REDIVERSE:
Biodiversity within and between European Red Dairy Breeds – Conservation through utilization

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and the REDIVERSE Consortium
Project leaders: Dirk Hinrichs and Georg Thaller

ERPF Meeting
Madrid, May 20, 2019

- Motivation
- Objectives of ReDiverse
- ReDiverse partners
- Work packages
- Expected outcomes of ReDiverse

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- European Red Dairy Breeds (ERDB) represent a unique source of genetic diversity
  - Complex histories of gene flow and connectedness
  - Local adaptation to various environments
  - Cultural heritage

- ERDB have a reputation for superior functional characteristics
  - High fertility
  - Outstanding udder health
  - Low incidence of stillbirth
  - Good conformation of legs and claws

- European Red Dairy Breeds (ERDB) represent a unique source of genetic diversity

Despite their qualities, ERDB are increasingly replaced by higher yielding breeds (e.g., Holstein-Friesian)

- ics

- good conformation of legs and claws

Importance of genetic diversity

Genetic diversity – a resource deserving protection

- Animal genetic diversity is a unique and irreplaceable heritage
- Potential to adapt to changing environments
- Ensures future breeding options
- Genetic diversity in livestock declines significantly
- Globally, 16% of all livestock breeds have been lost during the last 100 years (Scherf, 2000)

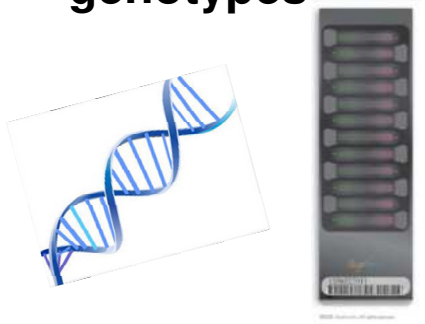
Utilization will ensure conservation!

Genomic selection

phenotypes

reference population

genotypes

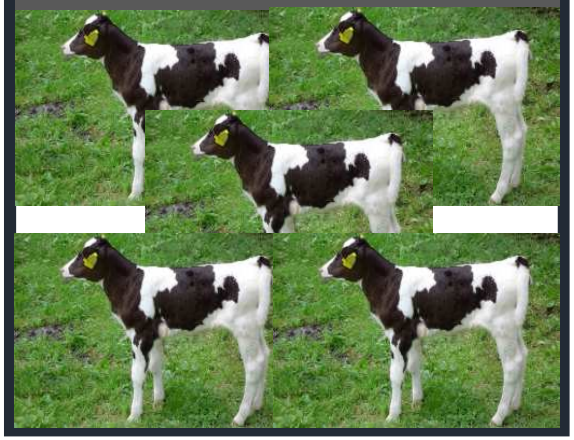


Statistical analysis

$$y = Xb + \sum Z_i s_i + e_i$$

Estimation of SNP-effects

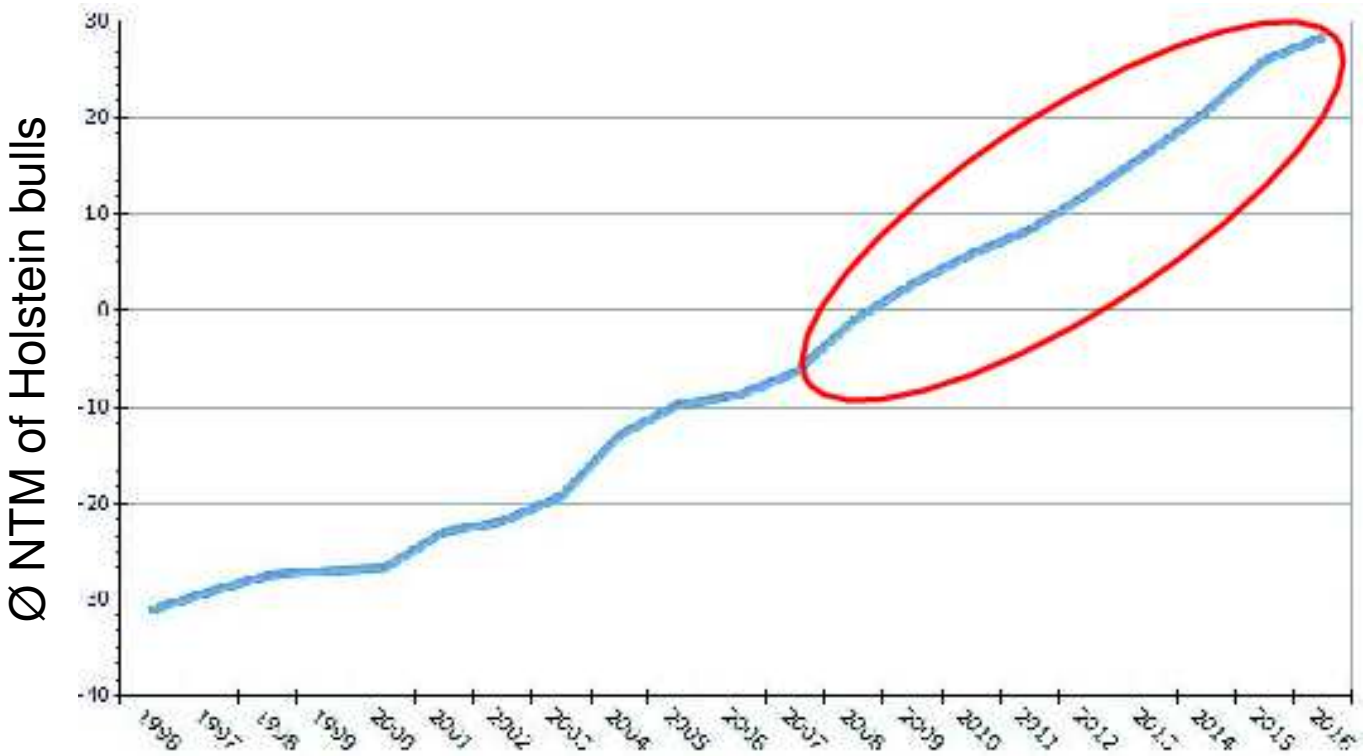
selection candidates



Selection based on genomic estimated breeding values

Impact of genomic breeding

Genetic gain (NTM) in Nordic Holstein bulls



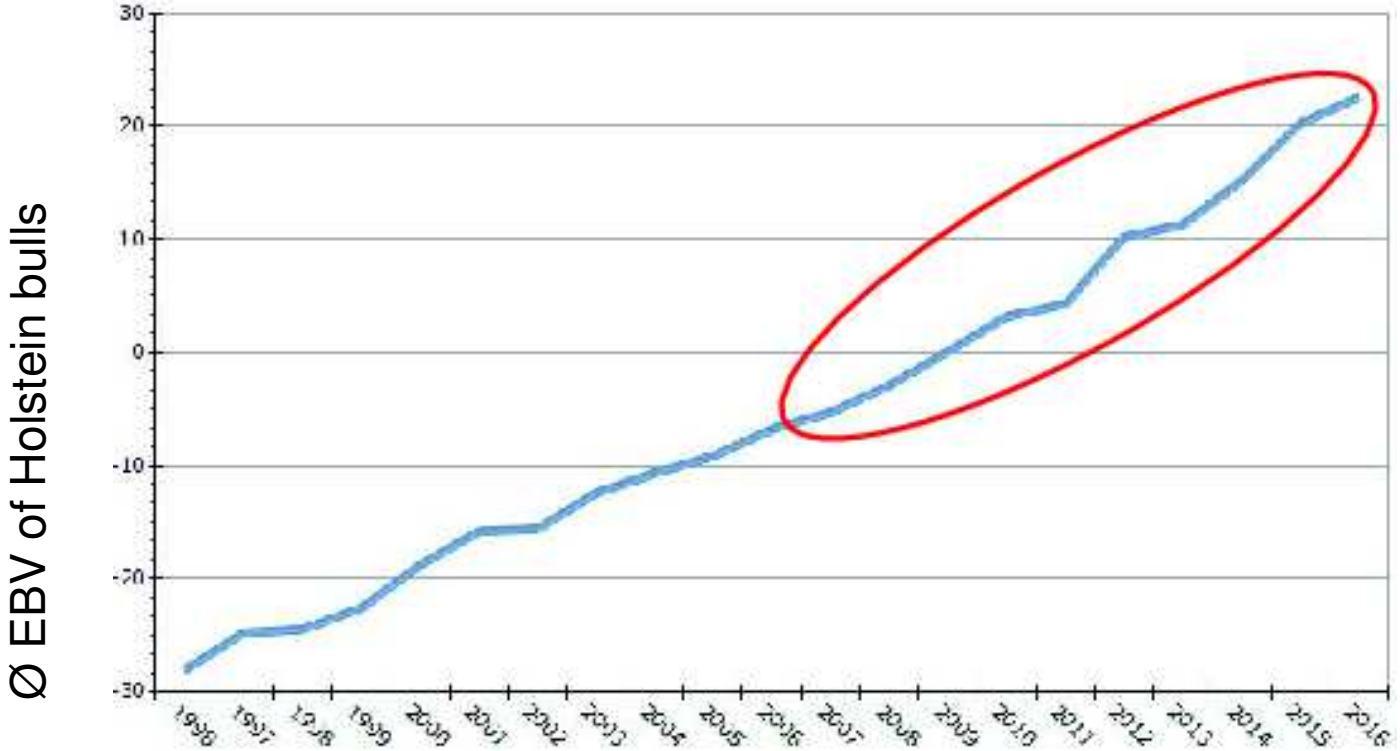
Breeding values

NTM 2000-2007 = +3.2 per year
NTM 2010-2013 = +4.8 per year

+50% genetic gain

Impact of genomic breeding

Genetic gain (NTM) in Nordic Red bulls



Breeding values

NTM 2007-2011 = +2.5 per year
NTM 2011-2016 = +3.8 per year

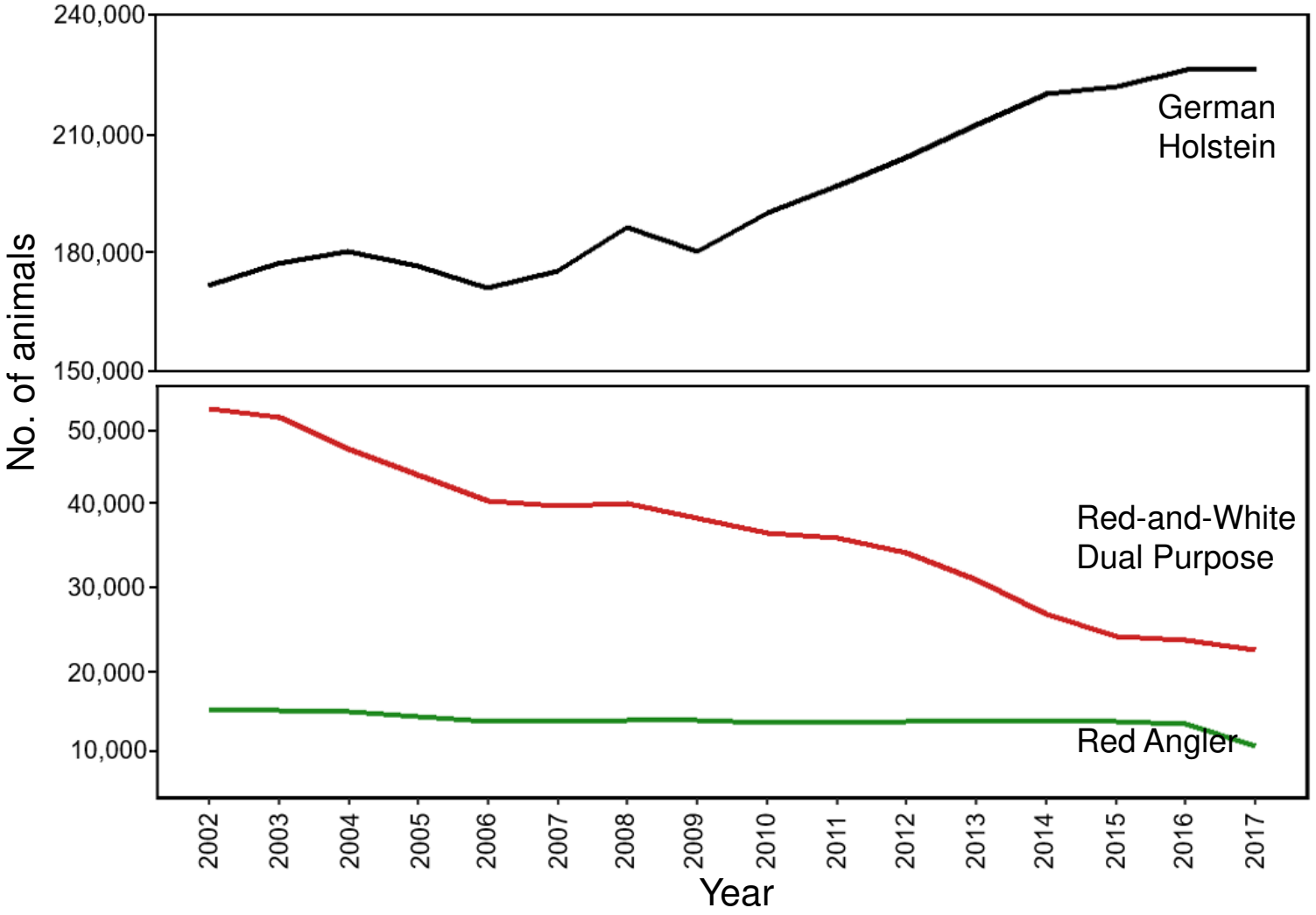
+50% genetic gain

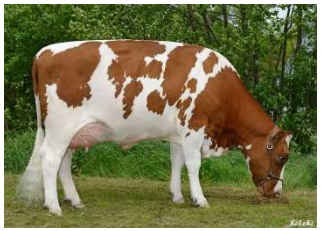
Eurogenomics helps Holstein

- Many Holstein bulls are tested
- Holstein populations have large reference populations
- Now Germany, France, Spain, the Netherlands, Poland, Denmark, Finland and Sweden share their reference
- Shared development of customized Holstein chip
- Big improvement of gain
- In Red breeds: testing of huge numbers of females with EG chip expands red breed reference

Dairy breeds in Northern Germany

Development of dairy cows under milk recording in Schleswig-Holstein



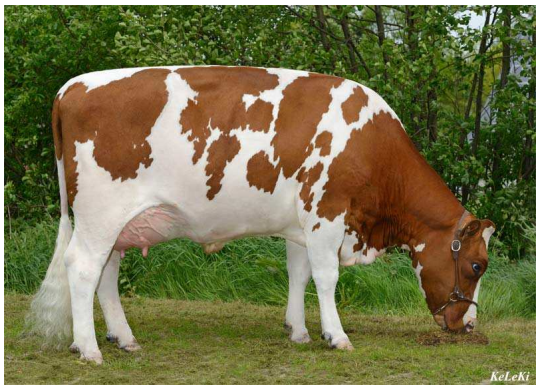


(LKV, 2017)

Dairy breeds in Northern Germany

Table: Average performances of breeds (LKV SH, 2017)

	Red Angler	Red-and-White Dual Purpose	German Holstein
Number of animals in milk recording (2017, SH)	10,257	20,730	233,003
Milk yield (kg)	7,766	6,771	8,804
Fat %	4.60	4.34	4.09
Protein %	3.61	3.50	3.41



How to help the ERDB?

- Support cooperation in breeding
- Support cooperation in breeding value prediction
- Protect unique characteristics
- Exploit advantageous characteristics in breeding
- Understand farmers' needs and priorities

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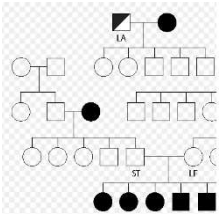
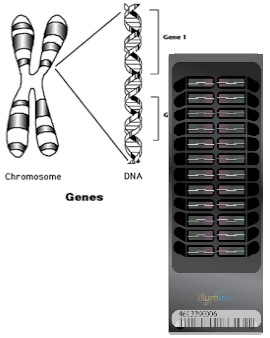
REDIVERSE – main objectives

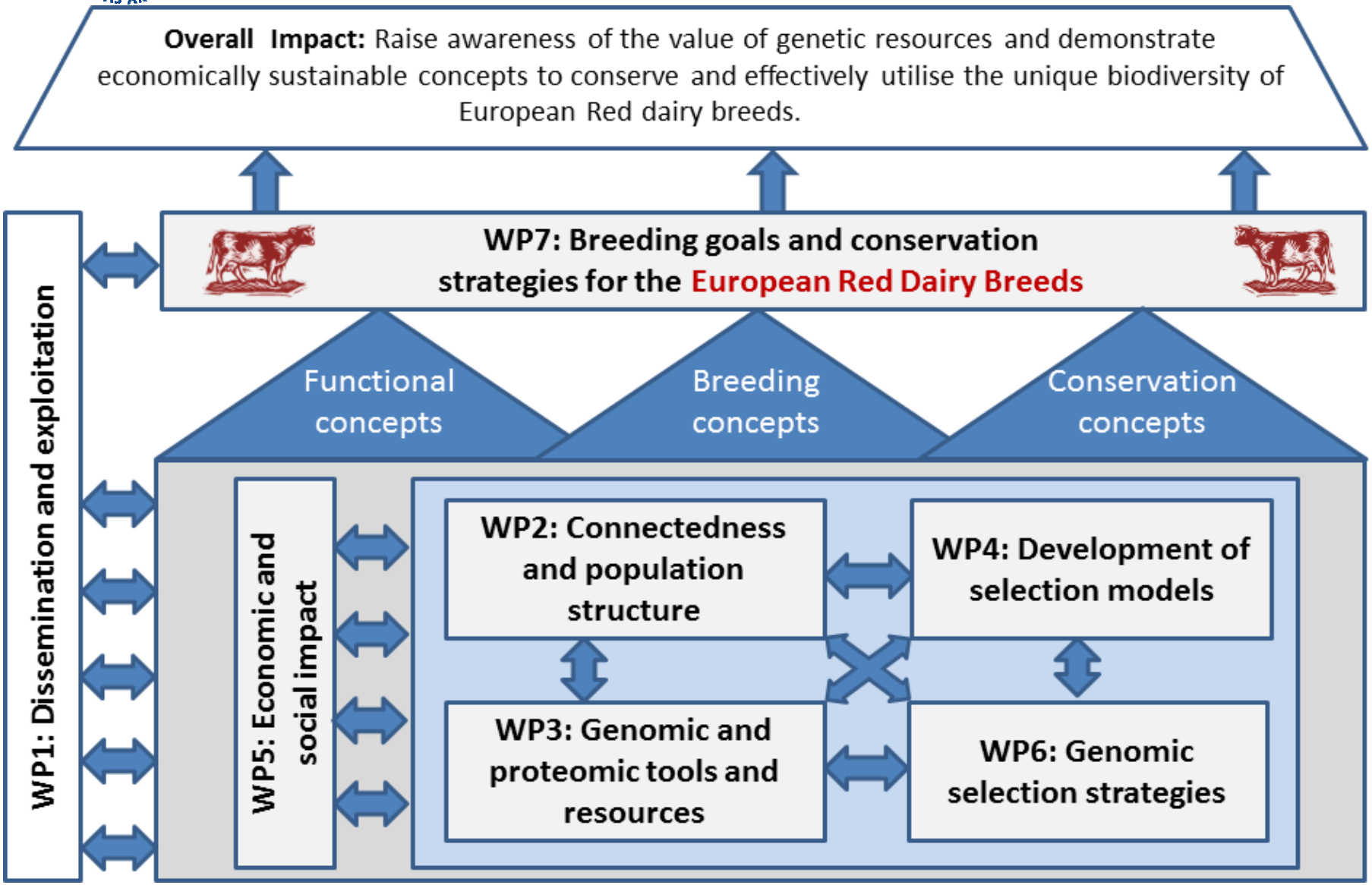
Development and implementation of methods and strategies for sustainable use of genetic diversity provided by European Red Dairy Breeds



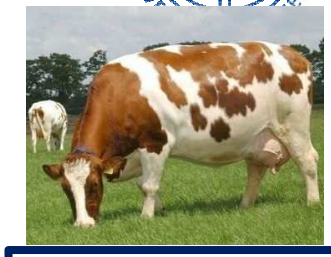
- Investigation of population structure and genetic composition of Red dairy breeds
- Genetic analyses →Cooperative reference population
  →Breed-specific SNP-Chip
- Proteomic analyses →Identification and characterization
- Design and evaluation of breeding programs to ensure genetic gain and genetic diversity
- Survey of farmers‘ preferences keeping Red Dairy breeds



ReDiverse – Project Structure

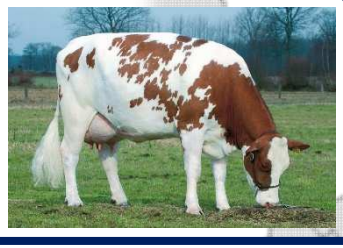


European Red Dairy Breeds



Breed	Herdbook animals
Meuse–Rhine-Yssel	17,771
Groningen White Headed	2,488
Deep Red	1,563
Dutch Red Friesian	700

Breed	Herdbook animals
Finnish Ayrshire	190,000
Swedish Red and White Cattle	130,000
Modern Red Danish Cattle	40,000



Breed	Herdbook animals
Modern Angeln Cattle	10,257
Red and White Dual Purpose	2,846
Vorderwald Cattle	6,050
Hinterwald Cattle	600

Breed	Herdbook animals
Latvian Brown	44,280
Lithuanian Red	30,295
Estonian Red	18,000

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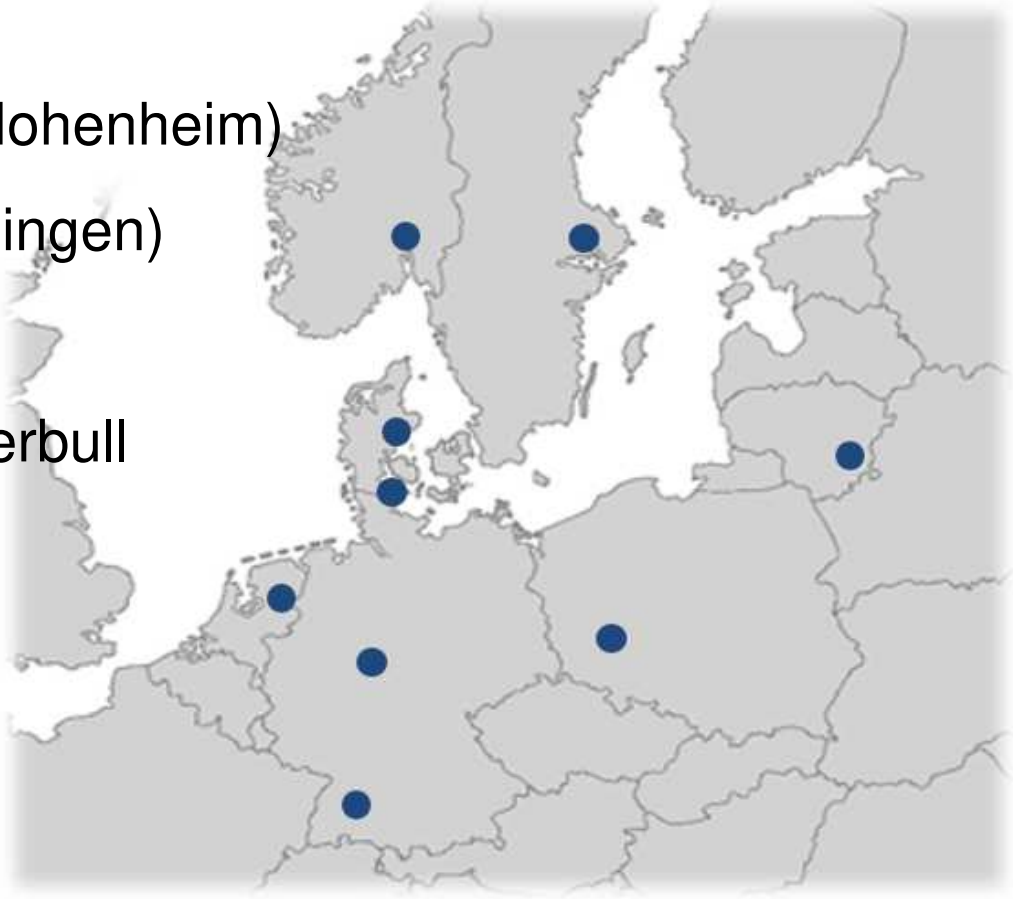
REDIVERSE partners

Academic partners

- Germany (Kiel, Kassel, Hohenheim)
- The Netherlands (Wageningen)
- Denmark (Aarhus)
- Sweden (Uppsala) w. Interbull
- Norway (Ås)
- Lithuania (Vilnius)
- Poland (Wroclaw)



REDIVERSE partners

Industrial partners

- CRV
- Rinderzucht Schleswig-Holstein eG
- Viking Genetics
- Lithuanian Red Cattle Improvement Association
- Animal Breeders Association of Latvia
- Geno

- Motivation
- Objectives of REDIVERSE
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WP 2 – Genetic connectedness + population structure

Leader WP2: Dirk-Jan De Koning, SLU Sweden

- Investigation of population structure and genetic connectedness
  - → Determination of genomic relationships and distances between breeds
- Investigation of phenotype recording schemes between ERDB
  - → Defining clear phenotypes tol be recorded across countries within a reasonable time
  - → Harmonization of recording schemes
- Determination of recent migration from other breeds
- Identification of key animals for further genotyping and sequencing

WP 2 – Genetic connectedness and population structure

Numbers of pedigree information per sex and reporting country

	FEMALE	MALES	TOTAL
Lithuania	9 789	9 211	**19 000**
Denmark, Sweden, Finland	4 855 904	1 490 092	**6 345 996**
Netherlands	2 217 343	256 627	**2 473 970**
Germany	4 089	815	**4 904**
Latvia	58 025	4 517	**62 542**
Poland	6 893	713	**7 606**
Norway	1 648 872	445 426	**2 094 298**
TOTAL	**8 800 915**	**2 207 401**	**11 008 316**

(S.Nyman & A.M.Johansson, 2018)

Verification of pedigree information → 3 009 686 duplicates

WP 2 – Genetic connectedness + population structure

Existing evaluation schemes for Red Dairy Breeds by trait/country

Trait/ Country	Production	Udder health	Conformation	Longevity	Calving ease	Female fertility	Workability
Lithuania	X	X					
Denmark, Sweden, Finland	X	X	X	X	X	X	X
Netherlands	X	X	X	X	X	X	X
Germany	X	X	X	X	X	X	X
Latvia	X	X					
Poland							
Norway	X	X	X	X	X	X	X

(S.Nyman & A.M.Johansson, 2018)

WP 3 – Development of genomic and proteomic tools

Leader WP3: Bernt Guldbrandtsen, Aarhus University

AARHUS UNIVERSITY

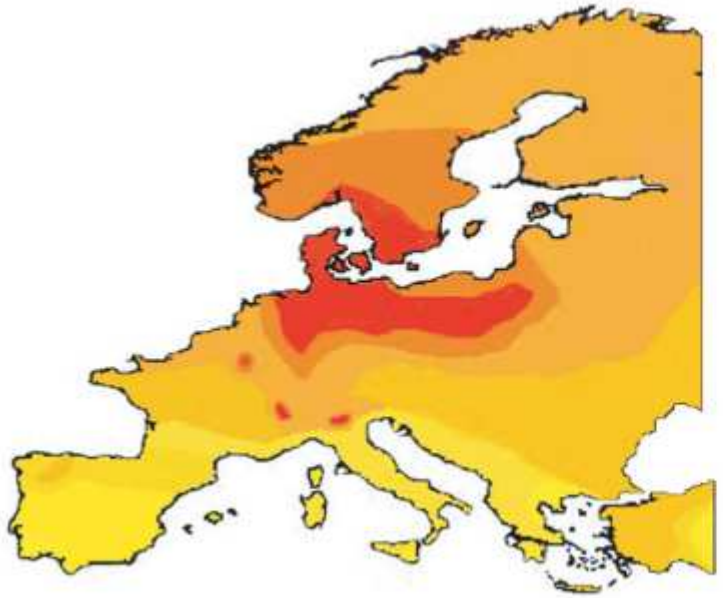
- Analysis of genomic data with respect to patterns of milk protein variants
- Design of a SNP chip customized for ERDB
  - → Improved QTL results
  - → Promotion of milk protein variants
  - → Support of genomic prediction
- Identification of breed differences at sequence level
- Detect admixture in genomic data

ERDB chip add-on

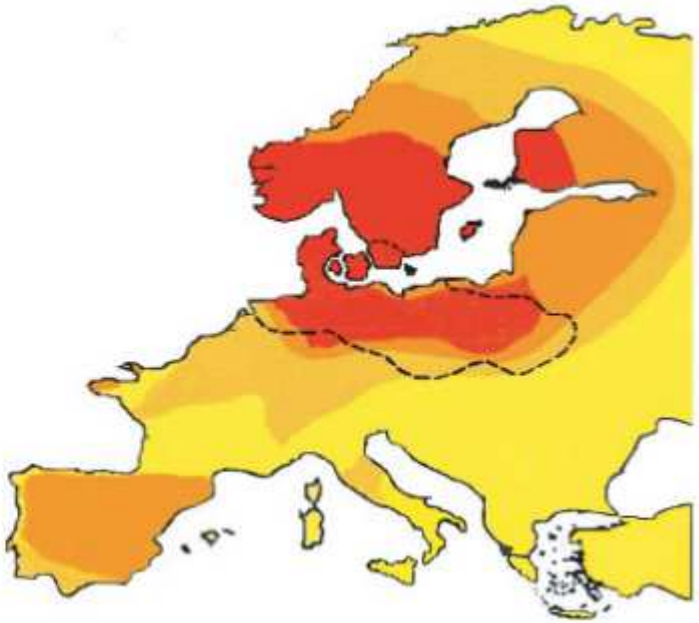
- Design a customization of chips suitable for Red Dairy Breeds
- To include:
  - QTL-associate SNP
  - Breed private SNP
  - Imputation support SNP for Red Dairy Breeds
  - Red Dairy Breed milk protein variants
- Will include findings from whole-genome sequencing in Red Dairy Breeds
- Deploy chip in Red Dairy populations with too small reference populations

Milk protein variants

Milk protein diversity



Incidence of lactose tolerance

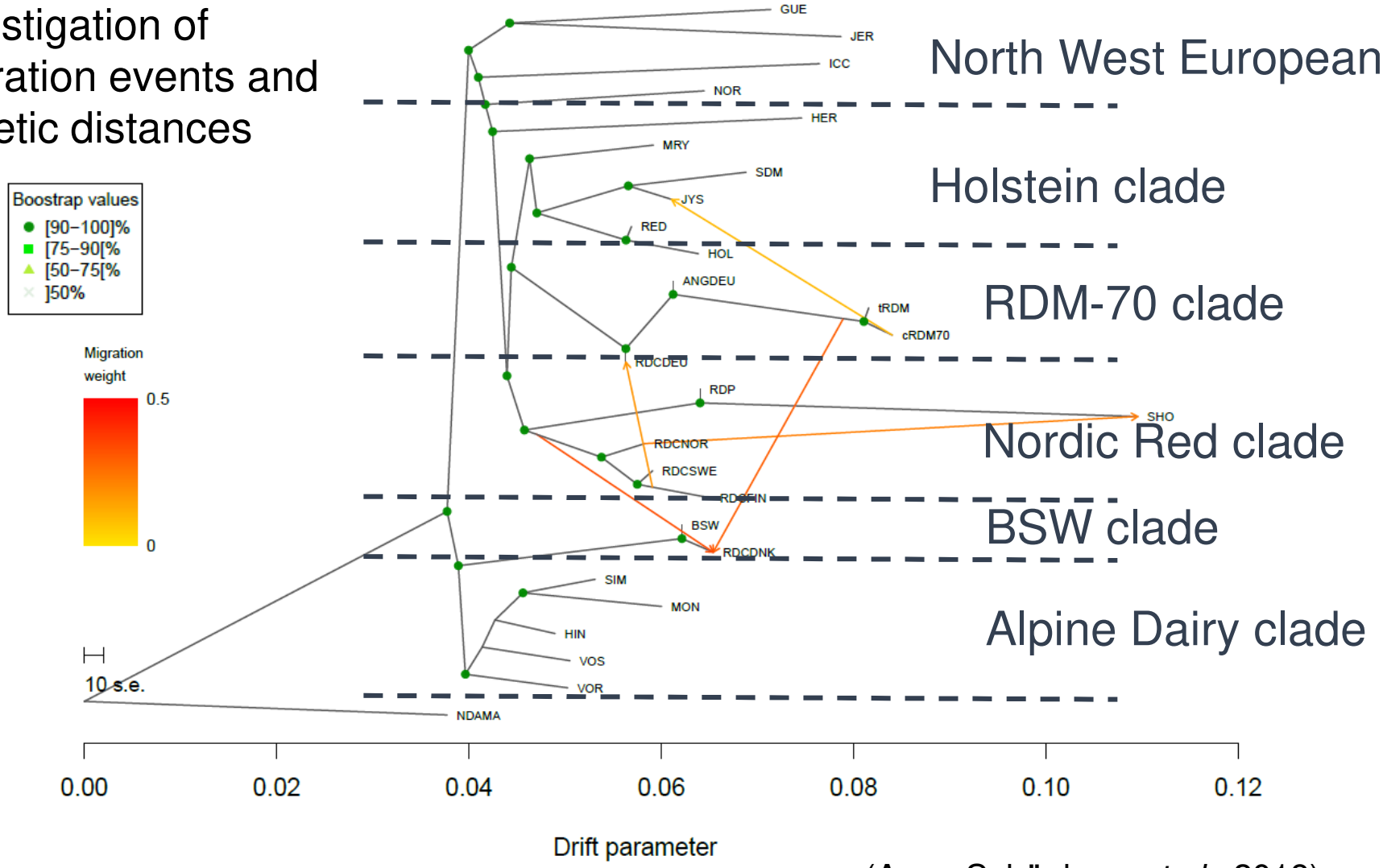


Adapted from Beja-Pereira *et al.* (2003)

➡ Beja-Pereira *et al.* (2003) have found coincidence between the milk protein diversity in cattle breeds and the geographic distribution of the lactase persistence allele in humans

TreeMix analysis

Investigation of migration events and genetic distances



(Anna Schönherz *et al.*, 2018)

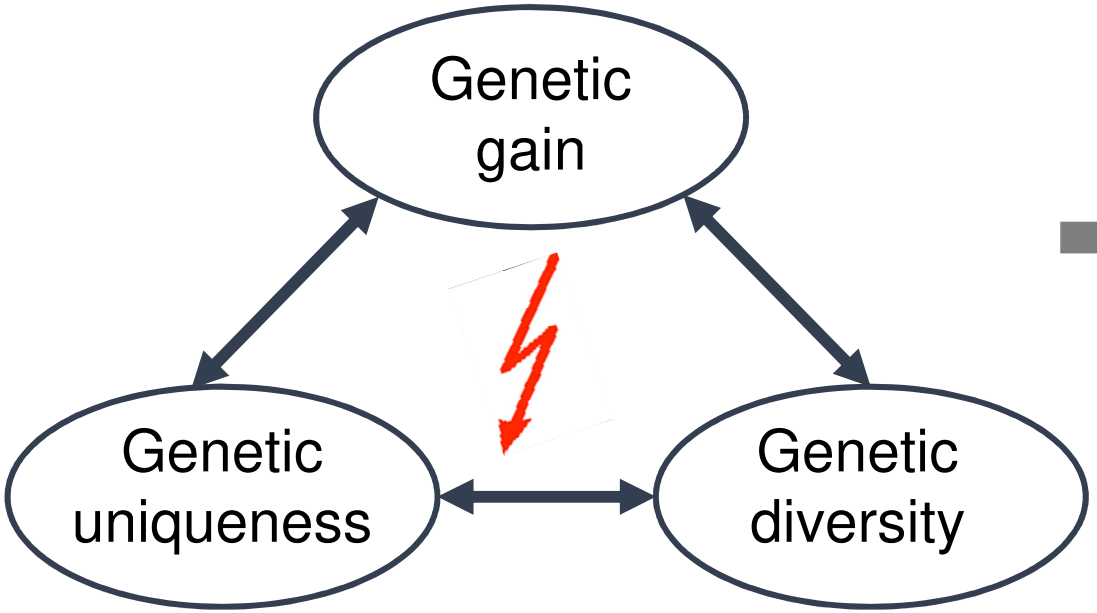
WP 4 – Development of selection methods

Leader WP4: Jörn Bennewitz, University of Hohenheim

- Development and evaluation of selection methods
  - → Maximization of purebred and crossbred performance while preserving genetic uniqueness of ERDB
- Development of breeding programs for the genomic prediction of crossbred performance
- Comparison of simulated breeding programs
  - → Focusing on genetic gain and genetic uniqueness

WP 4 – Development of selection methods

Conflicting objectives in animal breeding programs



R-package **optiSel**
(Wellmann, 2019)

Development and evaluation of selection methods to maximize performance while preserving the genetic diversity and genetic uniqueness provided by ERDB

WP 5 – Economic and social impact

Leader WP5: Uwe Latacz-Lohmann, Kiel University

Christian-Albrechts-Universität zu Kiel

- Assessment of benefits and costs of conserving genetic diversity at the farm level
- Evaluation of farmers‘ preferences keeping and breeding Red Dairy Cattle
- Determination of farmers‘ preferences for the introduction of Red Dairy Cattle genes in high yielding breeds (e.g., HF)

→ <u>Applied methods:</u> Quantitative approaches from social sciences, e.g., discrete choice experiments, interviews

WP 5 – Economic and social impact

Which determinants influence farmers‘ participation in conservation programs for dairy cattle breeds?

➡ Discrete Choice Experiments, 159 German cattle breeders

	Contract 1	Contract 2	Opt-out
Compensation payment	250€/LU/year	250€/LU/year	No contract
Collective Bonus (population increase > 5%)	40€/LU/year	0€/LU/year	
Conservation breeding program (pairing)	No	Yes	
Keeping conditions	No requirements	Access to free-range area or pasture	
Contract duration	5 yrs	1 yrs	
I choose	□	□	□

(Julia Schreiner, 2018)

WP 5 – Economic and social impact

	Coefficient	WTA [€/LU/year]
Compensation payment	0.015***	-
Bonus = 40€/LU/year	-0.0689	5
Bonus = 80€/LU/year	0.453***	-30
Conservation breeding program	-0.159	11
Access to free-range area or pasture	0.230	-15
Access to free-range area or pasture+ prohibition of slatted floors	-2.475***	165
Contract duration = 1 year	0.2706	-18
Contract duration = 5 years	0.4674	-31
Contract duration = 10 years	-1.627***	108

(Julia Schreiner, 2018)

- Monetary incentives contribute to farmers‘ willingness to participate in conservation programs
- Contract duration → short term contracts were more attractive for farmers → flexibility, independence

WP 5 – Economic and social impact

What are motivations for farmers keeping and breeding Red Dairy cattle?

➡ Q-methodology (systematic analysis of subjective attitudes), carried out with 66 cattle breeders

Some results:

+ ‚ERDB are characterized by good health, claws and conformation → lower veterinary costs‘

+ ‚ERDB show higher values for milk ingredients (fat + protein) → guarantee for income even milk price is low ‘

+ ‚We are keeping ERDB due to traditional reasons, we are emotionally attached‘

+ ‚We are keeping ERDB because we are concerned about the cultural value of our region ‘

Genomic selection strategies

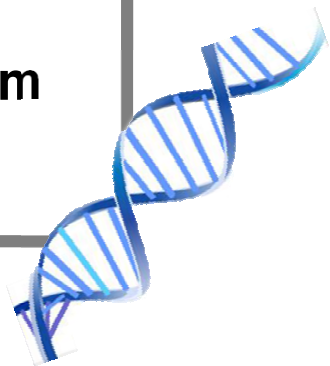
Leader WP6: Mario Calus, Wageningen University

- Improvement of genomic prediction methods for across-breed evaluations and for heterogeneous populations

  → Focusing on maintaining genetic diversity

- Investigation of the potential for implementation of genomic selection in ERDB

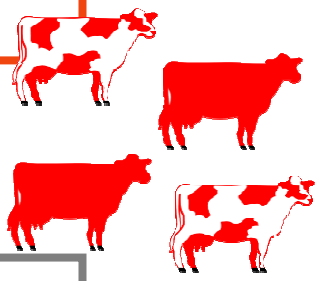
Improve competitiveness and create a long-term perspective for European Red Dairy Breeds



WP 6 – Genomic selection strategies

Challenges: European Red Dairy breeds

- Small population sizes
- Few progeny tested bulls
- Heterogeneous populations



Possible solution:

- Multi-breed reference population
- Composition of reference population ?
- Which breeds are useful to include ?
- Connectedness

WP 6 – Genomic selection strategies

Estimation of M_e (effective number of chromosome segments)

- Indicator for relatedness
- Directly predict expected accuracy

Data

- BovineSNP50 data of 5 Dutch Red dairy breeds

Breed	N
MRY	423
Groningen White Headed (GWH)	129
Dutch Belted (DB)	41
Dutch Friesian (DF)	352
Deep Red (DR)	44

(Jovana Marjanovic, 2018)

WP 6 – Genomic selection strategies

Results

	MRY	GWH	DB	DF	DR
MRY	293				
GWH	17906	151			
DB	14883	16315	104		
DF	16452	10890	7625	212	
DR	3662	17516	17047	14560	149

Within M_e

Between M_e

(Jovana Marjanovic, 2018)

- MRY and DR are most closely related
- DF was most closely related to DB
- For GWH, DF was the closest breed
- The most distant relationships DR and DB, DR and GWH, and GWH and MRY

Genomic selection strategies

Results

	MRY	GWH	DB	DF	DR
MRY	293				
GWH	17906	151			
DB	14883	16315	104		
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Between M_e

(Jovana Marjanovic, 2018)

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- DF was most closely related to DB
- For GWH, DF was the closest breed
- The most distant relationships DR and DB, DR and GWH, and GWH and MRY

- M_e shows high variability in relatedness
- Multi-breed RP should be much larger than single-breed RP

WP 7 – Development of breeding goals + conservation strategies

Leader WP7: Morten Kargo, Aarhus University

AARHUS UNIVERSITY

- Breeding goal setting for European Red Dairy Breeds
  - Development of national and transnational breeding objective and improvement programs
  - Conservation of genetic diversity

- Evaluation of breeding schemes with respect to genetic gain, genetic diversity and promotion of breed-specific characteristics

Economic weights

Calculation of economic values for Red Dairy breeds

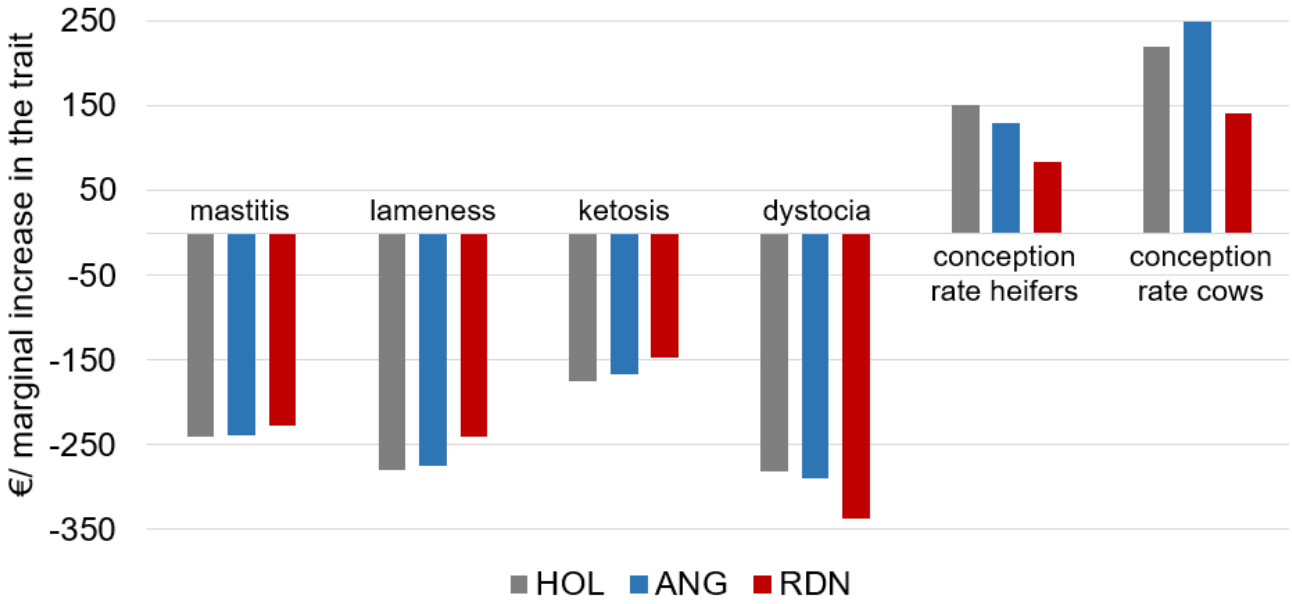
- Determination of optimal economic selection indices for regional production conditions
- Economic values were already calculated for 3 German dairy breeds (Holstein-Friesian (HOL), Angler (ANG), Red-and-White Dual Purpose (RDN))

Applied methods:

- Bio-economic model SimHerd (Østergaard et al., 2005)
  - → Simulation of typical structures in dairy herds (heifers+lactating cows)
  - → Input: phenotypic records (performance, health, reproduction)
- Multiple regression with mediator variables (Østergaard et al., 2016)
  - → Prevention of “double counting” of effects

WP 7 – Development of breeding goals + conservation strategies

Economic values for selected traits



<u>Differences in EV's are due to different assumptions for:</u>

- Performance levels
- Incidence rates
- Reproduction levels
- Market prices

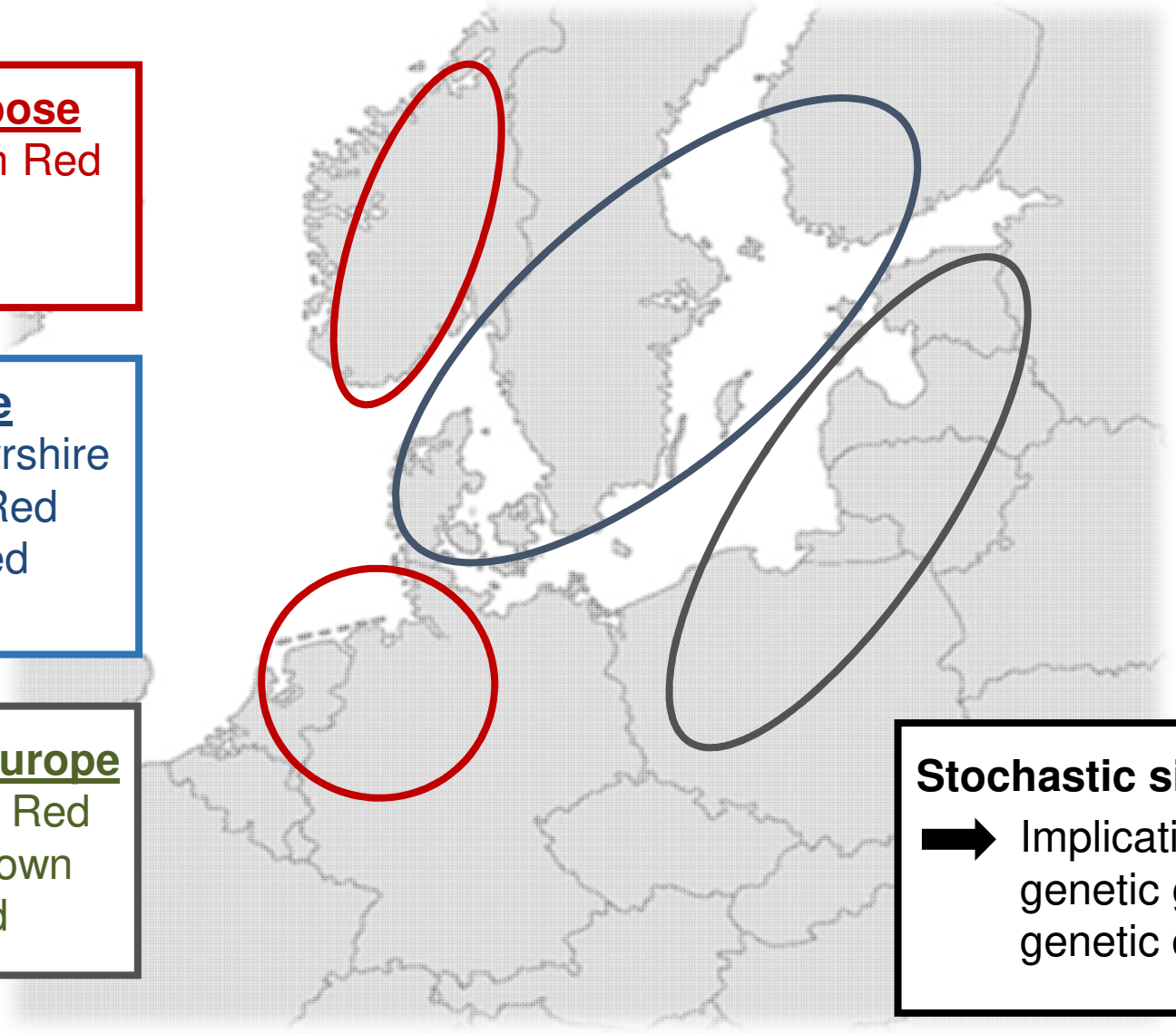
➢ Calculation of economic values for other European Red Dairy Breeds next

Breeding goal clusters - Example

Dual purpose
Norwegian Red
MRY
RDN

Dairy type
Finnish Ayrshire
Swedish Red
Danish Red
Angler

Eastern Europe
Lithuanian Red
Latvian Brown
Polish Red



Stochastic simulations:

➡ Implications on genetic gain and genetic diversity

- Motivation
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Expected outcomes

- Sustainable management of genetic diversity provided by European Red Dairy Breeds
- Formation of aligned breeding objectives
- Collaboration in evaluation
- Shared genomic resources

Ultimately: *preservation* of European Red Dairy Breeds by improved breeding *utilizing* their *unique* characteristics

Thank you for your attention!

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ERA-NETSUSAN