Selection Indexes: Application and Comparison of Various Production Indices Available to the U.S. Sheep Industry

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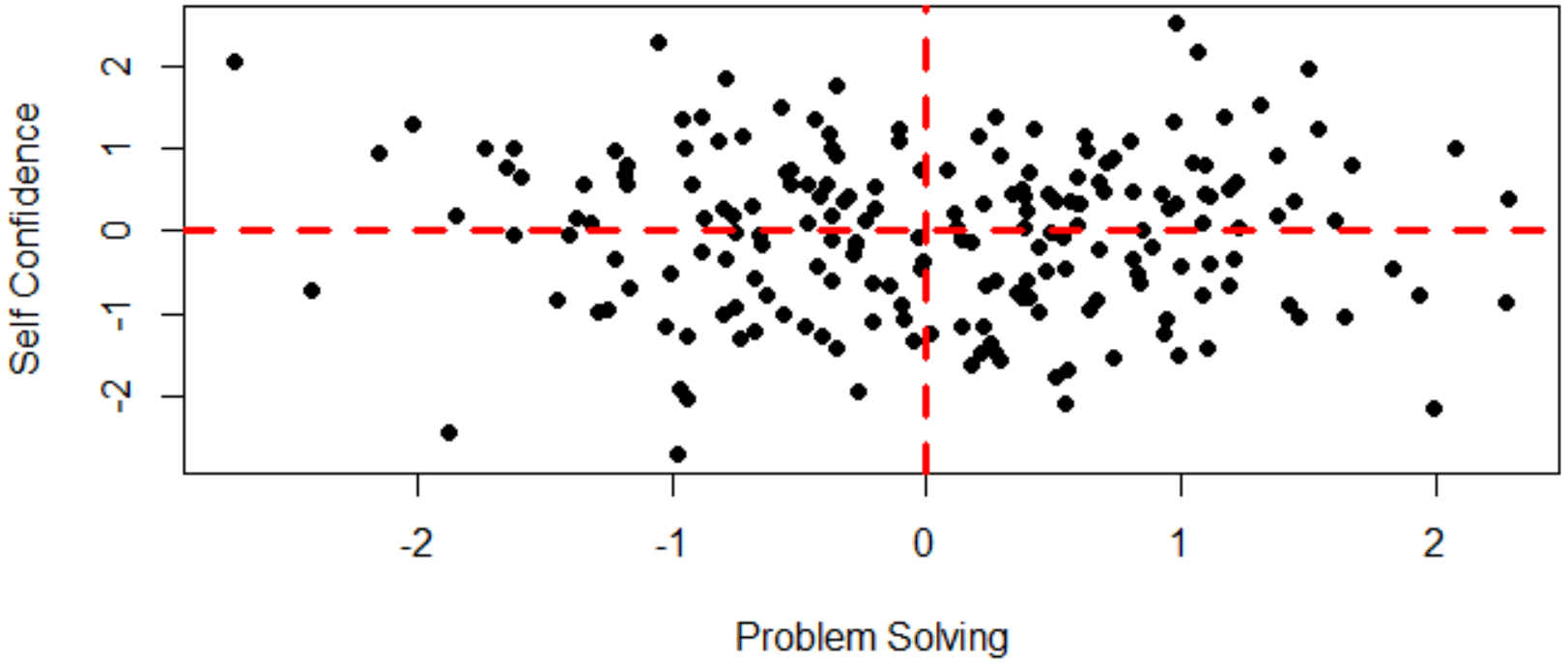
What makes “the best” leader?

- An effective leader is one who *optimally* combines superior problem-solving skills with a high degree of self-confidence.

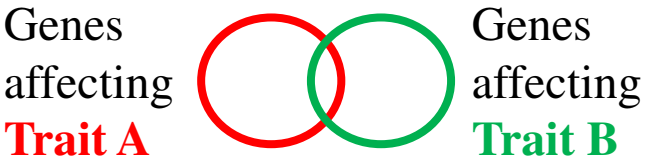


Identifying the “best” replacements

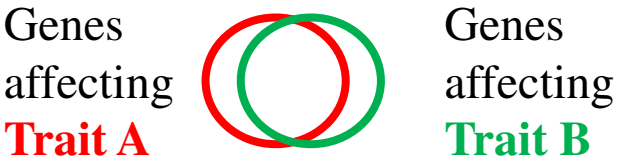
- We are typically interested in improving our flocks for multiple traits simultaneously.
- What makes sheep genetically “better” or “worse” can be very specific to an operation.
  - Fleece traits, reproductive rate, parasite resistance, growth/carcass traits.
- **Challenges:**
  - Genetic correlations among traits can hinder (or benefit) multiple trait improvement.
  - How much emphasis, if any, should we put on each trait?
  - What selection/mating scheme will most rapidly achieve our objectives?

Genetic correlation

- A statistic, ranging from -1 to +1, that estimates the proportion of genes expected to affect two traits.
- Positive genetic correlation (+0.1 to +1): as the EBV of **Trait A** *increases*, the EBV of **Trait B** tends to *increase*.
- Negative genetic correlation (-0.1 to -1): as the EBV of **Trait A** *increases*, the EBV of **Trait B** tends to *decrease*.
- Weak genetic correlation (-0.1 to +0.1): as the EBV of **Trait A** *increases*, the EBV of **Trait B** changes little.



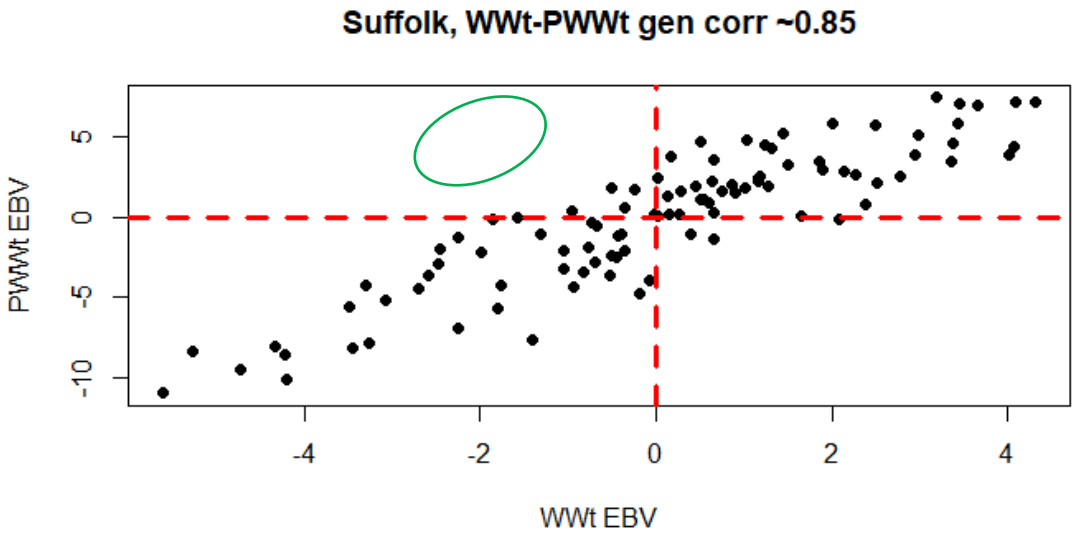
Weak genetic correlation



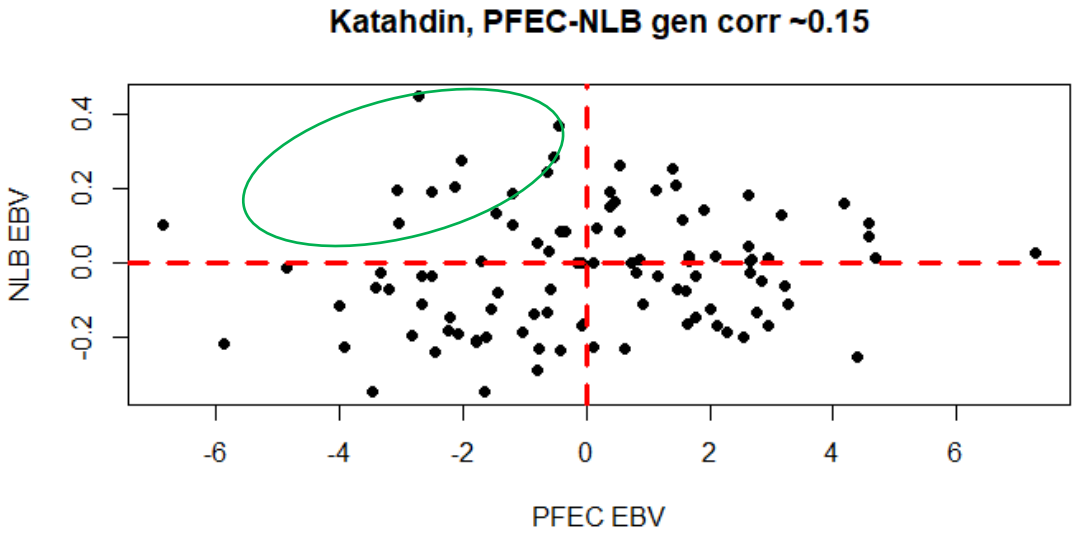
Strong genetic correlation

Simulated genetic correlation

Strong, positive genetic correlation between weaning and post-weaning weight – nearly all animals with high EBV for one trait also have a high EBV for the other trait.

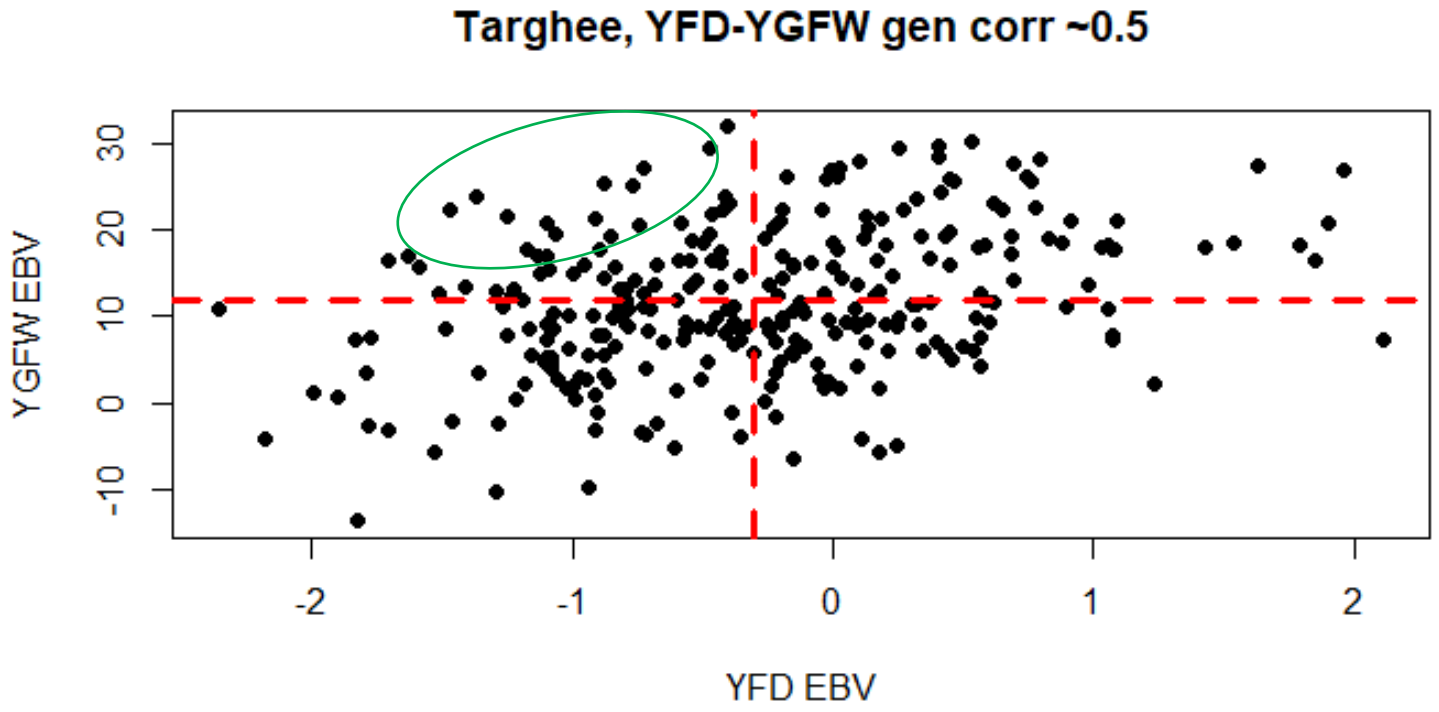


Weak genetic correlation between post-weaning FEC and number born – relatively easy to find animals with favorable EBV for both traits.



Real data

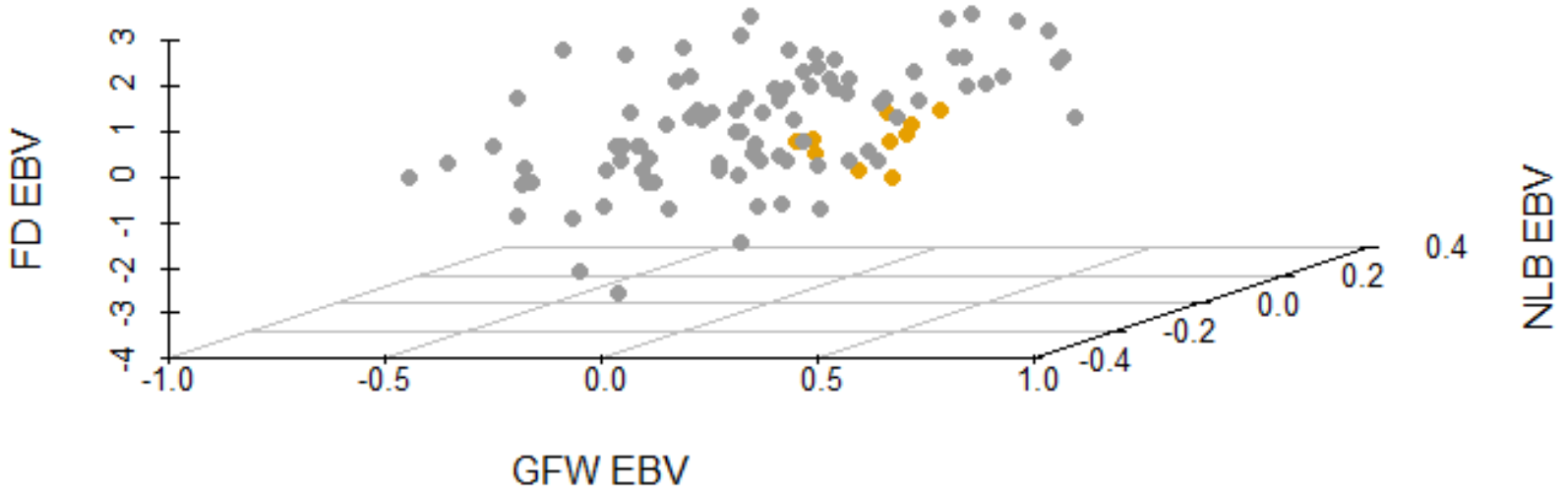
- Yearling fiber diameter and greasy fleece weight EBV for proven NSIP Targhee rams born from 2014-2020. Even with a moderate, positive (unfavorable) genetic correlation we can identify sires that are ***elite*** for both traits!



Multiple-trait selection strategies

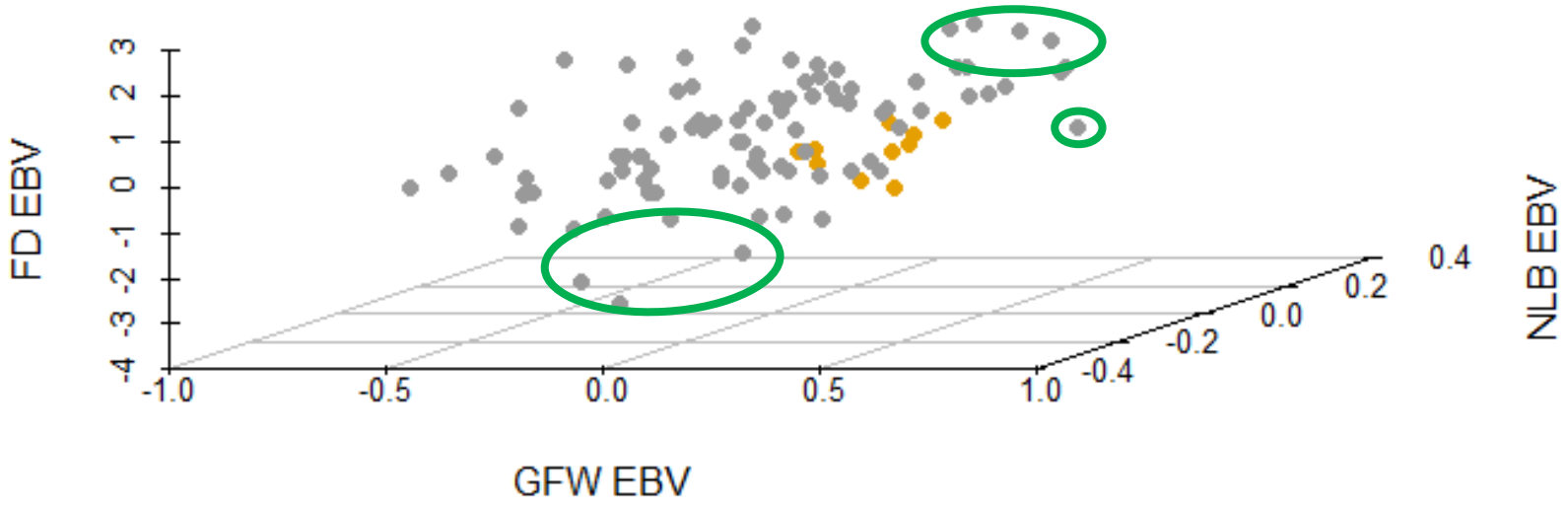
- **Independent culling levels:** Set thresholds for two or more traits, select replacements on favorable side of all trait thresholds.

GFW > 0, FD < 0, NLB > 0



Independent culling levels

- **Considerations:** What thresholds should we set?
- **Pros:** Simple when 2 or 3 traits considered.
- **Cons:** Becomes difficult to find individuals that meet all thresholds with many traits (> 3). Potentially lose individuals with very favorable EBV for one trait.



Multiple-trait selection strategies

- **Selection index:** Optimally weight individual traits by their relative importance toward a defined *breeding objective*. Select individuals with high index values.

$$I = w_1 EBV_1 + w_2 EBV_2 + \cdots + w_n EBV_n$$

Index value

Weighting factors

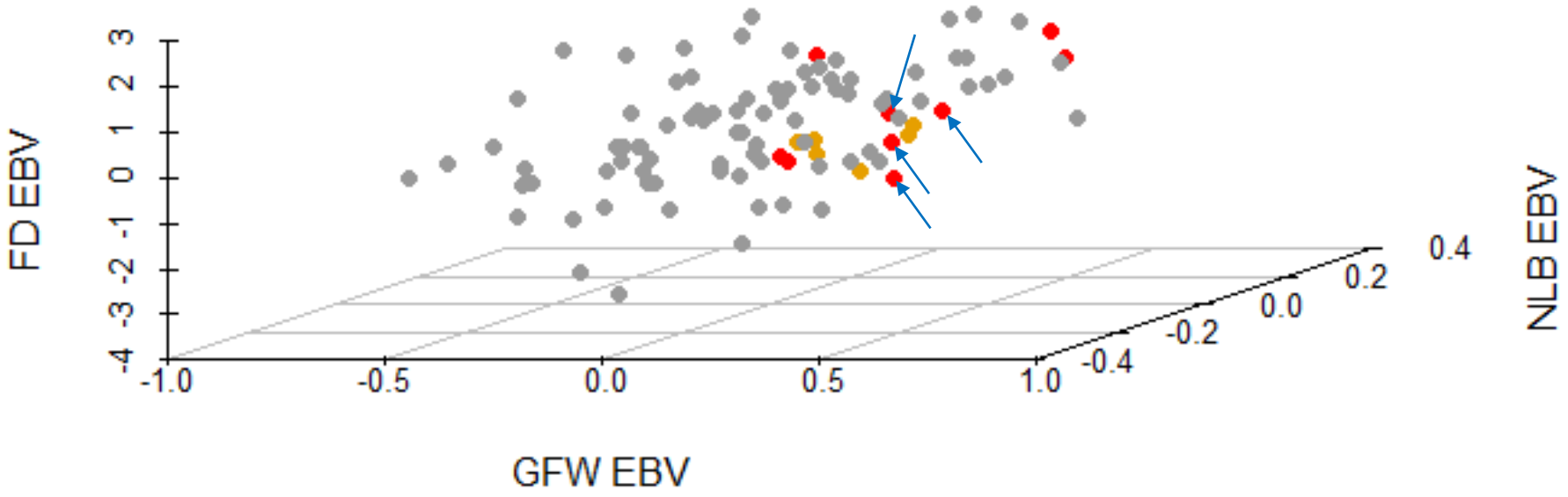
- **Ex.** Suppose we wanted to construct an index with relative emphasis of ~25% greasy fleece weight (increase), ~25% fiber diameter (decrease), and ~50% number born (increase).

$$I = 1.3 * EBV_{GFW} - 0.4 * EBV_{FD} + 6 * EBV_{NLB}$$

Selection index

Independent culling levels: GFW > 0, FD < 0, NLB > 0

Index: 25% GFW, 25% FD, 50% NLB



Top 10 Index
Independent culling levels

Selection index

$$I = w_1 EBV_1 + w_2 EBV_2 + \cdots + w_n EBV_n$$

- **Considerations:** What is our breeding objective?
- **Pros:** Simple to use, animals are compared with a single index value regardless of how many traits are considered. Very favorable EBV for one trait can override less desirable EBV in another trait.
- **Cons:** Deriving accurate weighting factors is challenging (time, $). Requires some level of consensus among multiple breeders.

Creating selection indexes

- **Step 1:** Define our breeding objective.
  - Productivity index: improve an unmeasured *composite trait* (e.g., total weight weaned, lean growth).
  - Economic index: improve sheep *profitability* in a defined production system (e.g., returns – variable costs).
- **Step 2:** Identify traits that are *reasonably* important toward achieving our breeding objective.
  - Dependent on production/marketing systems (FEC, fleece traits, carcass conformation).
  - Each additional trait reduces individual trait gains.

$$I_A = w_1 EBV_1 + w_2 EBV_2 + w_3 EBV_3$$

$$I_B = w_1 EBV_1 + w_2 EBV_2 + w_3 EBV_3 + w_4 EBV_4 + w_5 EBV_5$$

Creating selection indexes

- **Step 3:** Determine trait weighting factors.
  - Productivity index: Estimate relationships between the composite trait and the measured component traits.
  - Economic index: Simulate a lifecycle production system and estimate how genetic change in one trait impacts costs of production and returns.
  - Validate, repeat, validate, repeat…
- **Step 4:** Update indexes to reflect changes in flock performance, costs, and returns on a somewhat regular basis.

Carcass Plus Index

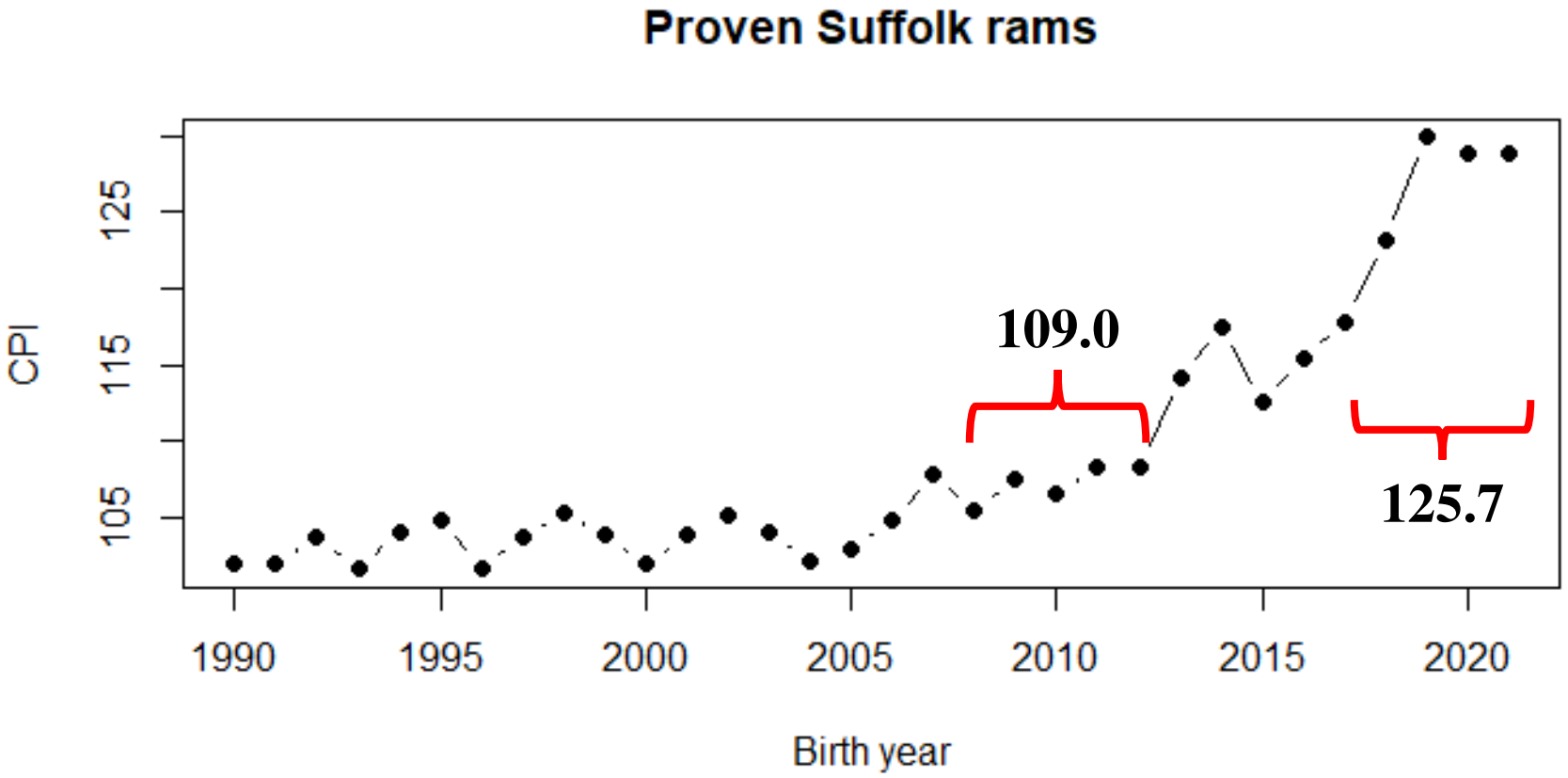
$$CPI = 100 + 2.3 * EBV_{WWt} + 3.5 * EBV_{PWWt} + 11.4 * EBV_{PWEMD} - 4.1 * EBV_{PWBF}$$

- A *desired gains* index developed by LambPlan (vetted by NSIP) to predict genetic merit for lean muscle growth.
  - Promotes high growth and muscling while maintaining leanness.
  - Determine where we want performance to be in the future, weight traits accordingly to get there.

Trait	Relative emphasis
WWt	~30%
PWWt	~35%
PWEMD	~30%
PWBF	~5%

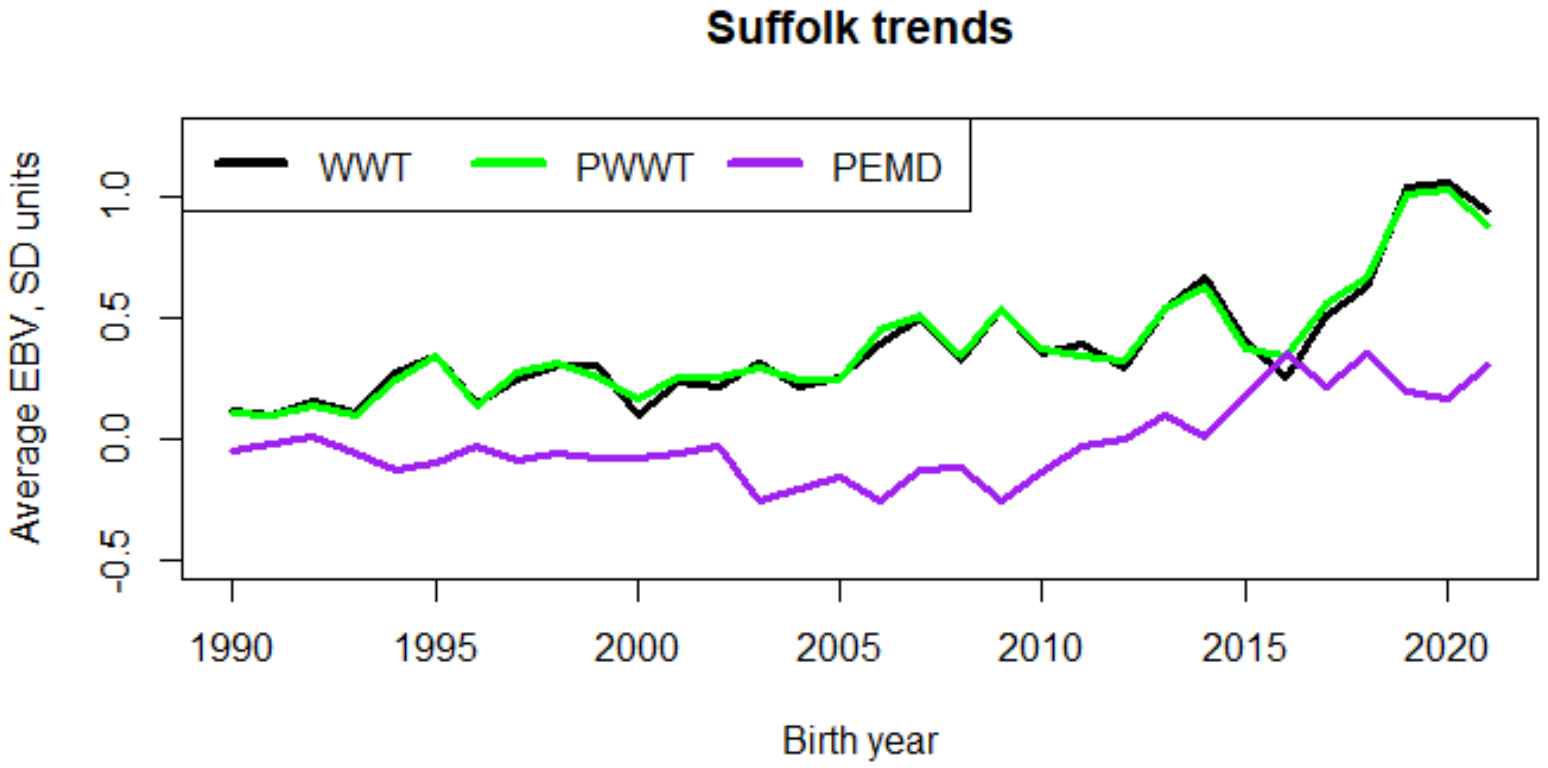
CPI progress – Suffolk

- Average CPI for 2017-2021 born rams was 17 points greater than 2009-2013 born rams.



Component trait progress - Suffolk

- From 2010 to 2020, gains in WWT (+1.9 lbs), PWWT (+3.7 lbs) and PEMD (+0.4 mm) despite antagonistic genetic relationship (-0.40).



Maternal productivity indexes

$$MPI_{Wool} = 100 + 0.6 * EBV_{WWt} + 2.6 * EBV_{MWWt} - 3.5 * EBV_{NLB} + 41 * EBV_{NLW}$$

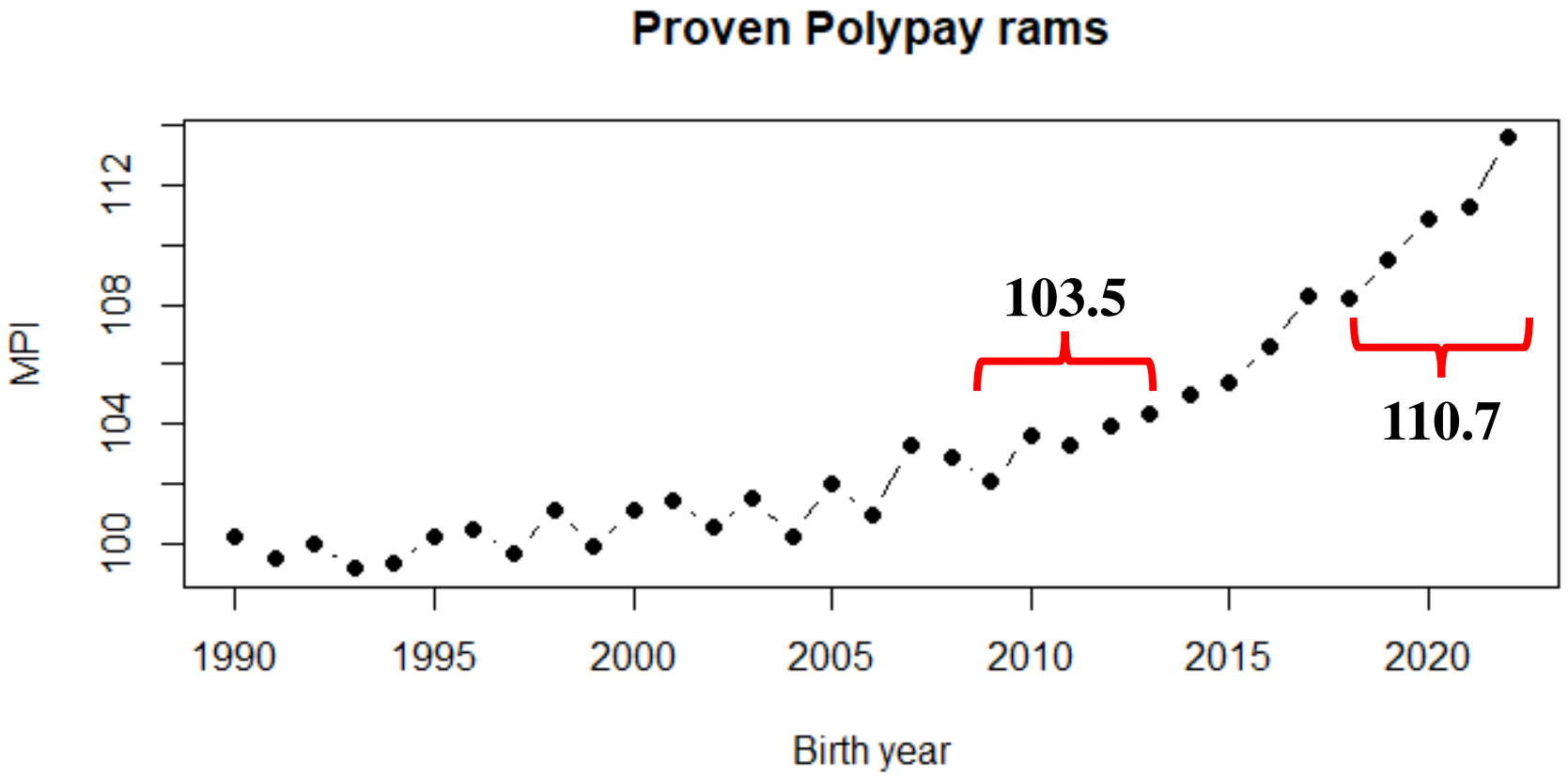
$$MPI_{Hair} = 100 + 0.1 * EBV_{WWt} + 0.4 * EBV_{MWWt} - 4.4 * EBV_{NLB} + 22 * EBV_{NLW}$$

- Productivity indexes developed by NSIP to predict genetic merit for total weight of lamb weaned.

Component trait	Genetic correlation with MPI_{Wool}
WWT	0.07
MWWT	0.31
NLB	0.40
NLW	0.94

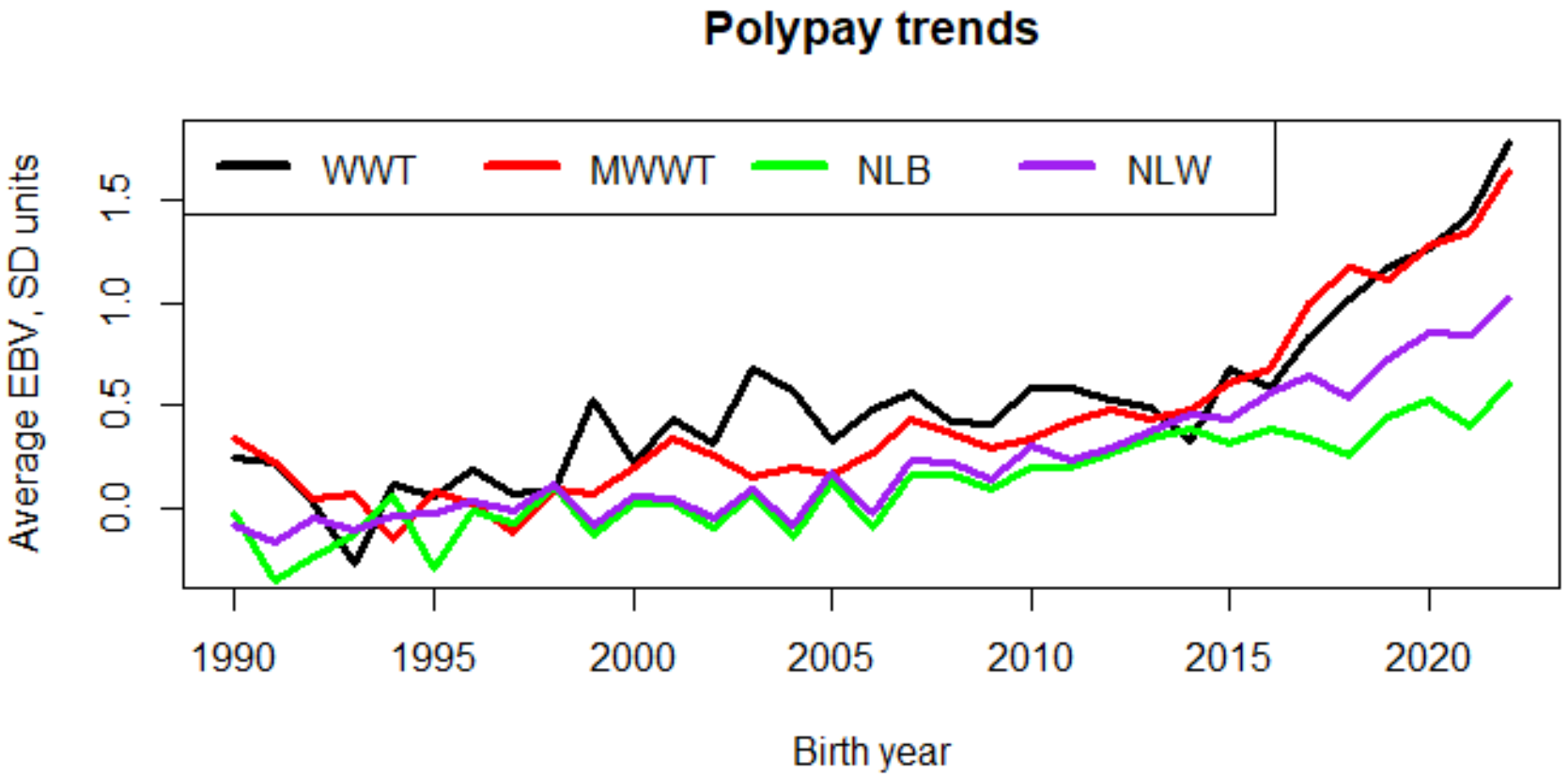
MPI progress – Polypay

- Average MPI for 2018-2022 born rams was 7 points greater than 2009-2013 born rams.



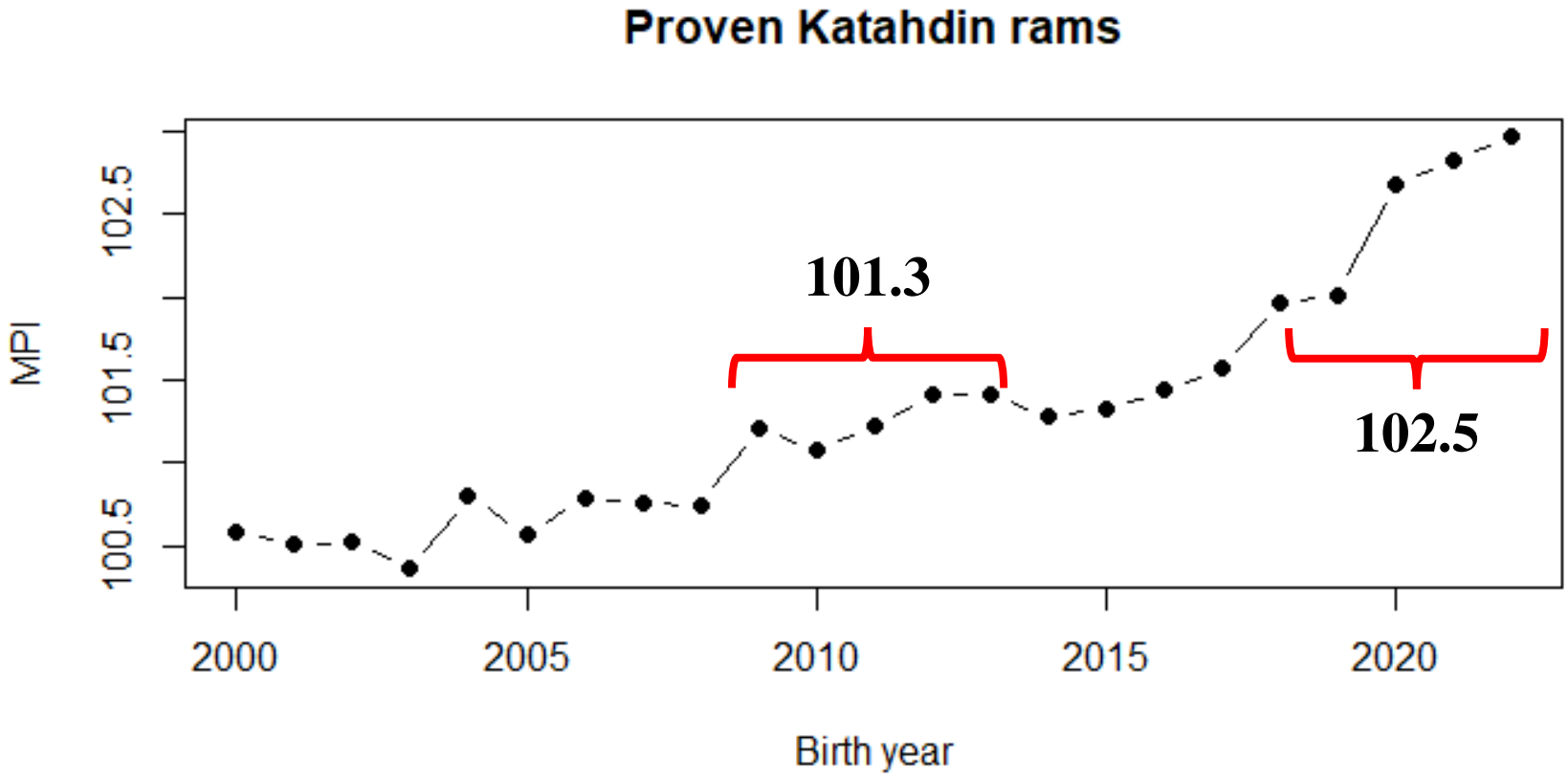
Component trait progress - Polypay

- From 2010 to 2020, gains in WWT (+2.1 lbs), MWWT (+2.1 lbs), NLB (+0.06 lambs), and NLW (+0.12 lambs).



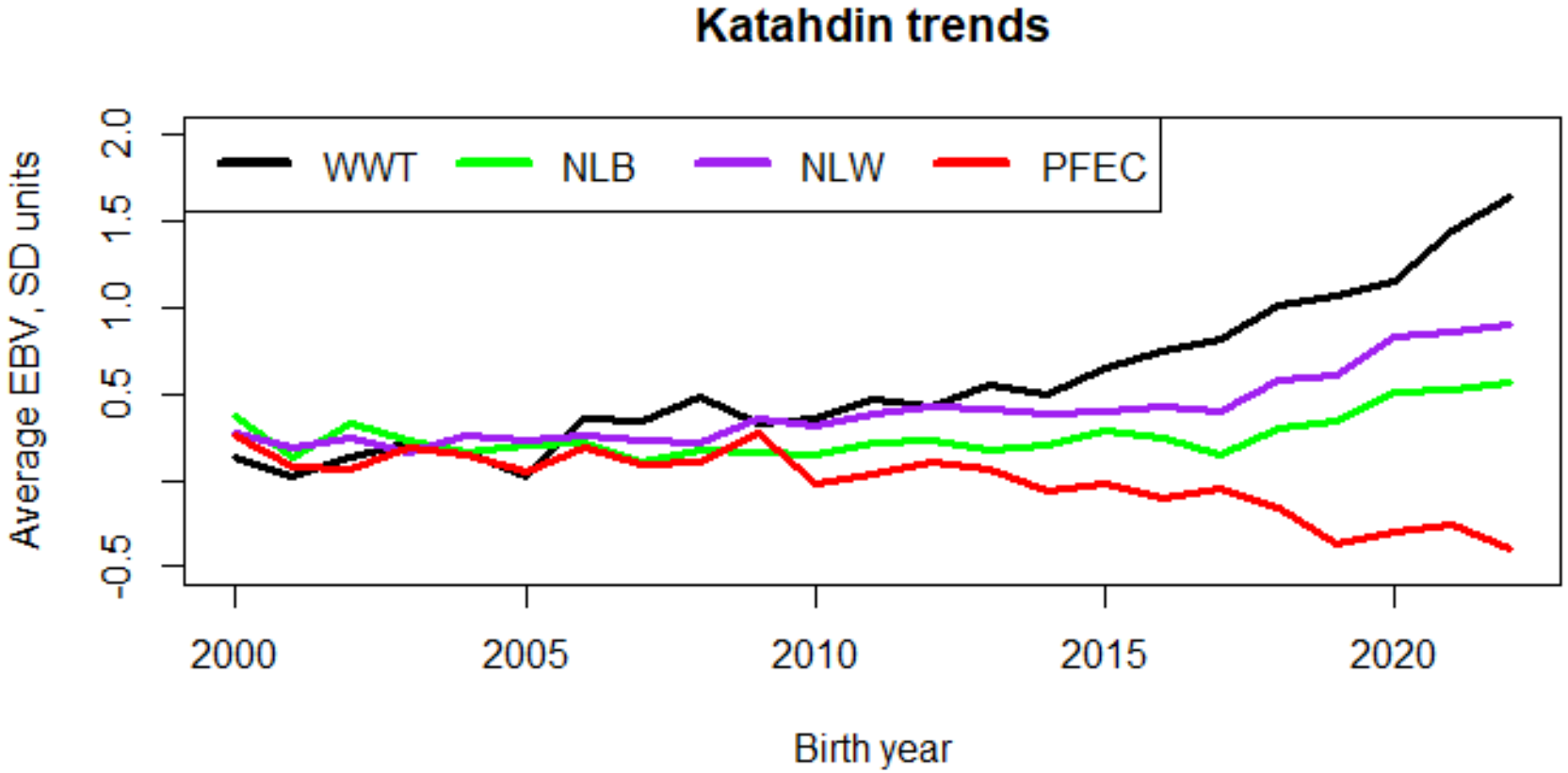
MPI progress – Katahdin

- Average MPI for 2018-2022 born rams was 1 point greater than 2009-2013 born rams.



Component trait progress - Katahdin

- From 2010 to 2020, gains in WWT (+2.3 lbs), NLB (+0.04 lambs), and NLW (+0.05 lambs). 21% reduction in PFEC.

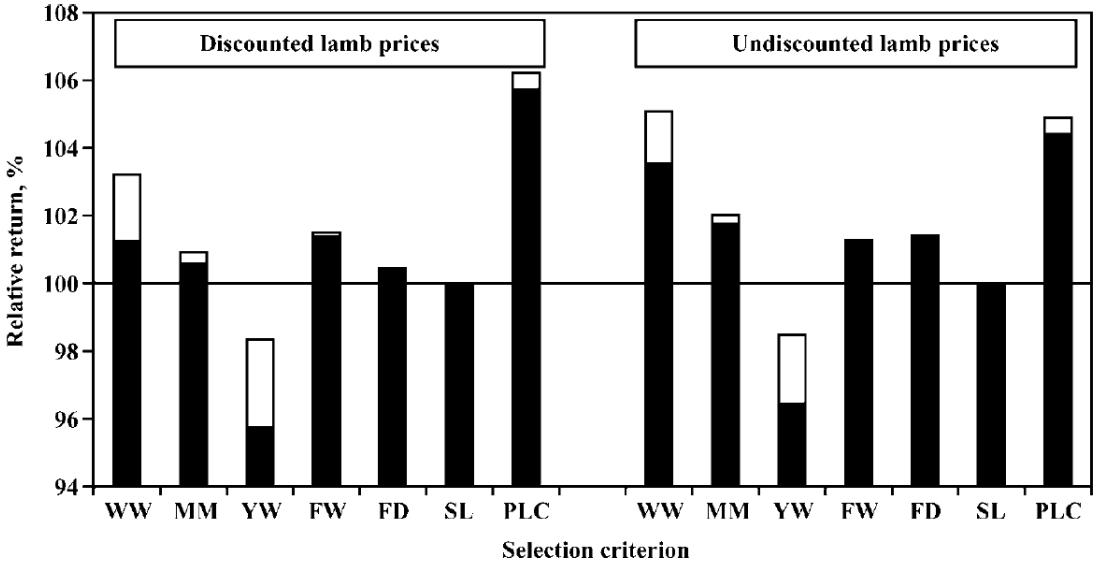


Western range index

$$WRI = 100 + 2.2 * EBV_{PWWt} + 0.6 * EBV_{MWWt} - 0.6 * EBV_{YWT} + 0.1 * EBV_{YGFW} - 0.5 * EBV_{YFD} + 36 * EBV_{NLB}$$

- Economic index developed by NSIP to predict genetic merit for profitability in a western range environment.

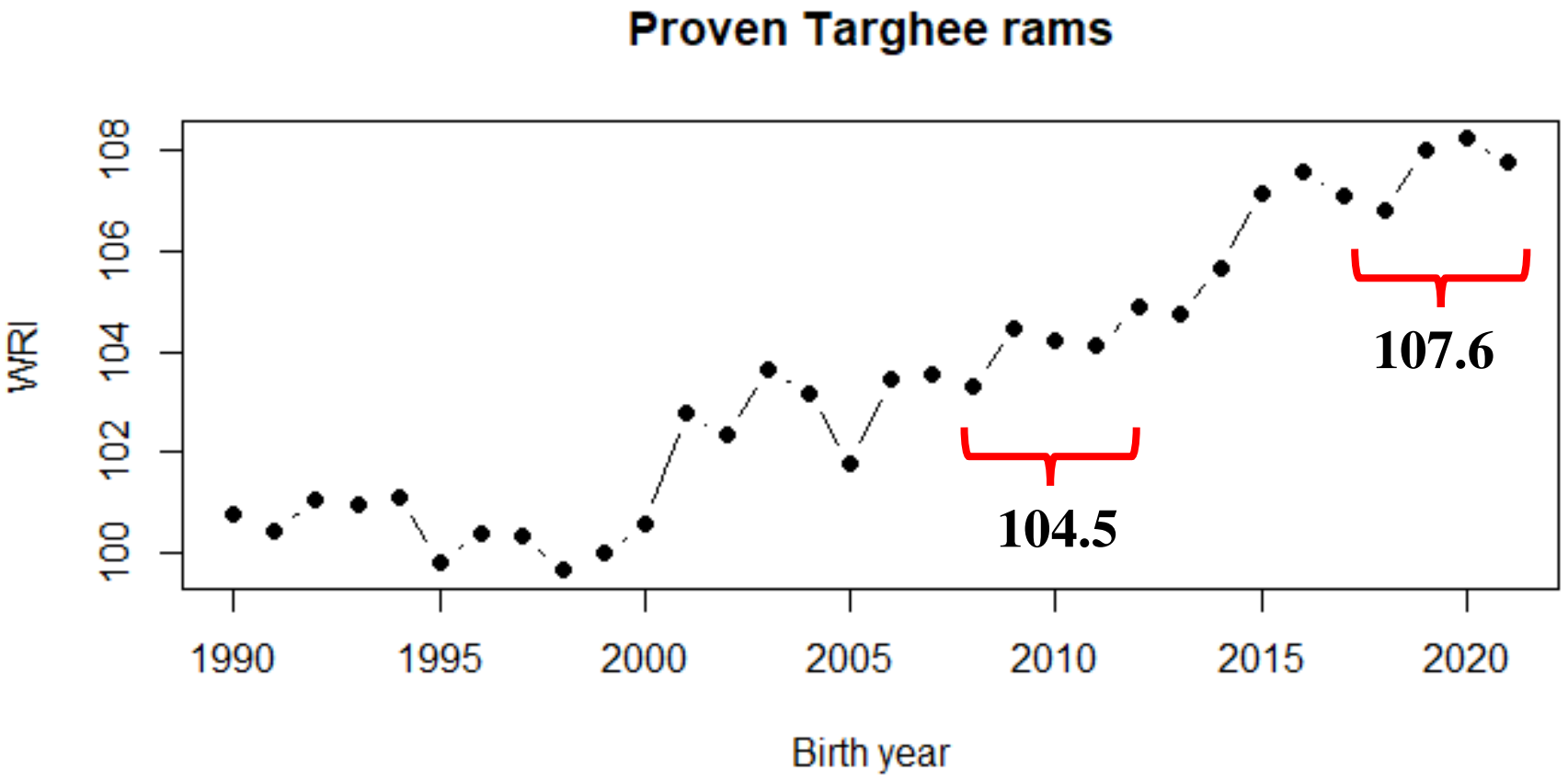
Across different lamb marketing, feed cost, average prolificacy, and triplet survival scenarios, increasing NLB and PWWT had the greatest impacts on flock profitability.



Borg et al., 2007

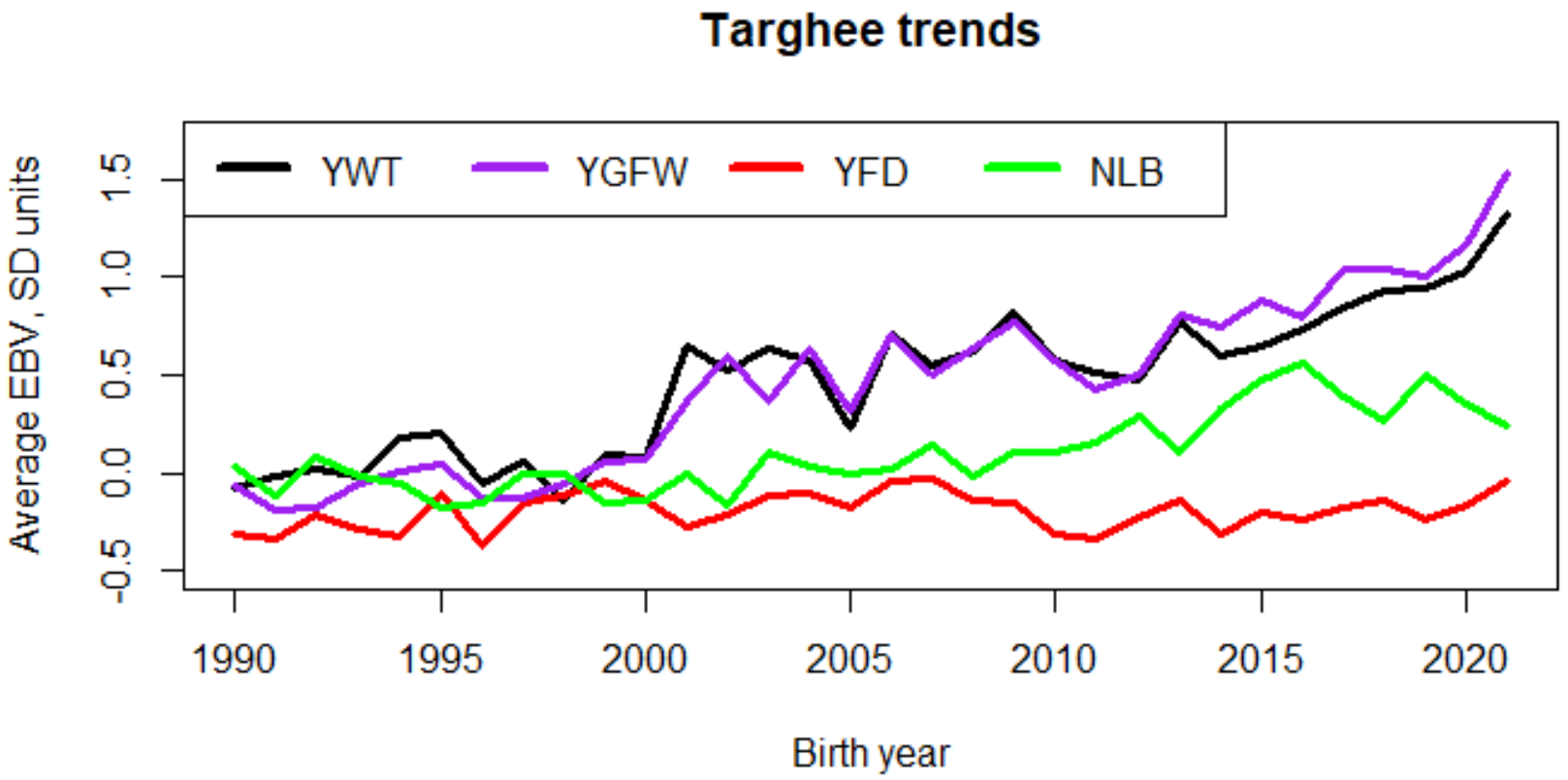
WRI progress – Targhee

- Average WRI for 2017-2021 born rams was 3 points greater than 2009-2013 born rams.



Component trait progress - Targhee

- From 2010 to 2020, gains in YWT (+3.3 lbs), NLB (+0.03 lambs), and GFW (+0.4 lbs), maintained YFD.



NSIP indexes in practice

- A well-designed selection index is the most efficient means of improving multiple traits simultaneously.
  - “Eliminates ‘analysis paralysis’, makes production decisions easier at home.”
  - “Makes purchasing decisions easier for buyers.” -Chase Hibbard, 2012
- Optimal selection indexes aren’t developed in a scientific vacuum – biases need to be set aside and two-way communication established to ensure a useful tool for multiple breeders.

Continued improvement

- **Carcass Plus Index:**
  - Simultaneously improves growth and muscling despite genetic antagonism (-0.40).
  - Doesn't consider costs and returns.
- **Maternal Productivity Index:**
  - Simultaneously improves multiple components of maternal ability.
  - Doesn't consider costs and returns. What about FEC?
- **Western Range Index:**
  - A true economic index for dual-purpose range sheep.
  - Developed in early 2000s with $0.76/lb lambs, $0.75/lb greasy wool, and $67/ton grass hay. Would current economics change the relative emphasis of traits?

Recognizing a true leader

- A special thanks to Dr. Ron Lewis for his selfless and tireless efforts to improve sheep populations throughout the world over the years. Cheers to a well-deserved retirement!