Improving Robustness & Climatic Resilience in U.S. Sheep Populations through Genomics (Sheep GEMS)

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U.S. DEPARTMENT OF AGRICULTURE

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Introduction

- Industry consists of a variety of sheep breeds raised across a range of geographies that not only differ in their climate but in their management systems
- Breeding robust animals that perform well under these conditions is key to the industry's sustainability
- Challenge
  - Nearly half (44%) of U.S. ewes are culled prematurely (i.e., for reasons other than age; USDA APHIS, 2014)
  - Approximately 7% of the total U.S. lamb crop dies each year from non-predator related causes (USDA APHIS, 2015)
  - Clinically healthy ewes with high milk somatic cell counts (>1 million cells/mL) result in economic losses of $19 to $32 per ewe (Knuth et al., 2021)

Introduction

- An option is to breed for greater robustness and climatic resilience
- But currently traits defining robustness and climatic resilience are largely absent in U.S. sheep genetic evaluations
  - Lamb survival
  - Ewe longevity
  - Udder health
  - Gastrointestinal parasite resistance

Addressing this limitation is the aim of Sheep GEMS

Questions asked

- What on-farm or on-ranch measurements will help us improve robustness and climatic resilience traits in our flocks?
- How much genetic (genomic) diversity is present in our U.S. sheep breeds for us to work with, and how can it be captured?
- How do we then pragmatically combine the genomic and performance information we collect to improve the robustness of our flocks?

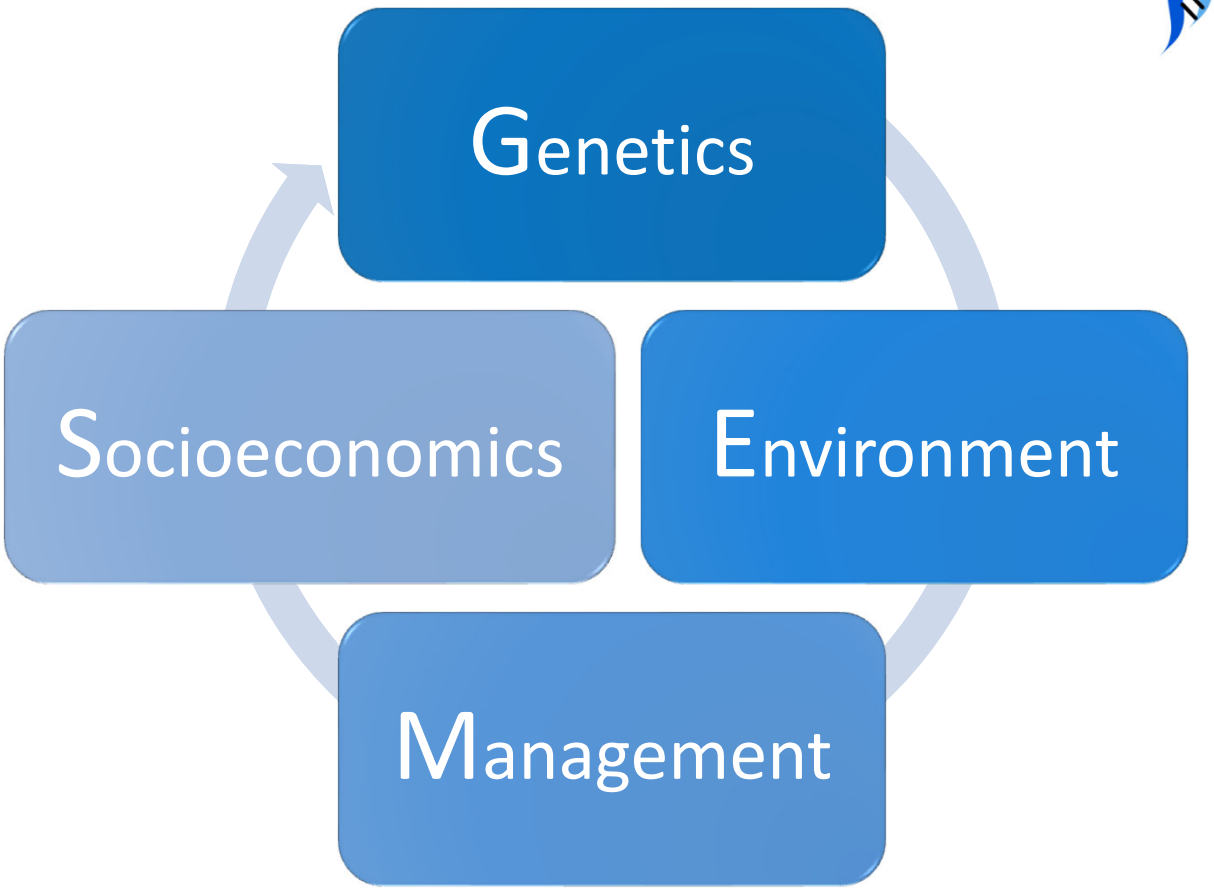
To answer

- We need to build and evaluate large numbers of sheep with relevant genomic and performance data
- In Sheep GEMS, this will entail >3,000 animals in each of Katahdin, Polypay, Rambouillet and Suffolk breeds with
  - Medium-density panel genotypes (50,000 markers)
  - Measures indicative of robustness and climatic resilience
    - Around lambing: ewe & lamb assistance codes; ewe udder depth, teat placement, body condition & FAMACHA score
    - At weaning: lamb fecal egg count & FAMACHA score; ewe body weight, body condition & FAMACHA score
    - Around breeding: ewe body weight & condition score
    - Year-around: ewe & lamb health intervention, disposition & death code

As outcomes

- Obtain more accurately estimated breeding values for traits currently recorded in NSIP and for novel robustness and climatic resilience traits
- Provide recommendations for cost-effective investment by the U.S. sheep industry to take full advantage of genomics

Why Sheep GEMS?



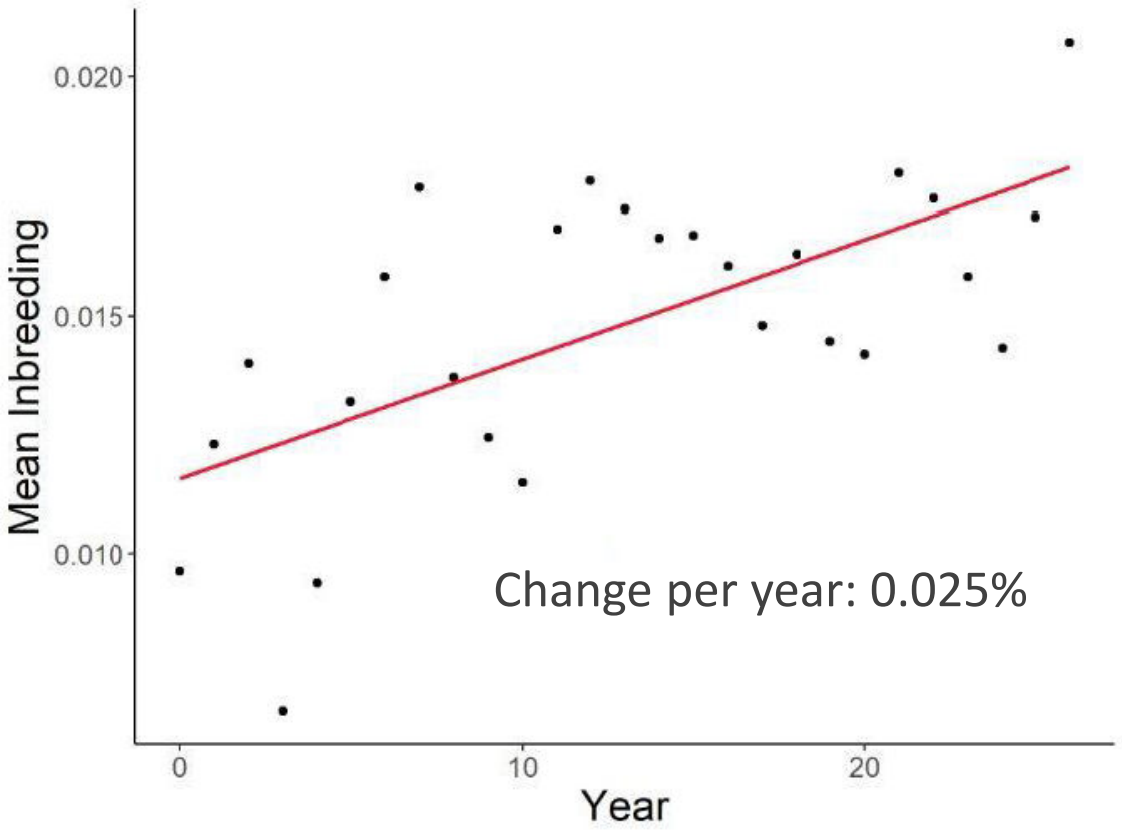
Genetics

- Genetic diversity
- Accuracy of breeding values
- Genetic conditions

Genetic diversity

- Question: Is there risk of loss in genetic diversity in Katahdin sheep as selection proceeds?
- Post-doctoral student: Sara Nilson
- Funding: Organic Agriculture Research and Extension Initiative grant no. 2016-51300-25723; Agriculture and Food Research Initiative Competitive grant no. 2022-67015-36073
- NSIP Katahdin pedigree records: 92,0230 animals born from 1984-2019

Genetic diversity



- Change in inbreeding is less than 1% per generation
- The rate of change for inbreeding did not differ across years
- Next step
  - Integrate these results with those based on genomic information (Becker et. al, 2022)

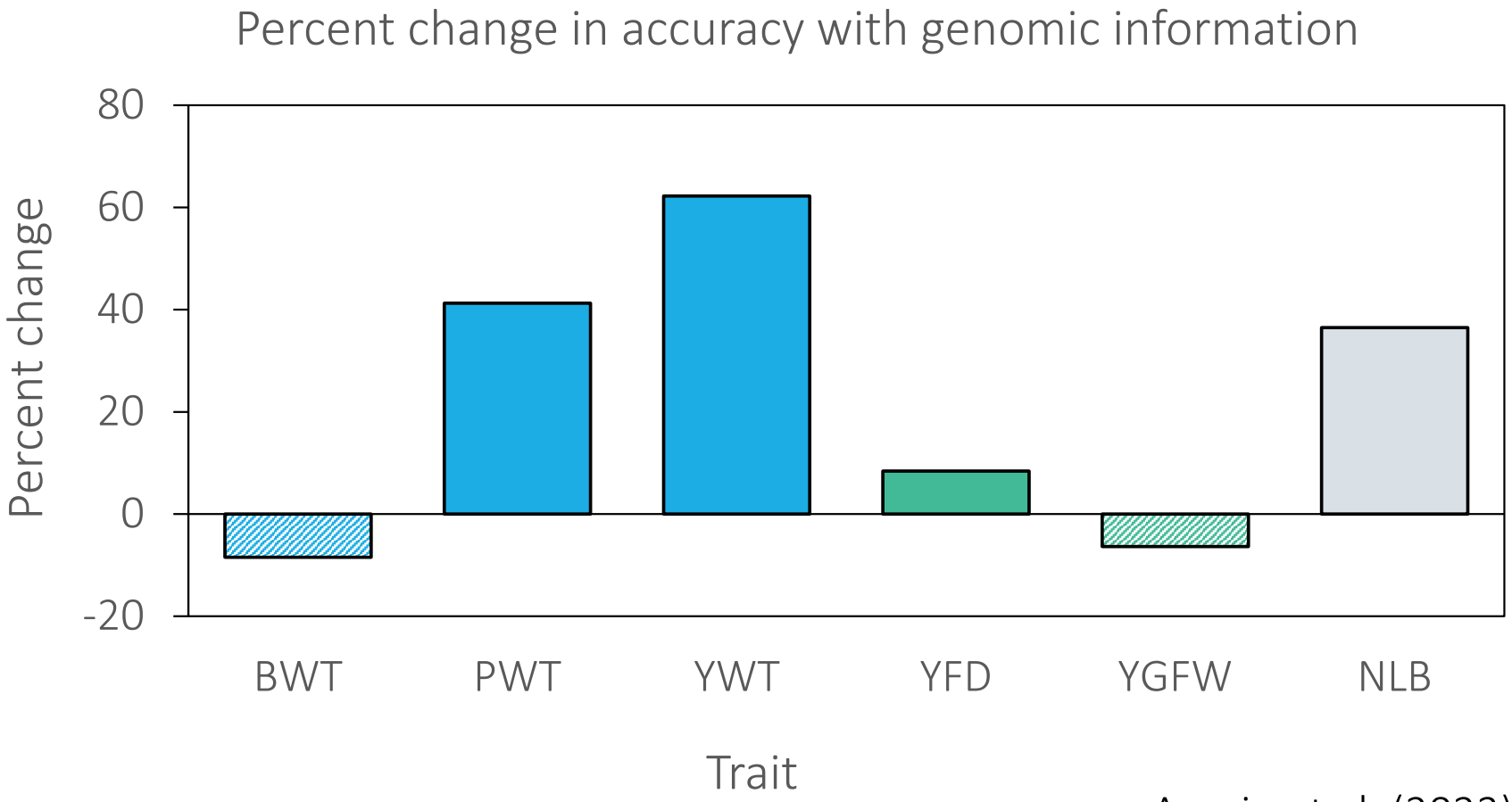
Nilson et al. (2023)

Answer: Loss of genetic diversity is currently not a major concern for NSIP Katahdin sheep

Accuracy of breeding values

- Question: Does including genomic information improve the accuracy of breeding value estimates in Rambouillet sheep?
- Doctoral student: Andre Araujo
- Funding: ASI Let's Grow Program; National Sheep Industry Improvement Center; American Rambouillet Sheep Breeders Association
- NSIP Rambouillet performance records
  - Weights - birth (BWT): 28,834; post-weaning (PWT): 23,306; yearling (YWT): 5,832
  - Yearling fleece - fiber diameter (YFD): 9,880; greasy weight (GFW): 11,872
  - Number of lambs born (NLB): 15,984
- Genomic data: 741 genotypes (medium- and high-density panels)

Accuracy of breeding values



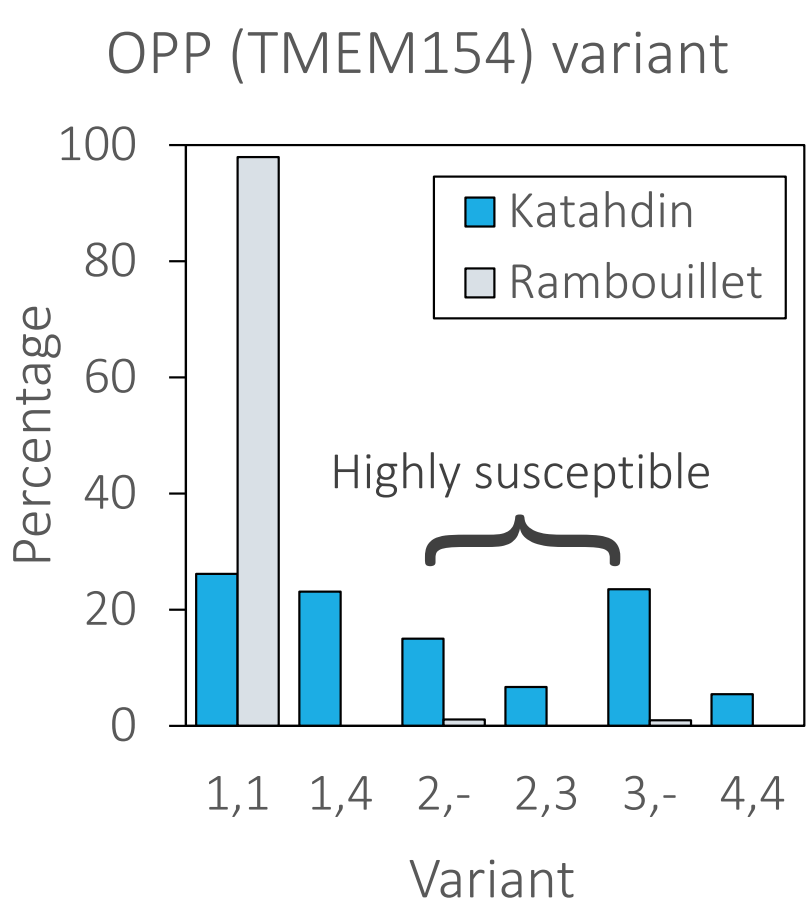
Araujo et al. (2023)

Answer: Accuracies are improved, often substantially. Benefits will accrue by collecting more genotypes

Genetic conditions

- Question: Can we reliably determine and report genotypes for five important genetic conditions?
  - Ovine Progressive Pneumonia (OPP) susceptibility; scrapie susceptibility (codons 136 and 171); Myostatin; Callipyge; Booroola FecB
- Primary school student: Ron Lewis
- Funding: ASI Let's Grow Program; National Sheep Industry Improvement Center; Organic Agriculture Research and Extension Initiative grant no. 2016-51300-25723; Agriculture and Food Research Initiative Competitive grant no. 2022-67015-36073
- Genomic data (medium-density panel)
  - 9,687 genotypes primarily from NSIP Katahdin and Rambouillet sheep
  - 15 genotypes on U.S. Meat Animal Research Center samples with known genetic conditions

Genetic conditions



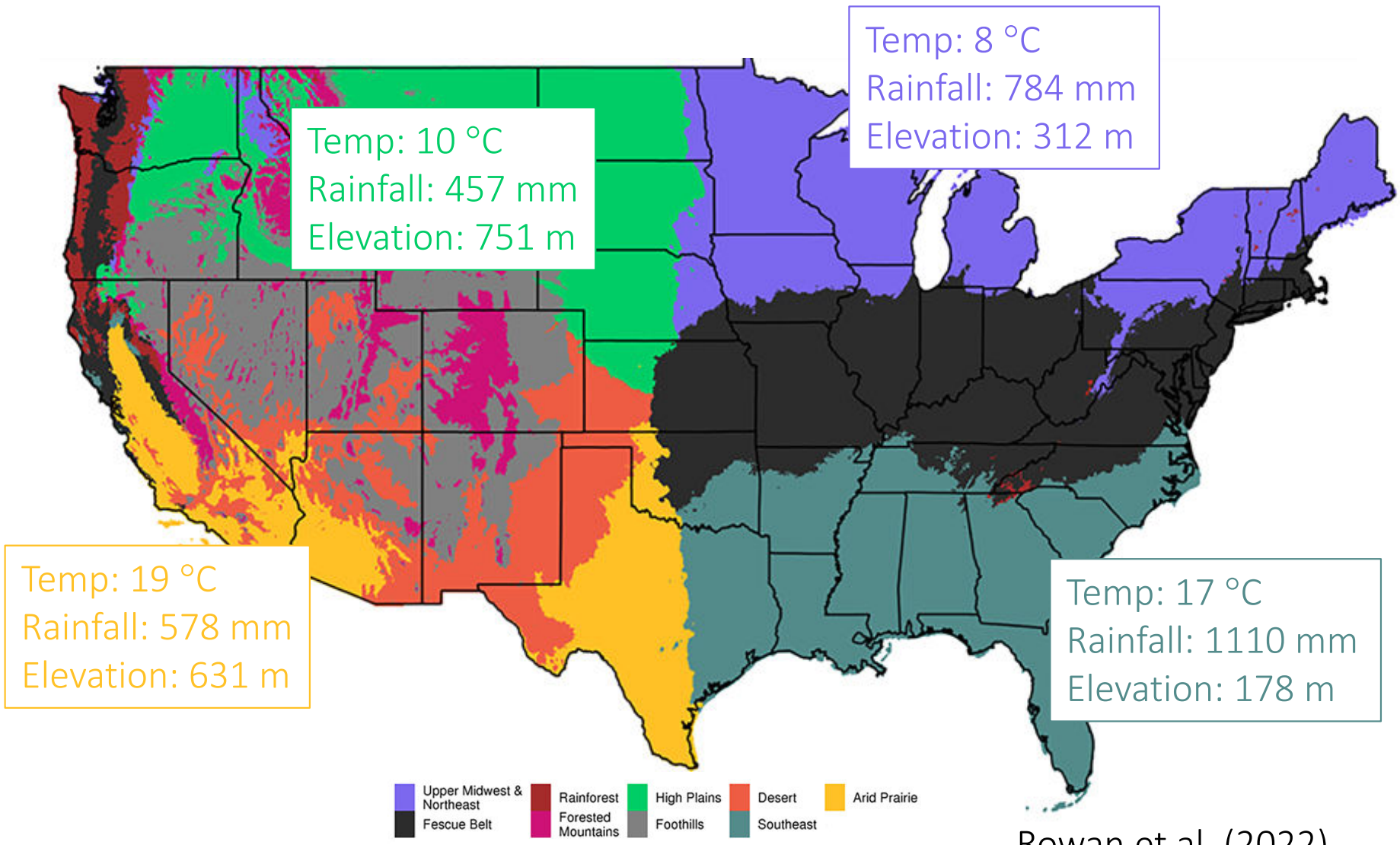
- Genotypes aligned perfectly with known genetic conditions
- Successively released a test run of results with information sheet
- Next step
  - Report results on all genotyped animals in NSIP genomic database to “owner” (i.e., producer submitting sample)
  - Some of those tests will be inconclusive

Answer: We can reliably determine and report the five validated genetic conditions

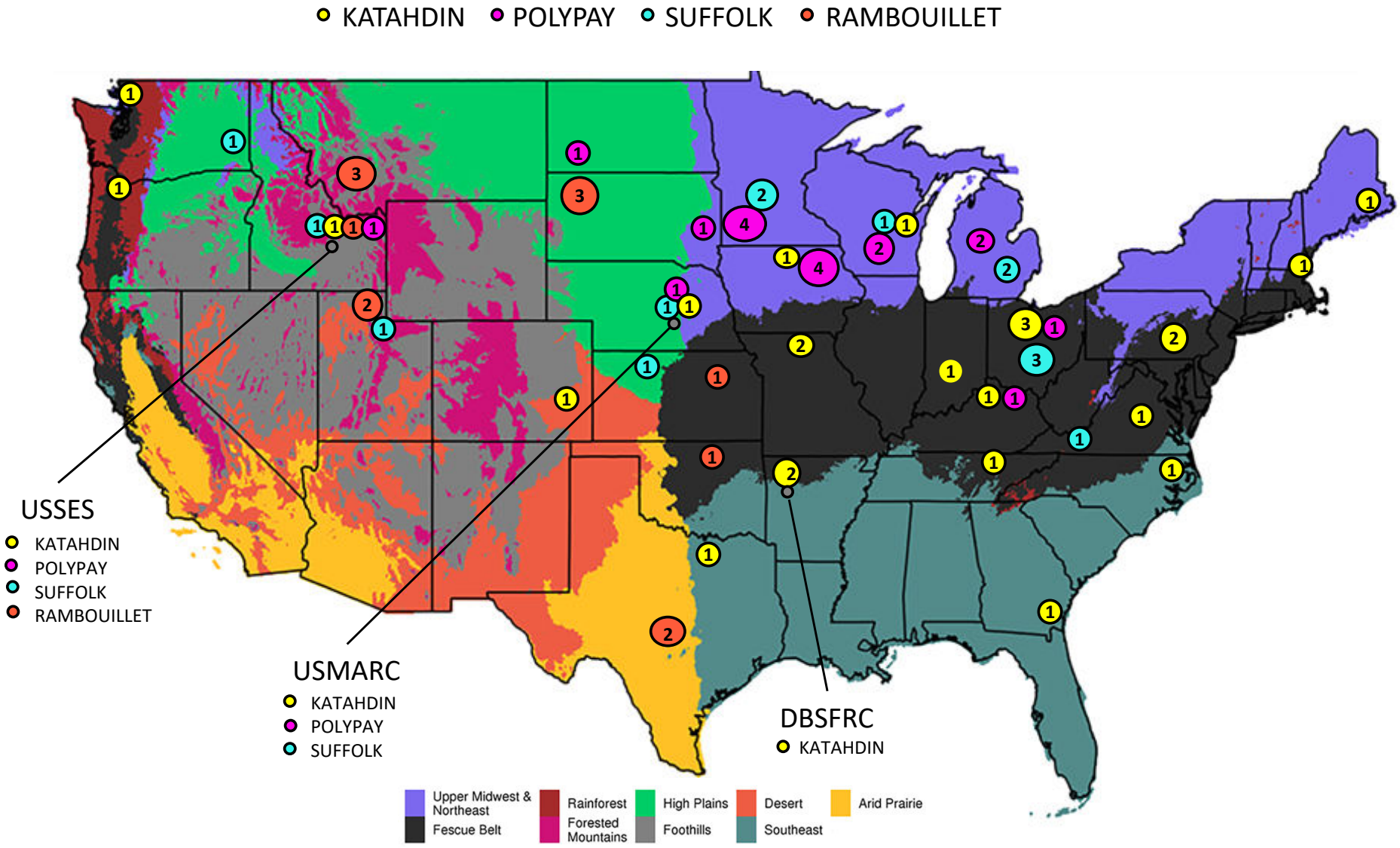
GEnvironment

- Climatic diversity

Climatic regions



Rowan et al. (2022)


KATAHDIN
POLYPAY
SUFFOLK
RAMBOUILLET
USSES
KATAHDIN
POLYPAY
SUFFOLK
RAMBOUILLET
USMARC
KATAHDIN
POLYPAY
SUFFOLK
DBSFRC
KATAHDIN
Upper Midwest & Northeast
Fescue Belt
Rainforest
Forested Mountains
High Plains
Foothills
Desert
Southeast
Arid Prairie

GEManagement

- Combining climate & management

Combining climate & management

- Question: Can we combine climatic and management information to more robustly define production environments (eco-management clusters)?
- Master student: Brian Arisman
- Funding: Organic Agriculture Research and Extension Initiative (OREI) grant no. 2016-51300-25723; Agriculture and Food Research Initiative Competitive grant no. 2022-67015-36073
- On-line survey collecting management information from NSIP Katahdin flocks: 40 flocks
- NSIP Katahdin OREI participant performance records (17 of those flocks)
  - 90-day weight, fecal egg counts, and FAMACHA scores on 3,426 lambs

Combining climate & management

- Using survey data, formed 9 eco-management clusters defined mostly by
  - Temperature
  - Rainfall
  - Grain supplementation on pasture
  - When lambs turned out to pasture
- Clusters explained more variation in performance in all three traits than climate or management alone
- Based on fecal egg counts
  - Clusters with hotter temperatures, greater rainfall, and pasture-born lambs had greater parasitism
  - Clusters with lambs turned out to pasture at older ages had less parasitism
- Next step
  - Using a similar strategy, define clusters for Sheep GEMS flocks to identify sire families better able to cope with environmental challenges

Arisman et al. (2023)

Answer: By combining information about the climate and management we improve our description of the production environment

GEMSocioeconomic

- Communicating results
- Encouraging adoption

Communicating results

- Question: How do we communicate project results to the U.S. sheep industry?
- Answer
  - Through traditional formats
    - Industry presentations (face-to-face meetings; webinars; podcasts)
    - Industry journals and newsletters
    - Project Advisory Board and Producer Advisory Group
    - Interviews of Innovation Flock participants
  - Through new formats?

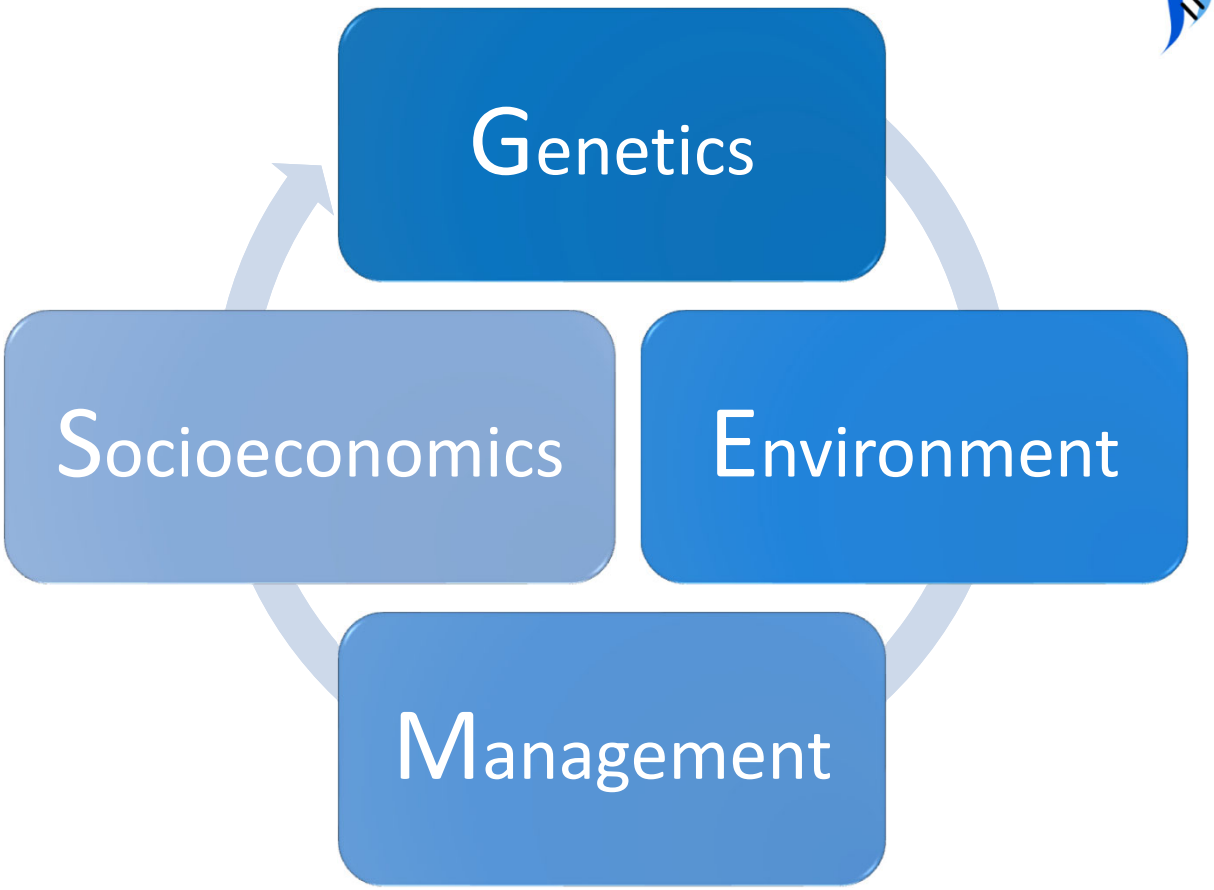
We need your ideas and help to keep the industry engaged and excited about Sheep GEMS

Encouraging adoption

- Question: How do we encourage adoption of our results by the U.S. sheep industry?
- Answer
  - Provide tools to implement project outcomes
    - Genomically-enhanced estimated breeding values for traditional and new traits
    - Economically-defined selection indexes combining these traits
    - On-farm or on-ranch data recording and capture systems
  - Demonstrate the value to bother
    - Return on investment
    - Satisfaction from contributing to the vitality and sustainably of the industry

Key is to continue to train and support talented young producers and scientists to keep the momentum going

Summing up



Thank you

SHEEP GEMS

USDA National Institute of Food and Agriculture
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AMERICAN Lamb RESOURCE CENTER

NSIP National Sheep Improvement PROGRAM

Sheep Genetics USA

American Rambouillet Sheep Breeders Association
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AMERICAN RAMBOUILLET
SHEEP BREEDERS ASSOCIATION

EST 2020 EASTERN ALLIANCE FOR PRODUCTION Katahdins

KATAHDIN HAIR SHEEP INTERNATIONAL

United SUFFOLK SHEEP ASSOCIATION

Finewool Breeders Consortium

AMERICAN POLYPAY ASSOCIATION
-Tomorrow's Sheep Today-

Thank you

USDA National Institute of Food and Agriculture
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- Project Advisory Board

  Matt Benz, Harvey Blackburn (Senior Scientist), Tom Boyer (Chair), Rusty Burgett, Brad Carothers, Alan Culham, Mike Duff, Lynn Fahrmeier, Jeremy Geske, Andrew Hess (Junior Scientist), Russell Kott, Dan Macon, Mark Meurer, Ben Pejsar, Bill Shultz, Todd Taylor, Cindy Wolf (Veterinarian)

- Producer Advisory Group

  John Anderson, John Bare, Matt Benz, Kristin Bieber, Gavin Blonquist, Rusty Burgett, Michelle Canfield, John Carlson, Amanda Everts, Lynn Fahrmeier, Jeremy Geske, Tom Hodgman, Russell Kott, Zach Meinders, Jim Morgan, Wacy Ortmann, Brett Pharo, Brenda Reau, Bill Shultz, Todd Taylor