex ratios along an elevational gradient
2010	Ecological Society of America (Pittsburgh, PA), oral paper – Ant-aphid interactions are mediated by host plant sex and ant colony nutritional status
2008	Society for Vector Ecology (Ft. Collins, CO), poster

Undergraduate Mentoring (N=10; *co-author [2]; ‡NSF-REU [3]; *in graduate school* [1])

University of California, Irvine

Kaitlyn Shimizu (2012-2014), Allen Phan (2012-2013), Lawrence Liu (2012), Alvis Lee (2011), Thao Dao (2011)

Rocky Mountain Biological Laboratory

*John Dryburgh** (2011, Susquehanna University), Sarah Rudeen*‡ (2011, Southern Oregon University), Alec Williams‡ (2012, San Bernardino Valley College), Guadalupe Flores‡ (2013, San Bernardino Valley College), Ana Chicas-Mosier‡ (Oklahoma State University)

Community Outreach

PlantShift, directed citizen science initiative focused on my Ph.D. research, 2013-present
National Lab Network, STEM Professional volunteer, 2011-present
Irvine Unified School District, Science Fair mentor, 2010-present