Using Genetic Selection to Improve Parasite Resistance in Sheep

Delma Kennedy

Ministry of Agriculture, Food and Rural Affairs

Ontario

What is the parasite problem?

Sheep can’t deal with large worm burdens as well as cattle

4 major GI parasites in Ontario

- ***Haemonchus* (barber pole worm)**
- ***Teladorsagia* (small brown stomach worm)**
- ***Trichostrongylus* (black scour worm)**
- ***Nematodirus***

multiple parasite species can occur on farms

- **proportions can differ between animals**

Control of Parasites – Integrated Pest Management

- **Grazing management** – rotational, mixed species
- **Nutrition** – Inc dietary protein = dec FEC, enhanced immune function
- **Vaccination** – Barbervax H contortus – frequent vaccination needed
- **Fungal biocontrol** – nematode trapping fungi destroy larvae in feces given every day
- **Bioactive forage** – tannins, lactones, alkaloids, saponins some control
- **Worm replacement** – reverted to original phenotype in 1.5yrs
- **Target selective treatment** – ADJ, FAMACHA

Source: Poli, Mario Andres et al. 2023. Genetic resistance to gastrointestinal parasites in sheep. CABI Reviews (2023) 18:1

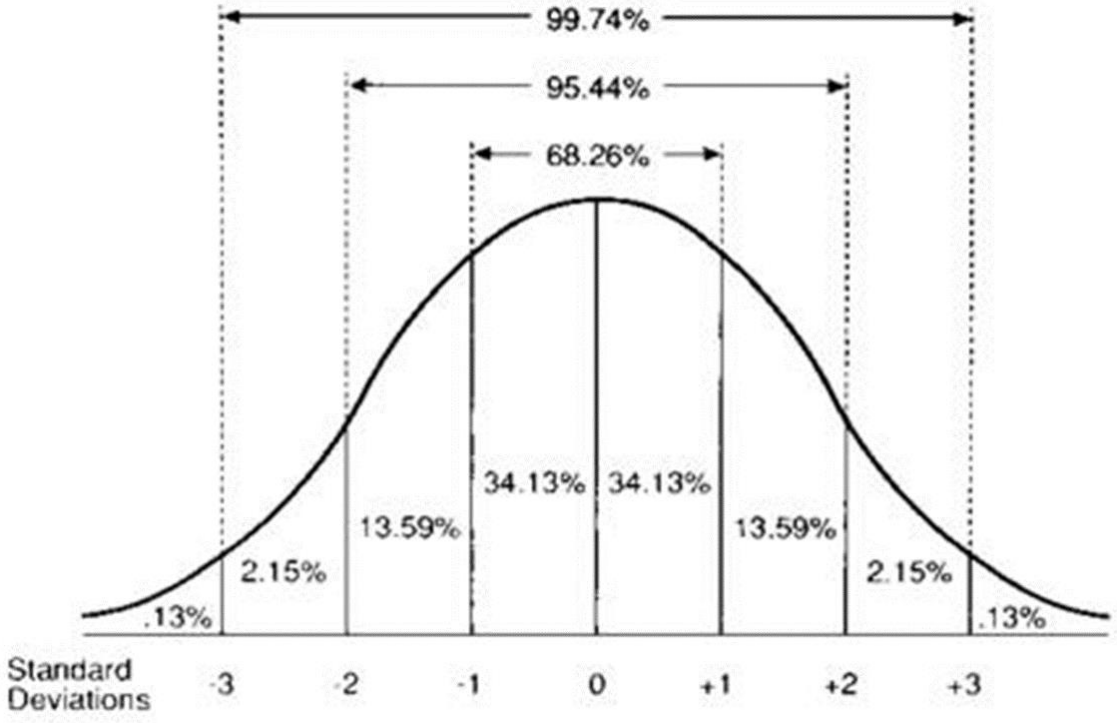
Immunity to Parasites or Parasite Resistance

- Resistance is ability of the sheep to control the parasite lifecycle by limiting establishment of ingested larvae, expelling adult parasites and/or controlling parasite fertility
- Development of immunity differences requires an initial exposure – immune system learns to adapt
- Sheep develop immunity to parasites – some better than others = variation = genetics ☺

Genetic Selection

There is variation in genetic resistance to parasites – this means you can select for it

- Longer term solution
- Fewer interventions needed
- Environmentally friendly
- Fecal egg counting is practical



Ontario

Selecting for resistance is not new

- Dec 1937 PW Gregory published paper “The possibility of establishing within breed lines of sheep that are genetically resistant to stomach worms
- Some breeds are known to be more parasite resistant

Breed difference Experiments, Louisiana State University

Breed	FEC (epg)	Blood Packed Cell Volume
Suffolk Ewes 1989	1225	23.9
Suffolk Lambs 1989	2279	21
Gulf Coast Native Ewes 1989	66	27.6
Gulf Coast Native Lambs 1989	1042	29.1
Suffolk Ewes 1990	740	22.3
Suffolk Lambs 1990	1924	26.3
Gulf Coast Native Ewes 1990	86	20.4
Gulf Coast Native Lambs 1990	434	30.7

Breed	# Dewormings
Suffolk Ewes 1989 -90	57
Suffolk Lambs 1989-90	46
Gulf Coast Native Ewes 1989-90	0
Gulf Coast Native Lambs 1989-90	11

Adapted from: Miller, J.E., Bahirathan, M., Lemarie, S.L., Hembry, F.G., Kearney, M.T., Barras, S.R., 1998. Epidemiology of gastrointestinal nematode parasitism in Suffolk and Gulf Coast Native sheep with special emphasis on relative susceptibility to Haemonchus contortus infection. Vet. Parasitol. 74, 55–74.

Ontario

Breeding for resistance in Merinos - AU

1973 use direct larval challenge and faecal egg counts (epg) to estimate genetic variation in resistance within flocks (Hc)

1977 estimates of heritability and genetic correlations with other traits

1978 begin selection experiments to demonstrate response to selection and create lines for immunology studies

Long term selection lines

CSIRO selection lines established in 1978:

- ***H. contortus***
- ***T. colubriformis***

UNE “Golden Ram” flock

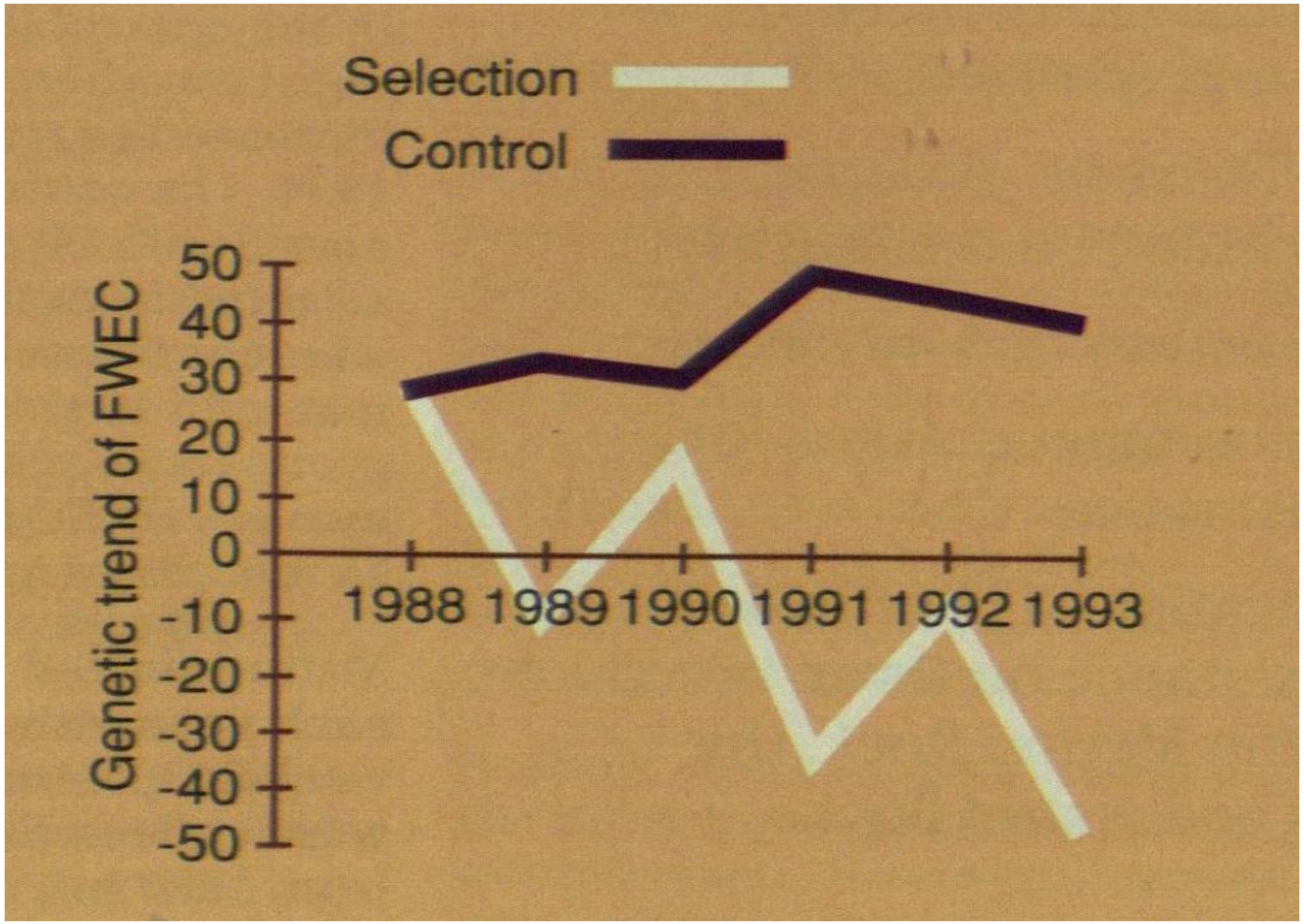
Hamilton selection lines (Victoria)

Rylington Park line (West Australia) established in 1987, sold 2020

Estimated heritabilities range from 0.2 to 0.3

Extensive research was done to improve genetic parasite resistance and establish protocols for selection

Response in Rylington Merino Selection Lines



1978 Selection lines
Moderately heritable
Added to Lambplan

1980-1992
Represents gain ~ 2.7% per year

Figure 3 Genetic Trend FEC. Karlsson, John; Greeff, Johan; and Harris, Julia (1995) "Breeding sheep for worm resistance," Journal of the Department of Agriculture, Western Australia, Series 4: Vol. 36: No. 2, Article 6.
Available at: https://library.dpird.wa.gov.au/journal_agriculture4/vol36/iss2/6

Ontario

Sheep selected for parasite resistance tend to have resistance to GIN parasites

- Early work in Australia was done with artificial infections of Haemonchus Contortus
- Natural infection work has shown that sheep selected that way are also resistant to other gastrointestinal worms like the small brown stomach worm, the black scour worm and the large bowel worm
- This makes selection easier because GINs can be counted without the need to identify species

Selecting for resistance also reduces pasture contamination

- Young lambs very susceptible to parasites
- By 12 months of age have developed some immunity
- Adult ewe – resistance levels high but immunity suppressed late pregnancy and early lactation

Worm Resistant less contamination than drenched

Early work in Australia showed resistant sheep contaminated pasture less than drenched, undrenched or control groups

Ontario

Change in drench usage for weaned lambs selected for worm resistance

- Early work in Australia (1980s) estimated that by using genetic evaluations with parasite resistance in the index at 70% emphasis would reduce the number of dewormings needed in lambs
  - 1st could be dropped after 9-13 years
  - 2nd after 11-16 years
  - 3rd after 13-18 years
- Deworming practices have changed since then but the concept that it takes time to change the genetics has not.

Ontario

New Zealand

- Increased breech soiling in low FEC Romney selection line
- Dag score now a trait
- Breeding for resistance = reduced pasture contamination
- CARLA = highly repeatable, can use drench if needed, one sample – but slower gain compared to selecting for FEC directly
- Have had breeding values since 2000.

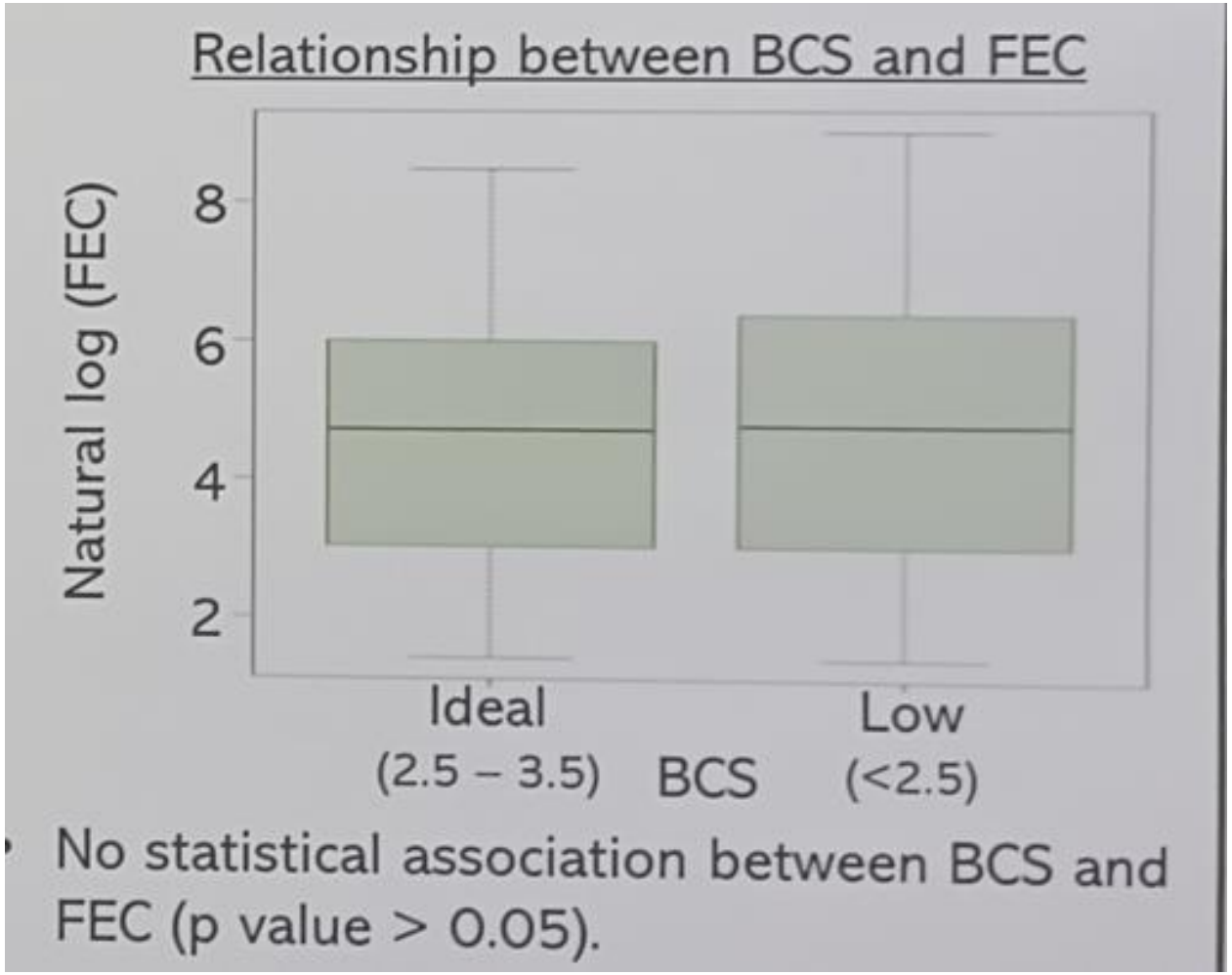
Source: SIL Dag Score Technical note: https://www.sil.co.nz/files/1500252357992.pdf

Ontario

Resistance vs Resilience

Resistant sheep have lower numbers of adult worms and shed fewer eggs

Resilient sheep have are not affected by the worm burden but do not have fewer worms or shed fewer eggs



Source: Lucie Weiland, Dr. Brad DeWolf, Dr. Andrew Peregrine. Evaluating the relationship between parasite fecal egg counts and FAMACHA, Dag and body condition score in Ontario pastured sheep. Poster Competition. OSF Annual Meeting Oct 2023.

Ontario

What is our experience in Ontario?

- **2006-2008** study what parasites – Gastrointestinal nematodes (GIN) were typical on farm
  - *Trichostrongylus axei, Teladorsagia circumcincta, Haemonchus contortus, Trichostrongylus colubriformis*

- **2008** – first identified anthelmintic resistance

- **2010 and 2011** – field study found resistance to almost all dewormers with Haemonchus contortus – most common resistant parasite

- One farm– wanted to start selecting sheep for parasite resistance.
  - **2012** Measured FEC in 17 rams
  - **2016** Started recording weight, BCS and FAMACHA

Ontario

Parasite Resistance is Heritable

- Biggest problem in Ontario is usually haemonchus – August – maybe into fall
- Selection for FEC little effect on production traits
- Moderately heritable 20-30%
- NZ had trouble with dagginess in selected animals
- NZ doesn’t recommend collecting FEC if mob average is less than 500 epg
- Best evaluation with 25-30 progeny per sire and two FEC
- Genetic differences are far more pronounced after the immune system is triggered by an initial exposure

Ontario Project

AU Grass Based Protocol

- Ensure lambs have had a worm challenge
- Weaned for at least 6 weeks at time of FEC
- Lambs > 23kg
- Ave group epg =>800
- Take individual fecal egg counts, weigh, drench

Accelerated RI flock
Lambs raised indoors
Short summer

Ontario producer protocol

- Lambs born winter, feedlot to grass after selection in August (1st exposure)
- 2nd exposure – following summer
- Rams to grass in May, test in July, (2 samples a week apart)
- Ewes lambing – 2nd exposure after weaning in August (1 sample)

Ontario

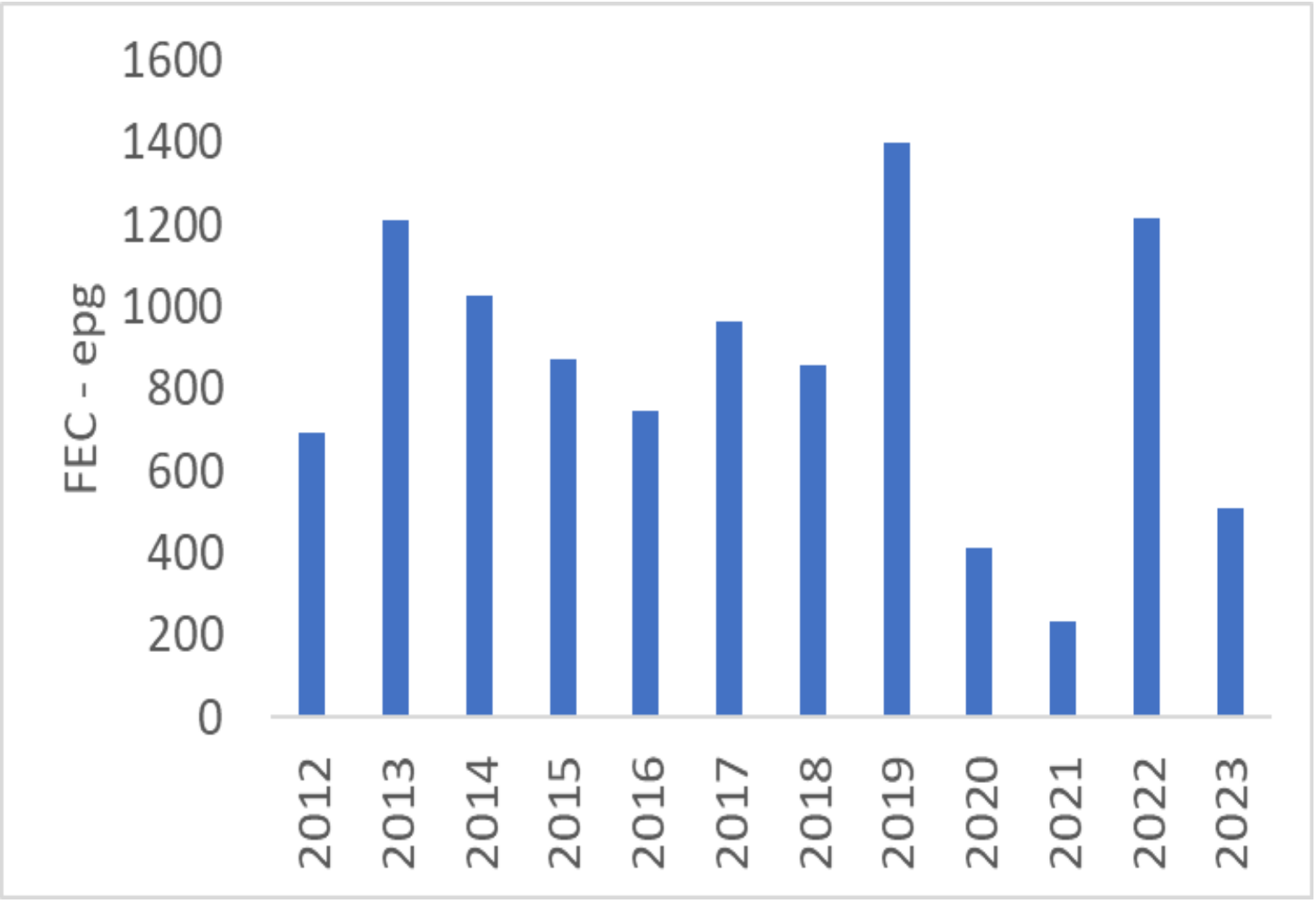
Variation Between Animals

Trait	Yearling Rams					Yearling Ewes				
Year	Records	Animals	Range	Mean	SD	Records	Animals	Range	Mean	SD
FEC_MM										
2012	27	17	0 – 2,700	717.6	800.1	-	-	-	-	-
2013	28	21	50 – 5,600	1,292.9	1,540.1	25	25	0 – 5,250	1,120.0	1,209.3
2014	64	32	0 – 6,600	1,032	1,542.5	89	89	0 – 16,750	1.020.8	1,856.8
2015	72	37	0 – 6,550	736.8	961.3	111	111	0 – 8,800	959.0	1,287.7
2016	68	34	0 – 17,500	1164	2,392.0	89	89	0 – 4,400	428.7	772.8
2017	66	33	0 – 8,000	1,514.4	1,685.9	82	82	0 – 2,900	522.6	685.8
2018	72	40	0 – 6,950	1,500.7	1,480.0	86	86	0 – 2,850	324.4	585.7
2019	91	46	0 – 16,600	1,311.5	3,081.2	16	16	0 – 12,400	1,900.0	3,674.1
2020	85	46	0 – 8,250	566.5	1,300.3	68	68	0 – 3,150	219.9	398.8
2021	122	61	0 – 3,200	329.9	433.0	80	80	0 - 400	86.2	96.8

Source: Erin Massender, Fall 2021

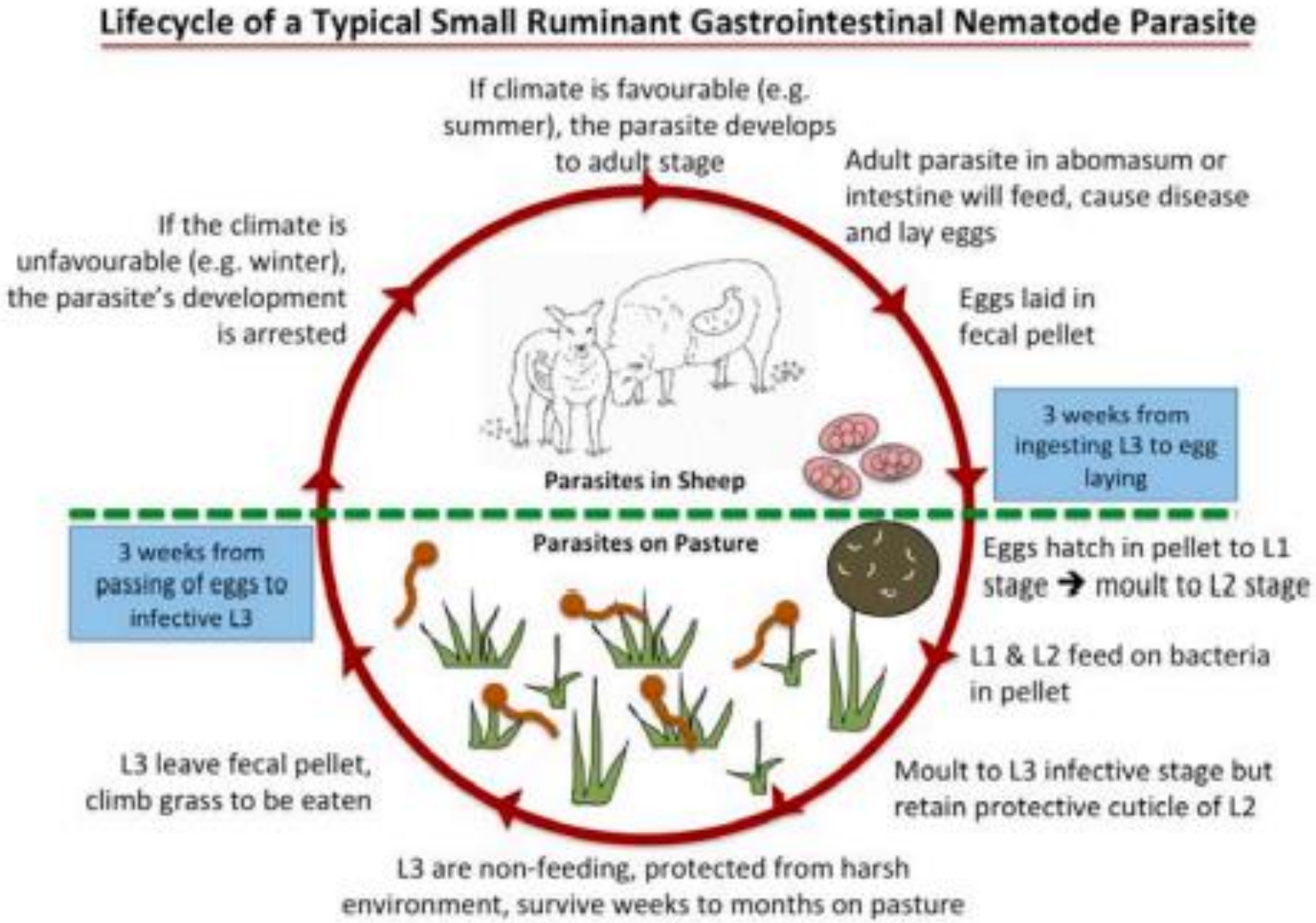
Ontario

Average FEC by Year



Some years, difficult to get high enough worm challenges for the best selection

Ontario



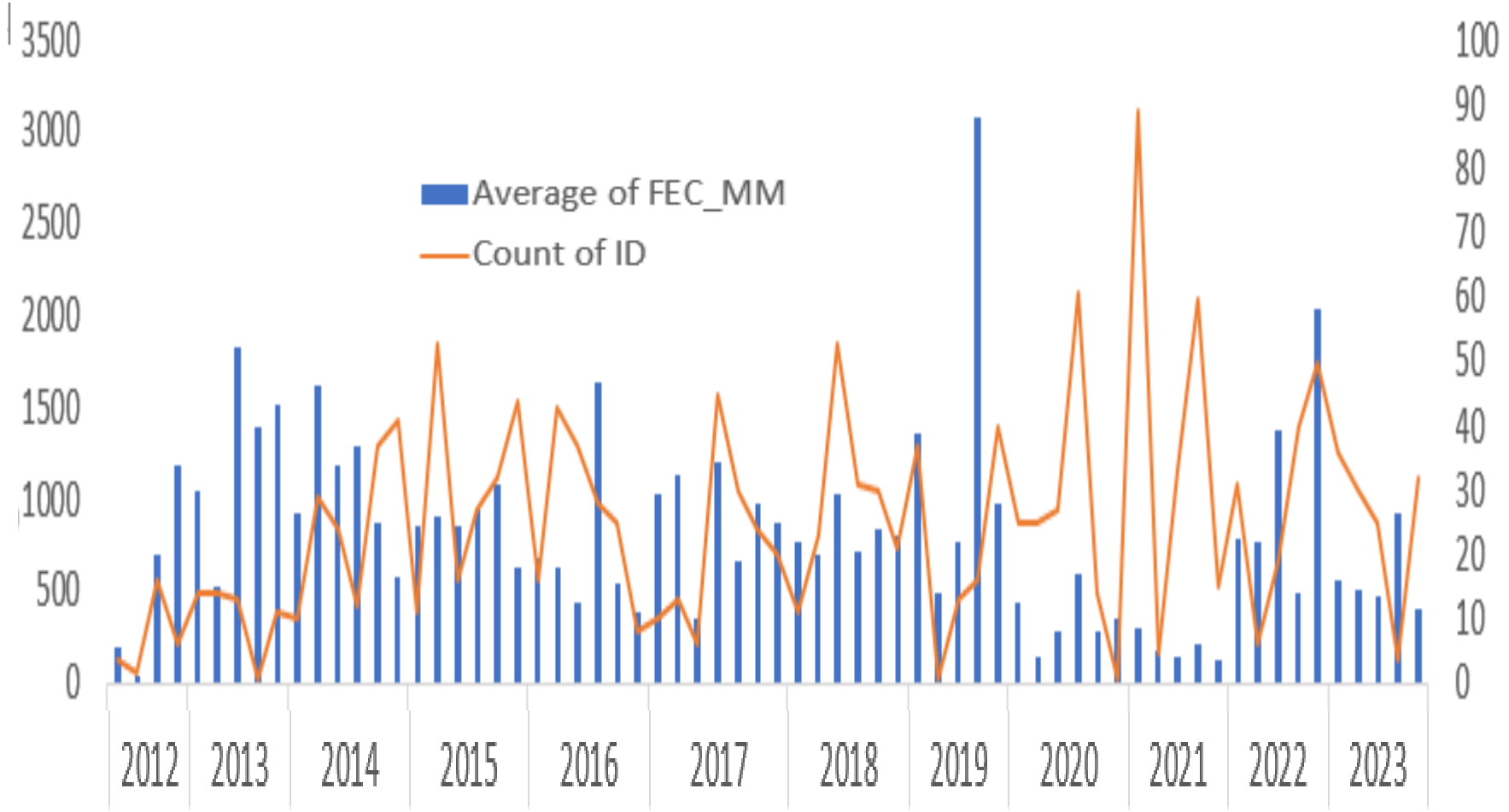
< 10 C no larval development
16-37C optimal larval development (variation by species)

Note: 3wks for development outside the sheep and 3 wks (16-21 days) in the sheep -

Source: Handbook for the control of internal parasites of sheep and goats – April 2019 University of Guelph.
https://www.ontariosheep.org/uploads/userfiles/files/Parasite%20Handbook_April_2019%20updated_reduced.pdf

Ontario

Average FEC of Progeny and Number of Progeny by Sire by Year of Test



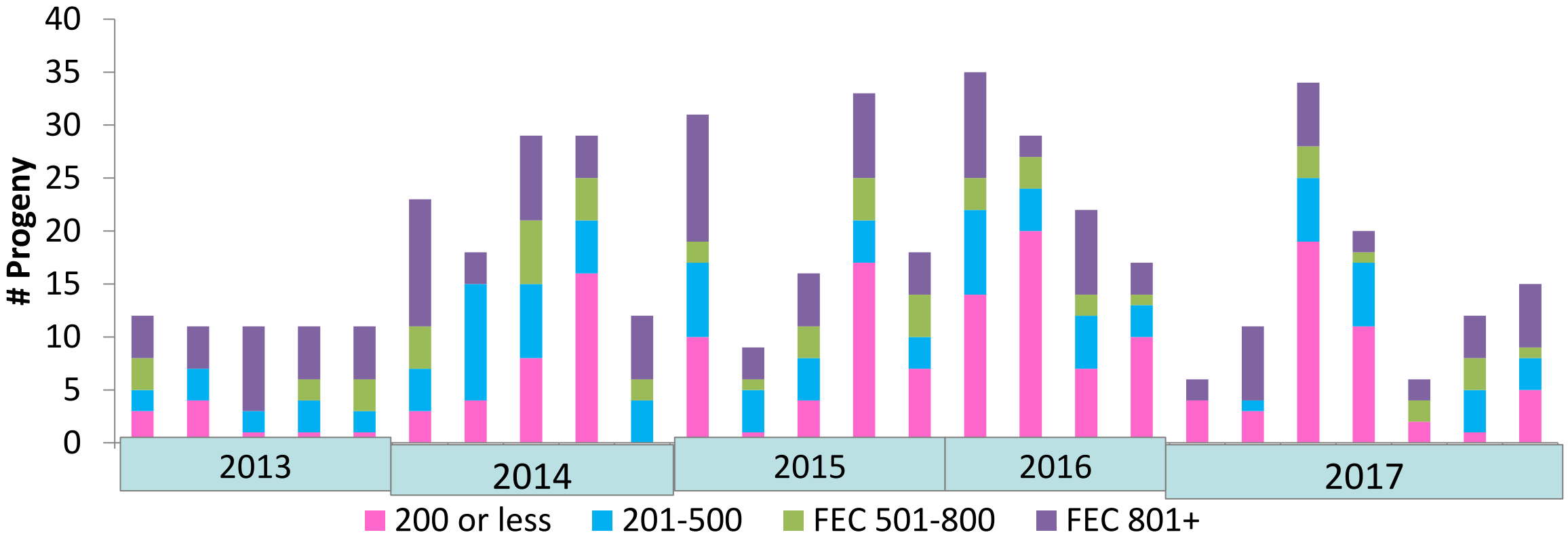
Another challenge:
progeny per sire to develop EBVs for improved selection

Graph Courtesy of Andrea Bajus

Ontario

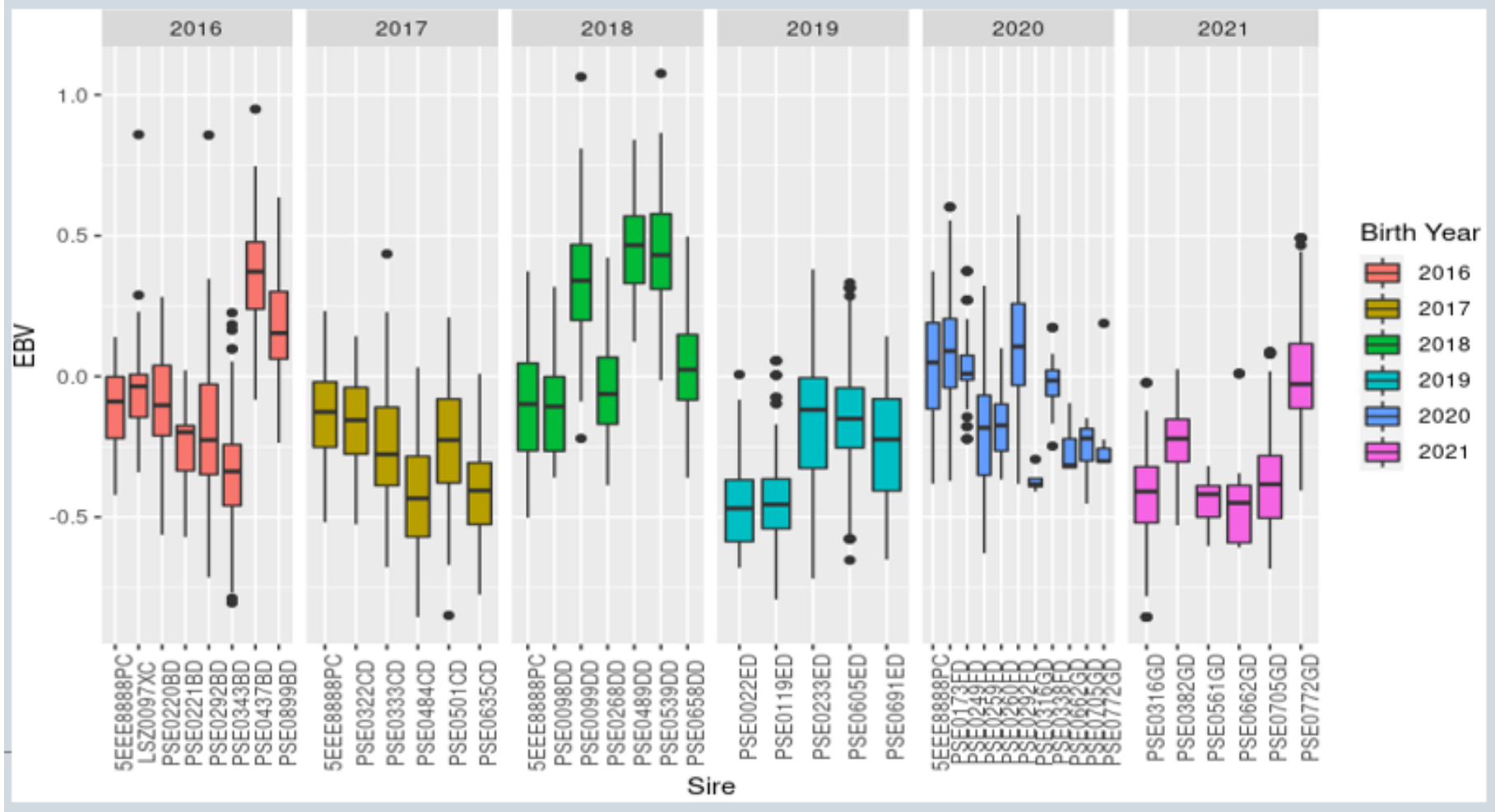
Sire Progeny FEC by Category

Range of values in sire progeny
Are we making progress?



Ontario

Variability in Progeny EBV by Sire

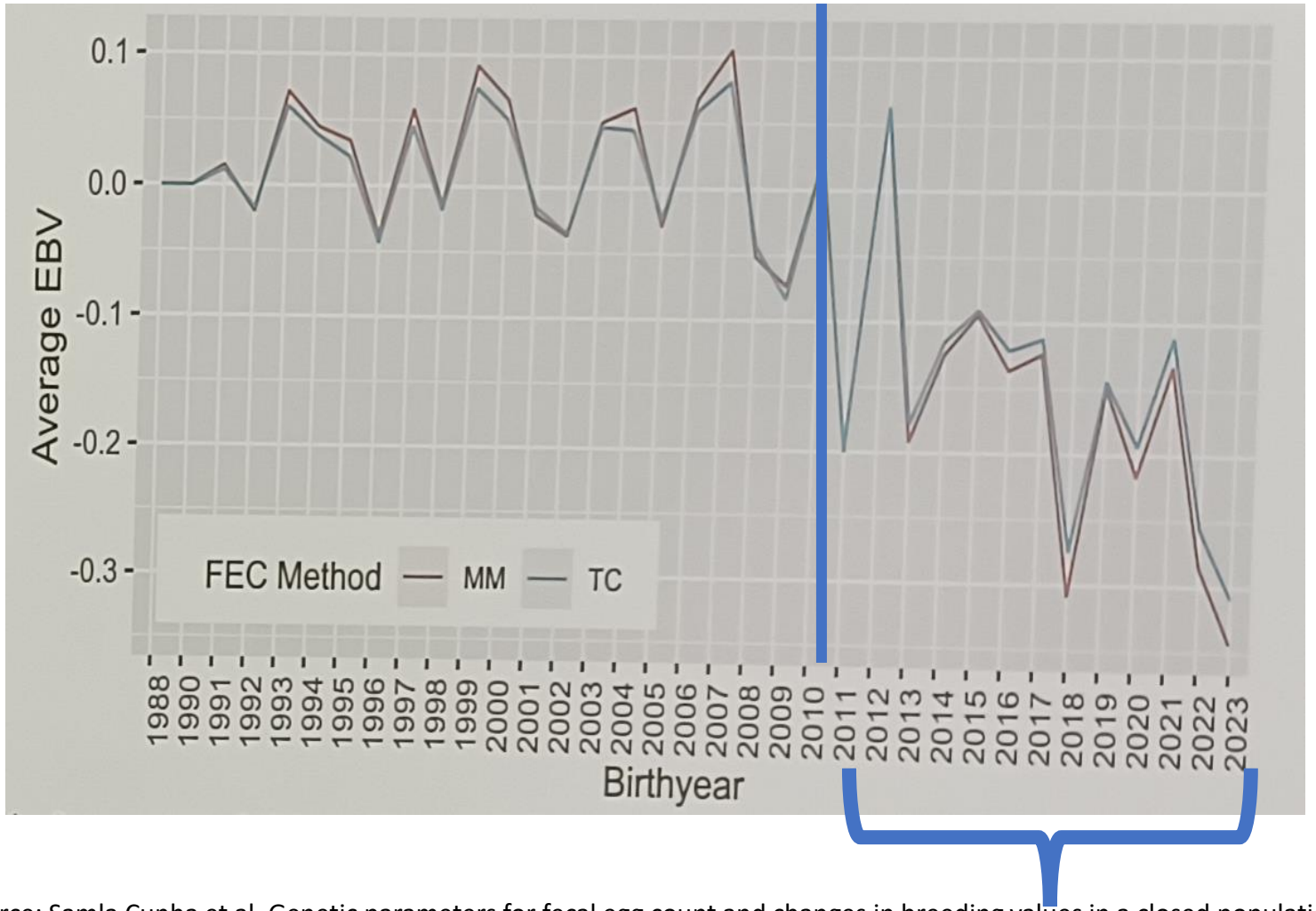


Use of EBVs takes out seasonal variation of FEC

Source: Erin Massender, Fall 2021

Ontario

Genetic Change



Annual genetic gain (2012-2023) = 2.8%

Up and down year to year - small #s of animals

Heritability = .14
AU = .2-.3 (artificial challenge)

Source: Samla Cunha et al. Genetic parameters for fecal egg count and changes in breeding values in a closed population of Arcott-Rideau sheep in Ontario. OSF Poster Competition Oct 2023. Figure 1. Average of the estimated breeding values (EBV) per birth year.

Ontario

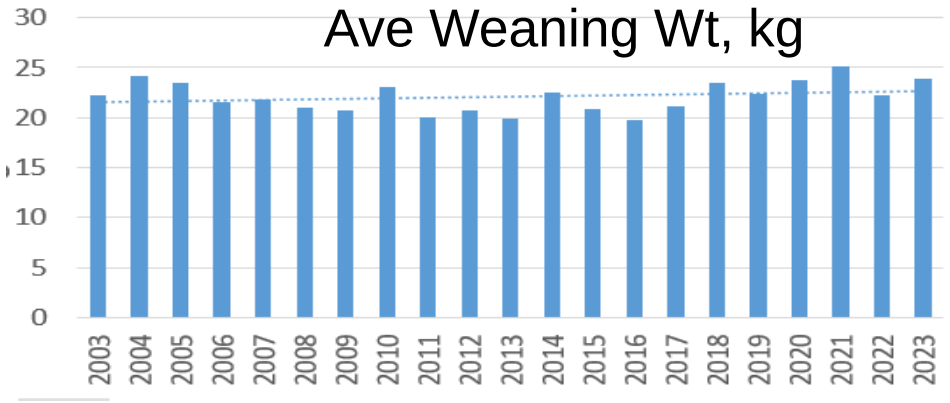
Why is genetic selection worth it?

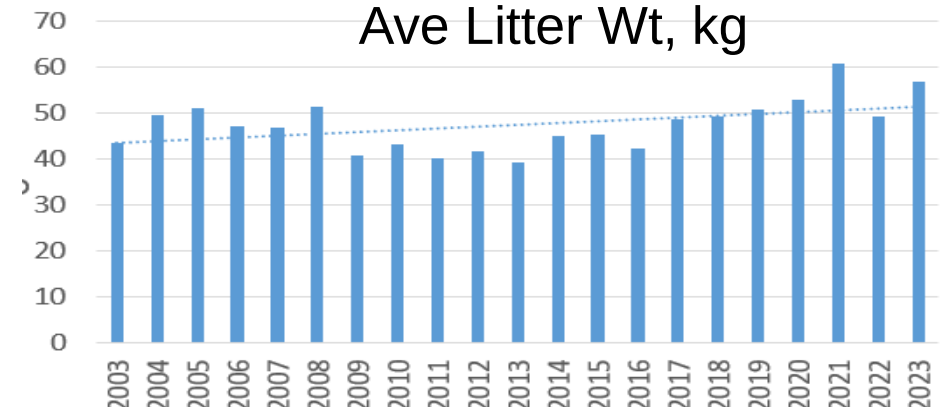
- Foundation of your sheep flock
- Ignoring it can be the difference between profitable and not
- When you do everything else right – genetics becomes your limiting factor

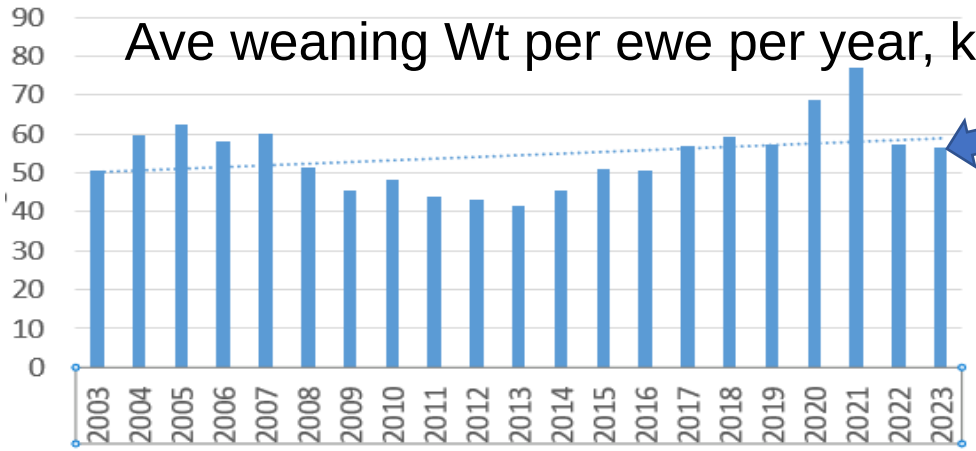
From:https://unsplash.com/s/photos/smart-car?license=free

Farmer Observations

- Less dewormer
- Can use pasture based on grass growth without worrying about the parasite lifecycle most of the time
- Animals look better
- Increased production, maybe less ewe stress
- Best thing ever did







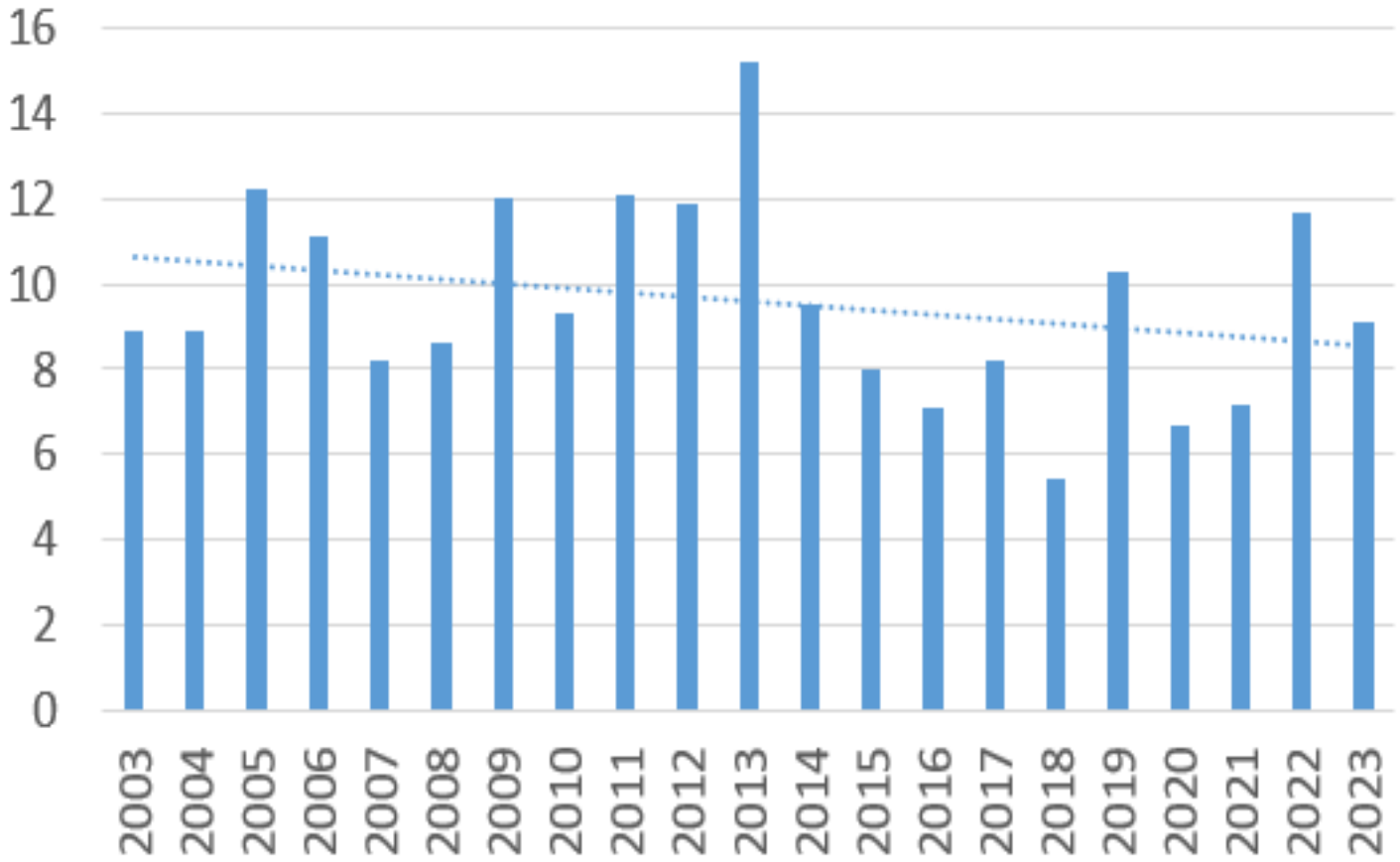
Fall lambing not included yet

Flock Performance

Progeny weight has changed
2008 Anthelmintic resistance identified
2012 First rams selected
2013 tested replacement ewes
2014 First progeny tested from selected rams

Ontario

Flock Performance



Flock Average Lamb Mortality %

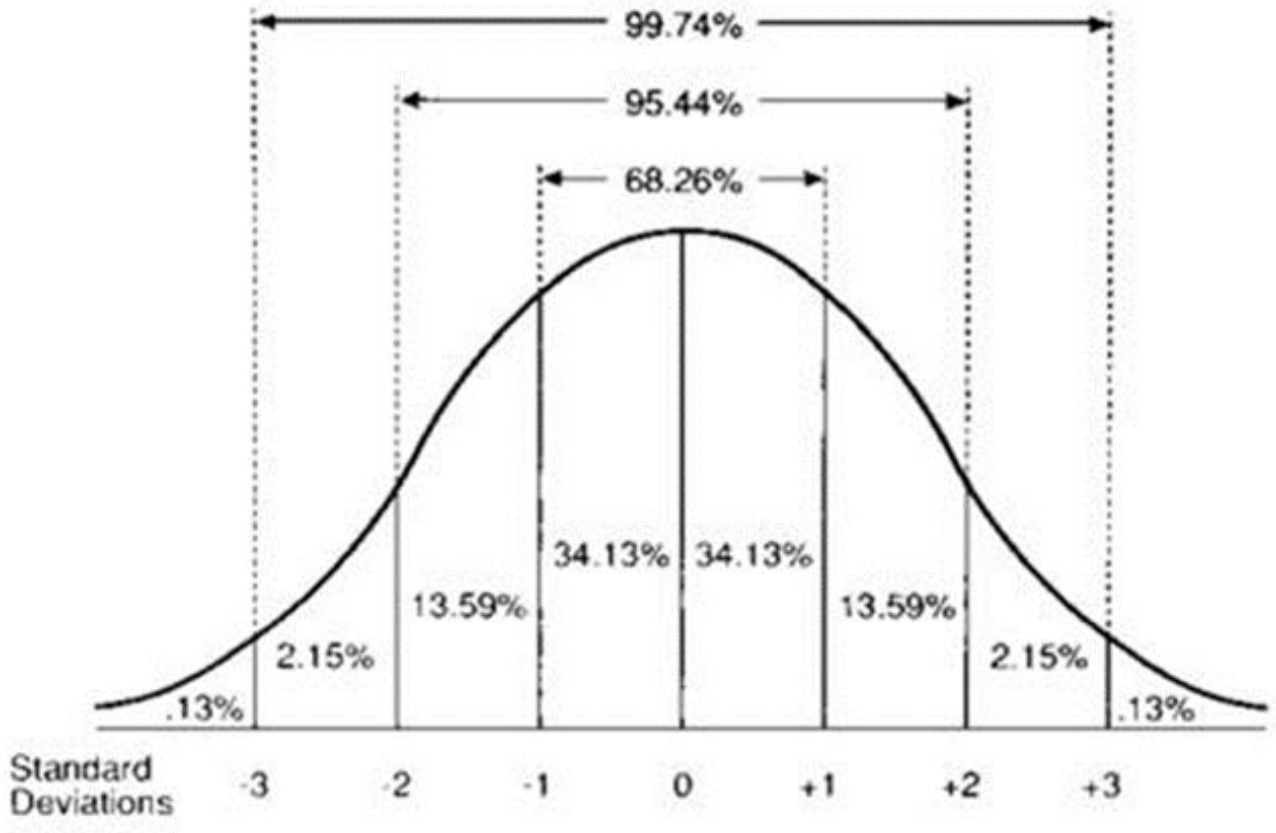
Same time has had better success in controlling mortality

Production improvements have paid for FEC selection

Ontario

How to begin selecting for FEC on your farm

- Who to measure?
  - Lambs
  - Rams
  - Ewes
  - Replacement animals
- What can you afford?



Ontario

On Farm FEC Measurement

Genetic differences are more likely to be identified when egg counts are high and variable with a minimum number of zero counts

Grass Based Protocol

- Ensure lambs have had a worm challenge
- Weaned for at least 2-3 weeks at time of FEC
- Minimum 10-12 weeks of age
- Lambs > 23kg
- Ave group epg =>800
- Take individual fecal egg counts, weigh

Lambing born/raised in Barn

- Lambs must have initial challenge and recover
- A 2nd challenge ave group epg =>800 (5-6 weeks after drenching/recovery)
- With our short season – 2nd grass season?

Ontario

On farm Selection

- Identify high FEC replacements – 1 sample
  - Remove high shedders
- Selecting small number of animals from a group – 2 samples for more accuracy
- Example:

Ewes, August 2015

Ontario

2012 Tested Rams, 2014 Progeny

Ram Lambs

13 – 15 mos (July 16th)

1st FEC
- Group Ave 854
- Range 0-2700
- 18% zero

2nd FEC
- Group Ave 440.9
- Range 0–1300
- 18% zero

ID	BirthDate	FEC	FEC
619	24-Mar-11	**850**	**0**
699	28-Mar-11	**1400**	**150**
783	30-Mar-11	**0**	
831	01-Apr-11	**1100**	
868	02-Apr-11	**0**	
869	02-Apr-11	**2550**	**400**
888	02-Apr-11	**150**	**300**
889	02-Apr-11	**75**	**300**
932	04-Apr-11	**50**	**50**
10	06-Apr-11	**450**	
11	06-Apr-11	**2700**	**1250**
80	09-Apr-11	**2500**	
81	09-Apr-11	**400**	**1300**
190	18-May-11	**700**	
191	18-May-11	**500**	**0**
282	26-May-11	**1100**	**700**
403	04-Jun-11	**0**	**400**

Repeated measure in same infection cycle increases accuracy by 25% in AU

ID	Ave Progeny FEC	# Prog
11YC	1633	29
81YC	1183	24
191YC	1300	12
888YC	877	37
932YC	579	41

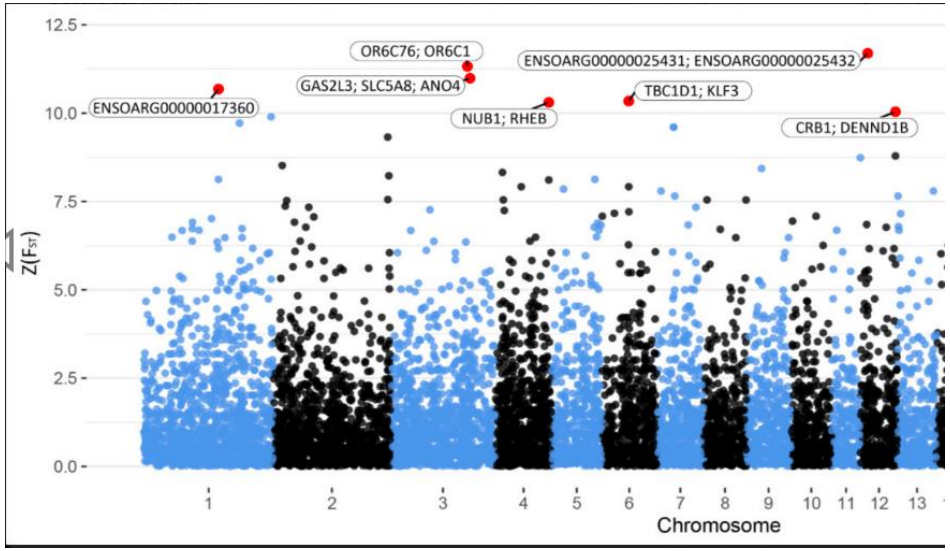
Ontario

Waiting for Genomics?

- Genetics is not a simple science!
- In the early 80s – map the genome choose the traits needed.
- Turns out it is more complicated than that!! (Epigenetics)
- This is mother natures way of ensuring a species can adapt to environment change.

Genomics

- Work has begun
- Improves accuracy = speed of change
- Does not change the need to record FEC
- Parasite resistance – many genes with small effects. Need many phenotypic records to understand differences between results obtained from diff studies
- How the genetics of resistance in our sheep compare to those in other countries?



Manhatten plot, candidate genes for milk yield. Source: Abousoliman I, Reyer H, Oster M, Murani E, Mohamed I, Wimmers K. Genome-Wide SNP Analysis for Milk Performance Traits in Indigenous Sheep: A Case Study in the Egyptian Barki Sheep. Animals. 2021; 11(6):1671. https://doi.org/10.3390/ani11061671

Ontario

CARLA - Saliva test developed in NZ

Advantages

- Cheek swab easy to do
- Not affected by drenching
- Good CARLA response = less egg shedding
- May be able to identify replacements in fall of first year on grass

Disadvantages

- Cost - Currently not available in Canada
- NZ estimates Carla selection will reduce FEC ~ half of the rate of selecting for FEC directly
- Still need a significant challenge, and preferably a recent challenge

FEC Digital Counting

ParaSight System Technology

For Veterinary practices – will digitally count FEC for dogs, cats, sheep, goats, horses, cattle and chickens

2017 – research paper tested evaluation of accuracy of smartphone based automated parasite egg counting – don't see anything commercial

Hopefully will reduce cost per sample

Ontario

Conclusions

- Genetic resistance to parasites
  - Reduces parasite load on pasture
  - Reduces dewormer use
  - Enables other management techniques to work better
  - Can be done on your farm with FEC now
  - 10 year project

Ram Lambs May 24, 2023

Ontario

Ontario