

Project Summary

Overview testing

Intellectual Merit

Broader Impacts

Project Description

Introduction

nicely written intro goes here

Objectives

Objective I: do this cool thing

talk about the objectives here, then list them specifically:

1. *Do ...?*
2. *Do ...?*
3. *Is there evidence of ...?*

Objective II: Determine the extent to which ...

Maize was domesticated in...

Rationale and Significance

rationale and significance

Research Plan

Assess the evolutionary role of ...

first subsection stuff

Does the potential for ...?

lots of subsection stuff

Is i...?

subsection stuff

Can a widespread species serve as ...?

subsection stuff

Potential Challenges potential challenges

Broader Impacts

stuff here

subsection

stuff

subsection

stuff

Results From Prior NSF Support

don't think I need this section

References Cited

- K. J. Gilbert and M. C. Whitlock. Evaluating methods for estimating local effective population size with and without migration. *Evolution*, 69(8):2154–2166, July 2015.

Biographical Sketch — Kimberly Julie Gilbert

A. Professional Preparation

| Institution, Location | Major | Degree | Year |
|--|---------|--------|-----------------|
| University of Virginia, USA | Biology | B.Sc. | 2010 |
| University of British Columbia, Canada | Zoology | Ph.D. | 2016 (expected) |

B. Publications

Five Publications Most Closely Related to the Proposed Project

1. **Gilbert KJ**, MC Whitlock (2015) Evaluating methods for estimating local effective population size with and without migration. *Evolution*, 68(8), 2154-2166.
2. **Gilbert KJ**, MC Whitlock (2015) Q_{ST} - F_{ST} comparisons with unbalanced half-sib designs. *Molecular Ecology Resources*, 15(2), 262-267.
3. Caplins SA, **KJ Gilbert**, C Ciotir, J Roland, SF Matter, N Keyghobadi (2014) Landscape structure and the genetic effects of a population collapse. *Proceedings of the Royal Society B*. 281: 20141798; doi: 10.1098/rspb.2014.1798
4. Keller SR, **KJ Gilbert**, PD Fields, DR Taylor (2012) Bayesian inference of a complex invasion history revealed by nuclear and chloroplast genetic diversity in the colonizing plant, *Silene latifolia*. *Molecular Ecology*, 21(19), 4721-4734.
5. Whitlock MC, **KJ Gilbert** (2012) Q_{ST} in a hierarchically structured population. *Molecular Ecology Resources*, 12(3), 481-483.

Four Other Significant Publications

1. Santiso X, L Lopez, **KJ Gilbert**, R Barreiro, MC Whitlock, R Retuerto (2015) Patterns of genetic variation within and among populations in *Arbutus unedo* and its relation with selection and evolvability. *Perspectives in Plant Ecology, Evolution and Systematics*, 17(3), 185-192.
2. Vines TH, RL Andrew, DG Bock, MT Franklin, **KJ Gilbert**, NC Kane, EJ Kleynhans, J-S Moore, BT Moyers, S Renaut, DJ Rennison, T Veen, S Yeaman (2013) Mandated archiving greatly improves access to research data. *FASEB Journal*, 27(4), 1304-1308.
3. **Gilbert KJ**, RL Andrew, DG Bock, MT Franklin, NC Kane, J-S Moore, BT Moyers, S Renaut, DJ Rennison, T Veen, TH Vines (2012) Recommendations for utilizing and reporting population genetic analyses: The reproducibility of genetic clustering using the program STRUCTURE. *Molecular Ecology*, 21(20), 4925-4930.
4. Vines TH, AYK Albert, RL Andrew, F Débarre, DG Bock, MT Franklin, **KJ Gilbert**, J-S Moore, S Renaut, DJ Rennison (2014) The availability of research data declines rapidly with age. *Current Biology*, 24, 94-97.

C. Select Conference Presentations (chosen from 11 presentations)

- 2015 Validating SNP loci underlying local adaptation in lodgepole pine; KJ Gilbert, S Yeaman, KE Lotterhos, KA Hodgins, H Suren, JA Holliday, S Nadeau, SN Aitken, MC Whitlock *Poster, 15th ESEB Congress, Lausanne, Switzerland*
- 2014 Evaluating methods for estimating effective population size in the presence of migration; KJ Gilbert & MC Whitlock *Oral presentation, Evolution, Raleigh, USA*
- 2012 Range expansion and adaptation across heterogeneous environments; KJ Gilbert & MC Whitlock *Poster, Evo-WIBO Conference (Evolutionary Biology in the Pacific Northwest), Port Townsend, USA*
- 2011 Inferred invasion history of *Silene latifolia* into North America utilizing population genetic data and approximate Bayesian computation; KJ Gilbert, SR Keller, PD Fields, DR Taylor *Poster, 13th Congress of the European Society for Evolutionary Biology, Tuebingen, Germany*

D. Grants and Awards

Cordula and Gunter Paetzold Fellowship UBC \$18,000CAD 2015 – 2016

maybe still want to change around which pubs go in 5 most important?

| | |
|---|-------------|
| <i>Declined</i> ; Zoology Graduate Fellowship UBC \$11,000CAD | 2015 – 2016 |
| Ann and William Messenger Graduate Fellowship UBC \$700CAD | 2015 |
| Zoology Graduate Fellowship UBC \$11,000CAD | 2014 – 2015 |
| Frieda Granot Graduate Scholarship in Interdisciplinary Research UBC \$200CAD | 2013 – 2014 |
| Theodore E Arnold Fellowship UBC \$7,750CAD | 2013 – 2014 |
| Patrick David Campbell Graduate Fellowship UBC \$8,050CAD | 2013 – 2014 |
| <i>Declined</i> ; Zoology Graduate Fellowship UBC \$10,000CAD | 2013 – 2014 |
| BRITE Fellowship UBC \$10,500CAD <i>per annum</i> | 2011 – 2013 |

E. Synergistic Activities

1. **Working Groups:** Participated in the NESCent Reproducible Science Hackathon (2014), a 21-member working group aimed at developing a curriculum and workflow for teaching reproducible science to researchers of any background. Participated in the SimBank NESCent Catalysis Meeting (2014) which was a 25-member working group to create a collection of openly available simulation results to facilitate testing of statistical population genetic and phylogeographic methods.
2. **Teaching:** Teaching assistant for Fundamentals of Evolutionary Biology (Fall 2012-Spring 2013) where I taught three sections per term of 45 students each and lead discussion-based tutorials. Teaching assistant for Fundamentals of Biostatistics (Fall 2013, 2014, 2015). Taught two sections of 70 students total in 2013, and in 2014 and 2015 served as the lab coordinator for 254 and 276 students enrolled in the course, respectively, while teaching one section of 36 and 35 students respectively.
3. **Service:** Served as a Graduate Student Council Member for the American Society of Naturalists (2013-2016, chair 2015-2016). Served as the graduate student representative on the 2014 evolutionary biology CRC2 job search for the Department of Zoology, University of British Columbia. Organize the Biodiversity Research Centre's weekly evolution discussion group (2014-2016), for students, post-docs, and faculty from the departments of Zoology, Botany, Forestry, and Fisheries to discuss current papers in evolutionary biology. Reviewer for *Molecular Ecology Resources*, *Ecology and Evolution*, *Tree Genetics & Genomes*.
4. **Outreach:** Volunteer mist-netting and bird banding with local Vancouver non-profit organization Wild Research (2013-2015) where I participated in winter, spring migration, and fall migration bird monitoring at Iona Island Bird Observatory, taught volunteers proper bird handling, aging, data collection, and mist net extraction techniques, and assisted in educating public visitors to the station about the species conservation and monitoring, and the general tasks of running a banding station.

F. Collaborators (Total: 25)

U Alberta Jens Roland; *U Basel* Peter Fields; *U British Columbia* Dan Bock, Diana Rennison; *U Calgary* Sam Yeaman; *UC Davis* Serena Caplins; *U Cincinnati* Stephen Matter; *CIRB Paris* Florence Débarre; *Colorado State* Brook Moyers; *U Colorado* Nolan Kane; *U Coruna* Rodolfo Barreiro, Lúa López; *Kwantlen Polytechnic U* Michelle Franklin; *U Laval* Jean-Sébastien Moore; *Mol. Ecol. Managing Editor* Timothy Vines; *U Montreal* Sébastien Renaut; *U New England (Australia)* Rose Andrew; *UT Austin* Thor Veen; *Trent U* Claudia Ciotir; *U Santiago de Compostela* Rubén Retuerto Franco; *Xabier Santiso*; *U Vermont* Stephen Keller; *U Virginia* Douglas Taylor; *Western U* Nusha Keyghobadi; *Women's Health Research Institute* Arianne Albert

Graduate Advisor (Total: 1) *University of British Columbia* Michael C. Whitlock

Biographical Sketch — Jeffrey Ross-Ibarra

1 Professional Preparation

| Institution | Area | Degree / Training | Dates |
|------------------------------------|----------|-----------------------|------------|
| University of California Riverside | Botany | BA, MS | 1998, 2000 |
| University of Georgia | Genetics | PhD | 2006 |
| University of California Irvine | Genetics | Postdoctoral Research | 2008 |

2 Professional Appointments

| Position | Institution | Dates |
|------------------------|---|--------------|
| Associate Professor | University of California Davis | 2012-present |
| Assistant Professor | University of California Davis | 2009-2012 |
| Profesor de Asignatura | Universidad Nacional Autónoma de México | 2001 |

3 Products

Most Relevant to the Proposed Research

- Mezouk S, **Ross-Ibarra J** (2014) The pattern and distribution of deleterious mutations in maize. (2014) *G3* 4:163-171
- Hufford MB, Xun X, van Heerwaarden J, Pyhäjärvi T, Chia J-M, Cartwright RA, Elshire RJ, Glaubitz JC, Guill KE, Kaeppler S, Lai J, Morrell PL, Shannon LM, Song C, Springer NM, Swanson-Wagner RA, Tiffin P, Wang J, Zhang G, Doebley J, McMullen MD, Ware D, Buckler ES, Yang S, **Ross-Ibarra J** (2012) Comparative population genomics of maize domestication and improvement. *NATURE GENETICS* 44:808-811
- Cook JP, McMullen MD, Holland JB, Tian F, Bradbury P, **Ross-Ibarra J**, Buckler ES, Flint-Garcia SA (2012) Genetic architecture of maize kernel composition in the Nested Association Mapping and Inbred Association panels. *PLANT PHYSIOLOGY* 158: 824-834
- van Heerwaarden J, Doebley J, Briggs WH, Glaubitz JC, Goodman MM, Sánchez González JJ, **Ross-Ibarra J** (2011) Genetic signals of origin, spread and introgression in a large sample of maize landraces. *PNAS* 108: 1088-1092
- **Ross-Ibarra J**, Tenaillon M, Gaut BS (2009) Historical divergence and gene flow in the genus *Zea*. *GENETICS* 181: 1399-1413.

Additional Products

- Gerke JP, Edwards JW, Guill KE, **Ross-Ibarra J**, McMullen MD (2015) The genomic impacts of drift and selection for hybrid performance in maize. *GENETICS In Press*
- Takuno S, Ralph P, Swarts K, Elshire RJ, Glaubitz JC, Buckler ES, Hufford MB, and **Ross-Ibarra J** (2015) Independent molecular basis of convergent highland adaptation in maize. *GENETICS* 200:1297-1312
- Wills DM, Whipple C, Takuno S, Kursel LE, Shannon LM, **Ross-Ibarra J**, Doebley JF (2013) From many, one: genetic control of prolificacy during maize domestication. *PLOS GENETICS* 9(6): e1003604.
- Studer A, Zhao Q, **Ross-Ibarra J**, Doebley J (2011) Identification of a functional transposon insertion in the maize domestication gene *tb1*. *NATURE GENETICS* 43:1160-1163.

- Gore MA, Chia JM, Elshire RJ, Sun Q, Ersoz ES, Hurwitz BL, Peiffer JA, McMullen MD, Grills GS, **Ross-Ibarra J**, Ware DH, Buckler ES (2009) A first-generation haplotype map of maize. *SCIENCE* 326: 1115-1117.

4 Synergistic Activities

- Faculty Development Award in recognition of university service, 2015
- Editor, G3, PeerJ, Axios Reviews
- DuPont Young Professor 2012-2014 and faculty advisor DuPont Pioneer graduate student symposium in plant breeding 2012-present
- Functional Genetics of Maize Centromeres US-Mexico exchange program, 2011-present
- Presidential Early Career Award for Scientists and Engineers 2009

5 Collaborators and Other Affiliations

Collaborators and Co-editors (Total: 56)

Cornell U Peter Bradbury, Jeffrey Glaubitz, Susan McCouch, Qi Sun, Feng Tian, Sharon Mitchell; *USDA-ARS* Edward Buckler, Sarah Hake, James Holland, Sherry Flint-Garcia, Mike McMullen, Doreen Ware, Jode Edwards; *U Southern California* Peter Ralph; *UC Davis* Alan Bennet, Daniel Runcie, Ed Taylor, Graham Coop, Keith Bradnam, Ian Korf, David Neale, Amélie Gaudin; *UC Irvine* Kevin Thornton; *Carnegie Institute* Davide Sosso; *Stanford* Wolf Frommer; *LANGEBO* Ruairidh Sawers; *U Georgia* Kelly Dawe; *Arizona State* Reed Cartwright; *U Missouri* James Birchler, Katherine Guill, David Wills; *Beijing Genomics Institute* Song Chi, Xun Xu; *U Wisconsin* John Doebley, Jiming Jiang, Shawn Kaeppler; *Syngenta* William Briggs; *Monsanto* Lisa Kanizay; *Dupont Pioneer* Andy Baumgarten, Justin Gerke, Oscar Smith, Tabare Abadie; *U Minnesota* Roman Briskine, Peter Morrell, Chad Myers, Nathan Springer, Peter Tiffin; *MIT* Mary Gehring; *NC State* Major Goodman; *INRA* Clementine Vitte, Maud Tenaillon; *Brigham Young* Clinton Whipple; *Danforth Center* Anthony Studer; *Universidad de Guadalajara* Jesus Sánchez González; *Iowa State* Carolyn Lawrence; *U Hawaii* Gernot Presting; *UC Riverside* Mitchell Provance

Graduate Advisors and Postdoctoral Sponsors (Total: 3)

UC Riverside Norman Ellstrand; *U Georgia* James Hamrick; *UC Irvine* Brandon Gaut

Thesis Advisor and Postgraduate Sponsor (Total: 14)

Postdoctoral: *Iowa State* Matthew Hufford; *Graduate U Advanced Studies* Shohei Takuno; *U Oulu* Tanja Pyhäjärvi, *KWS* Sofiane Mezmouk; *Wageningen* Joost van Heerwaarden; *USDA* Tim Beissinger; *UC Davis* Kate Crosby, Sayuri Tsukahara, Simon Renny-Byfield, Jinliang Yang **Graduate:** Dianne Velasco, Paul Bilinski, Anna O'Brien, Michelle Stitzer

Biographical Sketch — Kevin Richard Thornton

6 Professional Preparation

| Institution | Area | Degree / Training | Dates |
|---------------------------|----------|-----------------------|------------|
| University of Puget Sound | Botany | BA | 1997, 2000 |
| University of Chicago | Genetics | PhD | 2003 |
| Cornell University | Genetics | Postdoctoral Research | 2007 |

7 Professional Appointments

| Position | Institution | Dates |
|---------------------|---------------------------------|--------------|
| Associate Professor | University of California Irvine | 2012-present |
| Assistant Professor | University of California Irvine | 2007-2012 |

8 Products

Most Relevant to the Proposed Research

- **Thornton, K. R.** (2014) A C++ template library for efficient forward-time population genetic simulation of large populations. *Genetics* 98:157-166 PMID: 24950894
- **Thornton, K.** (2003) libsequence, a C++ class library for evolutionary genetic analysis. *Bioinformatics* 19(17): 2325-2327 PMID 14630667
- **Thornton, K. R., A. J. Foran, and A. D. Long** (2013) Properties and modeling of GWAS when complex disease risk is due to non-complementing, deleterious mutations in genes of large effect. *PLoS Genetics* 9: e1003258. PMID 23437004

Additional Products

- Cridland, J. M., **K. R. Thornton** and A. D. Long (2015) Gene expression variation in *Drosophila melanogaster* due to rare transposable element insertion alleles of large effect. *Genetics* 199: 85-93.
- Baldwin-Brown, J., A. D. Long, and **K. R. Thornton** (2014) The Power to Detect Quantitative Trait Loci Using Resequenced, Experimentally Evolved Populations of Diploid, Sexual Organisms. *Molecular Biology and Evolution* 31: 1040-1055. PMID 24441104
- Open-source software: <http://molpopgen.github.io/fwdpp/>
- Open-source software: <http://molpopgen.github.io/libsequence/>

9 Synergistic Activities

- Open-source software: <http://molpopgen.github.io/fwdpy/> This software is unpublished, and will be a key resource for this proposal.
- Editor, G3

10 Collaborators and Other Affiliations

Collaborators and Co-editors (Total: 7)

- *Cornell University* Andrew G. Clark
- *North Carolina State University* Trudy Mackay
- *Princeton University* Peter Andolfatto
- *Rochester University* Daniel Garrigan, Daven C. Presgraves
- *UC Irvine* Anthony (Tony) Long
- *University of Kansas* Stuart MacDonald

Graduate Advisors and Postdoctoral Sponsors (Total: 2)

University of Chicago Manyuan Long
Cornell University Andrew G. Clark

Thesis Advisor and Postgraduate Sponsor (Total: 3)

Postdoctoral: Rebekah R. Rogers **PhD Thesis Advisor:** Julie M. Cridland, Jaleal S. Sanjak

Data Management Plan

Data Types

This proposal will generate genotype and full-genome sequence data, phenotype data, analytical code, germplasm, and publications.

Data Archiving, Plan for Sharing, Public Access Policy

Genotype and Sequence Data EDIT THIS WHOLE DOCUMENT

Dissertation Summary - Kimberly J. Gilbert

A major obstacle in evolutionary biology is the difficulty of population genetic inference in the face of confounding factors, such as demographic history. My dissertation work has focused on several topics related to this broad area of research:

1. Evaluating the ability of statistical genetic methods to estimate effective population sizes in the face of migration (?)
2. Assessing the factors related to local adaptation at range edges during species expansion
3. Validating SNP loci under selection for adaptation to climate in lodgepole pine (*Pinus contorta*)

Effective population size, N_e , is a fundamental parameter in population genetics, evolutionary biology, and conservation biology, yet its estimation can be fraught with difficulties. Several methods to estimate N_e from genetic data have been developed that take advantage of various approaches for inferring N_e . The ability of these methods to accurately estimate N_e , however, has not been comprehensively examined. This part of my dissertation work employed seven of the most cited methods for estimating N_e from genetic data (Colony2, CoNe, Estim, MLNe, ONeSAMP, TMVP, and NeEstimator including LDNe) across simulated datasets with populations experiencing migration or no migration. The simulated population demographies were an isolated population with no immigration, an island model metapopulation with a sink population receiving immigrants, and an isolation by distance stepping stone model of populations. We found considerable variance in performance of these methods, both within and across demographic scenarios, with some methods performing very poorly. The most accurate estimates of N_e can be obtained by using LDNe, MLNe, or TMVP; however each of these approaches is outperformed by another in a differing demographic scenario. Knowledge of the approximate demography of population as well as the availability of temporal data largely improves N_e estimates.

Species range edges have boundaries that cannot always be explained ecologically or geographically, which leaves the question of what evolutionary forces may prevent populations at range edges from adapting and expanding the species range further. A large body of theoretical work has investigated many evolutionary parameters' effects on local adaptation in edge populations, but one area lacking in research is that of the interaction of the landscape with the ability to locally adapt. This study investigates how more realistic, heterogeneous environmental gradients (compared to the linear gradients that previous studies investigate) may interact with dispersal distance and the effect size of mutations. I have simulated a range of parameter combinations that show a strong relation of mutation effect size on the ability to spread across the landscape. As environmental heterogeneity increases, migration load (reduction in fitness due to dispersal away from an area previously adapted to) increases, and local adaptation becomes more difficult, especially in smaller populations at the range edge, slowing the speed of expansion across the landscape.

A history of range expansion can confound many inferences that population genetics aims to understand. Identifying the loci that underlie traits contributing to local adaptation is one such inference that is a major goal in evolutionary biology today. The lodgepole pine (*Pinus contorta*) is a major timber tree in the Pacific Northwest which has a history of expansion post-glaciation, and either one or putatively a second glacial refugia from which this expansion occurred. Climate change is spurring foresters to plant trees for future harvest that will be best adapted to future climates for optimal yield, hence identifying loci underlying adaptation to climate change is a key goal. I am conducting a validation study of SNP loci identified through GWAS, genotype-environment association, and F_{ST} outlier tests to assess how often these methods may produce false positives as a result of population structure and spatial autocorrelation of genetic clines due to range expansion with gradients in environmental variables (i.e. temperature and precipitation). I have sampled a provenance trial (common garden study) in British Columbia to compare performance of populations from a range of native temperatures (MAT -3.7°C - 11°C) planted across test sites of varying temperature (MAT -1.4°C - 5°C) from which I will be able to test if predicted alleles do indeed show increased performance in mature, natural-grown trees.