NSF EPSCoR

2018 - 2023

GEM3
Genes by Environment
Modeling · Mechanisms · Mapping

Strategic Plan

RII Track-1: Linking Genome to Phenome to Predict Adaptive Responses of Organisms to Changing Landscapes

Idaho EPSCoR
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Principal Investigator: Janet Nelson, Ph.D.
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Idaho EPSCoR RII Track-1 Project

RII Track-1: Linking Genome to Phenome to Predict Adaptive Responses of Organisms to Changing Landscapes

Genes to Environment: Modeling, Mechanisms, and Mapping (GEM3)

Vision

Idaho will lead the nation with thriving, collaborative, and inclusive research to discover and predict how plants, animals, and people interact and adapt to changing environments, resulting in the sustainable management of natural resources.

Mission

Discover fundamental knowledge of genetic mechanisms and train a diverse workforce to inform evidence-based management of natural resources.

Project Goal

Enable the research community to understand the factors for, and forecast the outcomes of, how genetic diversity and phenotypic plasticity affect response to environmental change, shaping both population response and adaptive capacity.

This *Strategic Plan* establishes the conceptual, programmatic, and administrative framework for accomplishing the goals and objectives of the NSF EPSCoR RII Track-1 award: *Linking Genome to Phenome to Predict Adaptive Responses of Organisms to Changing Landscapes* (OIA-1757324). It identifies project goals and strategic objectives and explains specific actions to be undertaken to achieve those goals. The Strategic Plan outlines metrics and milestones to ensure objectives are met and outcomes are achieved within the award period.

GEM3, a statewide project, combines research strengths in bioinformatics, complex modeling, ecology, fisheries science, genomics, geospatial science, remote sensing, and social-ecological science (SES) to contribute to the national challenge of understanding the "*Rules of Life: predicting phenotypes from what we know about the genome and environment.*"

A growing number of studies demonstrate how genotypes control the expression of specific traits in organisms responding to environmental change and reveal correlations between genetic variation and population-level response to environmental disturbance. It is known that the capacity of species to respond to social-ecological change is constrained by organismal genetic and phenotypic plasticity, which are a function of "genotype by environment" (GxE) interactions occurring within larger SES. It is also known direct links exist between genetic expression and phenotypic tolerance to selective pressures.

GEM3 seeks to determine the mechanisms underlying population-level responses to environmental change and the feedback effects between SES and population responses. The approach entails determining how environmental processes, including land use changes, influence genome-to-phenome mechanisms and the adaptive capacity of populations. Bridging these gaps will advance predictive models of population-level adaptive capacity under scenarios of future change.

Two focal taxa will be studied: one aquatic (redband trout) and one terrestrial (sagebrush). These taxa are integral to ecosystems in Idaho and the American West and are central to land-use management decisions that drive the economy of the region.

Approach

Research

Idaho's landscapes span a range of environmental gradients (e.g., temperature, aridity) and encompass divergent social-ecological contexts, from designated wilderness to expanding urban areas. These "natural laboratories" enable the systematic discovery of mechanisms of genomic expression for species in changing environments.

GEM3 will identify how genetic diversity interacts with the environment to alter phenotypes linked to the adaptive capacity of populations (Figure 1). Specifically, GEM3 will:

1. Use spatially-explicit iterative modeling and mechanistic experiments to elucidate factors that can be integrated into modeling to forecast genotypes to phenotypes for the study systems (trout and sagebrush).
2. Use agent based models (ABM) to forecast behaviors of key populations under different social-ecological scenarios. This work will support the identification of resulting ecosystem vulnerabilities and potential management interventions.
3. Use novel scaling processes, from genome to phenome, from organisms to populations across landscapes to "forecast futures" using modeling to test and generate hypotheses, experimental studies to identify mechanisms, and mapping to identify natural patterns. Outcomes of these case studies will help to discern pertinent factors that may be universal regardless of species or systems (e.g., wild vs. managed) as well as elucidate mechanisms that are highly responsive to abiotic, biotic, and human stressors.

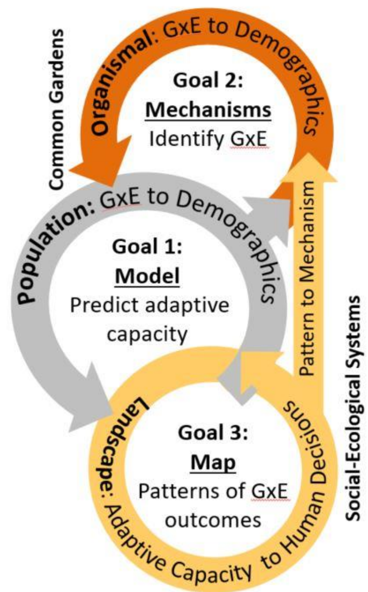

Figure 1: Overview and integration of research objectives to understand GxE outcomes in organisms, populations, and landscapes

Leveraging and harnessing the power of decades of data, GEM3 will advance discovery of GxE mechanisms and outcomes to address the gap between population dynamics of mission-driven agencies and foundational research in landscape ecology associated with predicting effects of environmental change. GEM3 will enable agencies and stakeholders to identify activities most likely to affect adaptive capacity of populations so that resources are appropriately allocated and targeted to benefit society, while preserving biological diversity upon which human society depends. A Seed Funding program will allow GEM3 to respond to new opportunities as well as pursue high impact, potentially transformative research and education projects. It will create a mechanism to catalyze new research on focal species, species interactions, ecosystems, genomics/phenomics, or other emerging areas related to the scope of GEM3.

Education

A fully integrated research, education and workforce development program will be implemented to increase the number, diversity and preparation of skilled scientists and engineers in GEM3 fields (bioinformatics, computational biology, conservation genetics, ecosystem management). The GEM3 research and education ecosystem includes three research universities, four primarily undergraduate institutions and more than a dozen public, private and nonprofit collaborators and stakeholders.

GEM3 adopts a Vertically Integrated Projects (VIPs) strategy to establish an on-ramp for students and provide a range of training, mentoring and professional development support to both students and faculty. The goals are to: (1) provide a statewide mechanism for transdisciplinary science, and (2) grow the next generation of conservation science leaders and workers. GEM3 will increase the participation of underrepresented minority (URM) group members in Science, Technology, Engineering, and Mathematics (STEM) (including Hispanics and Native Americans); low-income, rural and/or first-generation students; and women in Idaho's STEM enterprise.

Alignment with State S&T Plan

GEM3 includes a statewide participatory research program committed to the concept of Idaho EPSCoR's "ONEIdaho" vision of an integrated, productive, and creative research culture and community of Idaho researchers that transcends institutional boundaries. GEM3 researchers will work across institutions on pilot studies and case studies, fostering integration of science and stakeholders, integration of science disciplines, and integration of research and education.

The State of Idaho has demonstrated its commitment to develop research through EPSCoR by contributing to the non-federal required cost share. GEM3 is fully aligned with and guided by Idaho's S&T plan, *Strategic Research Plan for Idaho Higher Education,* approved by the State Board of Education. The Idaho EPSCoR Committee selected GEM3 following an analysis by Elsevier Global Strategic Alliances and a rigorous year-long external review process. The topic was deemed to have the highest impact based upon factors including: (1) contribution to long-term economic and educational priorities of the state; (2) seamless integration of the academic strengths and priorities of the state's research universities; (3) ability of primarily undergraduate institutions (PUIs) to contribute to the integrated research, education, and workforce development activities; (4) industry demand for a larger, more diverse, and better trained biological sciences workforce; and (5) value added to national strategic priorities (e.g., the NSF research Big Idea Understanding the Rules of Life). A core group of GEM3 researchers and educators, many with existing cross-institutional and cross-discipline collaborations, worked together to develop and refine the research and education program.

Expected Benefits

GEM3 leverages its strengths in bioinformatics, complex modeling, data management, ecology, fisheries science, genomics, and SES to create an integrated research and education program for Idaho. State capacity for environmental social science data collection, analysis, and translation to management actions will be increased through the hiring of new faculty with expertise in social science. State capacity to map and monitor changes in the environment, phenotypes of plants and animals, and land use will be increased through investments in on-ground telemetry, unmanned aerial vehicles, and satellite imagery, and by leveraging existing expertise in collecting and analyzing remotely sensed data. Infrastructure investments will enable Idaho EPSCoR to: develop scientific leaders; build new capacity in genome to phenome science through the recruitment and mentoring of 6 new faculty; acquire new tools and equipment; catalyze collaborative research across the state; and grow and diversify the State's STEM workforce.

Primary Partners and Project Management

The GEM3 team science-based management plan provides project management and oversight and facilitates integration and collaboration across teams and institutions to meet project goals. General oversight of Idaho EPSCoR is provided by the *Idaho EPSCoR Committee*. The *Executive Committee* (ExComm), which includes the State Committee Chair, Vice Chair, the respective Vice Presidents for Research at the University of Idaho (UI), Idaho State University (ISU), and Boise State University (BSU), is charged with statewide management and implementation. The *GEM3 Research and Education (R&E) Convergence Team*, comprising members of Research, Workforce Development, and Diversity, will: (1) facilitate effective team science/education strategies, (2) implement the GEM3 research, education and workforce development agenda, and (3) deliver and ensure project outcomes. Guidance and assessment of progress will be provided by the *Project Advisory Board (PAB)* and the *External Evaluator*.

Project Implementation

Strategic Planning Process

The strategic planning process was initiated by RII Track-1 Leadership. The plan was organized around four questions: (1) Who are we as ONEIdaho? (2) Where do we want GEM3 to take us? (3) What do we do to get there? and (4) How will we know if we have achieved our goals?

Overview of the Strategic Plan

This plan describes a series of specific goals, objectives and actions to enhance excellence in key priority areas to be integrated through science-based investments and case studies. Integration permeates all aspects of the Strategic Plan. The ONEIdaho concept, which links UI, BSU, ISU, and PUIs in Idaho, is embedded throughout the plan. The plan includes specific, measurable outcomes that are consistent with an external evaluation plan and achievable, in light of known risks and opportunities.

Summary of GEM3 Goals

Research & Education

- Goal 1: Discover mechanisms and model populations across space and time.
- Goal 2 Sagebrush: Understand genotypic X phenotypic mechanisms that translate to adaptive capacity of populations.
- Goal 2 Trout: Identify genetic, environmental, and phenotypic mechanisms that translate to adaptive capacity of populations.
- Goal 3: Map genotype by environment outcomes in populations across complex SES to inform management decisions.

Workforce Development & Education

- Goal 4: Provide the scaffolding to support transdisciplinary science and grow the next generation of conservation science leaders and workers.

Diversity

- Goal 5: Attract, retain, and develop a diverse academic research community of faculty and students in GEM3-related areas.

Partnerships & Collaborations

- Goal 6: Facilitate integration of science into management and policy and provide opportunities for knowledge sharing and development of professional networks between students and potential future employers.

Communication and Dissemination

- Goal 7: Strengthen research and education capacity through collaboration and recognition.

Sustainability

- Goal 8: Develop and establish the practice of nationally competitive GEM3-related research and education at participating institution.

Management, Evaluation and Assessment

- Goal 9: Ensure continual progress and timely attainment of project goals and outcomes.

Overall Project Integration

The goals of the GEM3 project cannot be achieved by a single institution working alone. By adopting a ONEIdaho approach, researchers from participating academic institutions and partnering agencies will work together, leveraging the scientific expertise at each institution. We also foster project integration by implementing co-supervision of graduate students and postdoctoral fellows and co-delivery of Vertically Integrated Projects (see Workforce Development).

The GEM3 research components (Mechanisms, Mapping, and Modeling) are highly integrated and inter-dependent. Outputs produced by one component often serve as inputs elsewhere in the project. For example, new genetic data acquired by the Trout Mechanisms team will be used by the Modeling team to parameterize new agent based models. These interactions create a complex and temporally dynamic project structure.

We visualize this project structure in two related ways. First, Figure 2: Conceptual Diagram of GEM3 Research shows the core research components of our strategic plan in an integrated timeline. For each component, time flows inward towards the center of the concentric circles. Large-scale tasks for each component are indicated as colored lines that flow inward. Integration of tasks is indicated by color – OUTPUTS are shown as small dots colored according to their destination component. INPUTs are shown as triangles that are colored to indicate the SOURCE of the input. Second, Table 1: GEM3 Research Overview Timeline shows the execution of the project over time as a Gantt chart, but does not capture the interdependencies of the components.

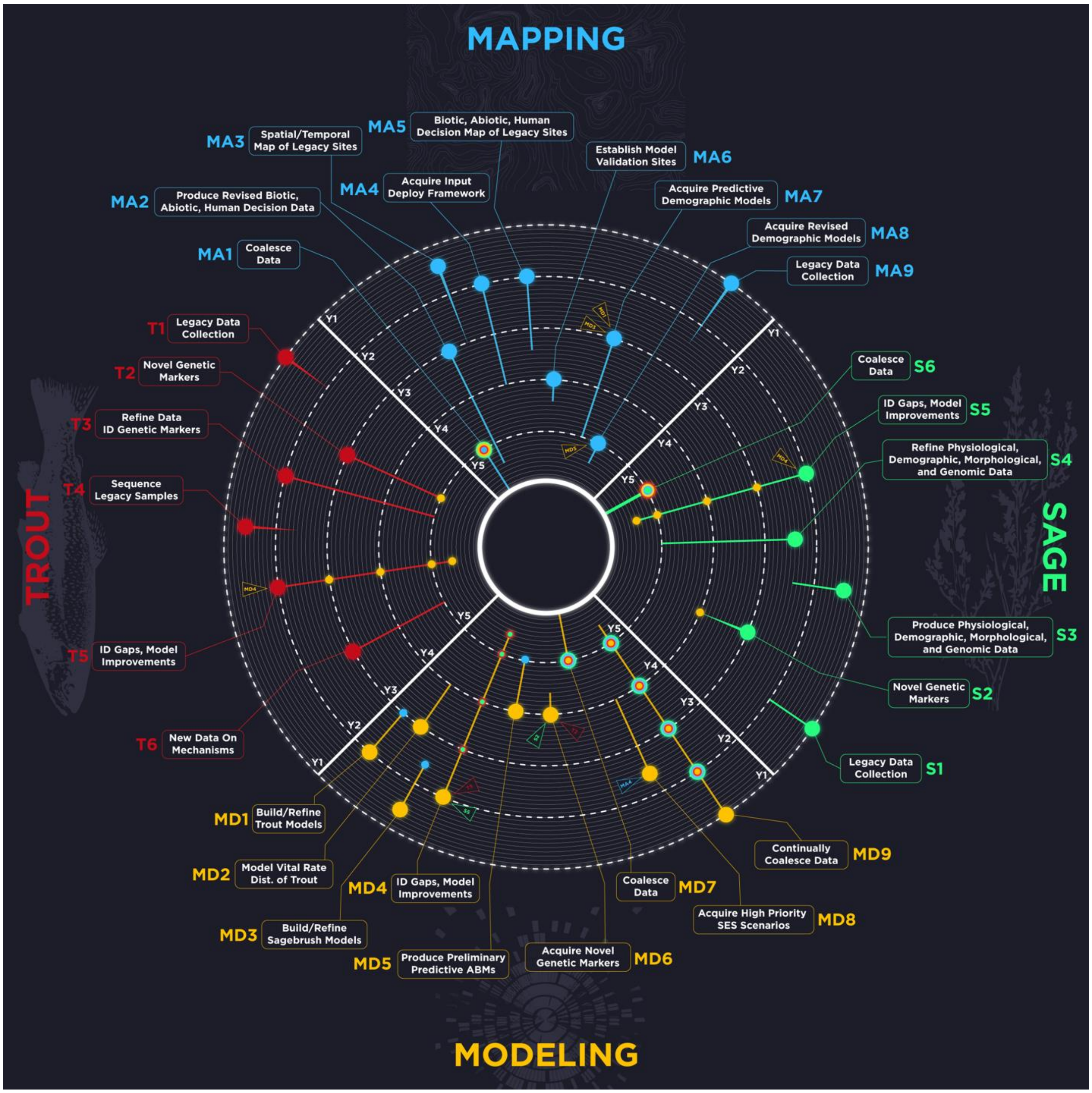

Figure 2: Conceptual Diagram of GEM3 Research

Table 1: GEM3 Research Overview Timeline listed by component and activity.

	Y1	Y2	Y3	Y4	Y5
Modeling:					
MD9 Coalesce legacy and novel data from Mapping and Mechanism teams.					
MD3 Output: Build/refine models that predict sagebrush demographics and vital rates.					
MD4 Work with Mechanisms and Mapping teams to identify data gaps and model improvements.					
MD1 Output: Build and refine models that predict distribution of trout. Develop ABMs for sagebrush.					
MD8 Acquire high priority SES scenarios from Mapping team.					
MD2 Output: Species-specific ABMs. Model vital rate distribution of trout.					
MD6 Acquire novel genetic markers from Mechanisms teams.					
MD5 Output: Preliminary predictive ABMs for both species.					
MD7 Coalesce results from Mappers and Mechanisms teams and develop generalizable and predictive ABMs.					
Sagebrush Mechanisms:					
S1 Collect legacy data on genetics/ distribution. Select common garden sites.					
S3 Output: New physiological, demographic, morphological, and genomic data.					
S5 Work with Modeling team to identify data gaps and model improvements.					
S4 Output: Refined physiological, demographic, morphological, and genomic data.					
S2 Output: Novel genetic markers.					
S6 Coalesce results from Mappers and Modelers and develop a unified framework of mechanisms driving sagebrush populations.					
Trout Mechanisms:					
T1 Collect legacy samples for genetics and distribution. Sequence samples.					
T4 Output: Genetic data from legacy samples. Establish common garden studies.					
T5 Work with Modeling team to identify data gaps and model improvements.					
T3 Output: Refined data on distribution, growth, and performance. Identify genetic markers.					
T6 Output: New data on mechanisms driving maturation, fecundity, and abundance.					
T2 Output: Novel genetic markers.					
Mapping:					
MA9 Identify and collect site-specific legacy data. Test sensors. Work with partners.					
MA3 Output: Spatially and temporally explicit map of legacy sites.					
MA4 Acquire stakeholder input. Deploy SES framework and sensors.					
MA5 Output: Maps of biotic, abiotic, and human decisions data at legacy sites.					
MA7 Acquire predictive models of demographics from Modeling team.					
MA2 Output: Revised data on biotic, abiotic, and human decisions.					
MA6 Establish model validation sites.					
MA8 Acquire revised models of demographics relative to humans and GxE data.					
MA1 Coalesce results from Modeling and Mechanisms, and develop a unified framework of biotic, abiotic, and human decisions driving spatial distribution.					

Strategic Priorities and Action Plans

Research and Education

The following sections include tables that summarize project goals, objectives, and major activities, with key annual tasks (normal font) and milestones (bold font) identified for each year of the project.

Objectives (gray)
Major Activities (blue)
Tasks (regular font); **Milestones (bold)**

Research Area 1: *Modeling.* Develop, validate, and test integrative models that predict the adaptive capacity of populations across space and time.

Leads: Barrie Robison (Lead, UI) and Julie Heath (Co-lead, BSU)
Team: Abatzoglou (UI), Brandt (BSU), Burnham (ISU), Caudill (UI), Caughlin (BSU), Forbey (BSU), Hardy (UI), Hillis (BSU), Hohenlohe (UI), Hopping (BSU), Kliskey (UI), Rachlow (UI), Reinhardt (ISU), Roever (UI), Waits (UI), Wichman (UI), *Ecological Genomics Modeler hire (BSU), Quantitative Population Ecologist hire (BSU)*
Collaborators: Narum (CRITFC), Richardson (USFS)
Research Question: What genetic, environmental, and phenotypic mechanisms best predict adaptive capacity of populations responding to changing landscapes?
Summary: The intent is to determine mechanisms underlying adaptive capacity and population vulnerability, and reliably forecast population trends over space and time. The team will build statistical models to explain distribution and demography of the study organisms and simulate adaptive capacity and population densities through agent based models (ABMs) that integrate ecological, evolutionary, and social data and processes, using an iterative approach of inferring relationships based on empirical mechanism research, predicting traits and demographics through modeling, and comparing predicted and empirical data through mapping to discover key mechanisms and processes. The intellectual merit is knowledge creation about complex relationships that affect adaptive capacity and population resilience, and ecological forecasting for population-level adaptive capacity by developing methods to confront complex models with data. The research will contribute to state and federal management of wildlife, fish, and plant populations, and provide key insight into developing process-oriented models for ecological forecasting that could be applied to many systems.

*__Bold__ text within tables indicate annual milestones.

Research Area 1: MODELING						
Goal 1: Discover GxE mechanisms and model populations across space and time. • Objective 1.1: Build statistical models to explain distribution and demography of study organisms using legacy and empirical data. • Objective 1.2: Simulate adaptive capacity and population vulnerability using ABMs.						
Project Activities						
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible Parties**
Objective 1.1: Build statistical models to explain distribution and demography of study organisms using legacy and empirical data.						
Integrate data from existing legacy datasets and ongoing GEM3 data collection.						
1.1.A.	Create data sharing plan and agreement **S1: Legacy data inventoried** **T1: Legacy data inventoried**	Implement data sharing and metadata harvesting Verify metadata and identify data gaps **Data standards are established**	**Data inventory and services are published on website** Assess data use Integrate data catalog/services with website	Grow data inventory and service Publish data per sharing plan Assess data use **MD9: Novel data are inventoried**	Grow data inventory and services Publish data per sharing plan	Roever, Barney, Robison
Test hypotheses using legacy genetic, demographic, and geospatial data.						
1.1.B.	Identify additional hypotheses and statistical approaches	Parameterize models for demographic rates using legacy data **MD3: Sagebrush models are drafted**	Quantify impact of phenotypic and genotypic variation on demographic rates **MD1: Trout models are drafted**	Test statistical models for demographic rates **Models for both species published**	Revise statistical models for demographic rates	Heath, Robison, Caughlin

Objective 1.2: Simulate adaptive capacity and population vulnerability using ABMs.						
Develop Agent Based Models.						
1.2.A.	Identify key life history traits of study organisms Hire 3 post docs	Consult with SAGs MD4: **Model prototypes drafted to identify data gaps**	Hold Modeling workshop Test sensitivity of sagebrush adaptive capacity model	Consult with SAGs Incorporate second set of common garden results MD2: **Species specific agent based models are published**	Develop generalizable conceptual framework for multiple species MD7: **Models incorporate SES scenarios and are accessible to SAGs**	Heath, Caughlin, *Ecological Genomics Modeler (BSU)*, IBEST, CMCI, Waits, Caudill, Hohenlohe, *Quantitative Population Ecologist (BSU)*
Estimate adaptive capacity via forecasting.						
1.2.B.	Relate ABM predictions to data on abundance from Mapping output in Objective 2 Develop species distribution models that predict regional patterns of abundance	Obtain down-scaled climate data projections and other relevant environmental forecast data MD8: **High priority SES scenarios are identified**	Quantify deviation between observed and predicted data across the region	Publish paper environmental/human scenarios to forecast population resilience MD6: **Models incorporate genetic data**	Relate ABM predictions to data on abundance from Mapping output in Objective 2 MD5: **Predictive ABMs for both species are published**	Waits, Caudill, Hohenlohe, Heath, Caughlin

Research Area 2: *Mechanisms.* Use common garden experiments to identify genetic, environmental, and phenotypic mechanisms in organisms that translate to adaptive capacity of populations.

Leads: Ron Hardy (Lead; Trout, UI) and Keith Reinhardt (Lead; Sagebrush, ISU)
Team: Baxter (ISU), Buerki (BSU), Caudill (UI), Caughlin (BSU), Forbey (BSU), Hohenlohe (UI), Keeley (ISU), Loxterman (ISU), Novak (BSU), Small (UI), Waits (UI), *Genetics Scientist hire (ISU), Ecological Genomics Modeler hire (BSU)*
Collaborators: Narum (CRITFC), Germino (IDFG, BLM, USGS), Richardson (USFS)
Research Question: Does genetic variation differ across a gradient of core and marginal populations and demographic history (short vs long occupancy) relative to environmental conditions?
Summary: GEM3 will use a common garden design to assess relative contributions of genetic diversity and phenotypic plasticity in organisms that link to adaptive capacity of populations to reveal GxE interactions that influence expressed phenomes (G + E + GxE = phenome). Partitioning G (additive genetic variation), E (random environmental effects), and GxE (phenotypic plasticity) will provide estimates of G, E, GxE parameters for models (Goal 1) to predict the adaptive response of populations to environmental change. Temperature will be the primary focal environmental variable in the first common garden experiment because it can capture the environmental consequences of precipitation and geomorphic characteristics of landscapes. Data generated from common gardens will be used to compare responses of organisms that differ in genotypes or life history traits to environmental change to evaluate how abiotic variation across the landscape leads to deviations in predicted GxE outcomes identified from models in Goal 1. The team will focus on populations that are monitored yearly by partner agencies and for which historical data on population demographics are available. Populations from core and marginal environments will be prioritized as well as those that deviate from predicted demographics (occupancy and density) obtained in Goal 1. Selected populations will be sampled in conjunction with annual population surveys of redband trout and sagebrush populations by agency partners. Phenotypic responses include gene and protein expression, physiological and behavioral traits, growth, survival, and reproductive performance (age at maturity, fecundity). Additional common garden experiments will be conducted to assess the role of landscape processes beyond temperature change identified in modeling (Goal 1) and mapping of adaptive capacity across the landscape (Goal 3).

Research Area 2: MECHANISMS - SAGEBRUSH						
Goal 2S: Understand genotypic x phenotypic mechanisms that translate to adaptive capacity of populations. • Objective 2S.1: Construct a model genome for sagebrush. • Objective 2S.2: Measure genotypic and phenotypic responses of shrubs to environmental change.						
Project Activities						
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible Parties**
Objective 2S.1: Construct a model genome for sagebrush.						
Create community to sequence non-model species and generate a draft whole genome for *A. tridentata* subsp *tridentata* (diploid; 2n=2x).						
2S.1.A.	Establish sequencing strategies and partnerships Obtain and validate genomic legacy data and select plant for sequencing **S1: Collection of legacy data complete; tissue (organism) used for genomic work has been selected**	Consult with Mechanism and Modeling team to develop strategies to leverage sequencing data for linking genome to phenome Initiate first round of DNA and RNA sequencing on monophyletic group **S3: DNA and RNA sequencing performed; low copy genes annotated** **S5: Meetings among the 3M's occurred, data gaps identified, and approaches for linking G x E to phenotypes are**	Create bioinformatics pipeline to assemble and annotate the genome Share genomic data with Mechanism and Modeling Implement high throughput DNA and RNA sequencing **S4: The bioinformatics pipeline is developed and in use.** **S4: Genomic**	Maintain bioinformatics pipeline community to assemble and annotate the genome through partnerships, exchanges and VIPs Use community and WFD partners to assemble and annotate genome **S4: A sequencing community established, and roles of individuals determined**	Maintain bioinformatics pipeline community to assemble and annotate the genome through partnerships, exchanges and VIPs Use community and WFD partners to assemble and annotate genome **S4: Partnerships, exchanges, and VIPs among a community of bioinform-aticists have**	Buerki, Novak, *Ecological Genomics Modeler (BSU), Genetics Scientist (ISU)*

		agreed upon in writing	**data have been shared with the other M's** **S4: Sequencing pipeline has been established**		**occurred** **S4: Sequencing submitted to NCBI and** published	
Utilize genome sequence to identify functional and neutral genetic markers for subspecies and cytotypes of sagebrush.						
2S.1.B.	Obtain list of targeted functional markers from literature and appropriate reference genomes. Identify loci associated with thermal stress using existing genome-wide data **S1: Functional markers and reference genomes identified; stress loci determined**	Identify targeted functional markers Sequence functional markers Identify specific SNP loci to analyze diploid sagebrush (monophyletic group) **S2: Additional functional markers and reference genomes identified; additional stress loci determined**	Validate targeted enrichment sequencing approach Determine level and structure of genetic diversity within gardens relative to phenotypes **S4: Genetic structure and diversity published**	Create targeted enrichment bioinformatics pipeline Collect genotype by sequencing data at test sites based on model predictions	Map location of candidate genes to sequences genome Test loci in other subspecies and cytotypes of sagebrush **S6: Genetic mechanisms predicting demographics of subspp and cytotypes published**	Buerki, *Ecological Genomics Modeler (BSU)*, *Genetics Scientist (ISU)*, Novak

Objective 2S.2: Identify GxE parameters to explain phenotypic responses of organisms to environmental change.						
Establish GxE experimental design and common garden studies.						
2S.2.A.	Collate existing samples for legacy data set (provide information to modelers/mappers) **S1: Legacy data collected and shared with modelers/mappers**	Characterize GxE results that best support modeling and sequencing efforts **S3: New common garden studies established**	Manipulate gardens using targeted GxE	Manipulate gardens using targeted GxE **S4: Outcomes of common garden studies published**	Maintain and monitor gardens using VIP participants **VIP participants involved with monitoring and using data from the gardens**	Reinhardt, Buerki, Forbey, Novak, Germino, Richardson
Identify schemes for linking gene expression and environment and investigate role of alternative splicing.						
2S.2.B.	-	Conduct RNA extractions, sequencing and transcriptome assembly and annotation of diploid plants of diploid **S4: RNA has been extracted and sequenced, and transcriptome assembled and annotated**	Refine experimental design and environmental manipulations in common gardens **S4: Environmental manipulations informed by preliminary genomics' findings**	Sequence plant tissue transcriptomes and quantify variation and alternative splicing among genotypes & manipulations **S4: Transcriptomes from various plant tissues have been sequenced**	Sequence plant tissue transcriptomes and quantify variation and alternative splicing among genotypes & manipulations **S4: Link between alternative splicing, gene expression, and environment predicting phenotypes published**	Buerki, *Ecological Genomics Modeler (BSU), Genetics Scientist (ISU)*

Quantify phenotypical (e.g., physiological, morphological, phenological and demographic) variation.						
2S.2.C.	Collect data on legacy phenotypes in gardens S1: **Phenome legacy data have been collected**	Identify targeted phenotypes to study in gardens	Quantify targeted phenotypes in gardens S4: **Targeted phenotypes measured in gardens relative to GxE**	Quantify targeted phenotypes across landscapes S4: **Targeted phenotypes measured on ground and remotely sensed in and outside gardens**	S6:: **Predictions of phenotypes relative to GxE from remote sensing published**	Reinhardt, Buerki, Caughlin, Forbey, Germino
Quantify phenotypic plasticity of traits.						
2S.2.D.	-	Quantify differences in plasticity in phenotypes with GxE conditions in gardens S5: **Data gaps identified**	Quantify differences in plasticity of phenotypes with targeted GxE manipulations S4: **Differences in plasticity based on GxE relationships published**	Use data to construct evolutionary models and genetic algorithms	S6: **Plasticity predicted from evolutionary models and genetic algorithms published**	Reinhardt, Caughlin, *Ecological Genomics Modeler (BSU)*, Robison

Research Area 2: MECHANISMS - TROUT						
Goal 2T: Identify genetic, environmental, and phenotypic mechanisms that translate to adaptive capacity of populations. • Objective 2T.1: Assess genetic diversity of populations. • Objective 2T.2: Identify GxE parameters to explain phenotypic responses of organisms to temperature change.						
Project Activities						
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible Parties**
Objective 2T.1: Assess genetic diversity of populations.						
Establish GxE experiments through common gardens.						
2T.1.A.	Collect redband trout from selected populations T1: **Legacy samples obtained and subsets for sequencing selected**	Conduct and complete first common garden study T4: **Common garden studies established**	Continue common garden study for maturation and fecundity assessment	Continue common garden study for maturation and fecundity assessment	Complete common garden studies T6: **Outcomes of common garden studies published**	Hardy, Caudill, Hohenlohe, Small, Loxterman, Narum
Perform genotype-by-sequencing.						
2T.1.B.	Sample populations (integrates w/ Mapping) T5: **Data gaps identified**	Scan genome for candidate genes	Complete genome scan	T3: **Sequencing data submitted to NCBI & published to GEM3 data repository**	-	Loxterman, Small, Narum
Discover markers associated with thermal plasticity.						
2T.1.C.	-	-	Develop markers (SNPs) T2: **Novel genetic markers identified**	Develop markers (SNPs) T2: **Novel genetic markers identified**	Link markers (SNPs) with thermal plasticity T6: **Genetic markers predicting**	Loxterman, Small, Narum

					thermal plasticity published	
Epigenetic processes with bisulfate sequencing.						
2T.1.D.	-	-	Investigate methylation patterns in common garden samples	Investigate methylation patterns in common garden samples	Investigate methylation patterns in common garden samples T2: **Links between methylation and epigenetic processes published**	Hardy, Narum, Loxterman
Conduct analysis of genetic diversity.						
2T.1.E.	Obtain tissues and initiate sequencing (integrates with Modeling) T1: **Legacy samples collected for genetics and distribution**	Complete sequencing T1: **Samples sequenced**	Sample genotype legacy/focal populations at thermal plasticity SNPs (2T.1.C)	Sample genotype legacy/focal populations at thermal plasticity SNPs (2T.1.C)	Sample genotype legacy/focal populations at thermal plasticity SNPs (2T.1.C) T6: **Genetic diversity predicting plasticity published**	Hardy, Loxterman, Small, Narum, Waits, Hohenlohe
Objective 2T.2: Identify GxE parameters to explain phenotypic responses of organisms to temperature change.						
Assess gene expression through transcriptomics.						
2T.2.A.	-	Complete RNA-Sequencing on	Complete RNA-Sequencing on	Complete RNA-Sequencing on	-	Caudill, Small, Hohenlohe, Loxterman

		common garden samples	common garden samples	common garden samples **T3: Link between GxE and gene expression to predict phenotypes published**		
Assess physiological expression.						
2T.2.B.	-	Refine common garden design based on Y1 model outputs	Collect and describe physiological and morphological data	Collect and describe physiological and morphological data	**T6: Physiological phenotypes predicted from GxE published**	Small, Hardy
Assess behavioral expression.						
2T.2.C.	-	Assess thermal preference studies	Assess water column preference	**T6: Behavioral expression predicted from GxE published**	-	Small, Caudill, Hardy
Study demography.						
2T.2.D.	Collate and describe legacy data (w/ Modeling) **T4: Genetic data from legacy samples collected**	Collect and describe maturation and fecundity data **T6: New data on mechanisms driving maturation, fecundity and abundance collected**	Collect and describe maturation and fecundity data	Synthesize demographic data into models (w/ Modeling) **T3: Data on distribution, growth and performance refined**	**T6: Distribution, growth, and performance predicted from GxE published**	Caudill, Hohenlohe, Waits

Quantify phenotypic plasticity of traits.						
2T.2.E.	-	Quantify phenotypic plasticity of physiological responses to temperature	Quantify phenotypic plasticity of behavior to temperature	Quantify phenotypic plasticity of maturation and fecundity T6: **Data gaps identified**	Quantify phenotypic plasticity of maturation and fecundity T6: **Trout phenotypic plasticity predicted from GxE published**	Keeley, Baxter, Caudill, Hohenlohe

Research Area 3: *Mapping*. Map GxE outcomes in populations across complex SES to inform management decisions.

Leads: Donna Delparte (Lead, ISU) and Morey Burnham (Co-Lead, ISU)
Team: Brandt (BSU), Buerki (BSU), Caudill (UI), Caughlin (BSU), Forbey (BSU), Hardy (UI), Hohenlohe (UI), Hopping (BSU), Keeley (ISU), Kliskey (UI), Novak (BSU), Robison (UI), Waits (UI), Reinhardt (ISU), Freemuth (BSU), *Quantitative Population Ecologist hire (BSU), Data Scientist hire (BSU), Environmental Network Systems Scientist hire (BSU), Environmental Social Scientist hire (ISU)*
Collaborators: Narum (CRITFC), Richardson (USFS)
Research Question: What abiotic, biotic, and anthropogenic factors best explain deviations in predicted adaptive capacity of populations determined from Modeling and Mechanisms across SES systems?
Summary: Research Goal 3 is intended to develop a mechanistic understanding of links between genomic diversity, phenotypic plasticity, and SES change. Goal 3 investigators will use observations and correlative data from the field to visualize, validate and propose novel hypotheses related to the links among genotypes, environment, and phenotypic traits identified in Goals 1 and 2 that influence adaptive capacity of populations. Model predictions of adaptive capacity developed in Goal 1 and based on mechanisms linked to adaptive capacity in Goal 2 will be compared to observed population phenotypes and distribution patterns across the landscape to identify deviations from those predictions. Existing and forecasted SES factors will be assessed to determine their impact on the genotypic, environmental, and phenotypic factors that affect adaptive capacity of populations. GxE conditions leading to diversity in demographic phenotypes generated across the landscape will be input for ABMs in Goal 1, and inform designs (e.g., source genotypes and environmental conditions) of controlled common garden experiments described in Goal 2 to test how manipulation of genotypes and landscape processes can alter the adaptive capacity of populations. The team will couple advances in genomics, remote sensing, and computational technology to map mechanisms (Goal 2) and patterns (Goal 3) of GxE outcomes across natural landscapes with social science research approaches to determine where and how complex SES factors and human decisions govern these patterns.

Research Area 3: MAPPING						
Goal 3: Map genotype by environment outcomes in populations across complex SES to inform management decisions. - Objective 3.1: Map complex SES conditions. - Objective 3.2: Assess and characterize the range of abiotic and biotic that explain GxE outcomes across SES gradients. - Objective 3.3: Assess and characterize interactions between human decisions and GxE outcomes.						
Project Activities						
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible Parties**
Objective 3.1: Map complex SES conditions.						
Create mapping tools and SES framework.						
3.1.A.	Identify, test and order sensors for scaling up on-ground & Unmanned Aircraft Systems (UAS)	Validate sensors with abiotic and biotic data at 2-3 sites	Use sensors to collect high resolution SES data and share data types with stakeholders to identify future data needs **MA4: Deploy sensors across SES based on SAG and CBON input**	Validate new sensors to collect new data types and receive input on sensor needs from other systems **MA9: Remote sensing tools and data shared**	Apply remote sensing tools applied in other systems **MA3: Remote sensing of environment and phenotypes published**	Delparte, Forbey, Caughlin, Keeley, Reinhardt, Rachlow
Map SES conditions.						
3.1.B.	Map and analyze land use and land cover change and develop plan to perform quality control at legacy sites	Map and analyze land use and land cover change and perform quality control at legacy and sampling sites for models	Map and analyze land use and land cover change and perform quality control at legacy, sampling and validation sites for models	Improve land use and land cover change classifications based on sampling and validation sites	**MA5: Land use and land cover change maps published and products shared with stakeholders and participants**	Brandt, Delparte

			MA5: Datasets published to NKN site	Publish datasets to NKN site		
Objective 3.2: Assess and characterize the range of biotic and abiotic factors that explain GxE outcomes across SES gradients.						
Assess and characterize phenomic factors that explain GxE outcomes.						
3.2.A.	Plan and design CBON framework Map field and remotely sensed measurements of population demographics	Design CBON protocols High fidelity observers recruited and CBON variables identified **MA4: Maps of population demographics generated and published to NKN**	Validate predicted species distribution and demography data based on models and use data to refine models **MA6: CBON workshop held to identify phenotypes relative to GxE valued by stakeholders**	Analyze and synthesize CBON observations Use data to refine models and protocol **MA2: All CBON data synthesized and analyzed, and model refined**	Analyze and synthesize CBON observations and use data to refine models and protocols Catalog species distribution and demography metadata to NKN site **MA1: CBON data shared with modelers to integrate data into publications**	Caughlin, Reinhardt, Keeley, Caudill *Quantitative Population Ecologist (BSU)*, Burnham, Hopping, Kliskey, Waits, Hohenlohe
Assess abiotic and biotic mechanisms of deviation, including human decisions, from demographic distribution models.						
3.2.B.	-	-	Compare spatial predictions of demographics from initial model outputs with observed data	Test predicted and alternative biotic mechanisms **MA8: New model predictions based on biotic mechanisms generated**	Compare spatial predictions of demographics from revised model outputs **MA1: Spatial predictions of demographics published**	Caughlin, Keeley, Reinhardt, Forbey, Buerki, Hardy Delparte, Waits, Hohenlohe

Objective 3.3: Assess and characterize interactions between human decisions and GxE outcomes.						
Assess desirability of landscape configurations, interventions, and stakeholder decision making.						
3.3.A.	Develop preliminary SAG SAG workshops framed and developed SAG protocol developed and distributed to GEM3 research team	**MA5: SAG workshops held at core research sites**	Synthesize workshop outcomes for SES model input; interviews Develop potential interventions w/ stakeholder engagement & literature	Hold workshops at core research sites; interviews **MA4: SAG workshop held; maps of phenotypes relative to GxE shared**	Synthesize workshop outcomes for SES model input **MD7: MA1: Meetings held with modelers to integrate data**	Burnham, Kliskey, Hopping
Input stakeholder behavior into simulations and policy recommendations.						
3.3.B.	Identify data to be collected for SES mapping/ modeling	Meet with modelers to identify needed data **MA9: Collected data synthesized, analyzed, and described**	Deliver SES data to modelers and publish to NKN Continue to identify needed data Collect and describe data	Deliver SES data to modelers **MA9: 3D Visualization of SES data product produced**	**MA8: Future scenario workshops held at core sites to share predicted demographic relative to humans and GxE**	Burnham, Kliskey, Hopping, Delparte, Waits, Hohenlohe

Workforce Development

Lead: Donna Llewellyn (BSU)
Team: Davis (UI), Forbey (BSU), Loxterman (ISU), Martinez (ISU), Penney (UI), Perkins (CWI), Waits (UI), Cooper (CSI), Schmidt (LCSC)
Summary: Workforce development (WFD) will increase the number, diversity, and preparation of skilled scientists and engineers in GEM3 fields using a vertically integrated projects (VIP) strategy. The goals and objectives of the WFD component directly integrate with all of the research components and the diversity component by providing: (1) an on-ramp for students from historically underserved populations to get involved through introductory lab modules; (2) the infrastructure for the faculty involved in the GEM3 research components to align their instructional work with their research; and (3) professional development that will improve the ability of the GEM3 researchers and their graduate students to sustain an inclusive and diverse team. Key outcomes include: (1) mentor and peer-mentoring training for faculty, postdocs, graduate and undergraduate students, which will strengthen collaboration, sense of belonging, and retention to degree attainment; (2) cultivation of an enhanced "science identity" and broadened pathways into GEM3 STEM fields. Lab modules in the introductory science classes, authentic research in Core Teams, and summer research will improve recruitment to GEM3 STEM majors and retention to graduation; and (3) increased participation from members of URM populations; low-income, rural, and/or first-generation students; and women. (See GEM3 Metrics.)

Project Element 4: Workforce Development & Education

Goal 4: Provide the scaffolding to support transdisciplinary science and grow the next generation of conservation science leaders and workers.

- Objective 4.1: Adopt a VIP strategy and infrastructure at each university.
- Objective 4.2: Foster effective mentoring and collaboration that spans multiple levels within teams.
- Objective 4.3: Incorporate GEM3 lab modules into introductory lab science courses at universities and colleges.

Project Activities

	Year 1	Year 2	Year 3	Year 4	Year 5	Responsible Parties
Objective 4.1: Adopt a VIP strategy and infrastructure at each university.						
Develop and deliver VIP courses and infrastructure on each university campus and across the state.						
4.1.A.	Organize interested/related faculty	**1 course delivered/ university**	2 courses/ university	**3 courses delivered/ university**	5 courses/ university	Llewellyn, Davis, Loxterman
Recruit university undergraduate students to each VIP team and course.						

4.1.B.	Create student recruitment timeline	Recruit students to courses **Enrollment data collected**	Improve system for recruiting; continue recruiting	**Evidence of improved system for recruiting provided; continue recruiting**	Improve system for recruiting; continue recruiting	Llewellyn, Davis, Loxterman
Provide training & professional development to undergraduate and graduate/postdoc VIP participants and faculty leads.						
4.1.C.	Schedule professional development activities Develop materials and "train the trainer" plan	Refine topics and materials; loop in work with internships Toolbox Dialogue Initiative Training reaches 70%	Deliver professional development **GEM3 VIP students present at/attend ICUR**	Refine topics and materials; loop in work with internships **Toolbox Dialogue Initiative Training reaches 80%**	GEM3 VIP students present at/attend ICUR	Llewellyn, Forbey, Waits, Loxterman (Research/ Education Integration leads with Llewellyn)
Integrate faculty and students from 2-year and 4-year campuses in the VIP teams.						
4.1.D.	Integrate PUI targeted URM strategies into recruitment plan	**PUI students recruited and supported in summer research**	**PUI faculty involved in VIP**	Recruit and support PUI students in summer research	Implement plan including ambassadors & PUI contacts	Penney
Objective 4.2: Foster effective mentoring and collaboration that spans multiple levels within teams.						
Provide interdisciplinary graduate student research and mentoring.						
4.2.A.	Support faculty mentors with graduate students on each campus, with technology facilitating cross-institutional collaborations	**Two seminars/ university on interdisciplinary research methods and teamwork approaches sponsored**	Support faculty mentors with graduate students on each campus, with technology facilitating cross-institutional collaborations	**Two seminars/ university on interdisciplinary research methods and teamwork approaches sponsored**	-	Waits
Engage stakeholders to exchange data, inform research questions, and provide internship opportunities to the students.						

4.2.B.	Arrange meetings between researchers and stakeholders Develop Effective Practices guide for internship mentoring	**At least 1 internship sponsored per university** Arrange for VIP teams to visit stakeholder locations	Arrange meetings between researchers and stakeholders **New/more internship opportunities identified**	Share and formalize internships with appropriate university offices Arrange for VIP teams to visit stakeholder locations	Provide at least 4 internships per university **Internships formalized for sustainability**	Forbey, Loxterman, Waits
Objective 4.3: Incorporate GEM3 lab modules into introductory lab science courses at universities and colleges.						
Support graduate students to develop and teach GEM3 lab modules on home campuses.						
4.3.A.	Develop one module per university	**One module taught and an additional module tested/ university** Provide training for PUI faculty to vet concepts	**One additional module/ university taught**	Continue teaching modules from across state	Continue teaching modules from across state	Waits, Co-PIs Llewellyn, Davis, Loxterman, Co-PIs
Support graduate students to teach the lab modules on the partner 2-year and 4-year college campuses.						
4.3.B.	Work with partner campuses to fully integrate into their curriculum	**At least 2 modules taught on partner campus(es)**	Ensure that modules will fit PUI coursework	**2+ modules taught on partner campus(es)**	Fully integrate into PUI curriculum	Llewellyn, Davis, Loxterman, PUI liaisons, Co-PIs

Diversity

Leads: Sarah Penney (UI), Donna Llewellyn (BSU)
Team: Payne (BSU), Evans (ISU), Bisbee (UI), Bates (BSU), Wood Roberts (ISU).
Summary: GEM3 will increase the participation of underrepresented minority groups in STEM (underrepresented minorities (URMs), including Hispanics and Native Americans), low-income, rural and/or first-generation students, and women in Idaho's STEM enterprise. Idaho State Board of Education has a goal for 60% of young adults to hold a postsecondary degree or certificate by 2020; GEM3's goals support retention and degree attainment statewide. A diversity goal is to increase participation at all three institutions, and for GEM3 to lead the way with more ambitious diversity targets. (See GEM3 Metrics.)

Project Element 5: Diversity

Goal 5: Attract, retain, and develop a diverse academic research community of faculty and students in GEM3-related areas.

- Objective 5.1: Increase the diversity of the faculty participants working in GEM3 related areas across the participating universities.
- Objective 5.2: Increase the numbers and diversity of the STEM students and improve the inclusion across the state.

Project Activities

	Year 1	Year 2	Year 3	Year 4	Year 5	Responsible Parties
Objective 5.1: Increase the diversity of the faculty participants working in GEM3 related areas across the participating universities.						
Implement the Idaho START (System to Attract and Retain Talent) program at three universities.						
5.1.A.	Select GEM3-involved department on each campus Collect recruitment and retention practices	**Second department on each campus selected** Study career advancement practices and align for effectiveness	Fine tune data collection and update **Gap Analysis completed** Add 2-3 more departments Work with partner 2- and 4-year campuses	Expand to college or other unit-level at one or more campuses **R&R aligned with effective practices**	Study career advancement practices and align for effectiveness Institutionalize START across the campuses (3 MOUs)	Llewellyn, START team

Objective 5.2: Increase the numbers and diversity of the STEM students and improve the inclusion across the state.						
Grow the Idaho Diversity Network (IDN) and implement strategies developed through statewide collaboration.						
5.2.A.	**Host statewide IDN meetings tri-annually**	Increase IDN membership and e-news list-serve by 20% Implement 1 new priority area initiative	Host statewide IDN meetings tri-annually	Host statewide IDN meetings tri-annually **Two new priority area initiatives implemented**	Host statewide IDN meetings tri-annually Increase IDN membership and e-news list-serve by 20%	IDN Leadership Team
Promote and implement GEM3 diversity plan and training to increase participation from underserved populations.						
5.2.B.	Integrate PUI targeted URM strategies into recruitment plan **Statewide inclusive mentoring training hosted**	Implement plan in coordination with GEM3 VIP efforts **URM students recruited to SRE** Host statewide Inclusive Mentoring Training at UI	Implement plan in coordination with GEM3 VIP efforts Host Inclusive Mentoring training with ICUR at BSU	Implement plan in coordination with GEM3 VIP efforts Host statewide Inclusive Mentoring Training at ISU **URM students complete SRE**	Host Inclusive Mentoring training at universities Host Inclusive Mentoring training at PUIs	IDN Leadership Team, PUI contacts, Tribal education representatives

Partnerships and Collaborations

Lead: Ron Hardy (UI) & Jennifer Forbey (BSU)
Partners: Narum (CRITFC), Germino (IDFG, BLM, USGS), Richardson (USFS)
Summary: GEM3 will leverage state and federal resources to promote sustainable outcomes. Engagement of agency partners at all levels (biologists, land managers, policy makers, and administrators) will facilitate integration of science into management and policy and provide opportunities for knowledge sharing and development of professional networks between students and potential future employers.

Project Element 6: Partnerships						
Goal 6: Facilitate integration of science into management and policy and provide opportunities for knowledge sharing and development of professional networks between students and potential future employers. • Objective 6.1: Utilize existing legacy data to build models and tools that assist state and federal agencies with resource management. • Objective 6.2: Maintain and expand partnerships with other large NSF and federally funded projects. • Objective 6.3: Promote STEM opportunities among faculty at PUIs and career pathways for students.						
Project Activities						
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible Parties**
Objective 6.1: Utilize existing legacy data to build models and tools that assist state and federal agencies with resource management.						
Partner with state and federal agencies with responsibilities for species of interest.						
6.1.A.	Obtain genomic and demographic data from USGS, USFS, BLM, CRITFC, IDFG, and others	Communicate model output from legacy data with partners **MOUs finalized**	Test of model predictions in sites of interest to partners	**Model predictions tested in sites of interest to partners**	Test of model predictions in sites of interest to partners	Forbey, Reinhardt, Hardy (agency partners)
Strengthen partnership with Shoshone-Bannock Tribe for research collaborations and workforce development.						
6.1.B.	Recruit native students into internship and graduate student positions	Mentor native students as interns and graduates	**GEM3 outputs communicated to tribes and other agencies**	**Native students mentored as interns and graduates**	Communicate outputs of data to tribes and other agencies	Baxter
Objective 6.2: Maintain and expand partnerships with other large NSF and federally funded projects.						

Collaborate with research partners.						
6.2.A.	Utilize online access to information about the flora of Pacific Northwest	Share plant data and utilize online access to information about the flora of Pacific Northwest	**Plant data shared and online access to information about the flora of Pacific Northwest utilized**	Share plant data and utilize online access to information about the flora of Pacific Northwest	Share plant data and utilize online access to information about the flora of Pacific Northwest	Forbey and Hardy, Kliskey (research partners)
Formalize and collaborate with STEM Education, Diversity, and Workforce Development partners.						
6.2.B.	Draft MOUs with partners	Finalize 2 MOUs with partners	**Agreements for training and recruitment implemented**	Revise MOUs with partners	Implement agreements for training and recruitment	Forbey (education partners)
Objective 6.3: Promote STEM opportunities among faculty at 2-year and 4-year colleges and career pathways for students.						
Involve faculty and students from PUIs and tribes in GEM3.						
6.3.A.	Ensure educational alignment with PUI and tribal administrators	Recruit PUI and tribal college students to participate VIP courses, internships and facilitate transfer of credits	Recruit PUI and tribal students to pursue advanced degrees with GEM3 faculty	**PUI and tribal students recruited to pursue advanced degrees with GEM3 faculty**	Recruit PUI and tribal students to pursue advanced degrees with GEM3 faculty	Forbey and Llewellyn
Facilitate internship and career preparation opportunities.						
6.3.B.	Establish MOUs for internships with industry and agency partners	**Three internship opportunities with industry and agency partners provided**	Provide resume building and interview training with industry and agency partners	**Six internship opportunities with industry and agency partners provided**	Provide resume building and interview training with industry and agency partners	Forbey and Llewellyn (agency partners and stakeholders)

Communication and Dissemination Plan

Leads: EOD Coordinator, Sarah Penney (UI) and R&E Convergence Team (Ron Hardy (UI), Jennifer Forbey (BSU), Colden Baxter (ISU))
Summary: The intent of the GEM3 Communication and Dissemination Plan is to: (1) foster successful collaboration, including sharing of data and findings, across disciplinary, institutional, and other boundaries, and (2) help Idaho prepare a diverse, well-trained STEM workforce and scientifically informed citizenry.

Project Element 7: Communication and Dissemination

Goal 7: Strengthen research and education capacity through collaboration and recognition.

- Objective 7.1: Facilitate recurrent communication among GEM3 participants and institutions.
- Objective 7.2: Promote public, stakeholder, and student awareness and interest in GEM3 research.

Project Activities						
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible Parties**
Objective 7.1: Facilitate recurrent communication among GEM3 participants and institutions.						
Foster regularly occurring cross-project interaction.						
7.1.A.	Host bi-weekly R&E Convergence, 3 All-Hands, and 1 Annual Meeting	**Bi-weekly R&E Convergence, 3 All-Hands, and 1 Annual Meeting Hosted**	Host bi-weekly R&E Convergence, 3 All-Hands, and 1 Annual Meeting	**Bi-weekly R&E Convergence, 3 All-Hands, and 1 Annual Meeting hosted**	Host bi-weekly R&E Convergence, 3 All-Hands, and 1 Annual Meeting	Project Director, Co-PIs
Develop skills, shared platforms, and language to facilitate research and education collaboration.						
7.1.B.	**Statewide Collaborative Toolbox workshop hosted** Provide VIP and Working Group training **Data sharing platform developed**	Host 3 Collaborative Toolbox workshops **VIP and Working Group training provided** Implement data sharing platform	Host 1 statewide Collaborative Toolbox workshop Provide VIP training Review/revise Communication Charter	**Three Collaborative Toolbox workshops hosted** Update data sharing platform Provide communications training	Host 1 statewide Collaborative Toolbox workshop Review/Revise Communication Charter GEM3 data available to public	Penney, Schumaker

	Develop Communication Charter	Provide communications training				
Objective 7.2: Promote public, stakeholder, and student awareness and interest in GEM3 research.						
Disseminate scientific results.						
7.2.A.	-	Identify targeted conferences	Identify data to share with public **Presentations delivered at targeted conferences**	Present at targeted conferences	**GEM3 data available to public** Identify and present at targeted conferences	Co-PIs
Produce and distribute project results and communications material.						
7.2.B.	Publish 2 media releases Distribute 3 newsletters Participate in 3 stakeholder-sponsored events	Publish 3 media releases **Three newsletters and 2 videos distributed** Convert abstracts for the public	Publish 5 media releases Distribute 3 newsletters Participate in 6 stakeholder-sponsored events	**Six media releases published** Distribute 3 newsletters and 5 videos **Publication abstracts re-written for public audience**	Publish 6 media releases Distribute 3 newsletters and 7 videos Participate in 8 stakeholder-sponsored events	Penney
Develop partnership with other Idaho organizations with complementary goals for STEM research, diversity, and education.						
7.2.C.	Establish mutual objectives with STEM Action Center	**One joint activity with STEM Action Center supported**	Communication Fellows produce 6 media products	Support 3 joint activities with STEM Action Center	**Nine media products produced by Communication Fellows**	Penney

		Establish Communication Fellows program				

Sustainability

Leads: Colden Baxter (ISU) & Jen Forbey (BSU)

Summary: Sustainability of GEM3 activities is of paramount importance to ensure that investments from NSF, the State of Idaho, and stakeholders will continue after the award period. GEM3 will: (1) ensure ongoing education and human resources development and (2) support and sustain efforts to advance knowledge on how species adapt to external stressors in a changing environment.

Part 1: Education and Human Resources Development: For every participant to: (1) measurably increase in professional skills in data management and communications, and (2) retain 80% of the full-time permanent participants in the project five years beyond the award.

Part 2: Post RII Track-1 Extramural Funding: The vision and plan for sustaining the GEM3 research and education activities beyond the award period is based on two strategies: institutionalizing project outcomes (4.7.1) and building competitiveness for extramural funding. GEM3 investigators will build lasting collaborations that enable them to address complex questions and foster innovation. GEM3 will prepare participants for funding programs in multiple Directorates and Divisions of NSF, NIH and other agency program areas. Participating faculty are expected to submit at least two proposals/year to external funding programs. The GEM3 R&E Convergence Team will be key to helping identify and target funding opportunities.

Project Element 8: Sustainability						
Goal 8: Develop and establish the practice of nationally competitive GEM3-related research and education at participating institutions. • Objective 8.1: Build sustainable intellectual and transdisciplinary research capacity and expertise. • Objective 8.2: Build sustainable education, diversity, and workforce development capacity.						
Project Activities						
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Responsible Parties**
Objective 8.1: Build sustainable intellectual and transdisciplinary research capacity and expertise.						
Recruit and hire personnel.						
8.1.A.	Initiate START Recruit faculty	**Three new faculty hired** Fill graduate	**Three new faculty hired**	Fill graduate student openings Fill postdoc	Report impact of 6 institutionalized faculty hires	Co-PIs

		student cohort, hire postdocs		openings		
Develop and demonstrate research competitiveness and leadership.						
8.1.B.	Initiate transdisciplinary WFD training	Annually submit 2 proposals per RA or postdoc FTE Provide WFD training **2+ Proposal Working Groups formed**	Win cumulative $8M new funding	Submit 3 NSF CAREER proposals **Two proposals per research assistant or postdoc submitted**	Submit 3 NSF CAREER proposals	Co-PIs
Establish national recognition of GEM3 research.						
8.1.C.	-	**12 conference presentations delivered**	**10 peer-reviewed manuscripts published**	Publish 12 peer-reviewed manuscripts	Publish >24 Peer-reviewed manuscripts	Co-PIs
Enhance coordination and integration across existing institutional centers.						
Aspirational	Document current center capabilities and connections	Identify potential overlap of missions at centers	**MOU of action items for greater Idaho-wide integration of centers signed**	Initiate key action items	Promote success and benefits of integration	Project Director
Objective 8.2: Build sustainable education, diversity, and workforce development capacity.						
Institutionalize vertical integration project (VIP) model.						
8.2.A.	-	-	Establish capacity to sustain and track VIP courses and participants	**VIP established in curricula (e.g., courses in catalogs)**	VIP established in curricula (e.g., courses in catalogs)	Llewellyn
Institutionalize diversity best practices developed in START program.						

8.2.B.	-	Apply mentoring and retention programs (START)	-	**Mentoring and retention programs (START) applied**	Institutionalize START	START Coordinators
Increase opportunities for faculty/research positions filled by Native Americans or members of URM groups.						
Aspirational	Identify university and tribal leaders	**Working Group established**	Explore approaches for novel positions (e.g., extension positions) Seek institutional commitment to position (s)	**Institutional commitment to position (s) planned**	-	Project Director

Leads: Janet Nelson (UI) & Rick Schumaker (UI)
Key Participants: Bogar (UI), Hardy (UI), Forbey (BSU), Baxter (ISU), Reinhardt (ISU), Llewellyn (BSU), Penney (UI), Heath (BSU), Robison (UI)
Summary: Idaho's GEM3 EPSCoR management plan provides overall management and oversight and facilitates integration and collaboration across both teams and institutions to meet project goals. An established and successful team science-based management strategy will be utilized. General oversight is provided by the *Idaho EPSCoR Committee*, including the *Executive Committee* (ExComm), which includes the State Committee Chair, Vice Chair, the respective Vice Presidents for Research at UI, ISU and BSU.

Project Element 9: Management & Evaluation/Assessment

Goal 9: Ensure continual progress and timely attainment of project goals and outcomes.

- Objective 9.1: Provide effective and compliant oversight of day-to-day project implementation (operations).
- Objective 9.2: Generate and obtain information and external input to enhance program effectiveness (accountability).
- Objective 9.3: Instill practices and customs that enrich transdisciplinary integration across topic areas and institutions (integration).
- Objective 9.4: Foster RII alignment with state and national priorities (alignment).

Project Activities

	Year 1	Year 2	Year 3	Year 4	Year 5	Responsible Parties
Objective 9.1: Provide effective and compliant oversight of day-to-day project implementation.						
Manage administrative information and data sharing.						
9.1.A.	**Internal reporting system implemented** Host 10 leadership meetings Develop shared software platform Establish Working Groups Monitor budget	Review partnership agreements Use internal reporting system **10 leadership meetings hosted** Oversee Working Groups Monitor budget	Use internal reporting system Host 10 leadership meetings Oversee Working Groups **Budget spending monitored**	Review partnership agreements **Internal reporting system used** Host 10 leadership meetings Oversee Working Groups Monitor budget	Use internal reporting system Host 10 leadership meetings Oversee Working Groups Monitor budget	Project Director, Schumaker
Objective 9.2: Generate and obtain information and external input to enhance program effectiveness.						

Plan, monitor, and report progress.						
9.2.A.	Assess 4 internal progress reports, 1 PAB report, and 1 evaluation plan Submit annual report to NSF Develop Strategic Plan	Assess 4 internal progress reports, 1 PAB report, and 1 evaluation report Submit annual report to NSF **Strategic Plan, External Evaluation Plan implemented** Monitor milestones	Assess 4 internal progress reports, 1 PAB report, and 1 evaluation report Submit annual report to NSF Update Strategic Plan and External Evaluation Plan Monitor milestones	Assess 4 internal progress reports, 1 PAB report, and 1 evaluation report Submit annual report to NSF **Strategic Plan and External Evaluation Plan updated** Monitor milestones	Assess 4 internal progress reports, 1 PAB report, and 1 evaluation report Submit annual report to NSF Implement Strategic Plan, External Evaluation Plan Monitor milestones	Project Director, Schumaker,
Formally evaluate and assess program activities.						
9.2.B.	Conduct SWOT analysis Host 2 PAB meetings Respond to PAB report	Host 2 PAB meetings Respond to PAB and external evaluation reports **RSV delivered** Review proposal success	Assess seed funding outcomes Host 2 PAB meetings Implement response to PAB, RSV, and external evaluation reports	**NSF Site Visit hosted** **Seed Funding outcomes assessed** Host 2 PAB meetings Respond to PAB and external evaluation reports **Proposal success reviewed**	Host 2 PAB meetings Implement response to PAB, external evaluation, and Site Visit reports	Project Director, Schumaker, Bogar
Objective 9.3: Instill practices and customs that enrich transdisciplinary integration across topic areas and institutions.						
Bring people from different organizations and disciplines together in productive meetings/events.						

9.3.A.	Host 2 leadership retreats, 6 meetings of cross-component leads, and 1 Annual Meeting	**Two leadership retreats, 6 meetings of cross-component leads, and 1 Annual Meeting hosted**	Host 2 leadership retreats, 6 meetings of cross-component leads, and 1 Annual Meeting	**Two leadership retreats, 6 meetings of cross-component leads, and 1 Annual Meeting hosted**	Host 2 leadership retreats, 6 meetings of cross-component leads, and 1 Annual Meeting	Schumaker
Communication and Dissemination (see Activity 7.1.B.)						
Objective 9.4: Foster RII alignment with state and national priorities.						
Support State EPSCoR Committee governance.						
9.4.A.	Host 3 EPSCoR Committee meetings	Host 3 EPSCoR Committee meetings Participate in national events	**Three EPSCoR Committee meetings hosted**	Host 3 EPSCoR Committee meetings Participate in national events	Host 3 EPSCoR Committee meetings	Project Director, Schumaker
Administer RII Seed Funding Program.						
9.4.B.	**Guidelines for research and WFD awards formalized** Select and allocate 4 Research and 1 WFD awards	Select and allocate 4 Research and 1 WFD awards Monitor award progress	Revise guidelines **Three Research and 2 WFD projects awarded** Monitor award progress	Select and allocate 4 Research and 1 WFD awards Monitor award progress	Complete Research and WFD awards **Award accomplishments /outcomes reported**	Project Director, Schumaker

GEM3 METRICS

Integration	Y1	Y2	Y3	Y4	Y5

# cross-institutional publications acknowledging GEM3	0	1	2	3	4
Research, Education, WFD, & Seed Funding	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**
# publications acknowledging GEM3	3	6	10	12	40
# interdisciplinary publications acknowledging GEM3	2	5	8	10	20
# of publications with PUI faculty as co-authors	0	1	2	2	2
# publications with undergrads as co-authors	0	1	3	5	6
# new grants supporting GEM3 research	0	2	6	8	10
# national plus international conference presentations	4	12	15	20	30
# GEM3 collaborative proposals submitted	0	2	6	8	10
# new genotype to phenotype models developed	0	1	2	3	4
% of VIP metrics attained	100%	100%	100%	100%	100%
% retention of PUI faculty within VIP teams	100%	100%	100%	100%	100%
Vertically Integrated courses/institution (UI, BSU, ISU)	0	1	2	3	5
Faculty in VIP teams at each university (includes PUI faculty)	3	6	6	9	15
Postdocs involved in VIP teams across state	5	6	7	8	8
Graduate students involved in teams across state	7	8	9	10	10
Undergraduate students involved in VIP courses at each university	0	10	25	40	75
PUI students involved in teams	0	8	10	10	12
Students in summer research experiences (SREs)	0	23	23	23	23
# publications resulting from seed grants	0	3	5	6	12
# seed grants resulting in external grant awards	0	1	2	3	3
Diversity	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**
# of the 7 institution-level metrics in proposal w/ increases consistent w/ 5-year targets	4	6	7	7	7
# of the 7 GEM3-level metrics in proposal w/ increases consistent w/ 5-year targets	5	7	7	7	7
Total # STEM undergraduate enrollment	8717	8891	9069	9250	9435
Sustainability	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**
# MOUs formalized GEM3 partnerships	0	1	1	2	3
# of established courses that include GEM3 outputs	0	3	6	9	9
# of GEM3 postdocs placed in career positions	0	1	2	3	4

RISK MANAGEMENT PLAN

GEM3 Risk Catalog					
No.	**Risk**	**Risk Likelihood**	**Risk Impact**	**Immediacy of Impact**	**Major Actions or Mitigation Activity for high likelihood risks**
		High	**High**	**Immediate**	
		Medium	**Medium**	**Mid-Term**	
		Low	**Low**	**Distant**	
Risk Category: Research					
1	Successful integration of social science components in to the ABM process, as well as ABM/Participatory/scenario development into the stakeholder advisory group process.	Medium	High	Low	Establish collaboration between teams early, and jointly develop research questions and data collection protocols. Develop protocols collaboration and data handoffs. Foster extensive integration and teamwork across disciplines and universities.
2	Limited representation of the human system in the ABMs (focused on stressors in the form of population growth and land use change).	Medium	Medium	Medium	Identify and incorporate more holistic ways of representing human systems in ABMs.
3	Unclear plan for developing CBONs.	Low	Medium	Medium	Determine CBON sites, and develop implementation plan.
4	Short timeline for experimental data, especially when it needs to be included in iterative modeling efforts.	Medium	Medium	Low	Review status of experimental data quarterly and adjust timelines and resources if needed.
5	Amount of genetics work needed to be done on sagebrush before proposed modeling can be done.	Medium	Medium	Medium	Begin modeling with existing legacy data and review status of genetics work quarterly.
6	Genetic and genomics not addressing relevant complexity of within-species variation in the two focal species.	Medium	Medium	Medium	Revise *de novo* sequencing and gene assembly to incorporate alternative approaches.

7	Lack of clarity about life-history phenotypes (and other phenotyping details) with respect to modeling work.				Clearly identify integration among modeling frameworks and experimental validation, including links between phenotyping and modeling.
8	Inability to transfer knowledge to other focal species or systems.				Include trout and sagebrush empirical researchers in the modeling working groups.
9	Cross-institutional collaboration is difficult.				Co-mentoring of postdocs and grad students across institutions.
10	Key faculty are potentially overcommitted.				Regularly monitor time commitments, particularly when new awards and projects are granted. Work with department chairs to re-align time commitments, enlist complementary personnel, or provide teaching release.
Risk Category: Workforce Development					
11	Early inclusion/involvement of tribal members (especially in training and educational activities).				Engage in discussions early in first year, utilize tribal relations and existing connections and programs.
12	Few diverse students interested in GEM3 to recruit				Strengthen recruitment pathways with existing STEM programs.
13	Few opportunities for pre-college educational engagement for students or educators.				Promote plans for seed-grants for K-12 outreach activities linked to the project and make sure that all campuses are aware of partner organization STEM education opportunities.
14	Need for educational specialist.				Utilize input from college of education participants and their colleagues, and work with external evaluator on how to assess outreach and educational plan.
15	VIP approach being top-down to the PUI campuses.				Ensure PUI campuses are brought into the VIP and lab module development plans early rather than just being receivers of a finished product.
16	Lack of details about specific professional development plans and assessments for faculty, postdocs, graduate students, and undergraduates.				Utilize established mentoring plans and monitor and document compliance every six months.
17	Lack of existing structure at ISU and UI to set up VIP courses.				Meet in first quarter to start planning, have BSU share as much as possible, and meet with upper level administration and departmental leadership.

18	Potential reluctance of faculty to participate in VIP with fidelity, or to allow their graduate students to participate in all of the components.				Have leads meet with the faculty one-on-one to explain and offer support, have check-ins across the universities.
19	Ability to authentically engage students and faculty at our 2-year and 4-year partner campuses.				Engage partners during first quarter in planning, continue to keep them engaged with implementation throughout, and give them a voice.
Risk Category: Diversity					
20	Ability to recruit faculty from underrepresented groups, along with ability to support students from these groups.				Ensure that all campuses are ready to implement Idaho START faculty diversity recruiting and retention plan. Empower the coordinators for this during the first quarter, and have them meet with participants regularly.
21	Ability to meet diversity metrics for faculty.				Identify current URM faculty and see if can engage in any way. Recruit sabbatical visiting faculty who represent URMs. Implement START best practices in first year to recruit for new EPSCoR faculty positions.
Risk Category: Management and Communication					
22	Loss of purpose and focus for meetings, leading to loss of participation or interest.				Plan meetings carefully, seek participant feedback, respond to feedback, make meeting products easily available.
23	Significant change in university leadership statewide.				Engage State Committee to re-affirm roles and responsibilities; develop clarifying written agreements as needed.
24	Transition of PD/PI.				Seek to hire using inclusive best practices; leadership team remain cohesive and active; implement solid transition plan.
25	Complexity of interdependencies among components.				Additional effort to identify and clarify interdependencies; develop conceptual models.
26	Vague articulation of goals.				Clarify SMART goals; review Strategic Plan regularly and update annually.

APPENDIX A: Project Participants, Affiliations, and Roles

Project Leaders	Title	Affiliation	Department	Project Element(s)	Role(s)
Janet Nelson	Vice President	UI	Research & Economic Development	Project Leadership, Management/Evaluation & Assessment (Mgmt/Eval)	Interim Project Director, PI
Colden Baxter	Professor	ISU	Biology	Mechanisms, Communication, Sustainability, Mgmt/Eval	Co-PI, Sustainability Lead
Jennifer Forbey	Assoc. Professor	BSU	Biology	Modeling, Mechanisms, Mapping, WFD, Partnerships, Communication, Integration, Mgmt/Eval	Co-PI, Partnerships Co-Lead, Sustainability Co-Lead
Ronald Hardy	Director & Professor	UI	Aquaculture Research Institute	Mechanisms, Modeling, Mapping, Partnerships, Communication, Mgmt/Eval	Co-PI, Mechanisms (Trout) Lead, Partnerships Lead
Team Leaders	**Title**	**Affiliation**	**Department**	**Project Element(s)**	**Role(s)**
Morey Burnham	Research Asst./Professor	ISU	Sociology	Mapping, Modeling, Mgmt/Eval	Faculty, Mapping Co-Lead
Donna Delparte	Assoc. Professor	ISU	Geosciences	Mapping, Mgmt/Eval	Faculty, Mapping Lead
Julie Heath	Professor	BSU	Biology	Modeling, Mgmt/Eval	Faculty, Modeling Co-Lead
Donna Llewellyn	Executive Director	BSU	STEM & Diversity Initiatives	WFD	Faculty, WFD Lead
Sarah Penney	Education, Outreach, Diversity (EOD) Coordinator	UI	EPSCoR	Diversity, WFD, Communication, Mgmt/Eval	Staff, Diversity Lead, Communication Lead
Keith Reinhardt	Asst. Professor	ISU	Biology	Mechanisms, Modeling, Mapping, Mgmt/Eval	Faculty, Mechanisms (Sagebrush) Lead
Barrie Robison	Director & Professor	UI	IBEST	Modeling, Mapping, Mgmt/Eval	Faculty, Modeling Lead
Rick Schumaker	Asst. Project Director/Project Administrator	UI	EPSCoR	Mgmt/Eval	Asst. Project Director
Team Members	**Title**	**Affiliation**	**Department**	**Project Element(s)**	**Role(s)**
John Abatzoglou	Assoc. Professor	UI	Geography	Modeling	Faculty
Catherine Bates	Coordinator	BSU	STEM Diversity & LSAMP	Diversity	Other Professional

Yolonda Bisbee	Executive Director of Tribal Relations	UI	Office of Equity & Diversity	Diversity	Other Professional (START coordinator)
Ashley Bogar	Evaluation Director	UI	EPSCoR	Mgmt/Eval	Other Professional
Jodi Brandt	Asst. Professor	BSU	College of Innovation & Design	Modeling, Mapping	Faculty
Sven Buerki	Asst. Professor	BSU	Biology	Mechanisms, Mapping	Faculty
Christopher Caudill	Assoc. Professor	UI	Fish & Wildlife Sciences	Modeling, Mechanisms, Mapping	Faculty
T. Trevor Caughlin	Asst. Professor	BSU	Biology	Modeling, Mechanisms, Mapping	Faculty
Jeff Cooper	Asst. Professor	CSI	Soils, Water, and Natural Resource Management	WFD	Faculty
Melinda Davis	Director, STEM Education	UI	Education, Health & Human Sciences	WFD	Other Professional
Henry Evans	Assoc. Director	ISU	Office of Equity & Inclusion	Diversity	Other Professional (START coordinator)
John Freemuth	Professor & Executive Director	BSU	Public Policy & Administration, Andrus Center	Mapping	Faculty
Matthew Germino	Supervisory Research Ecologist	USGS	Snake River Field Station	Mechanisms	Other Professional/Research Collaborator
Vicken Hillis	Asst. Professor	BSU	College of Innovation & Design	Modeling	Faculty
Paul Hohenlohe	Assoc. Professor	UI	Biology	Mechanisms	Faculty
Kelly Hopping	Asst. Professor	BSU	College of Innovation & Design	Modeling, Mapping	Faculty
Ernest Keeley	Professor	ISU	Biology	Mechanisms, Mapping	Faculty
Andrew Kliskey	Assoc. Professor	UI	Forest, Rangeland, & Fire Sciences	Modeling, Mapping	Faculty
Janet Loxterman	Asst. Chair/Assoc. Professor	ISU	Biology	Mechanisms, WFD, Integration	Faculty
Sonia Martinez	STEM Diversity & Outreach Coordinator	ISU	Research Outreach & Compliance	WFD	Other Professional
Shawn Narum	Senior Scientist/Lead Geneticist	CRITFC	Fishery Science	Modeling, Mechanisms, Mapping	Other Professional/Research Collaborator (Genetics)
Stephen Novak	Professor	BSU	Biology	Mechanisms, Mapping	Faculty

Michelle Payne	Asst. Provost & Professor	BSU	Academic Leadership & Faculty Affairs	Diversity	Other Professional (START coordinator)
Dusty Perkins	Assoc. Professor	CWI	Biology	WFD	Community College Faculty
Janet Rachlow	Professor	UI	Fish & Wildlife Sciences	Modeling	Faculty
Bryce Richardson	Research Geneticist	USFS	Rocky Mountain Research Station	Modeling, Mechanisms, Mapping	Other Professional/Research Collaborator (Plant Genetics)
Carrie Roever	Environmental Data Manager	UI	Northwest Knowledge Network	Modeling, Data Management	Other Professional
Keegan Schmidt	Professor	LCSC	Natural Sciences and Mathematics	WFD	Faculty
Brian Small	Professor	UI	Fish & Wildlife Sciences	Mechanisms	Faculty
Lisette Waits	University Distinguished Professor & Department Head	UI	Fish & Wildlife Sciences	Modeling, Mechanisms, Mapping, WFD, Integration	Faculty
Holly Wichman	University Distinguished Professor & Director, CMCI	UI	Biology	Modeling	Faculty
Barbara Wood Roberts	Director Intercultural Competence Lab	ISU	Graduate Outreach Management	Diversity	Faculty
New Hire – Years 1-2	Genetics Scientist	ISU		Mechanisms (Sagebrush)	Faculty
New Hire – Year 2	Ecological Genomic Modeler	BSU		Modeling, Mechanisms	Faculty
New Hire – Year 2	Environmental Social Scientist	ISU		Mapping	Faculty
New Hire – Years 2-3	Environmental Network Systems Scientist	BSU		Mapping	Faculty
New Hire – Years 2-3	Quantitative Population Ecologist	BSU		Modeling, Mapping	Faculty
New Hire – Year 3	Data Scientist	BSU		Mapping	Faculty

APPENDIX B: Results of SWOT Analysis

In June 2018, members of the individual GEM3 components as well as GEM3 leaders met independently to develop SWOT analyses for their components. These analyses were discussed and refined by component leads as a group in an August 2018 meeting and again at the September 2018 Strategic Planning Meeting.

When asked to identify strengths, many GEM3 faculty pointed to the experience of the researchers, the interdisciplinary nature of the science and of the research teams, and the innovative approaches being applied. Major weaknesses cited included the integration of social sciences, funding limitations, and the potential difficulties involved in the complex nature of the proposed research.

Research (Modeling/Mechanisms/Mapping)

Strengths

- Experience in assembling and sustaining stakeholder panels and research methods associated with carrying out participatory modeling.
- Cluster of core facilities for ABM.
- Value of complex and spatially-explicit modeling frameworks and planned experimental validation as tools.
- Emphasis on origins of adaptive phenotypic variation as influenced by genes expressed differently across environments.
- Strong knowledge base for volatile and non-volatile chemicals, adaptive and physiological traits for sagebrush.
- Potential to inform resource management decision-making.

Weaknesses

- Successful integration of social science components in to the ABM process, as well as ABM/Participatory/scenario development into the stakeholder advisory group process, will require extensive integration and teamwork across disciplines and universities.
- Environmental and human dimensions associated with the phenomic information.
- Detail needed to understand the integration of decision-making heuristics into the ABM to assess both how decisions might change over time, and what impact those decision might have.
- Unclear plan for develop CBONs.
- Amount of genetics work needed to be done on sagebrush before proposed modeling can be done.
- Difficulty of attributing genomic variation to overlapping contributions of spatial genetic processes (e.g., isolation by distance), historical demography, and past vs current selective environments.

Opportunities

- A tighter integration of the ecological expertise at BSU with the evolutionary expertise at UI.
    - An eco-evo component can be included in the ABMs.
- A geospatial "layered" model of Idaho can serve as a foundation for other groups beyond EPSCoR, such as CMCI (regional health disparities).
    - NKN has expertise with these kinds of data.
- This group offers the potential for statewide coordination of strategies for research computing infrastructure and genomics infrastructure.
- Explore if an MOU be developed that offers "internal" client rates for in state Universities?

Threats

- Collaborating across institutions is difficult and requires perseverance and commitment.
- Key faculty are potentially overcommitted.
- "What if" alternative environments are key or interactive (e.g. low-dissolved O_2).

Workforce Development

Strengths

- Use of VIP as a unifying approach for education, training, and recruitment.
- Use of student ambassadors to recruit peers and providing a strong network and guidance for undergraduates to increase graduation rates.
- Inclusion of training on mentoring and diversity (see Review Number 1 under Workforce Development paragraph on page 2).
- The development of the lab modules (See Review Number 2 under Workforce Development on page 2).

Weaknesses

- Lack of inclusion/involvement of tribal members (especially in training and educational activities).
- Lack of a plan for recruiting diverse students.
- Lack of plans for educational engagement earlier than college level for students or educators.
- Concern about VIP approach being top-down to the PUI campuses.

Opportunities

- Potential to provide a system-wide curriculum.
- Engage with faculty and potential stakeholders at beginning of project.

Threats

- Potential reluctance of faculty to participate in VIPs with fidelity.
  - Mitigation – have leads meet with the faculty one on one to explain and offer support, have check-ins across the universities.
- Potential reluctance of faculty to allow their graduate students to participate in all of the components of the plan.
  - Mitigation - have leads meet with the faculty one on one to explain and offer support, have check-ins across the universities.

Diversity

Strengths

- Idaho Diversity Network (IDN) established and can be utilized to accomplish objectives.
- Funding identified to implement key GEM3 objectives.
- Successful track record and mentoring conference model to follow.
- PUI contacts identified (those who provided letters of support) have familiarity with EPSCoR and strong track record of identifying URM student participants and engaging their PUI faculty.

Weaknesses

- Ability to meet diversity metrics for faculty (although not a weakness indicated by reviewers).

Opportunities

- Exploring ways to expand the IDN to best meet needs of GEM3 in regard to statewide training.
- Potentially utilizing NSF INCLUDES such as The InterMountain Science, Technology, Engineering and Mathematics Launch Pilot (IM STEM) as way to scale up practices to other institutions.

Threats

- Exploring ways to expand the IDN to best meet needs of GEM3 in regard to statewide training.
- Ability to meet diversity metrics for faculty (Mitigation ideas above in Risk Management Plan).
- Working on specific actions and training for 4 new hires at BSU.

Partnerships and Collaborations

Strengths

- Use of existing USFS common garden plots and United States Fish and Wildlife Service (USFWS) Fish Culture Experiment Station, USDA ARS Reynolds Creek.
- Involvement of existing centers: Laboratory for Ecological, Evolutionary and Conservation Genetics (LEECG), Institute for Bioinformatics and Evolutionary Studies (IBEST), Center for Modeling Complex Interactions (CMCI), Center for Resilient Communities (CRC), and the Andrus Center for Public Policy.
- Partnership between science and education are strong at BSU with established infrastructure through VIPs and curriculum reform and the use of GA support from Biological Sciences and Ecology, Evolution, and Behavior programs.
- Leverage strong infrastructure of internship program established through NIH INBRE at Idaho Institutions and build industry partnerships and mechanisms for credit and paid positions through existing undergraduate programs.

Weaknesses

- Partnerships with tribes associated with education are limited. Potential mitigation is to leverage these educational partnerships that do exist at ISU that were built from previous EPSCoR.
- While partnership between science and education are strong at BSU the mechanisms used to create and sustain these may be difficult to transfer.

Opportunities

- Leverage infrastructure established for internships through NIH INBRE and existing curricula opportunities.

Threats

- Buy-in from faculty.
- Potential lack of interest in basic science for agency partners. Need to emphasize translation of basic science to their mission and vision.
- Ownership of data may be problematic especially with tribes. Potential mitigation is to establish agreements with sharing data that may have intellectual properties and to build trust by leveraging established relationships. One option is to formalize intellectual property (IP) agreements that do exist across to other institutions.

Communication and Dissemination Plan

Strengths

- Experience producing newsletters and other materials for distribution.
- Experience facilitating large multi-scale, multi-institutional collaborations.

Weaknesses

- Communications may not be recognized as a shared responsibility.

Opportunities

- Relevance of GEM3 research & education to Idaho citizens is high.
- Greater collaboration & potential for convergent research.

Threats

- Lack of time or number of individuals involved.
- Meeting-fatigue.
- Loss of purpose and focus for meetings, leading to loss of participation or interest.

APPENDIX C: Glossary of Abbreviations and Acronyms

ABM	Agent Based Model
BLM	Bureau of Land Management
BSU	Boise State University
CAREER	Faculty Early Career Development
CBON	Community-based Observing Network
CMCI	Center for Modeling Complex Interactions
CRC	Center for Resilient Communities
CRITFC	Columbia River Inter-Tribal Fish Commission
CWI	College of Western Idaho
EOD	Education, Outreach, and Diversity
EPSCoR	Established Program to Stimulate Competitive Research
ExComm	Executive Committee
FTE	Full Time Equivalent
GA	Graduate Assistantship
GEM3	Genes to Environment: Modeling, Mechanisms, and Mapping
GxE	Genotype by Environment
IBEST	Institute for Bioinformatics and Evolutionary Studies
ICUR	Idaho Conference on Undergraduate Research
ID	Idaho
IDFG	Idaho Department of Fish and Game
IDN	Idaho Diversity Network
IM STEM	Intermountain STEM Launch Pilot
INBRE	IDeA Network of Biomedical Research Excellence
INCLUDES	Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science
IP	Intellectual Property
ISU	Idaho State University
LEECG	Laboratory for Ecological, Evolutionary and Conservation Genetics
MOU	Memoranda of Understanding
NCBI	National Center for Biotechnology Information
NIH	National Institutes of Health
NKN	Northwest Knowledge Network
NSF	National Science Foundation
PAB	Project Advisory Board
PD	Project Director
PI	Principal Investigator
PUI	Primarily Undergraduate Institution
R&E	Research and Education
R&R	Recruitment and Retention
RII	Research Infrastructure Improvement
RSV	Reverse Site Visit
SAG	Stakeholder Advisory Group
SES	Social Ecological Science
SRE	Summer Research Experience
S&T	Science and Technology
SBOE	State Board of Education
SNP	Single-nucleotide Polymorphism
START	System to Attract and Retain Talent
STEM	Science, Technology, Engineering, and Mathematics
SWOT	Strengths, Weaknesses, Opportunities, and Threats
UAS	Unmanned Aircraft System
UI	University of Idaho
URM	Underrepresented Minority
USDA ARS	United States Department of Agriculture – Agricultural Research Service
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VIP	Vertically Integrated Project
WFD	Workforce Development