GEM3 Sagebrush Mechanism: G2P and G×E research

2020 Idaho EPSCoR Meeting

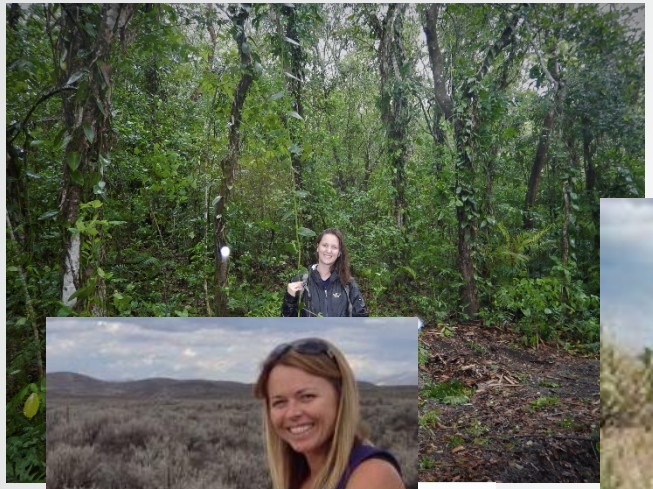
Anthony E. Melton

Postdoctoral Research Associate

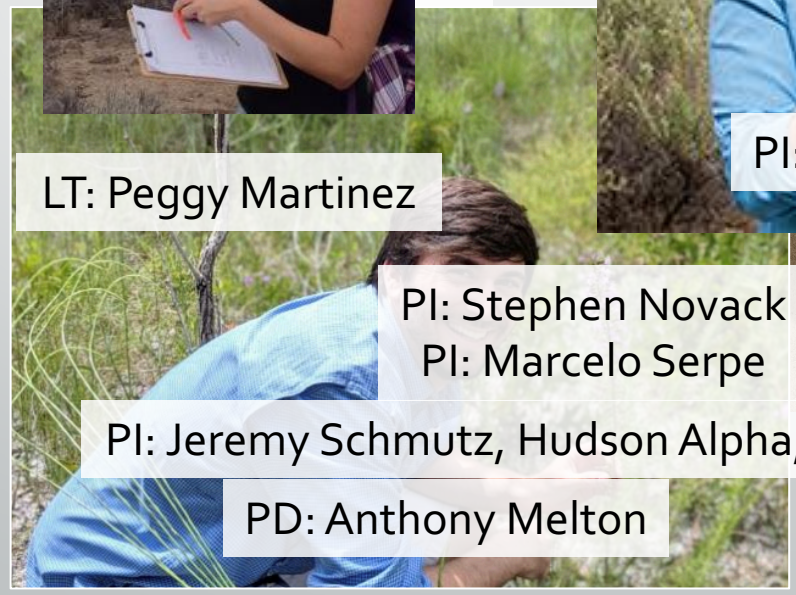
Sagebrush Genomics team

PI: Sven Buerki

PD: Stephanie Galla



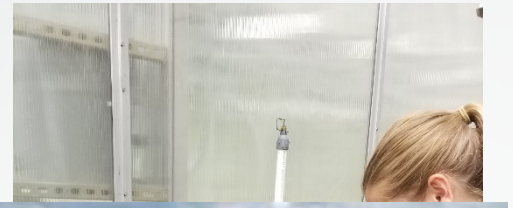
LT: Peggy Martinez



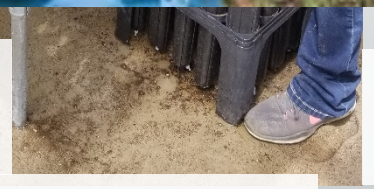
PI: Stephen Novack
PI: Marcelo Serpe

PI: Jeremy Schmutz, Hudson Alpha, Huntsville, AL

PD: Anthony Melton



PI: Jen Forbey



Recent grad:
Kara Navock, MS

PI: Bryce Richardson

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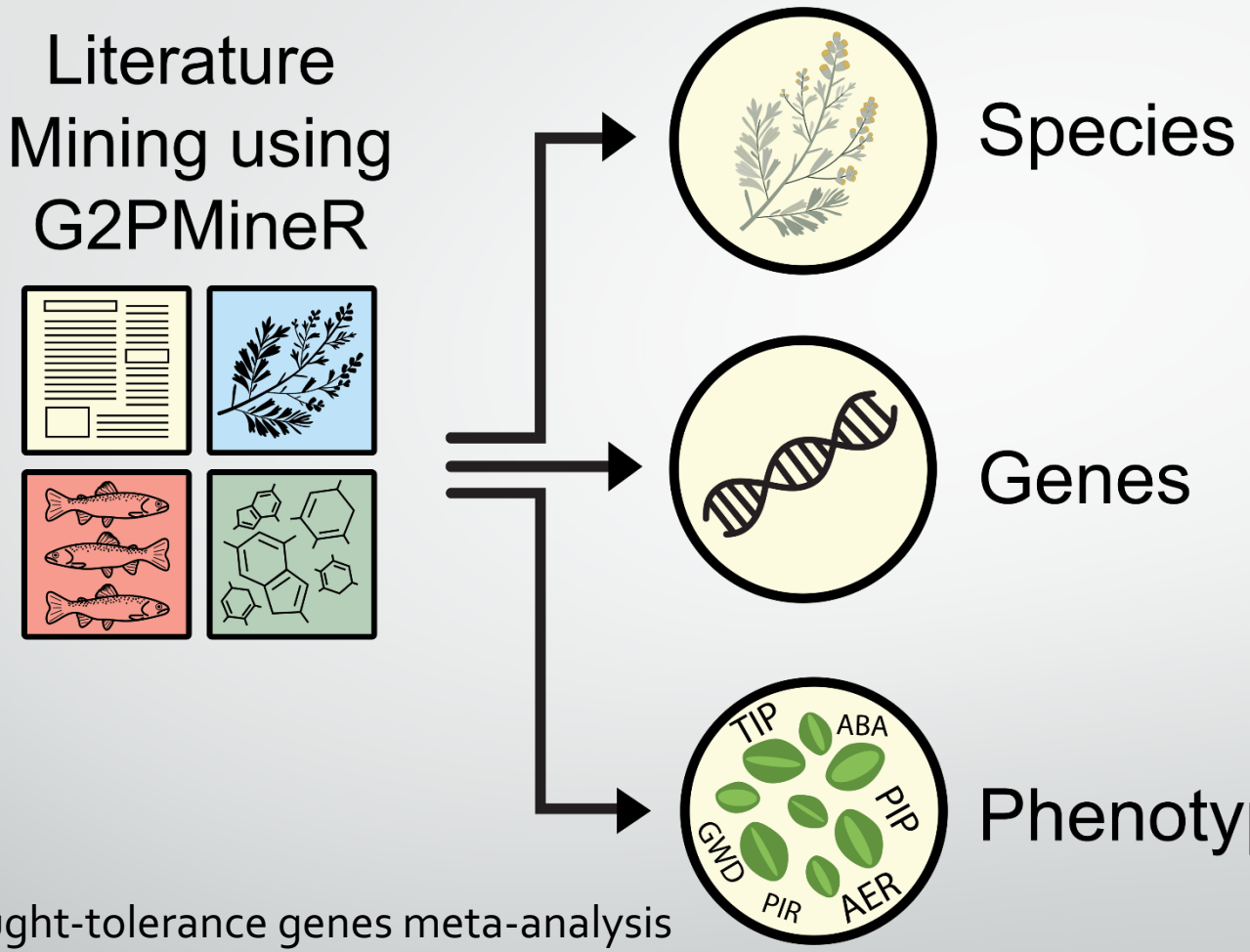
Genes by Environment
Modeling · Mechanisms · Mapping

Developing Bioinformatic Tools to Support G2P Hypotheses

- Created G2PMineR R package for literature reviews and meta-analyses
- G2P machine learning pipeline
- GEM3 RA

- Drought-tolerance genes meta-analysis
- SARE and VIP course mentor
- Fieldwork, collections of Sagebrush seeds/tissue from across distribution



- SARE 2020
- VIP 2020
- Identify candidate genes from literature and the mine genes from current draft genome
- Starting Biology graduate program spring 2021

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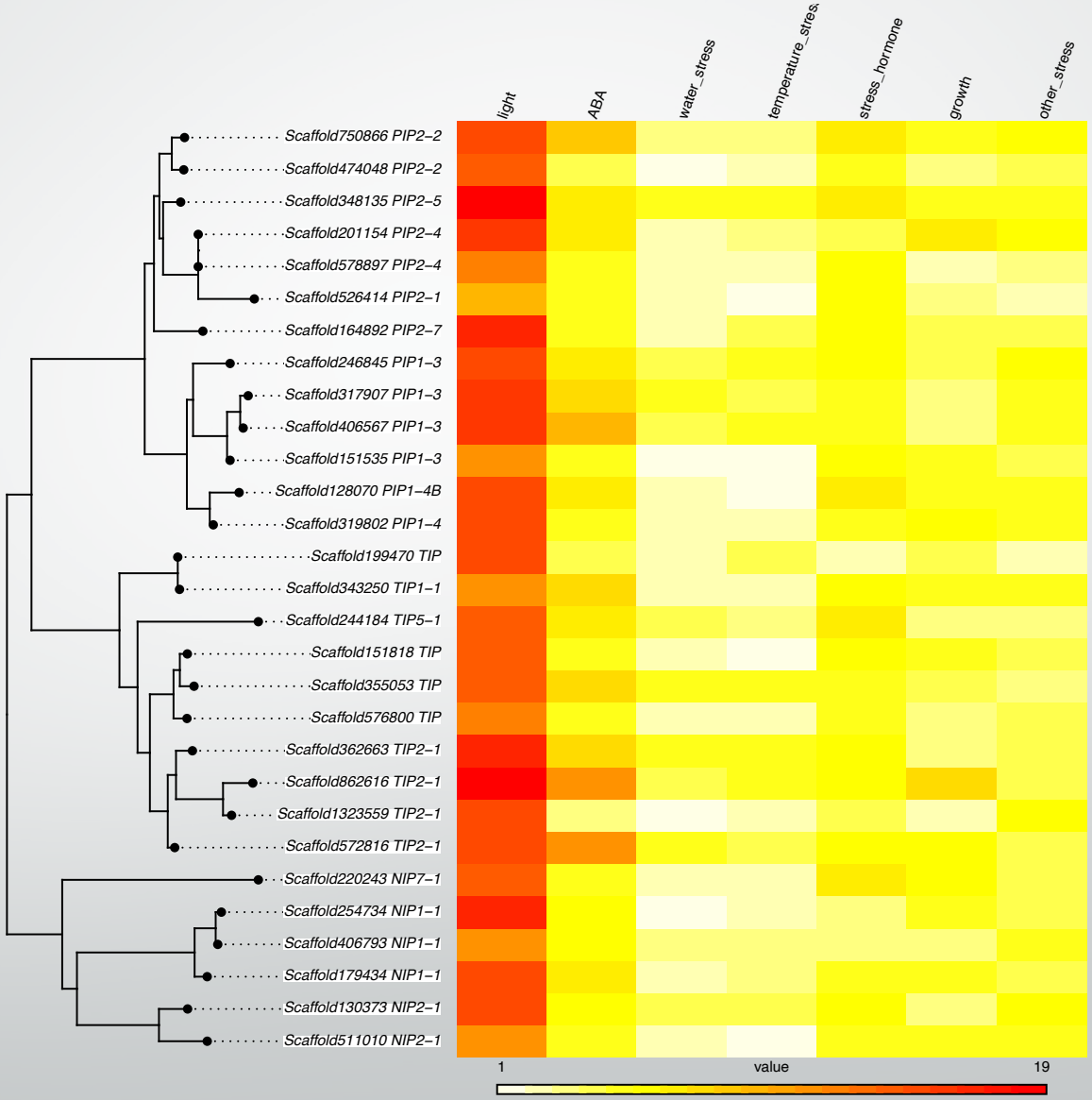
Genome Mining, Assembly,

Identification
ID scaffolds containing AQP genes via BLAST.

Validation
Create gene hypotheses via BLAST, perform phylogenetic reconstruction, and generate 3D models of hypothesized proteins.

Analysis
Categorize promoter elements, assess for differentiation of promoter element content.

- Genomics and transcriptomics of drought adaptation
- Aquaporin paper in prep, transcriptomics of G×E experiment, genome assembly/annotation
- VIP course mentor
- Fieldwork, collections of Sagebrush seeds/tissue from across distribution



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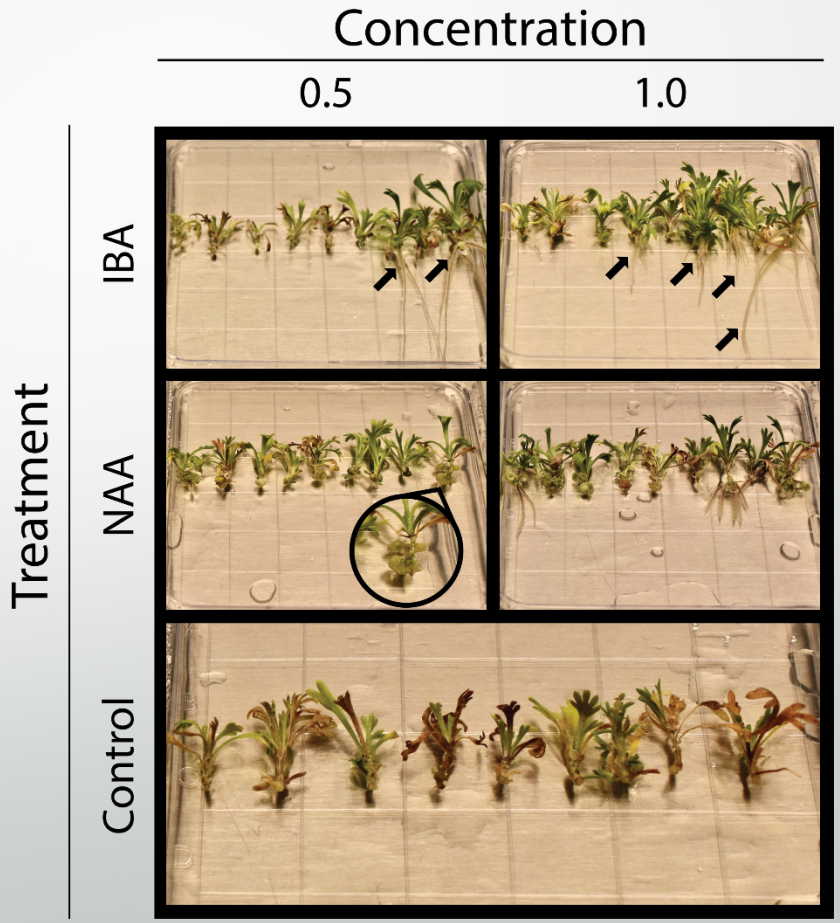
Developing Tools for Genome Sequencing and GxE Experiments

- Barron, R.; Martinez, P.; Serpe, M.; Buerki, S. Development of an *In Vitro* Method of Propagation for *Artemisia tridentata* subsp. *tridentata* to Support Genome Sequencing and Genotype-by-Environment Research. *Plants* 2020, 9, 1717.
- VIP course mentor

- Propagate clonal plant lines for genome sequencing and G ×E experiments



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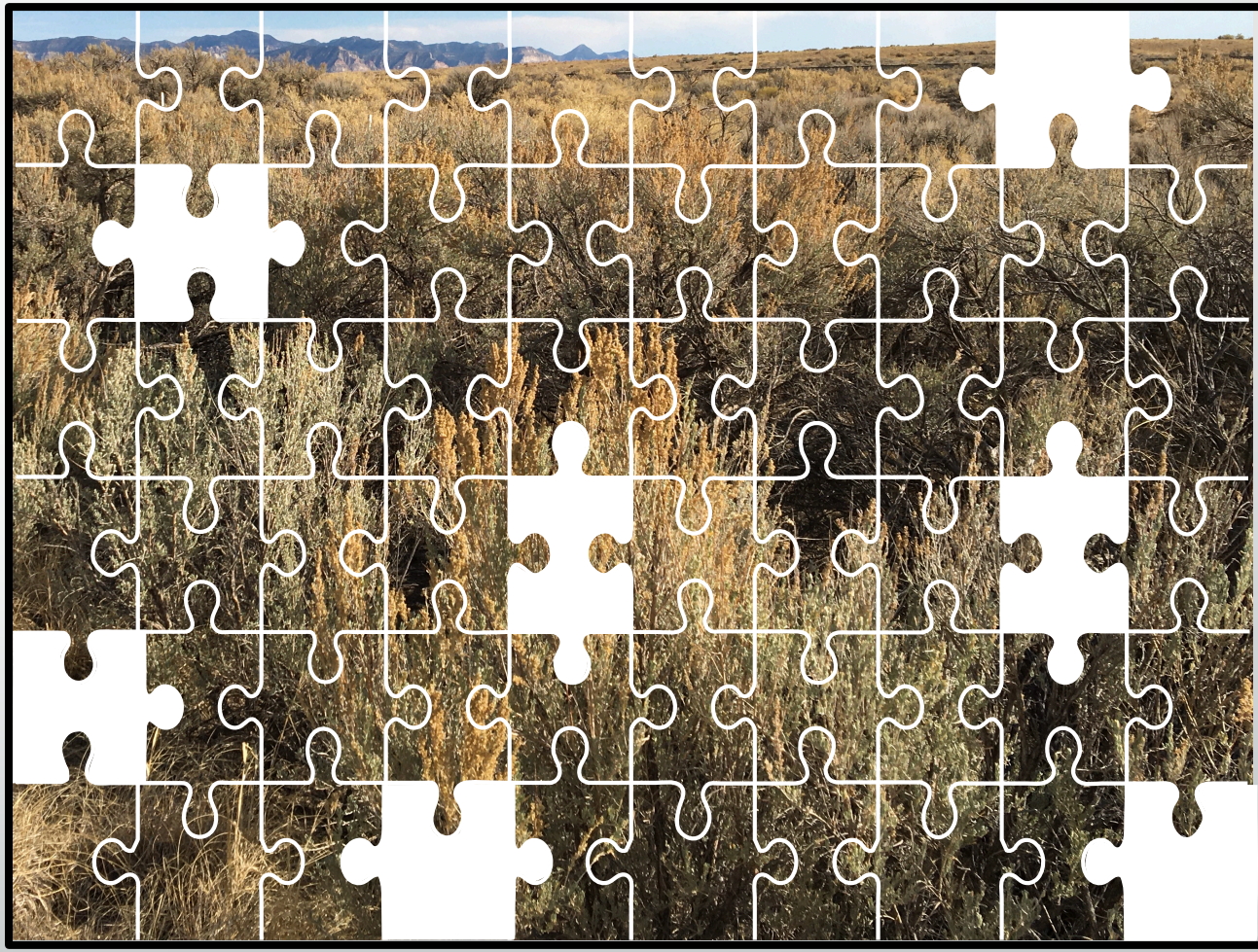
Towards the Future - Producing Sagebrush Genome

- Full genome to be assembled in 2021
  - Large, complex genome (~9 Gb)
  - Sequencing and assembly by Dovetail genomics (Dovetail ToL grant recipient)
  - Tissue cultures being cultivated for biomass (120g tissue = ~800 plantlets required!)
  - Should have required biomass by early to mid-March 2021
  - Sequencing and assembly will take ~7 months – should have fully assembled and phased genome by October 2021
  - Report at 2021 Annual Meeting



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End Talk 1 (Anthony) … Talk 2 (Donna)

Introduction: *GEM3 – Integration Lightning Research Talk*

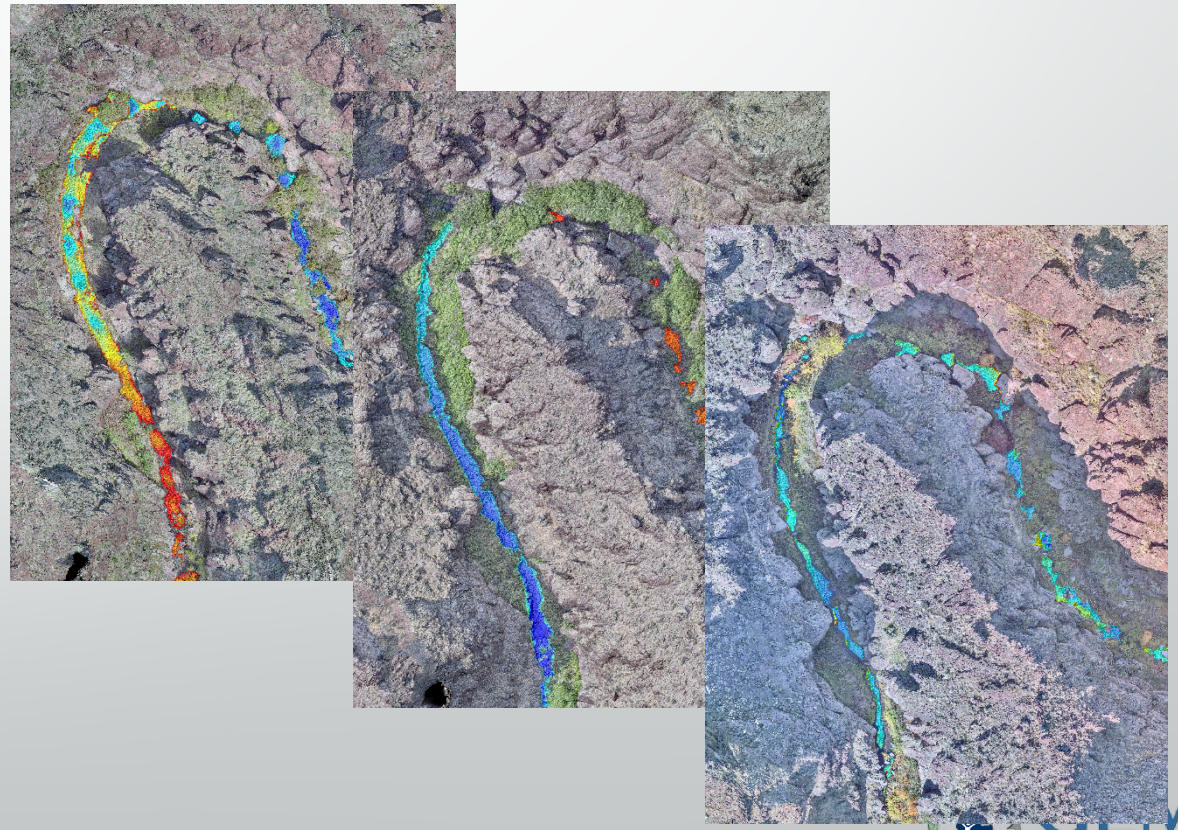
Integrating Sagebrush and Trout research: Big, Little Jacks, Duncan Creeks in Owyhee County

Big sagebrush recovery

- Demographic field data
- UAS monitoring (RGB, Multispectral)
- Satellite time-series

Trout monitoring

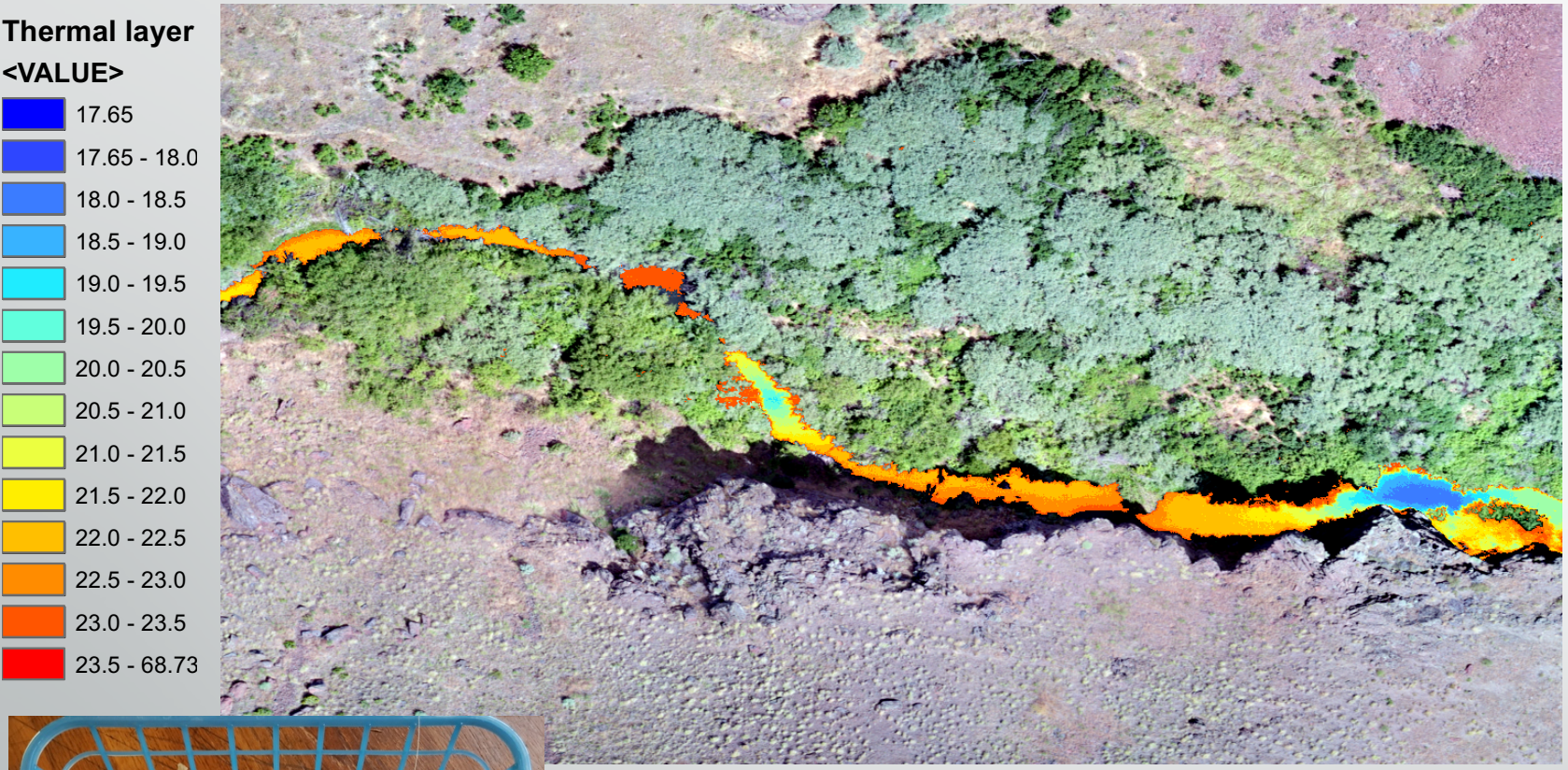
- UAS mapping of seasonal thermal refugia
- Riparian sagebrush mapping
- Vegetation influence on fish habitat

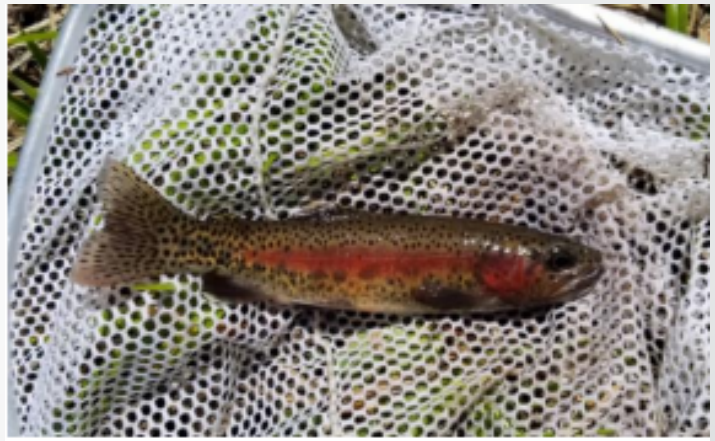


Slide Credits: GEM3 Researcher Andrii Zaiats and Mapping co-Lead Donna Delparte

Introduction: *GEM3 – Integrating Sagebrush and Trout research*

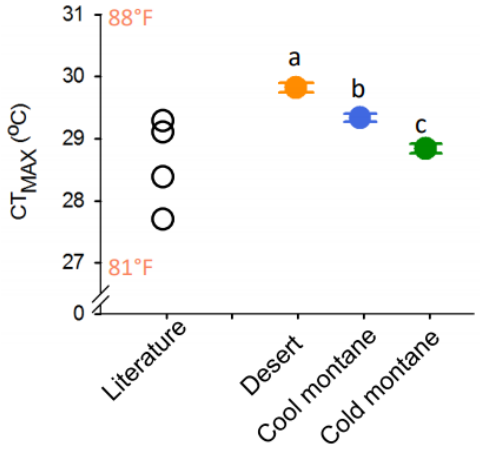
Little and Big Jacks, Duncan Drainages, Owyhee County





Temperature Loggers

Critical thermal maximum (CT_{MAX})

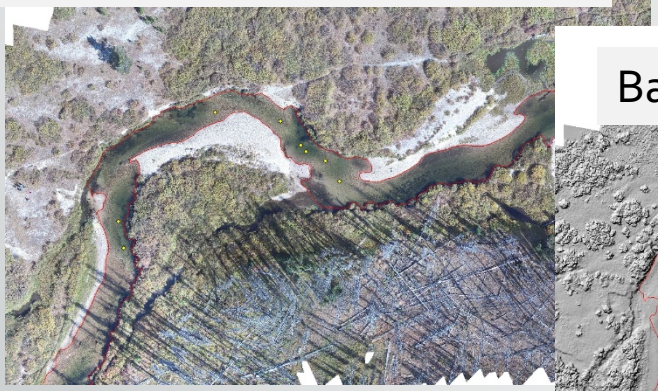


Slide Credits: GEM3 Postdoc Researchers Zhongqi Chen, Youngwoo Cho

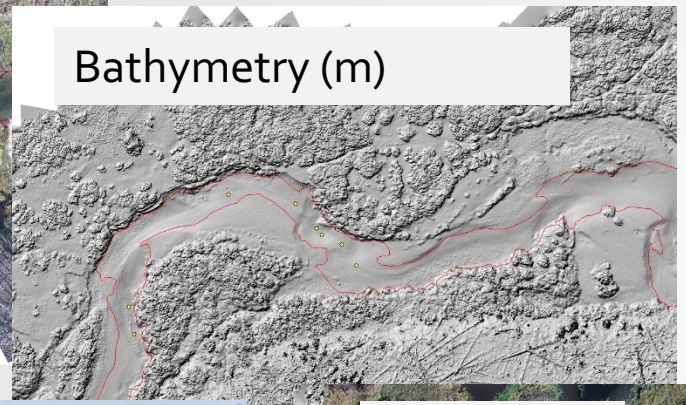
Introduction: *GEM3 – Integrating Sagebrush and Trout research*

UAS and Field Transect Derived Stream Characteristics/Habitat

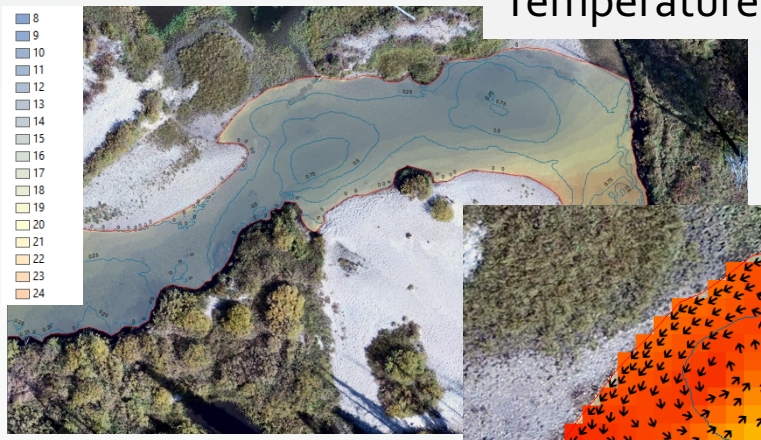
Orthomosaic



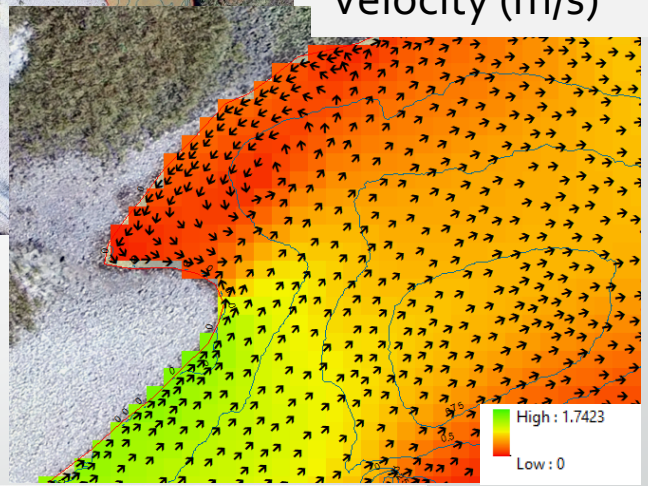
Bathymetry (m)



Temperature C



Velocity (m/s)

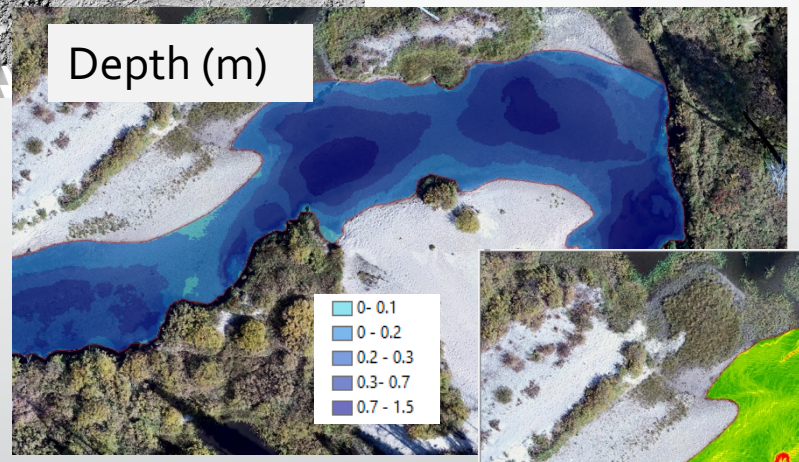


Habitat Samples

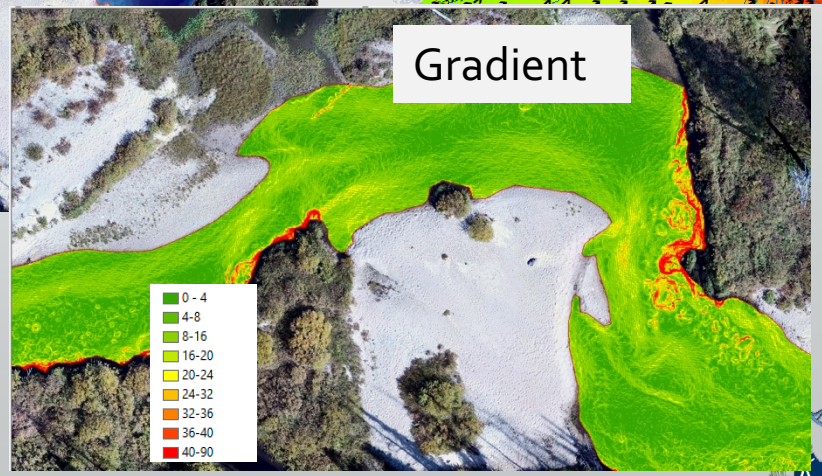
- stream depth
- current velocity
- temperature
- Invertebrate drift

NEI = energy gain – (energy costs + losses)

Depth (m)



Gradient



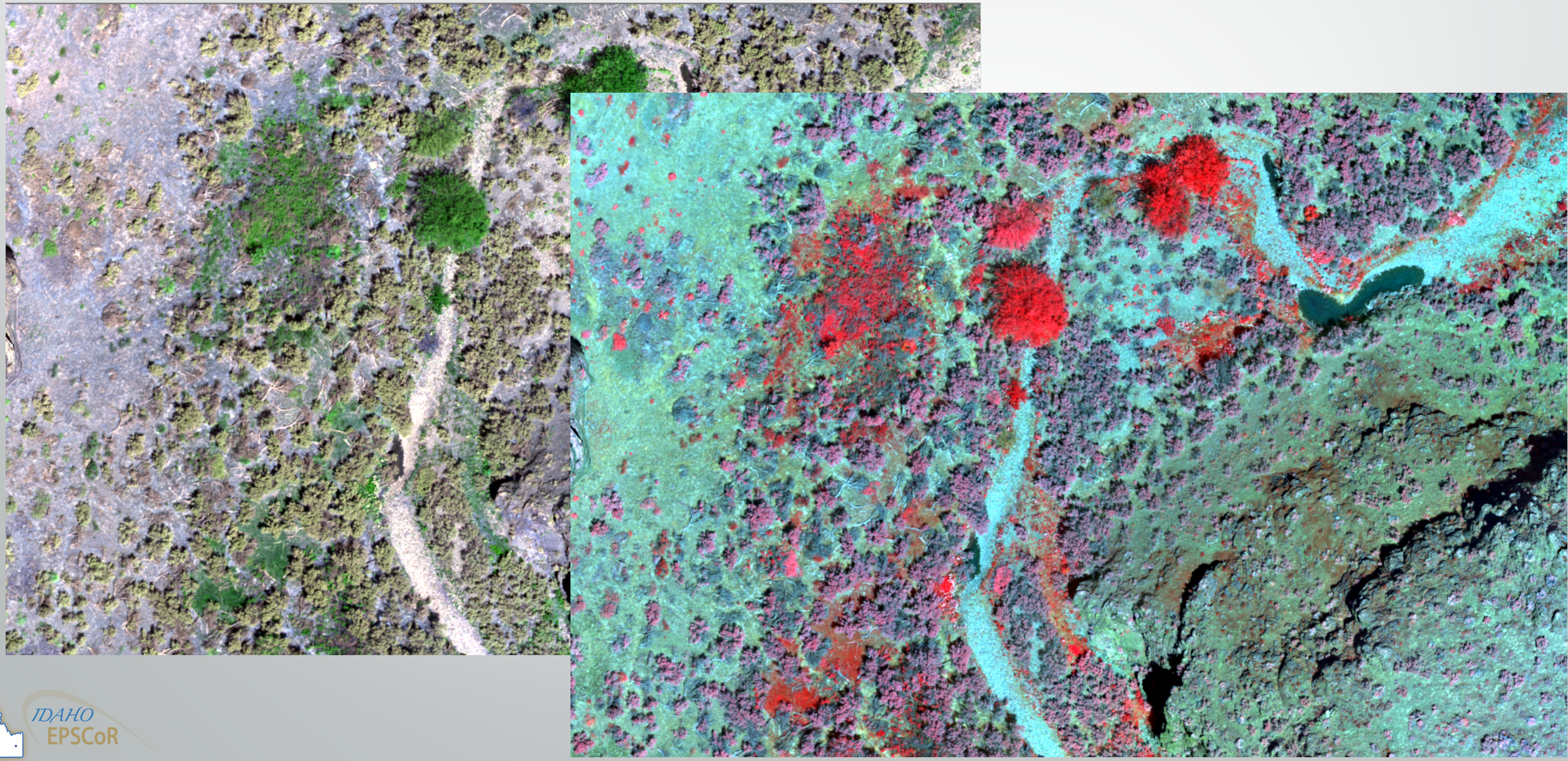
EPSCoR

Slide Credits: GEM3 Ernest Keeley, Donna Delparte

GEM3 Genes by Environment Modeling · Mechanisms · Mapping

Introduction: *GEM3 – Integrating Sage and Trout*

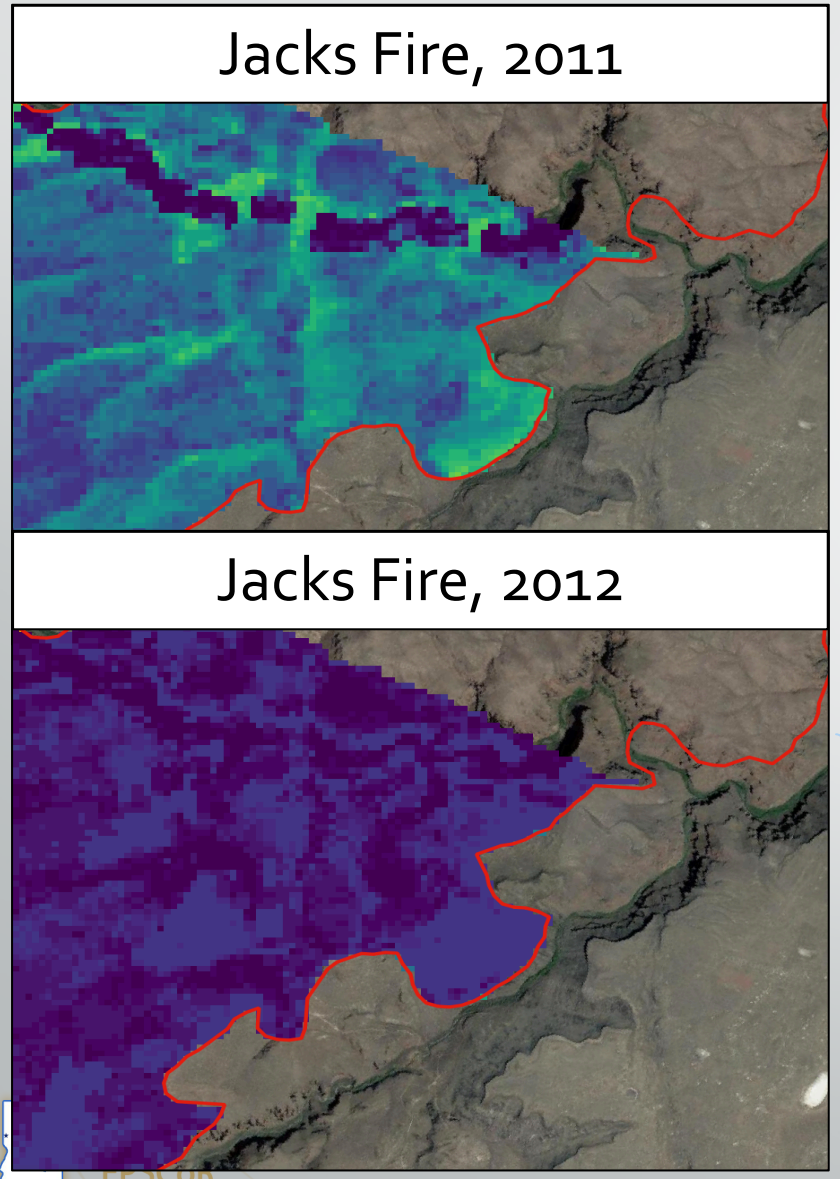
UAS Riparian Sagebrush Habitat Mapping along Duncan Creek

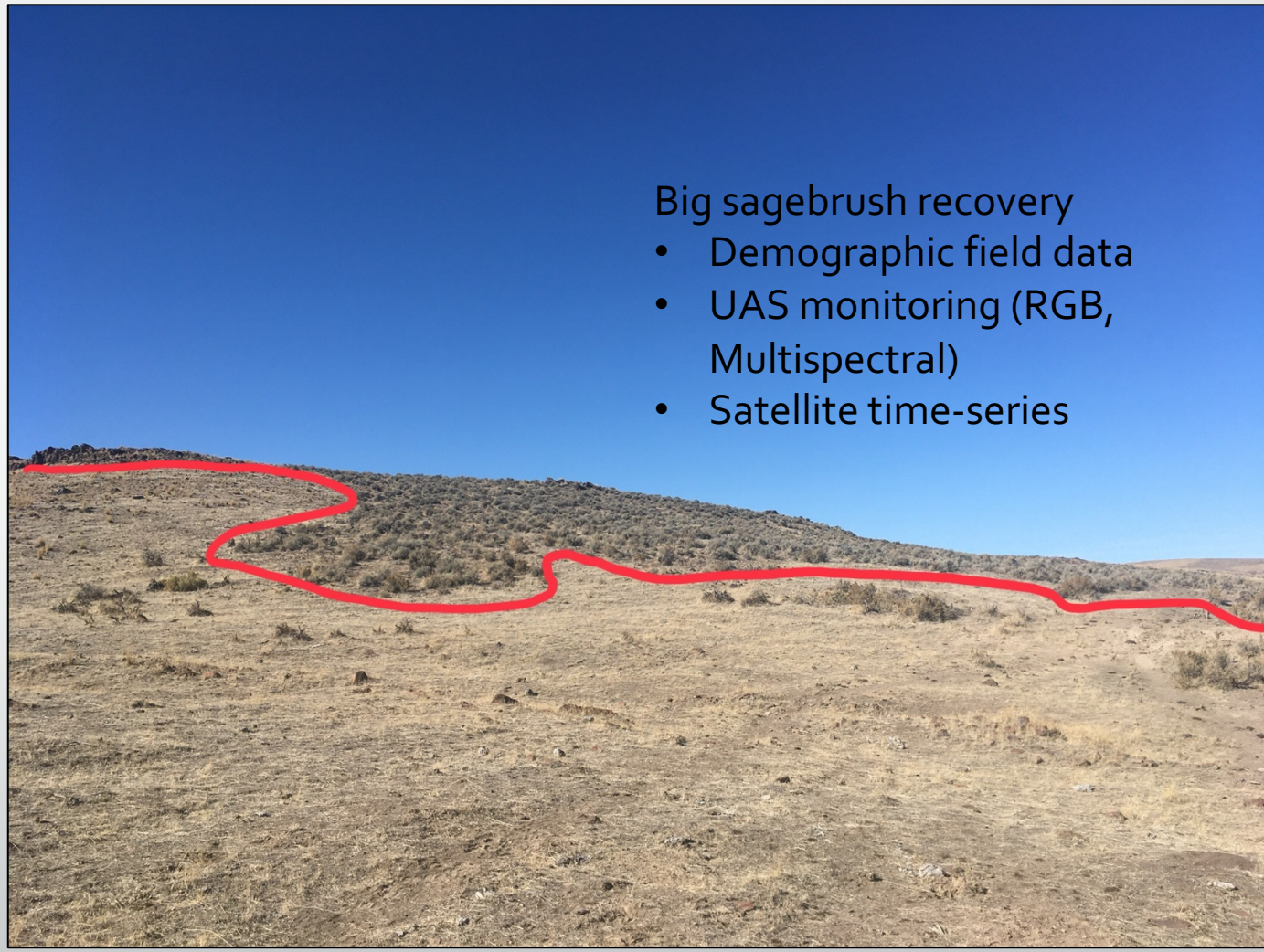


IDAHO EPSCoR

Introduction: *GEM3 – Integrating Sagebrush and Trout research*

Duncan-Big Jacks Drainages, Owyhee County





Slide Credit: GEM3 Researcher Andrii Zaiats

EPSCoR

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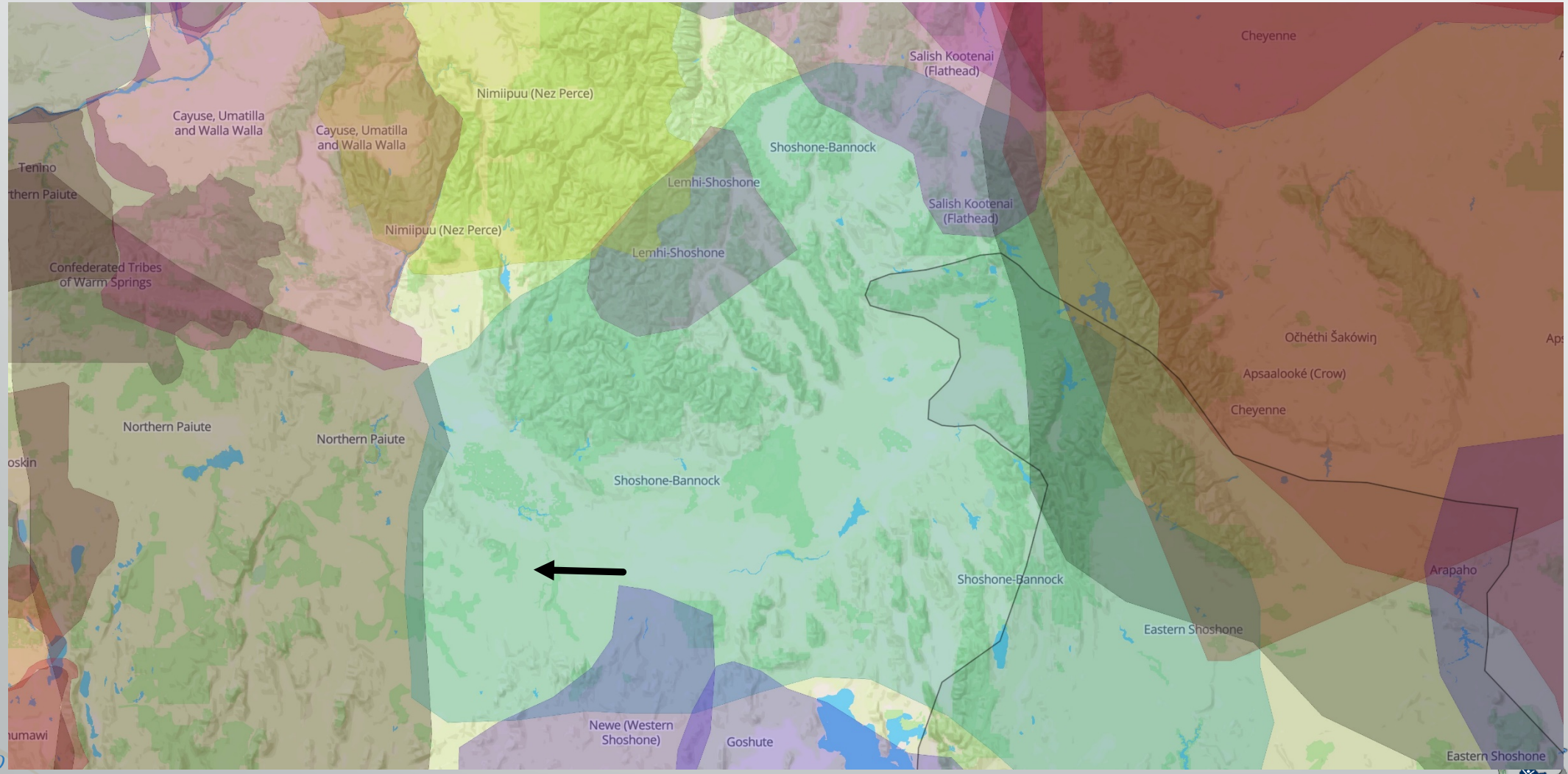
Introduction: *GEM3 – Integrating Sage and Trout: SES context*

Desert Stream (Big, Little Jacks and Duncan Creeks) are located on occupied Shoshone-Bannock land

Source: native-land.ca



Slide Credit: GEM3 Modeling Lead Trevor Caughlin

Introduction: *GEM3 – Integration SES Context: The Owyhee Initiative*

Big, Little Jacks and Duncan Streams

Designated Wilderness Area by the Omnibus Public Land Management Act of 2009 and signed into law by President Obama

Provision created by Senator Mike Crapo (R-Idaho) created more than 500,000 acres of Wilderness

"The Owyhee Initiative brought together ranchers, local officials, conservation groups (including The Wilderness Society, the Nature Conservancy and the Idaho Conservation League), outfitters, the Air Force, the Shoshone-Paiute Tribe and motorized recreationists on equal grounds to protect their common values. Gehrke [Wilderness Society Director] had to meet personally with every rancher who would be affected by the wilderness protection he was proposing." Source: magicvalley.com

Some controversy remains, particularly over cattle herding in the Wilderness Area

Owyhee Initiative has since become a model for collaborative partnerships between ranchers, federal agencies, and environmentalists across the west. Photo courtesy: owyheeinitative.org

Slide Credit: GEM3 Modeling Lead Trevor Caughlin

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End Talk 2 (Donna) … Talk 3 (Travis)

Trout Modeling: *Specific Objectives*

Main goal: When can genotypic traits or phenotypic plasticity "rescue" populations from environmental change?

Overall framework: Use spatially realistic ABMs to determine:

1) how genetics, plasticity and landscape interact to affect adaptive capacity
2) how outcomes vary across SES scenarios and management actions

Specific objectives:

- Build spatial demographic-genetic models for representative desert and montane sites.
- Refine models using GEM3 data.
- Model adaptive capacity under alternative SES conditions:
  - Climate
  - Land cover
  - Translocation / assisted migration
- **<u>Novel: Include G x E (plastic) traits under genetic control, including behaviors</u>**

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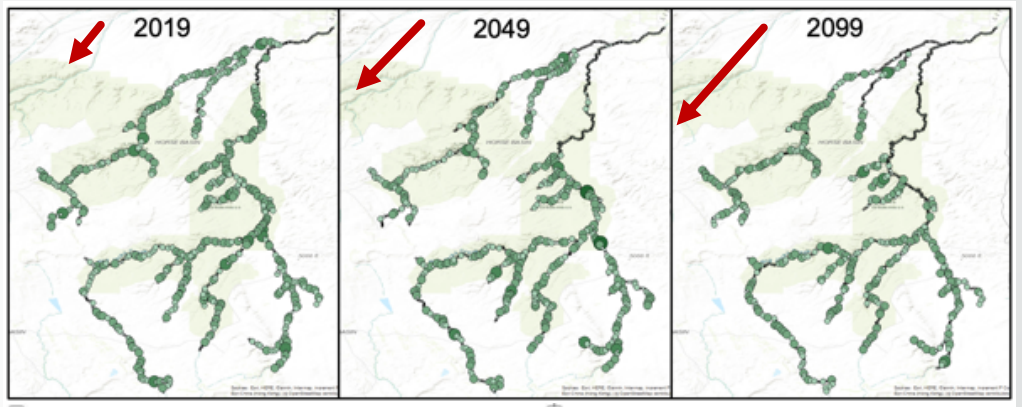
Trout Modeling: *Previous Simulation Highlight*

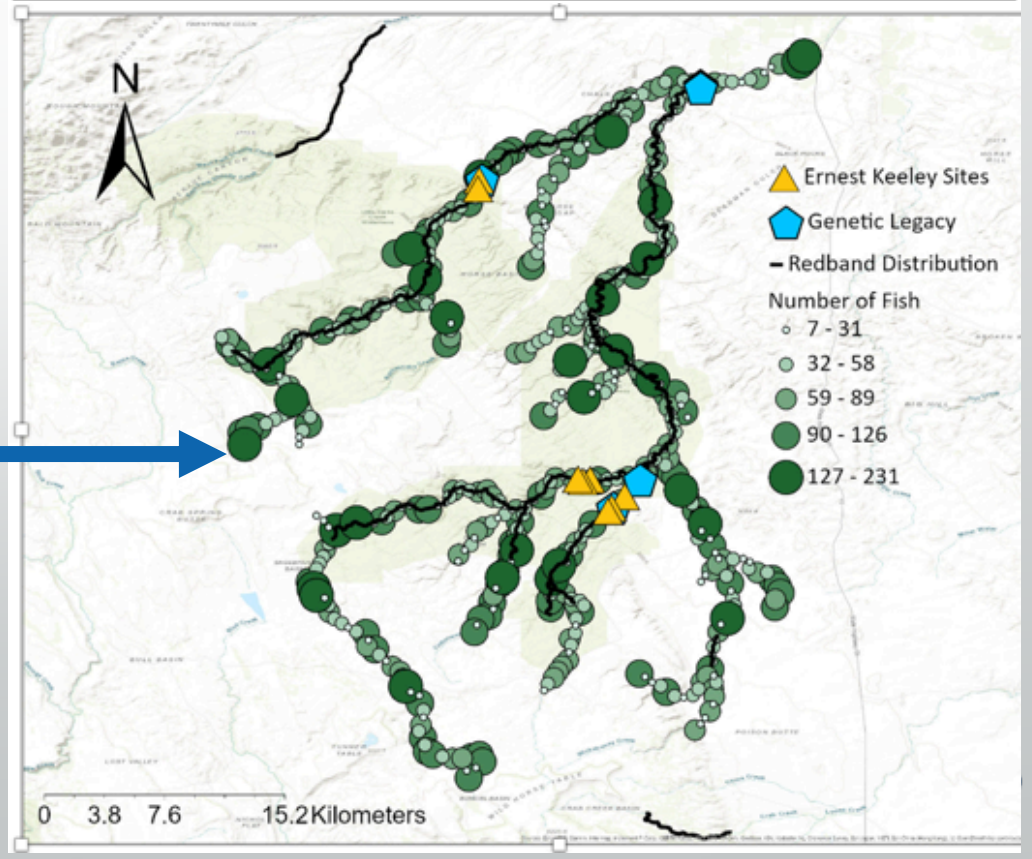
- Individual spatial demo-genetic model (CDMetaPOP)
  - Genotype (adaptive, neutral, *plastic*)
  - Phenotype (sex, size, movement history, fecundity)
- Genetic and habitat sample co-location.
- Draft simulations: Little Jacks Creek (desert)

Each 100 m patch has (not exhaustive):

- Carrying Capacity
- Temperature
- Habitat quality
- Genotype-specific mortality
- Capture rates (e.g. fishing)
- Connectivity

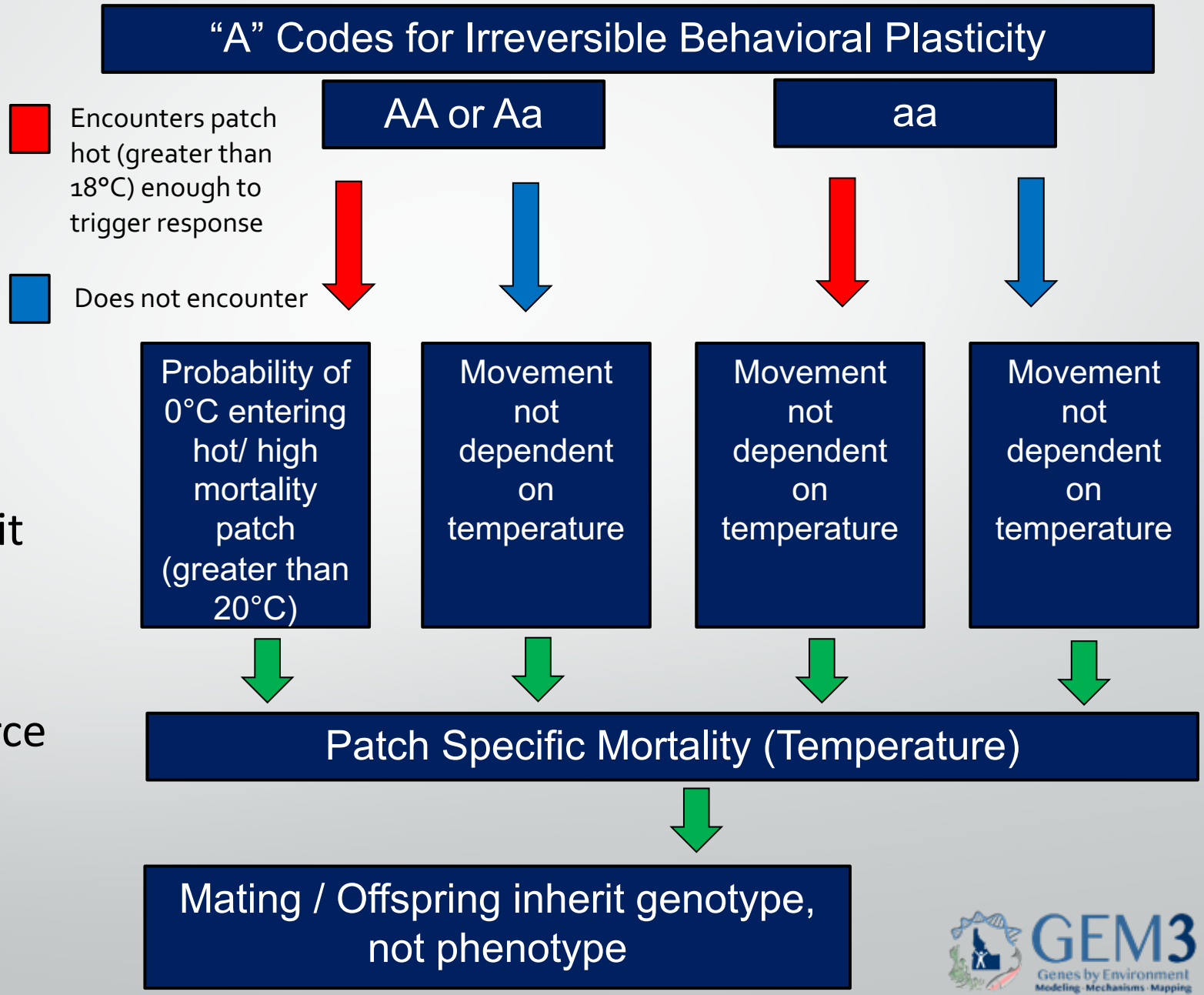
NorWeST summer stream temperature model





Trout Modeling: *Year 2 Modeling Simulation Highlight*

- Single locus behavioral plasticity: habitat selection
  1. Does not have plastic allele
  2. Have plastic allele and “off”
  3. Have plastic allele and “on”
- Temperature or habitat quality
- Represents the first spatially-explicit plasticity model with bonuses
- Does not capture all forms of plasticity (e.g. body size and resource limitation)



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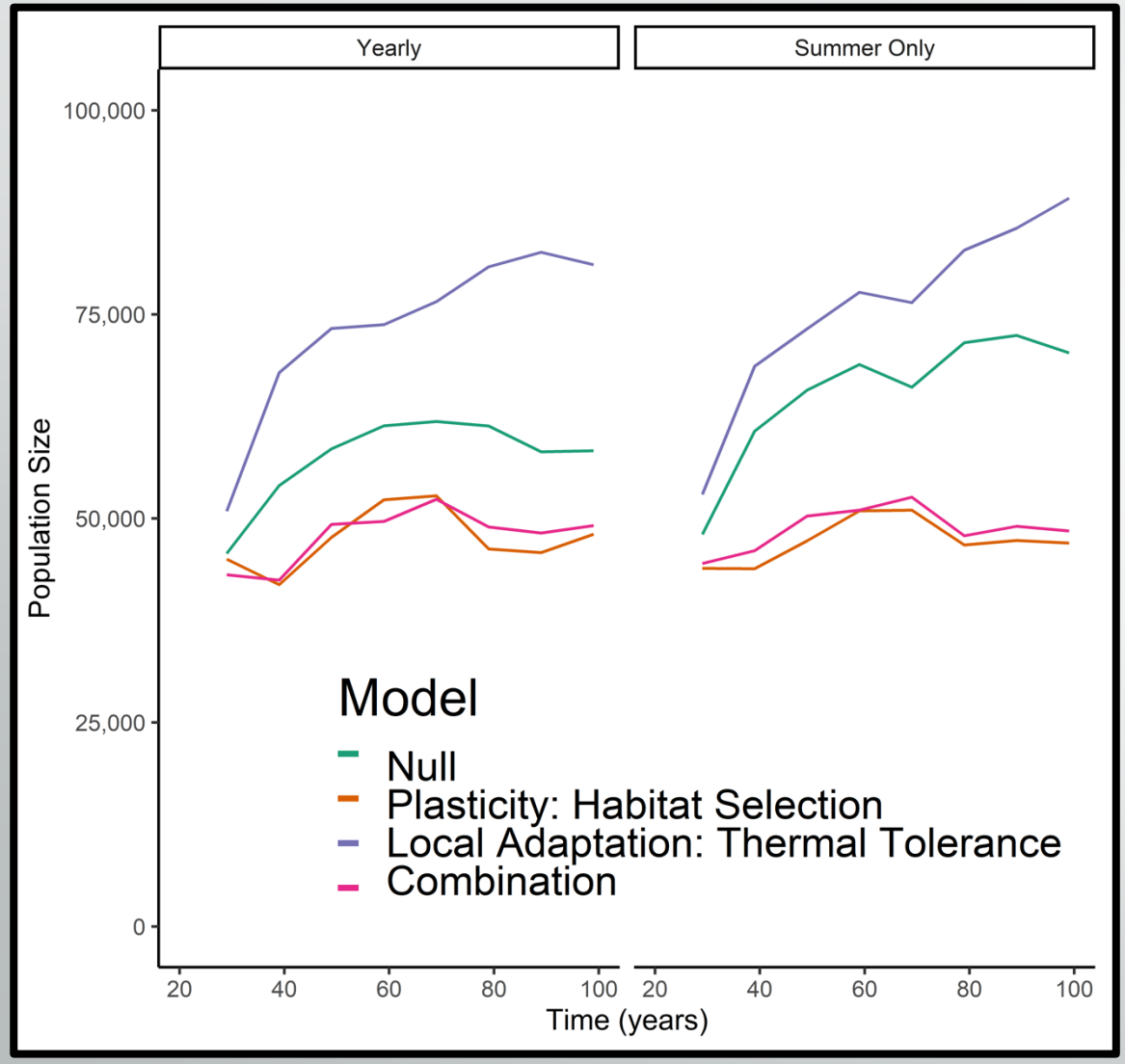
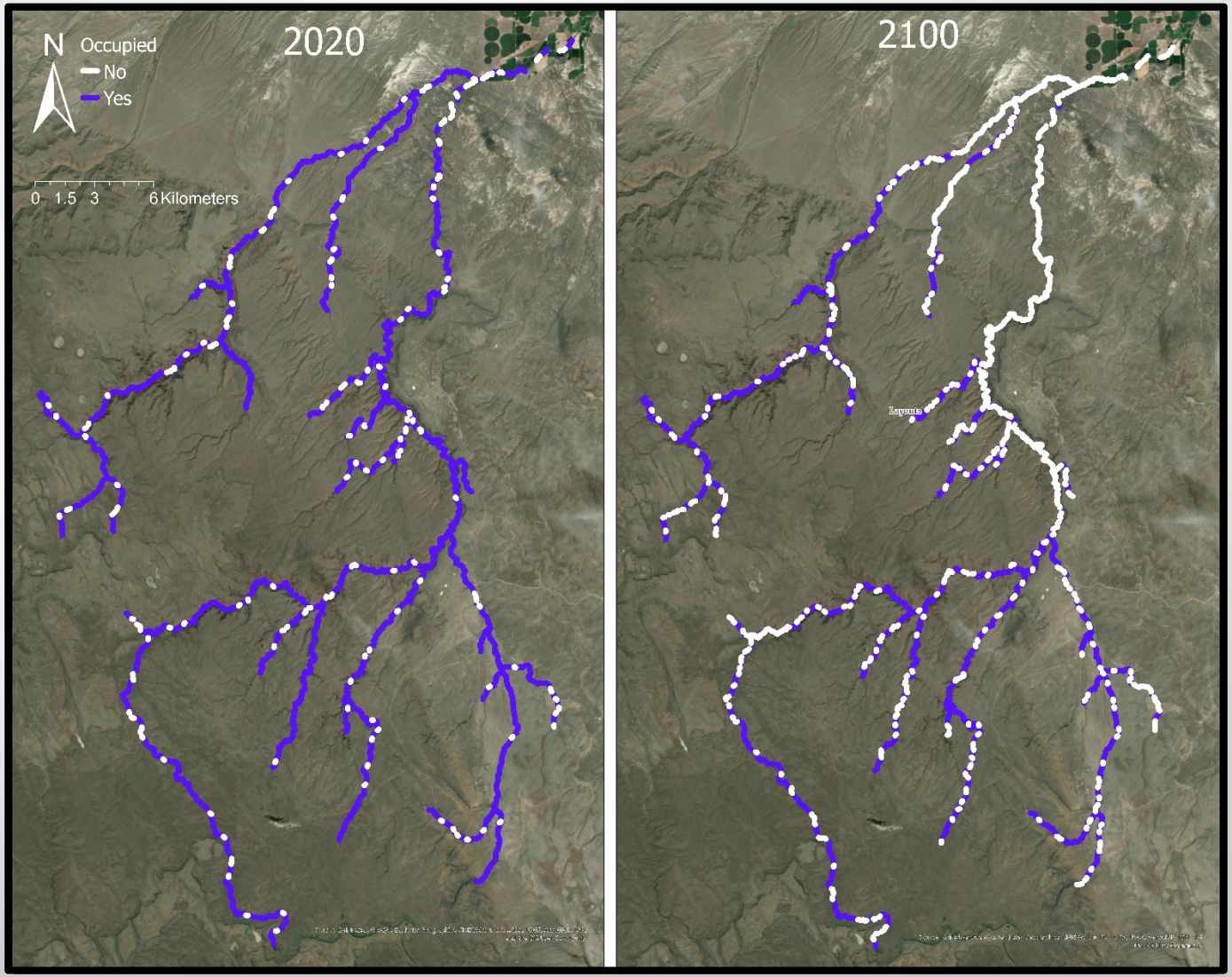
Trout Modeling: *Year 2 Modeling Simulation Highlight*





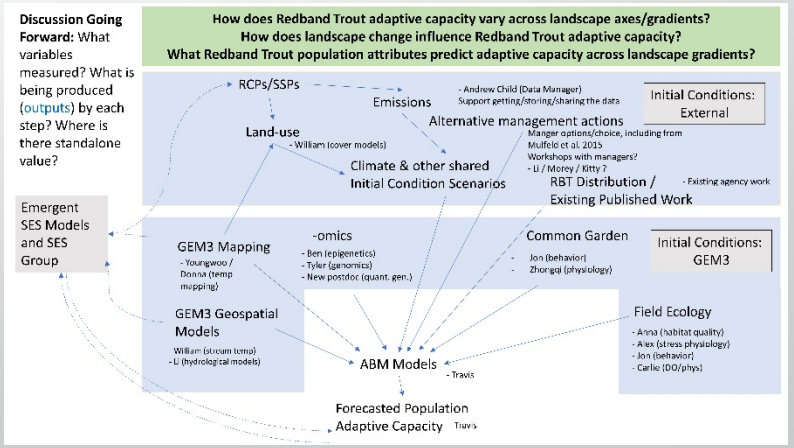
Trout Modeling: *Year 2 Modeling Simulation Highlight*

Model Construction:

- Model with and without cost of plastic response
- Additional types of plasticity: epigenetic mechanism for plastic response
- Move away from single locus models
  - Infinite alleles model already available for local adaptation

Model Refinement:

- Landscape, traits, genomics, and demographics based on field and common garden measurements and observations
- Incorporate refined climate change temperature data and models using SSPs for multiple RCP scenarios



Model Application:

- Expand model to new areas of redband trout and sagebrush habitat, including relevant management scenarios (such as translocation and riparian vegetation restoration).

End Talk 3 (Travis) … Talk 4 (Trevor)

GEM3 Research – *Modeling*

MAP
GENOMES, ENVIRONMENTS, & PHENOMES ACROSS COMPLEX SES

IDENTIFY GxE
MECHANISMS
LINKED TO ADAPTIVE CAPACITY

GOAL
PREDICT ADAPTIVE CAPACITY

MODEL
ADAPTIVE CAPACITY ACROSS SPACE & TIME

Trevor Caughlin

- **Project Overview**
  - **Introduction**
  - **Management, Eval, Assessment**
- **Research**
  - **Social Ecological System – Context**
  - **Mechanisms – Gene x Environment**
  - **Modeling – Adaptive Potential & Capacity**
  - **Mapping – Human Dimensions & Remotely**
- **Other Project Elements**
  - **Workforce Development**
  - **Diversity**
  - **Communication and Dissemination**
  - **Partnerships and Collaborations**
  - **Sustainability**
  - **Conclusions**

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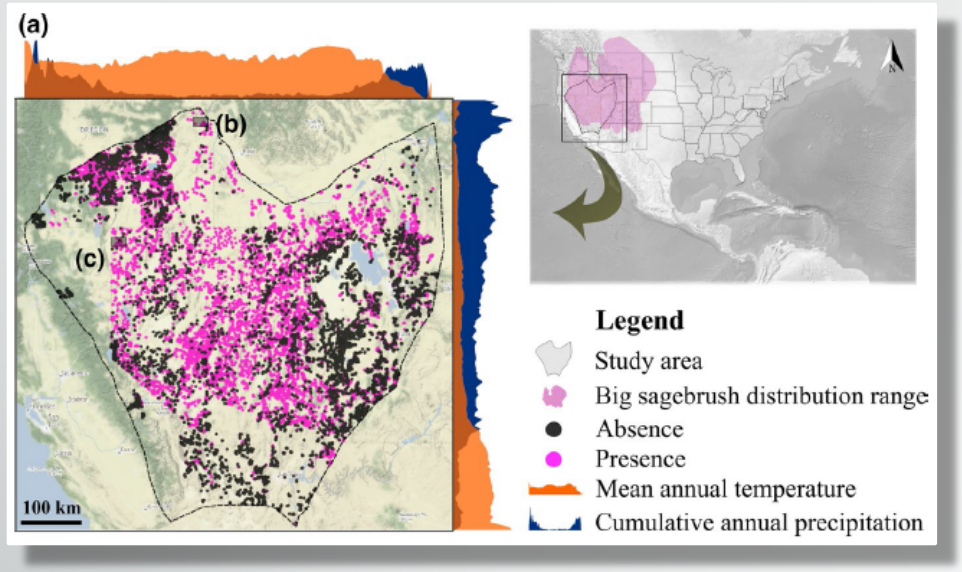
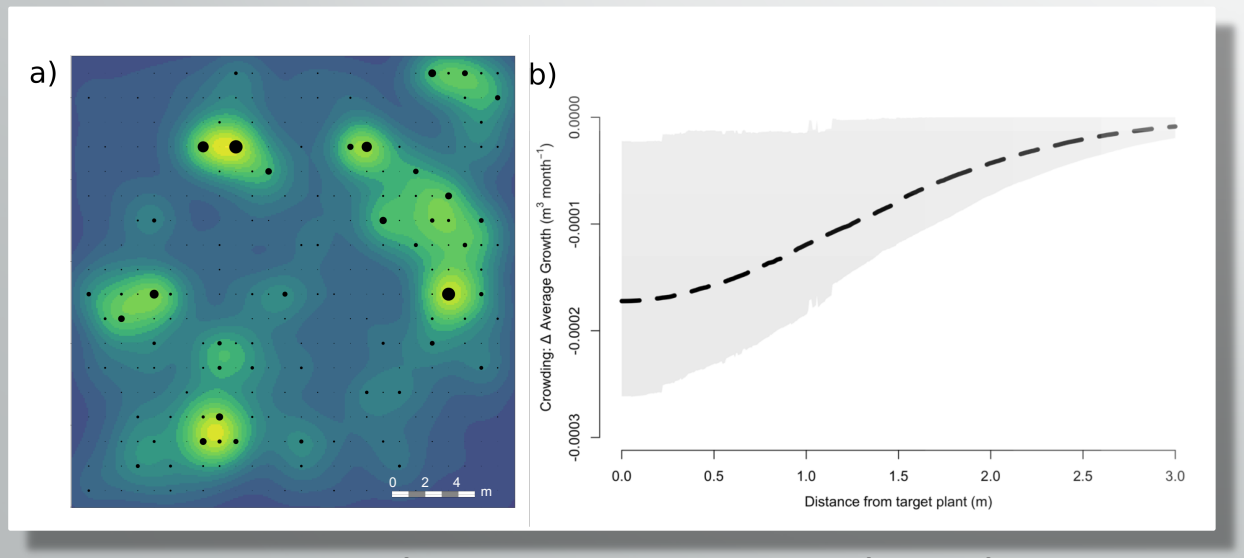
Genes by Environment
Modeling · Mechanisms · Mapping

Sagebrush Modeling: *Overall Approach*



Requena-Mullor et al. 2019, Global Change Biology



Zaiats et al. 2020, Functional Ecology

Map patterns

Mathematical models

Individual plant measurements

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Sagebrush Modeling: *Seed grant-enabled Integration*

SES context of sagebrush distribution

Jodi Brandt

Juan Requena

Matt Williamson

Relates to stakeholder working groups, led by Kelly Hopping, Morey Burnham and SES team

Map patterns

Mathematical models

Individual plant measurements

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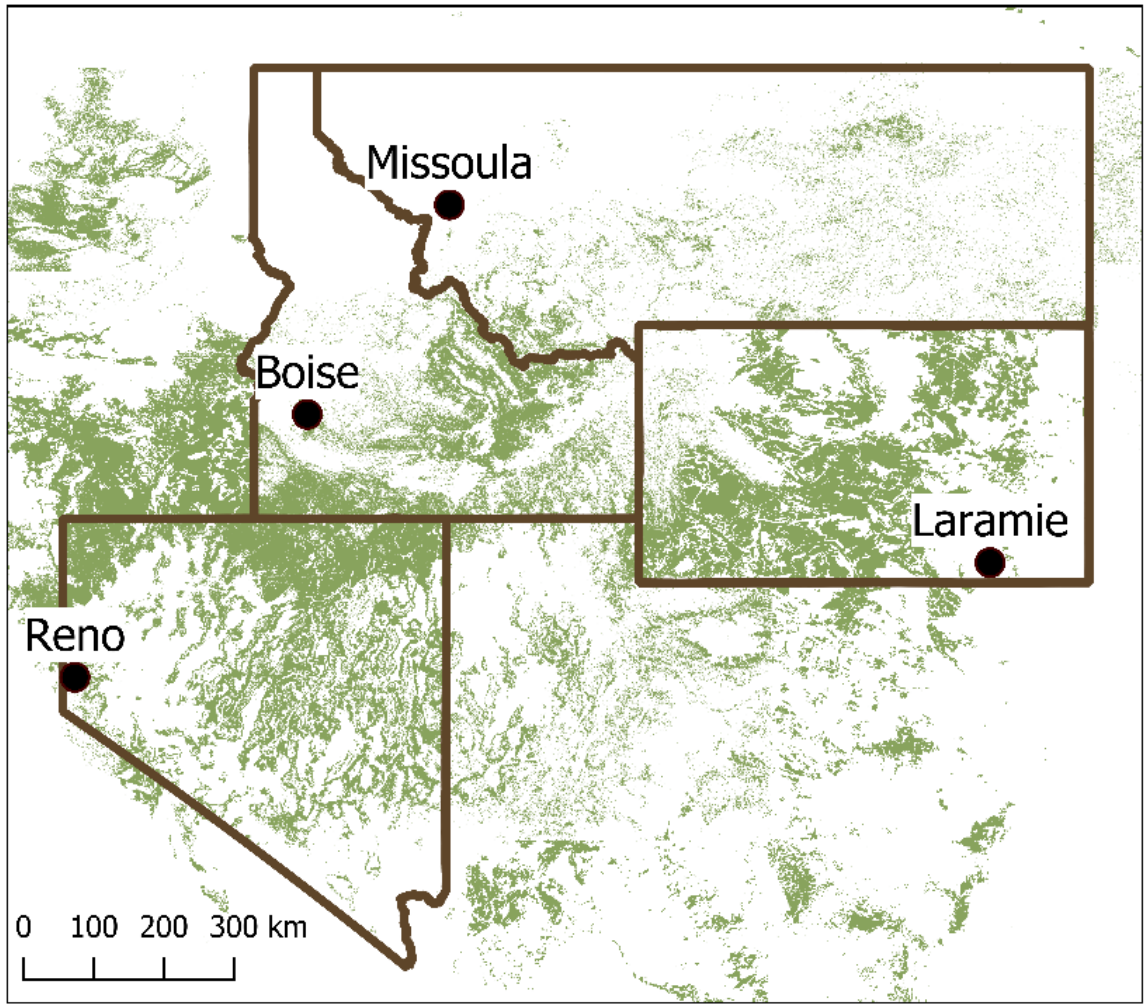
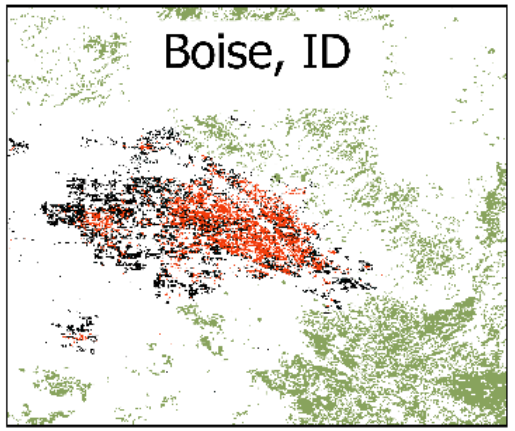
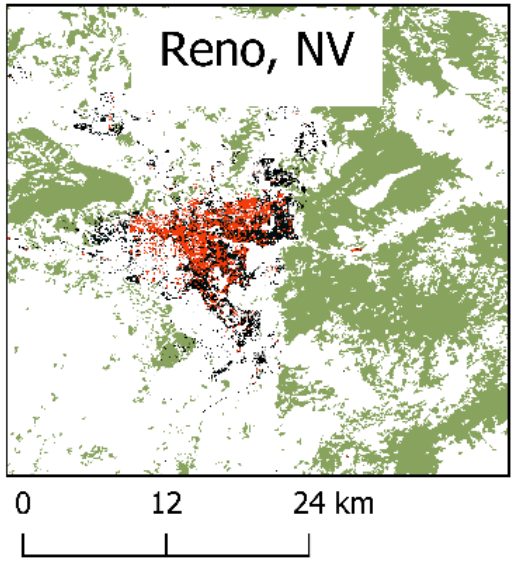
Sagebrush Modeling: *SES context*







Built-Up Land
Built before 2000
Built after 2000
Sagebrush habitat
Suitable habitat

Regional population increased by ~ 2 million people from 1989 to 2018

Human population is growing in the West

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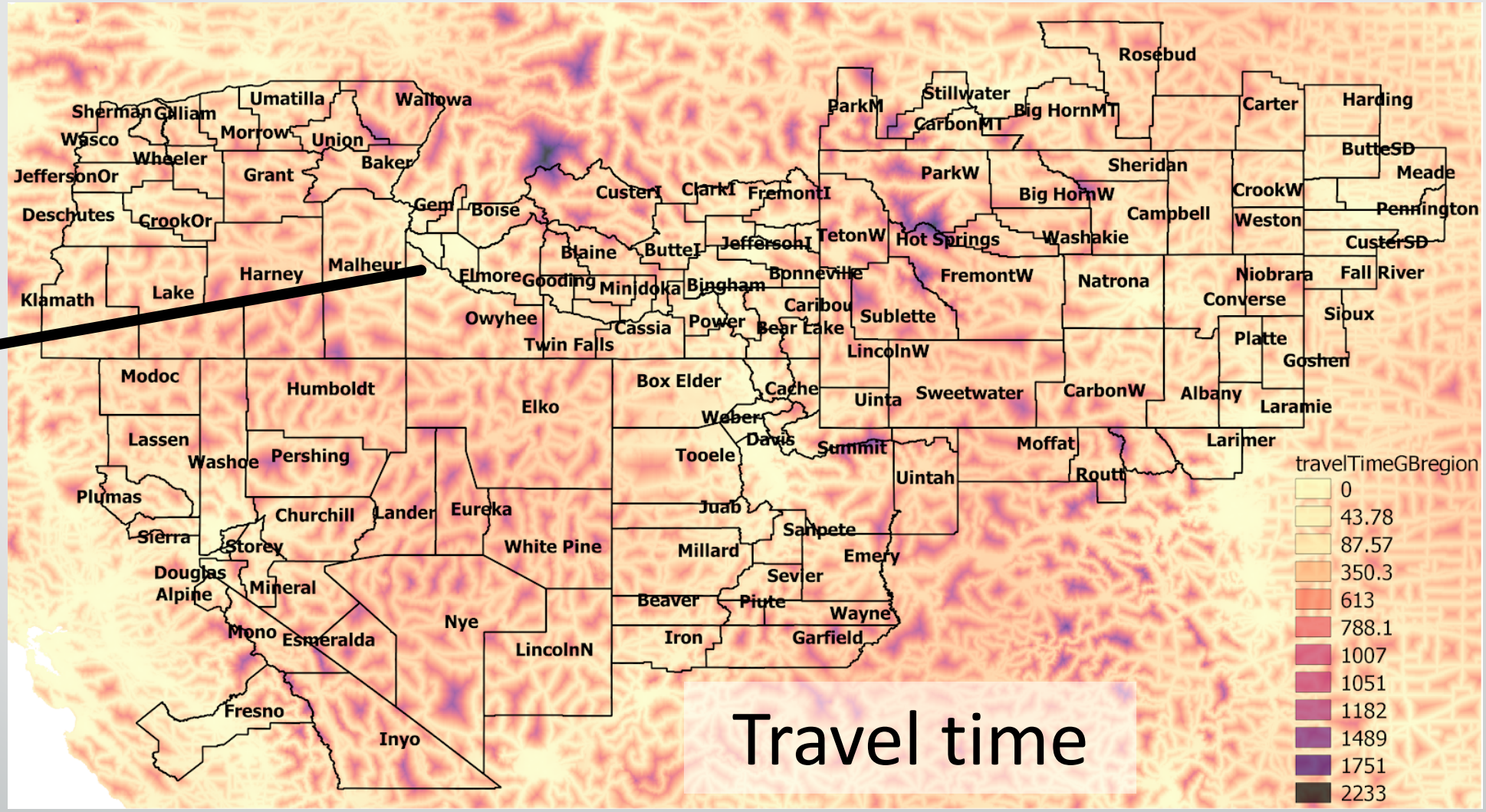
Sagebrush Modeling: *SES context*

From Murphy,ID SAG: "**the Owyhees have become a 'playground' for Boise residents**"

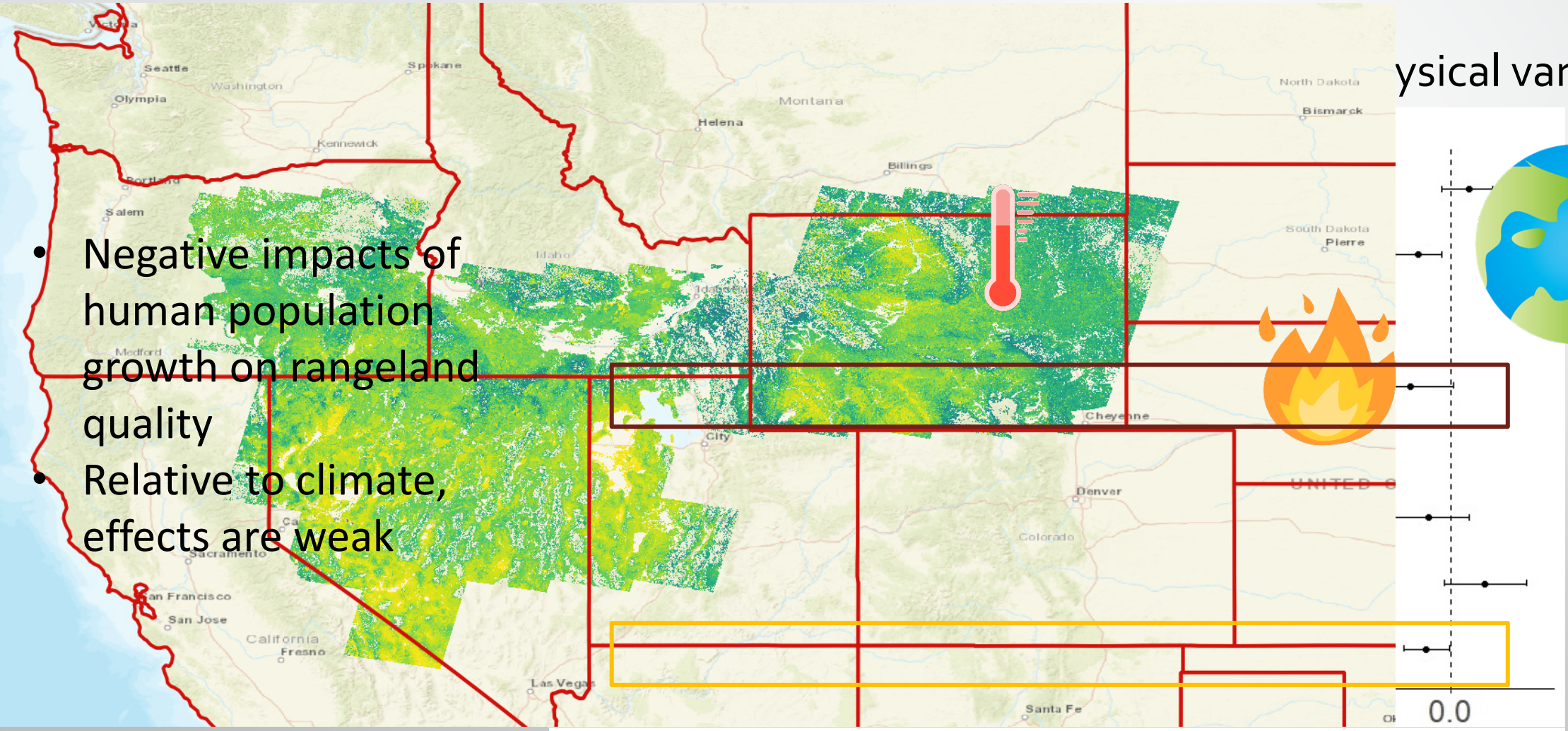


Impact of SES context on rangeland vegetation dynamics

Modeled Landsat-derived indices of rangeland quality from 1989 to 2018

ysical varia s?

- Negative impacts of human population growth on rangeland quality
- Relative to climate, effects are weak



Effect size for rangeland quality

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Sagebrush Modeling: *Seed grant-enabled Integration*

Map patterns

Mathematical models

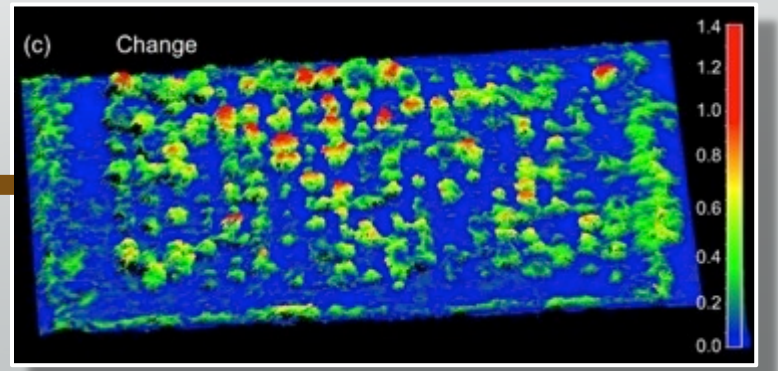
Individual plant measurements

Mechanisms of sagebrush demographic rates

Donna Delparte

Peter Olsoy

Megan Cattau



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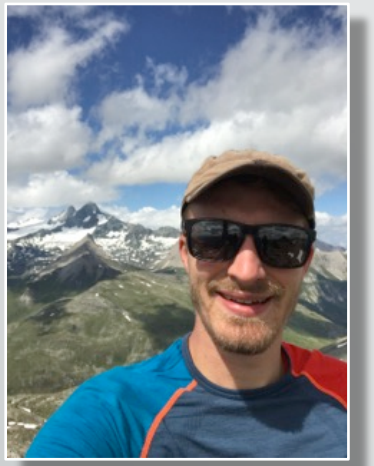
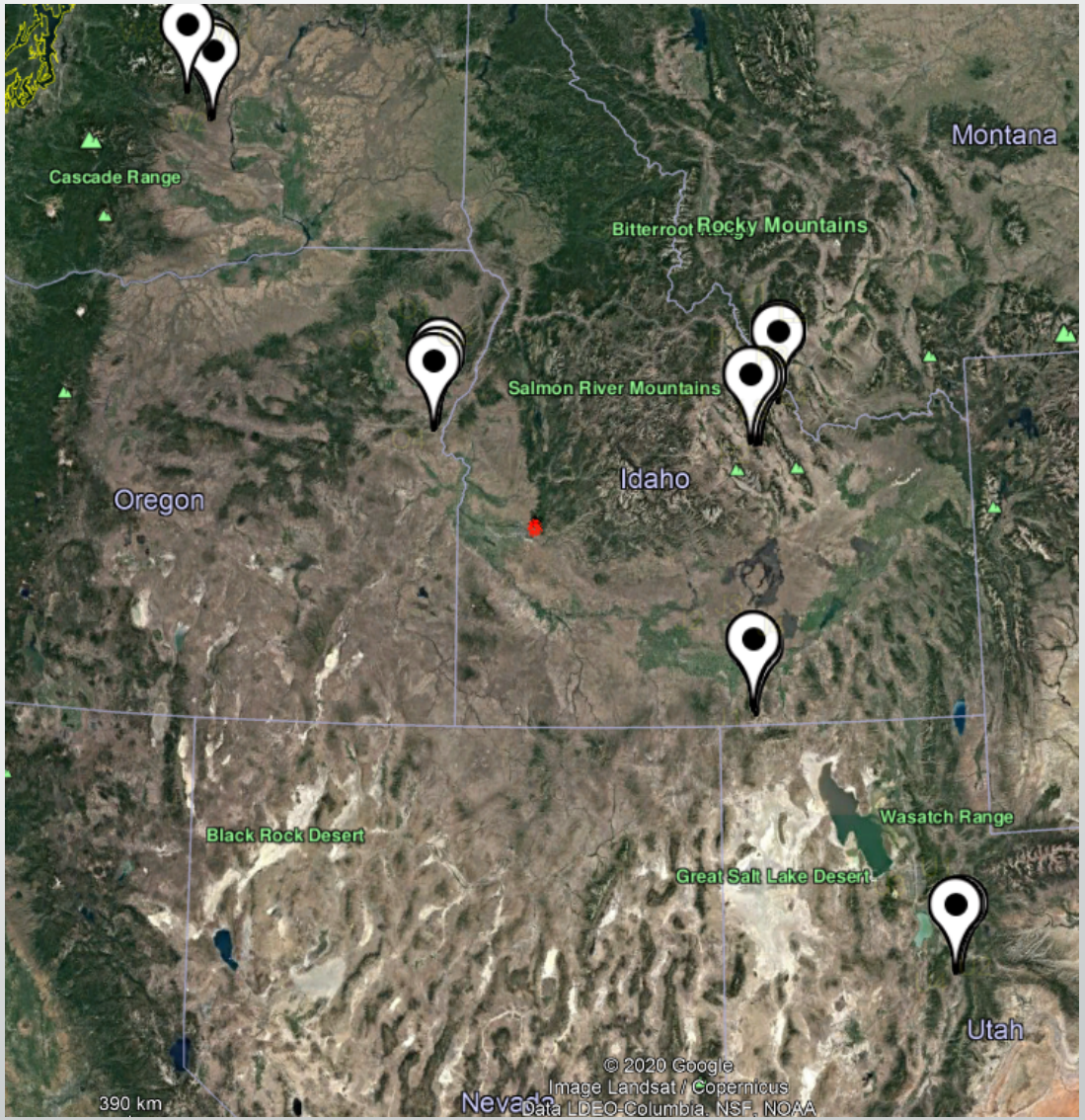
Sagebrush Modeling: *Integration with mechanisms*



Lukas Grossfurthner

Molly Garrett

- Landscape-scale measurements of sagebrush phenotype and genotype
- Tagged plants enable demographic measurements
- Can high-resolution UAS data detect sagebrush GXE interactions?



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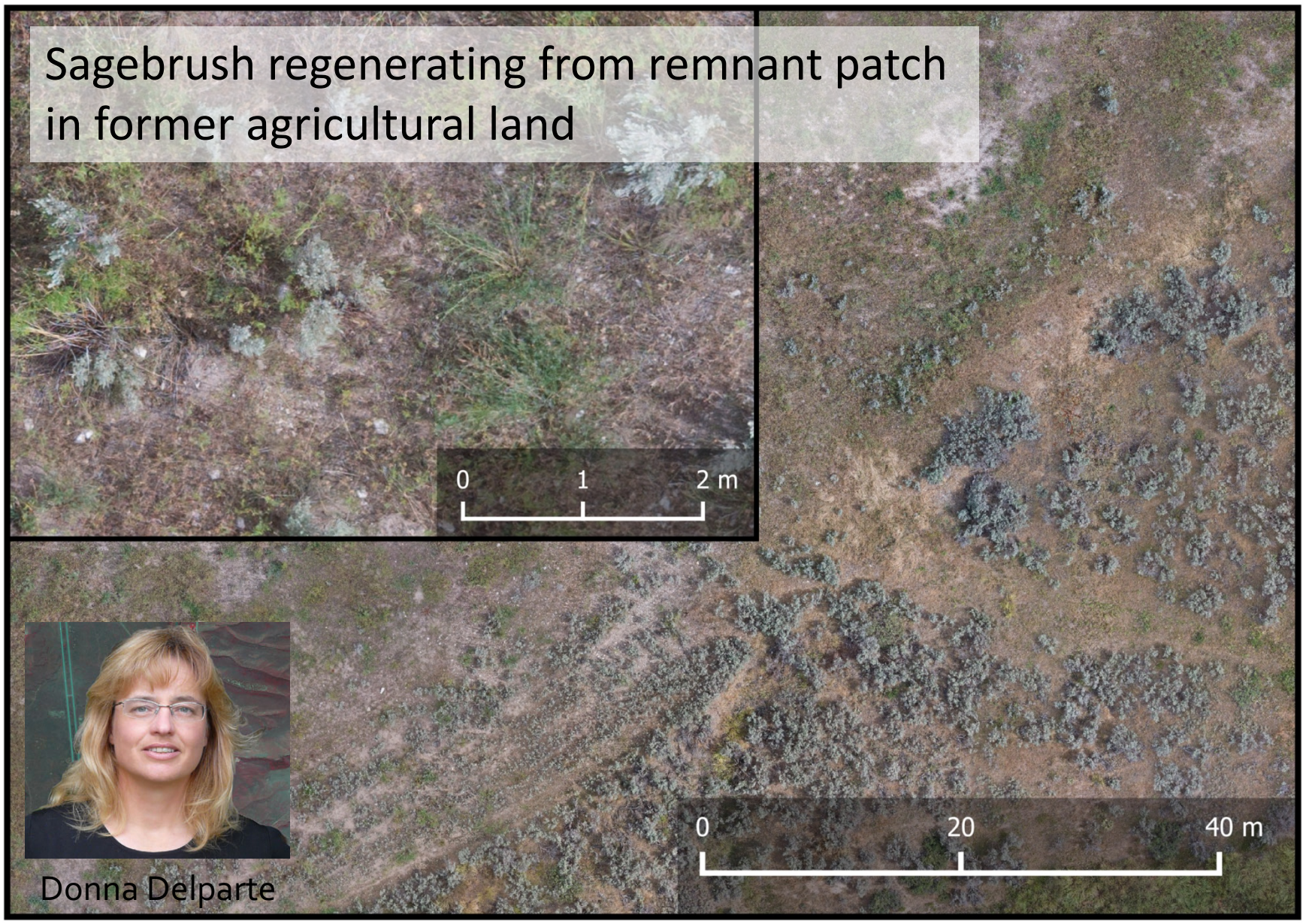
Sagebrush Modeling: *Integration with mechanisms*

Sagebrush regenerating from remnant patch in former agricultural land



Donna Delparte

Karthyn Turner

- Neutral loci to predict spatial patterns of relatedness in sagebrush
- Where are the new recruits coming from?

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Sagebrush modeling next steps for integration:

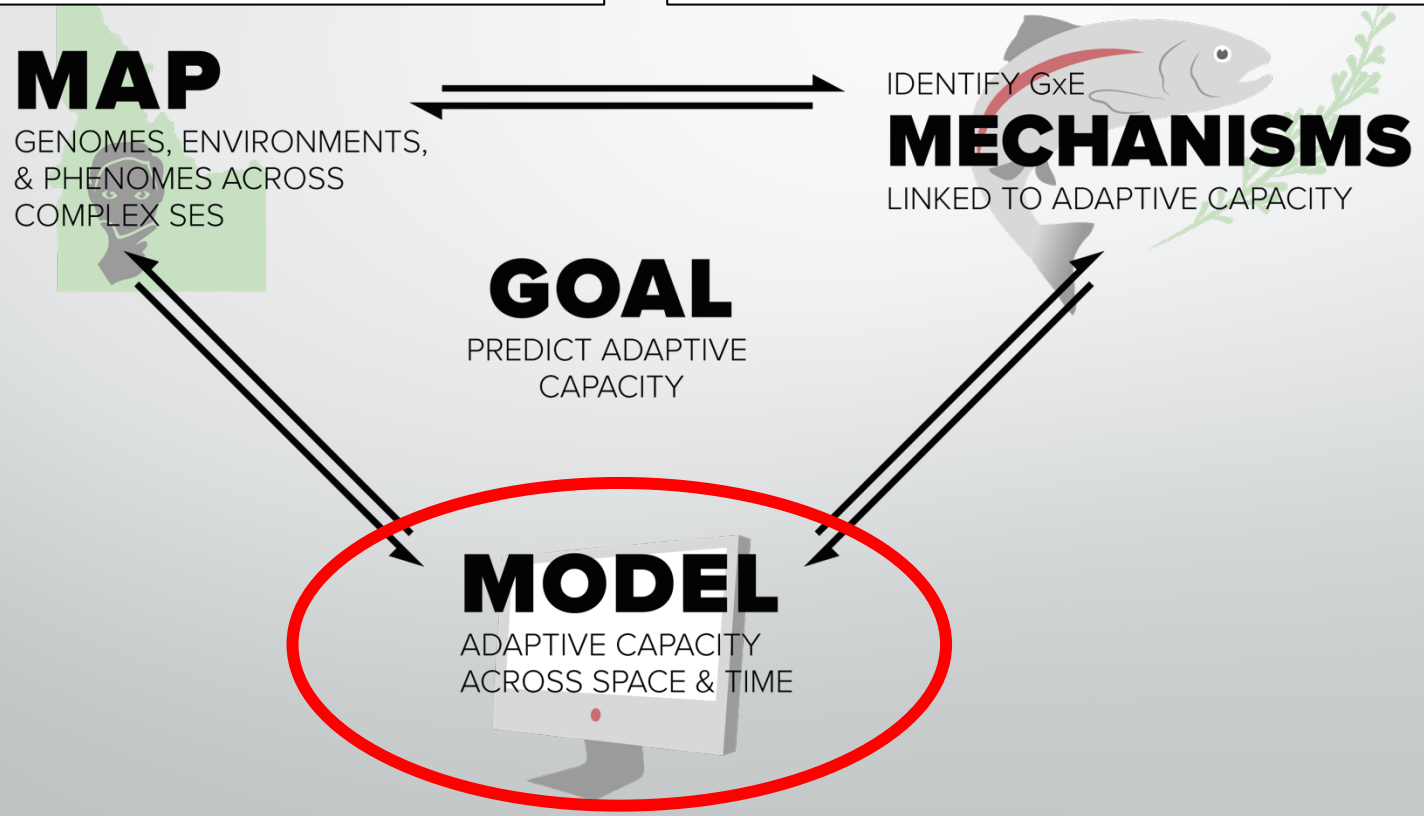
SES

a) Human perception of sagebrush dynamics
b) Identify feedback loops between human and natural systems

Mechanisms

Identify traits that:

a) Impact demographic rates
b) Have a genetic component (are heritable)
c) Can be measured with remote sensing



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End Talk 4 (Trevor) … Talk 5 (Morey)

SES Mapping: *Emergent Scenario development and analysis*

A scenario is a "hypothetical sequence of events constructed for the purpose of focusing on causal processes and decision points."

Herman Kahn and Anthony Wiene

The Year 2000: A Framework for Speculation on the Next Thirty Years (1967)

It is a narrative of a possible future; it is not a prediction, but a potential future that merits consideration

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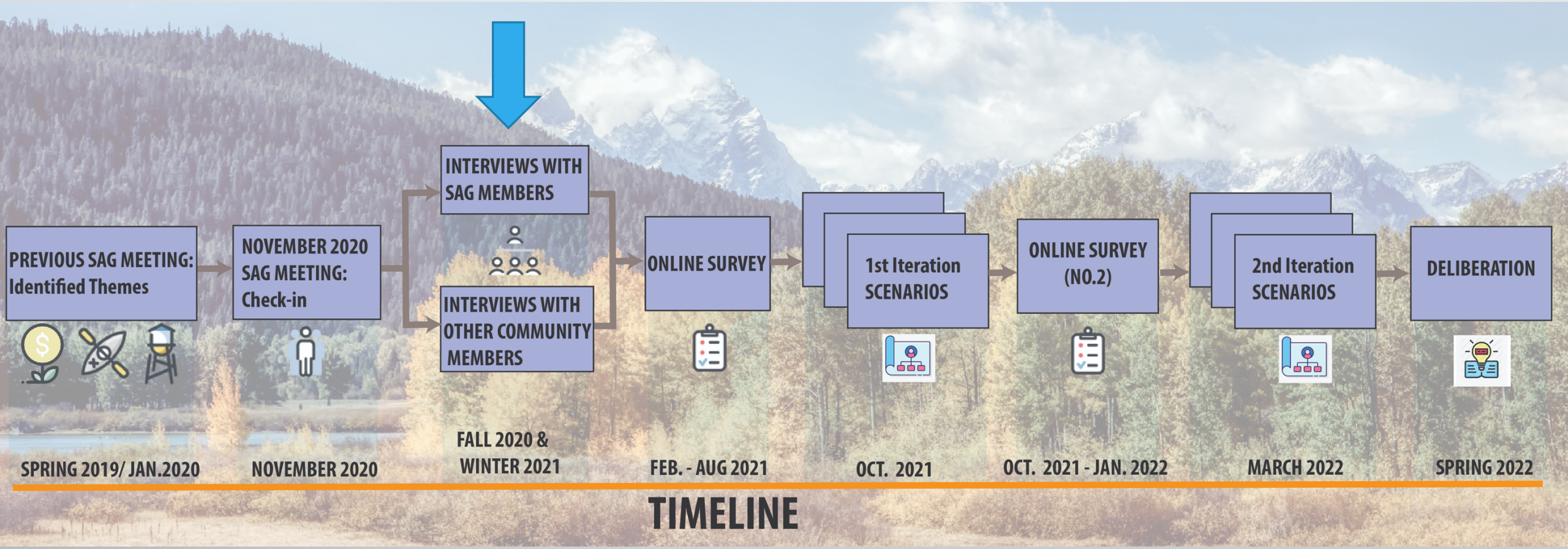
Stakeholder Advisory Groups

- Recruited diverse SAG members from local & state government, tribes, state & federal agencies, NGOs, private landowners
  - 26 members in Owyhee region
  - 17 members in Teton region

Mapping SES: *Summary*



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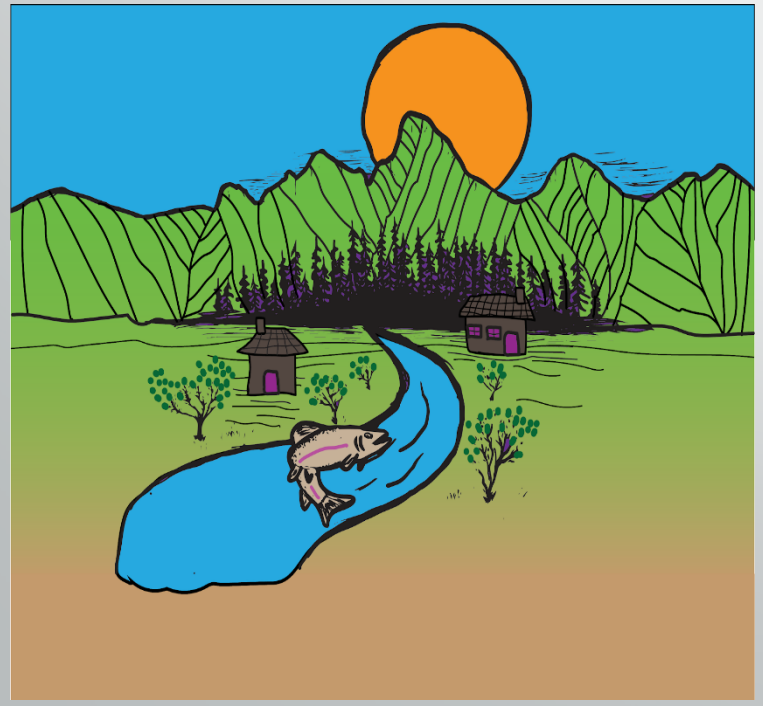
Mapping SES: *SAG-identified key questions and challenges*

- Private lands development and the transition from agricultural to amenity/based economy
- Wildlife and fisheries, with a focus on how recreation, housing development, and climate change affect wildlife migration and habitat



- Recreation and population growth, including how population growth in Treasure Valley and its role in the increasing recreational use of the Owyhees will interact with lack of infrastructure to support it
- How socioeconomic change will influence the character and viability of rural communities

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Mapping: *SES project integration*

Ben Ortner
Stakeholder narratives of anadramous fish restoration
(Idaho and Oregon)

Haley Netherton-Morrison
Mapping the sagebrush social landscape

Transdisciplinary methods:

Laticia Herkshan,
Georgia Hart-Fredeluces
Future research relationship between the Shoshone-Bannock tribes & ISU

Lizzie Jossie
Stream connectivity outcomes for stakeholders & Yellowstone cutthroat

Georgia Hart-Fredeluces
Global change & traditional stewardship of camas

Claudia Maldonado
LatinX belonging & integration

Megan Dolman
Development & vulnerability to wildfire in the Wildland-Urban Interface

Clara Buchholtz
Recreation trends & impacts in the Owyhee region

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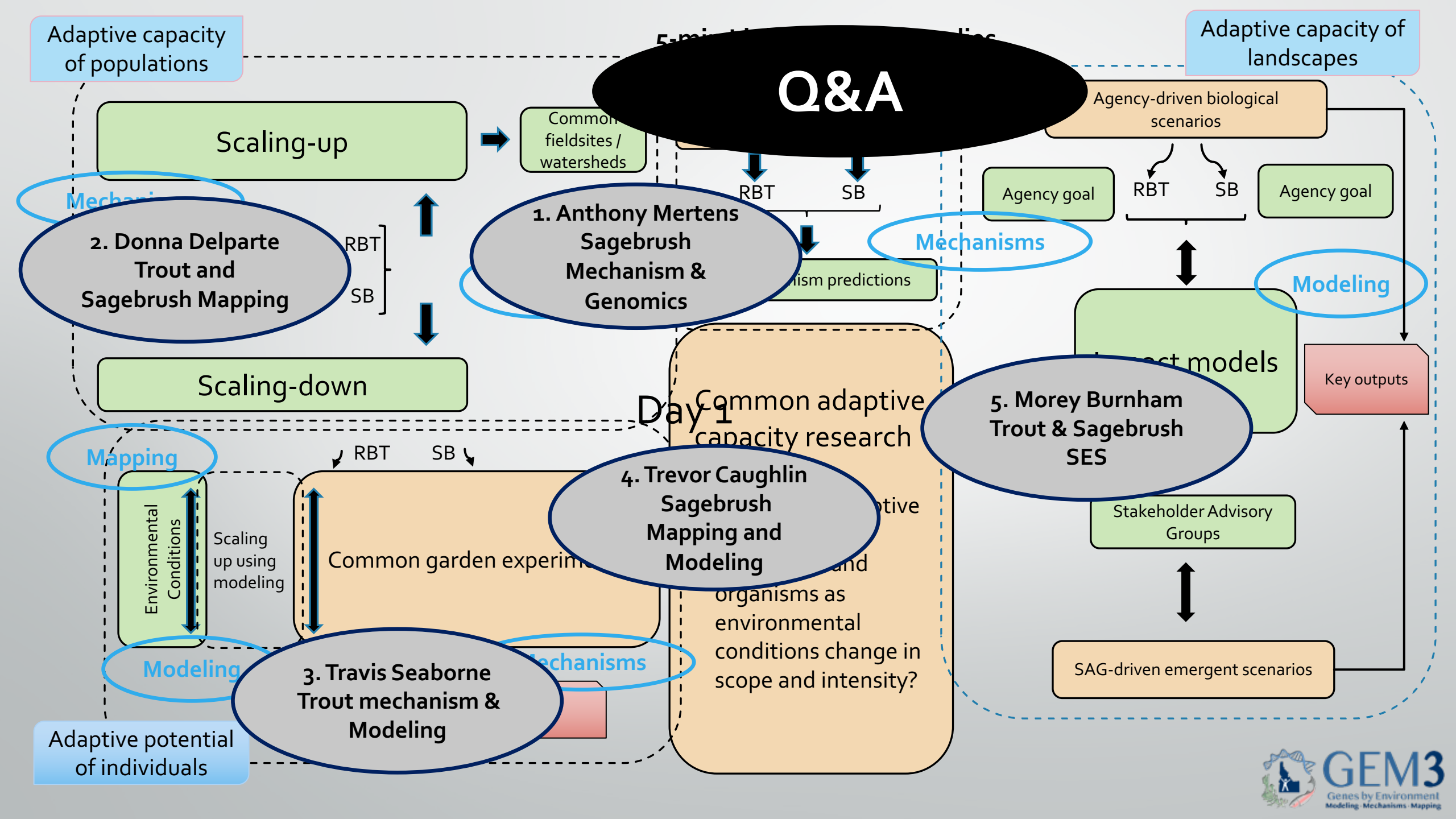
Adaptive capacity of populations
Adaptive capacity of landscapes
Q&A
Scaling-up
Scaling-down
Common fieldsites / watersheds
RBT
SB
1. Anthony Mertens Sagebrush Mechanism & Genomics
2. Donna Delparte Trout and Sagebrush Mapping
Mechanisms
Modeling
Mapping
Agency-driven biological scenarios
Agency goal
Agency goal
Key outputs
5. Morey Burnham Trout & Sagebrush SES
Stakeholder Advisory Groups
SAG-driven emergent scenarios
Day 1
Common adaptive capacity research
organisms as environmental conditions change in scope and intensity?
4. Trevor Caughlin Sagebrush Mapping and Modeling
Environmental Conditions
Scaling up using modeling
Common garden experim
3. Travis Seaborne Trout mechanism & Modeling
Adaptive potential of individuals
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