Lessons from studies in genetics of heat stress

Ignacy Misztal
University of Georgia

Animal Breeding and Climate Change

- Remarkable success of breeding
  - Kg milk 1944-2007: 23% feed, 35% water, 37% CO2 (Capper et al., 2009)
  - Broiler 1957-2001: grows 3 times faster using 33% feed (Havenstein et al., 2003)
  - …
  - > 50% gain via genetics (Shook, 2006; Havenstein et al., 2003).

- Challenge of climate change
- Do we need a special breeding for resilience?

Selection as optimization

- Domestication
- Intensive selection

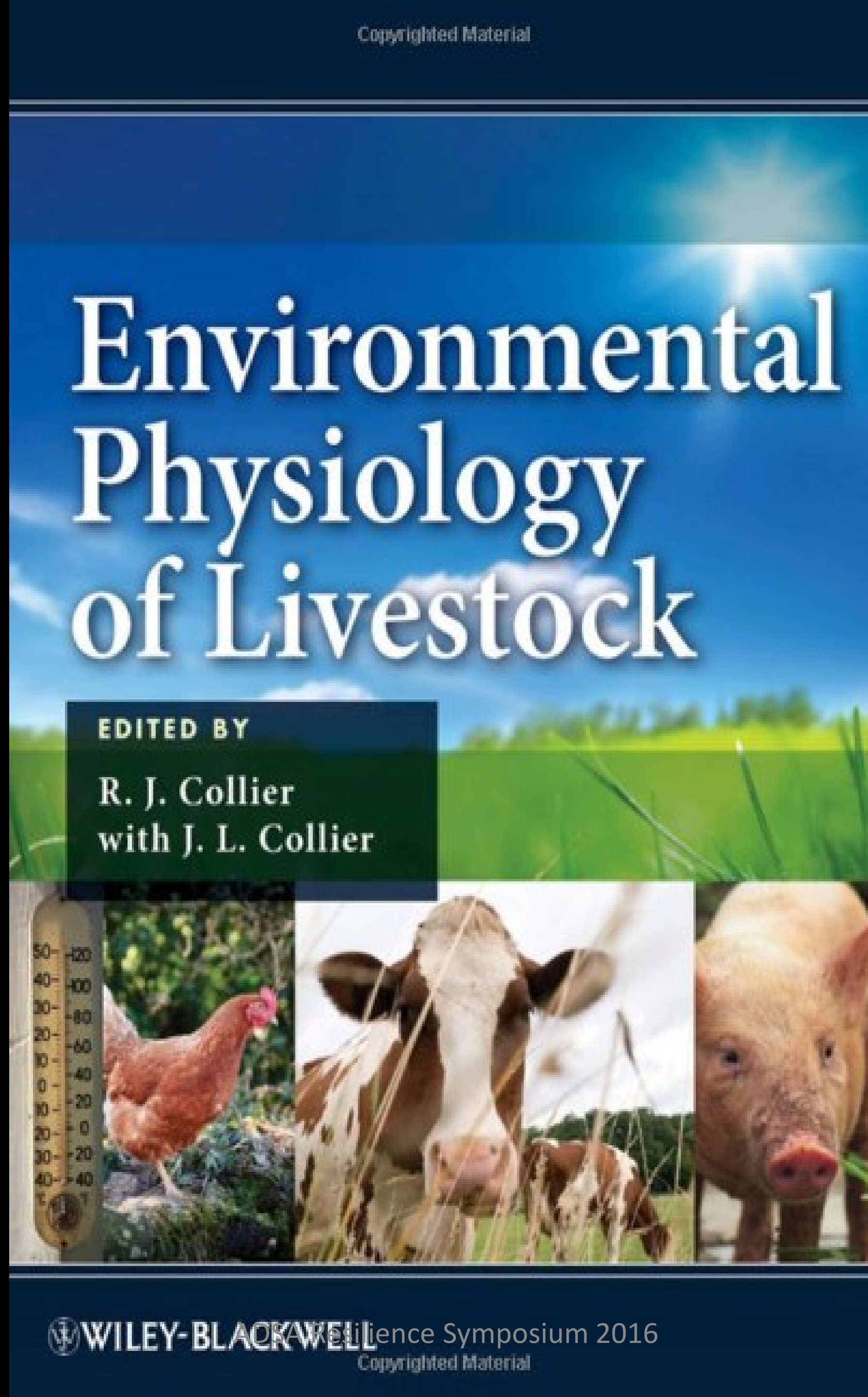
- Gains for preferred traits
- Correlated losses for other traits
- Effect of losses reduced/eliminated by management

- Very poor fitness of domesticated animals have when released back into the wild (Frankham, 2008).

Climate change

- Greater variations
- Hotter

- Extensive literature on heat stress/tolerance
- Heat tolerance as proxy for resilience
- Can one select for heat tolerance?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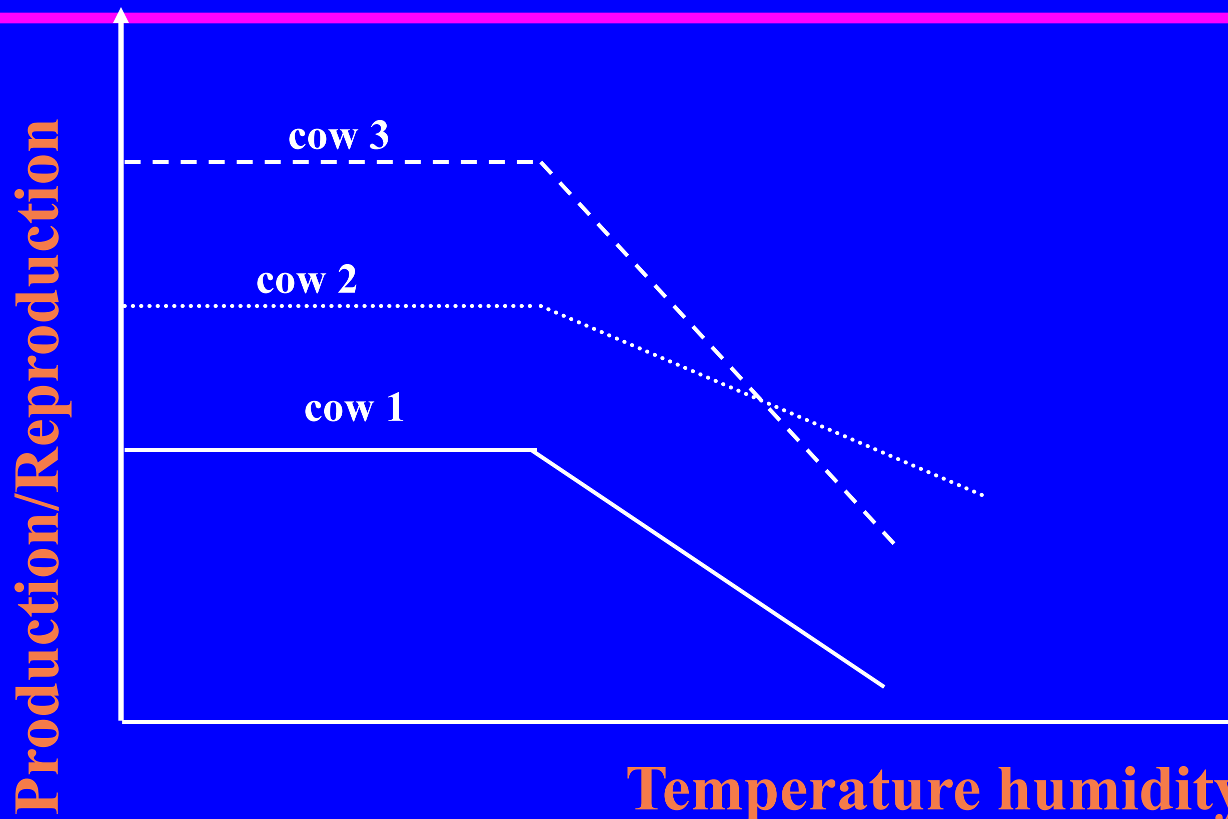
Challenge of heat stress

- Perceived reduction of heat tolerance in hot areas
- Little observable heat stress with DHI data (e.g., Wright et al., 2015)
- Mainstream selection in Holsteins in milder/colder climates
- Selection against heat tolerance?
  - If so, can one select for heat tolerance?

Assumption for heat stress model

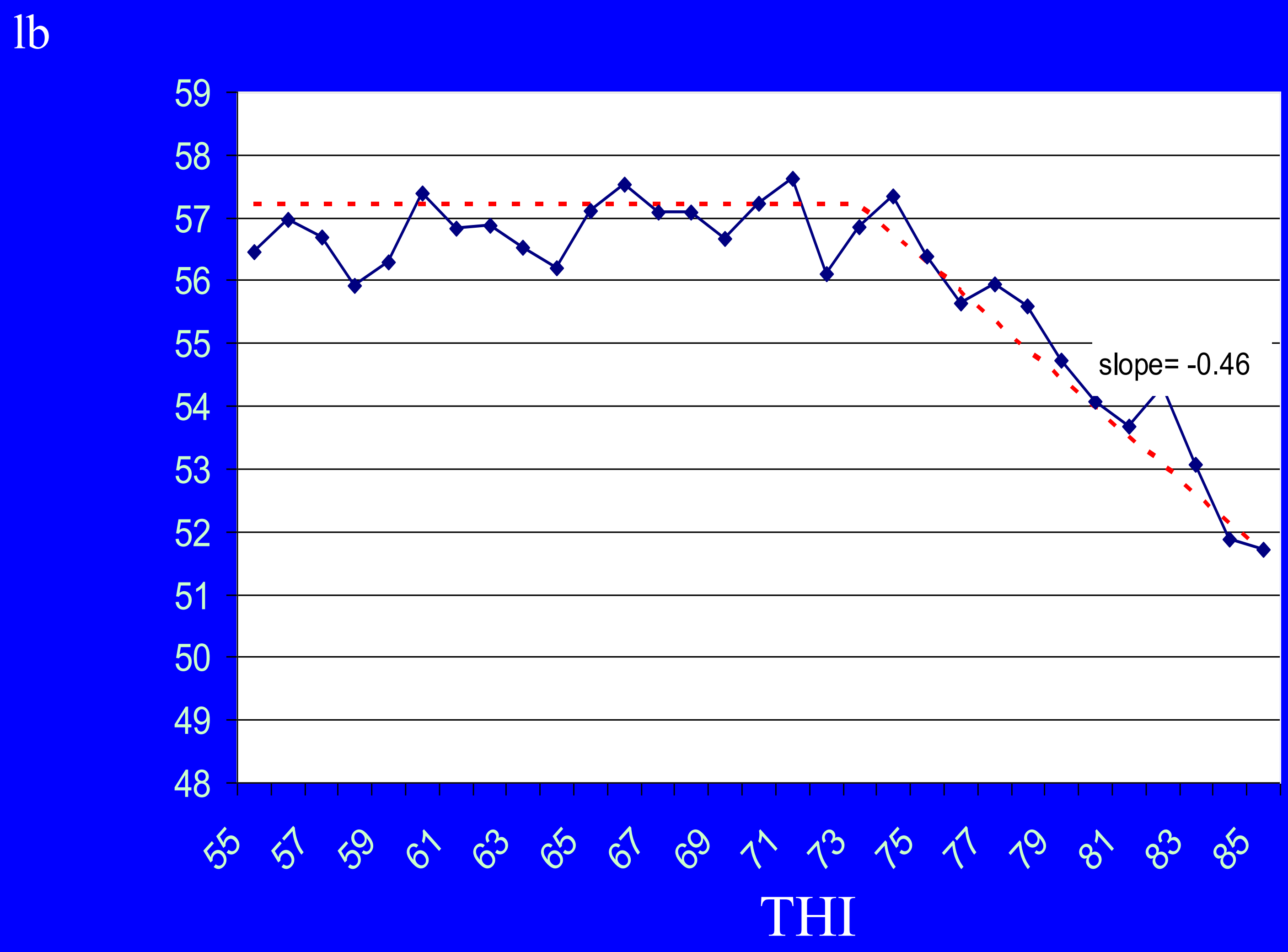


Ravagnolo et al., 2001

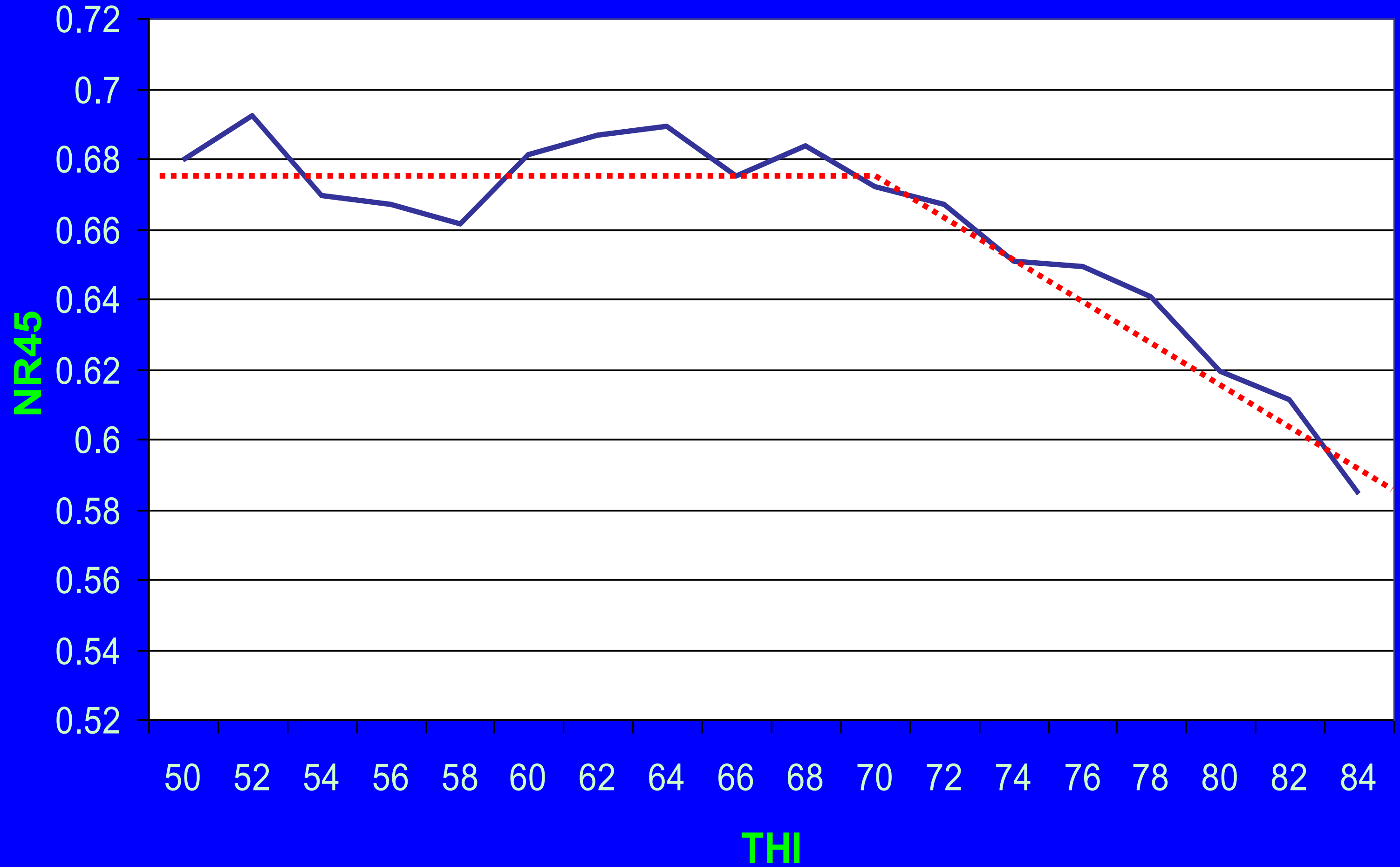
Breeding value: $BV = a + f(THI)*v$

a – regular breeding value v – heat-tolerance breeding value
f(THI) – function of temperature humidity index

Effect of THI on daily milk production



Effect of THI on Non-return rate at 45 days



Genetics results

- Heat stress begins at about 72F THI (22C at 100% humidity)
- Genetic variability for heat tolerance present but not big
- Relationship between regular and heat tolerance genetics antagonistic at ~ -0.4

Heat stress across USA

- Variation in heat tolerance across USA
- Genetic evaluation for heat stress with national data
  - Do colder regions contribute information about heat stress?
  - Profile of heat tolerant bull
  - Can one identify heat-tolerant sires?
  - What are they?

Bohmanova et al. (2005 and 2006)

Differences between most 100 and least 100 heat tolerant sires

Milk	-1100kg
Fat%	+0.2%
Pro%	+0.1%
Dairy Form	-1.4
Udder	+0.7
Longevity	+0.90
Fertility	+1.6
Index	+36

- Selection for fluid milk detrimental to heat stress
- Low accuracy of active sires for heat stress

Heat stress in later parities (Aguilar et al., 2009)

- US test days
- 3-trait RR and RPT models
- Heat stress effect

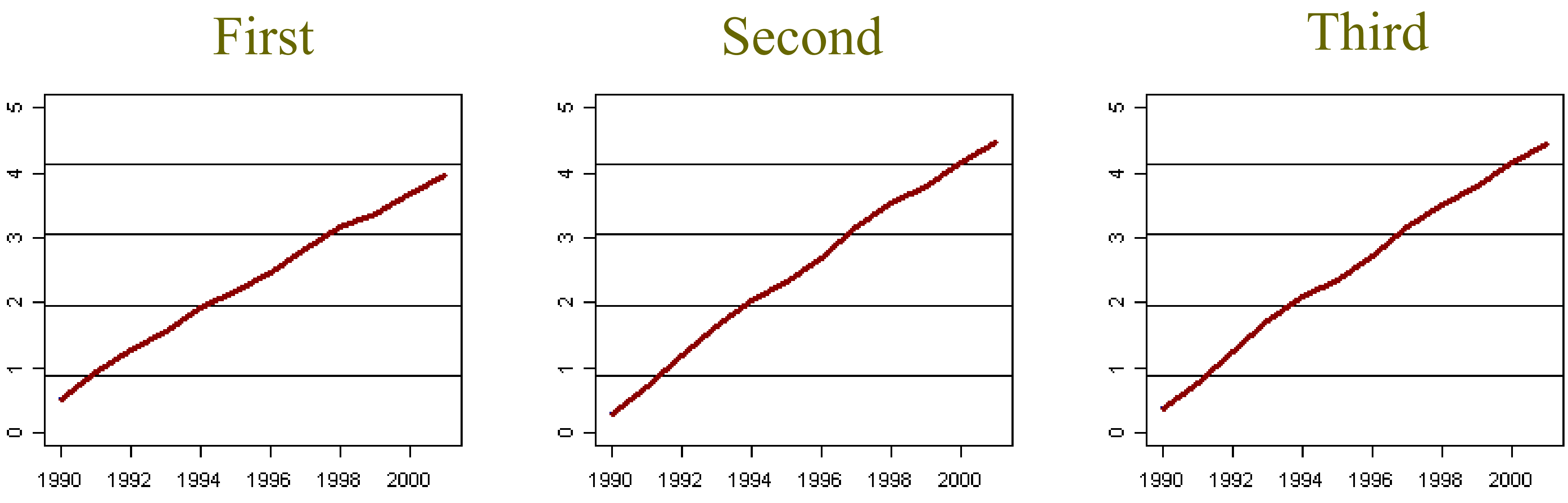
- Estimation of parameters
- National evaluation

Variances for three-parity test-day repeatability model

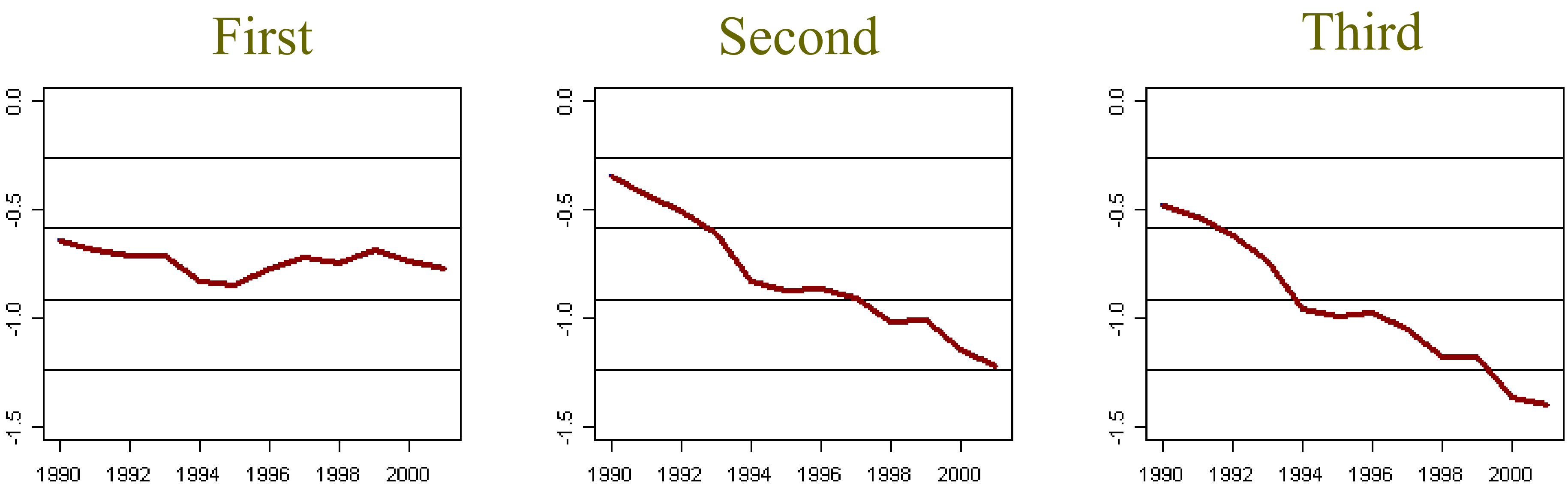
	Milk			Fat (kg*100)			Protein (kg*100)		
	1	2	3	1	2	3	1	2	3
[redacted]	5.6	7.5	6.5	74	94	109	43	57	52.2
[redacted]	4.0	7.0	9.0	37	75	142	22	48	108
[redacted]	-0.46	-0.38	-0.47	-0.39	-0.39	-0.30	-0.43	-0.36	-0.50

Genetic variance for heat stress increases up to 5 times

Genetic trends of daily milk yield for 3 parities – regular effect



Genetic trends for heat stress effect at 5.5º C over the threshold



- Improvement higher than deterioration
- Test days capture fraction of heat stress information
  (Freitas et al., 2005)

709

Relationships between Mortality and 305-d Milk Yield of Holstein Cows in Three Regions in US

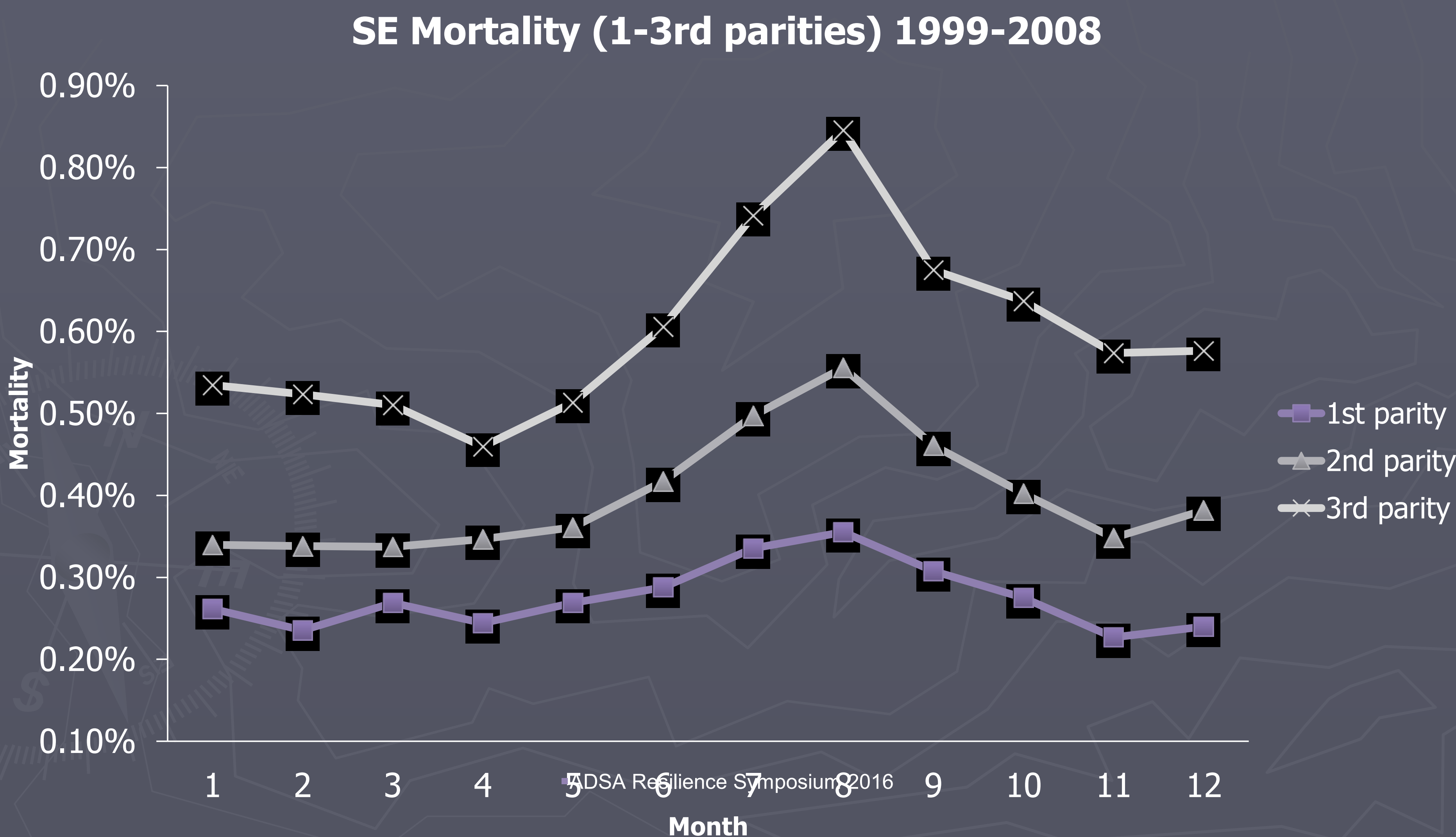
K. Tokuhisa*, S. Tsuruta, and I. Misztal

University of Georgia, Athens

The University of Georgia
Department of Animal and Dairy Science

Mortality in SouthEast

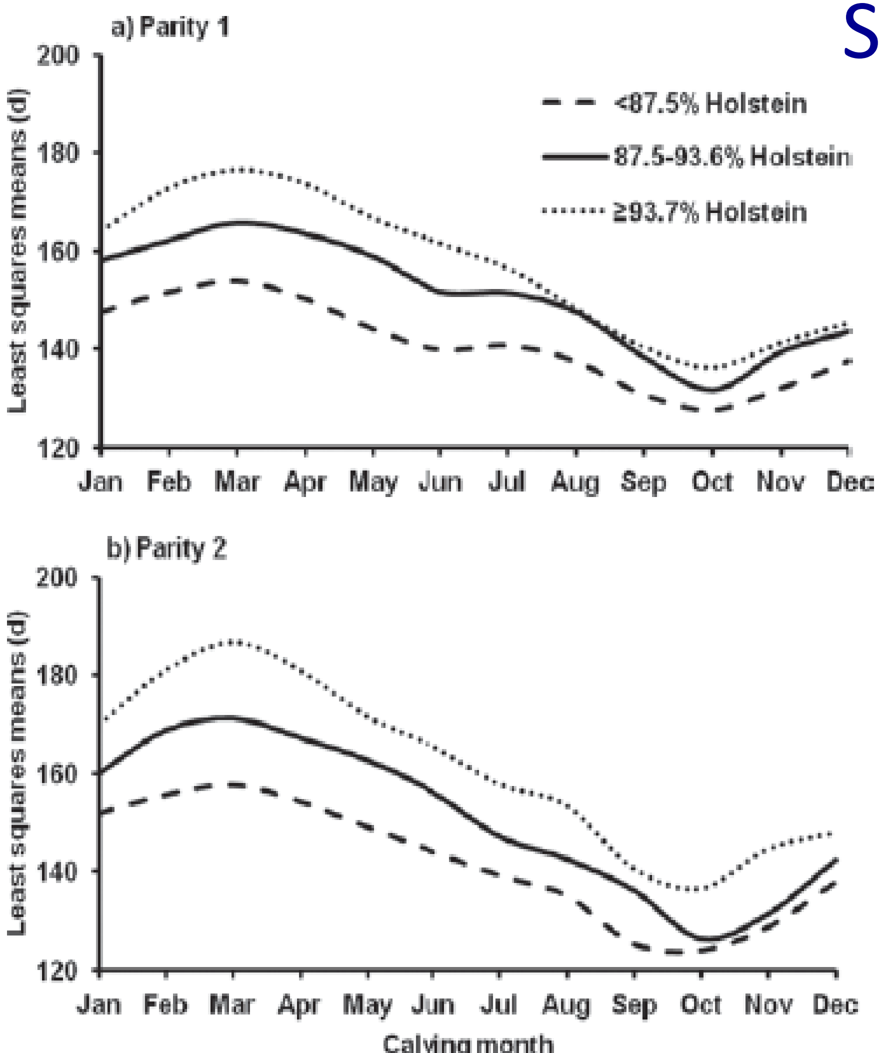
Tokuhisa et al. (2011)



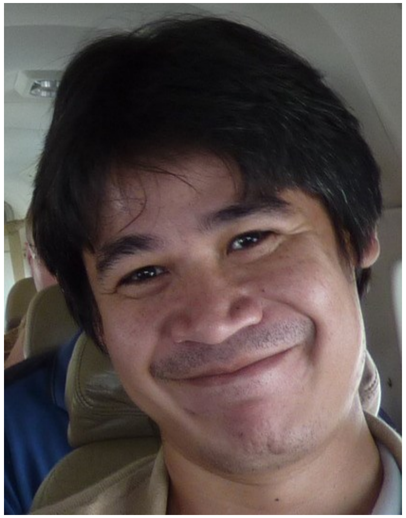
Is cost of heat stress higher than it seems?

- Low survival in SouthEast from parity to parity
- Due to increasing heat stress with parities?
- Selection for survival but not for mortality
- Available data only from better farms

Days open in Thai crosses



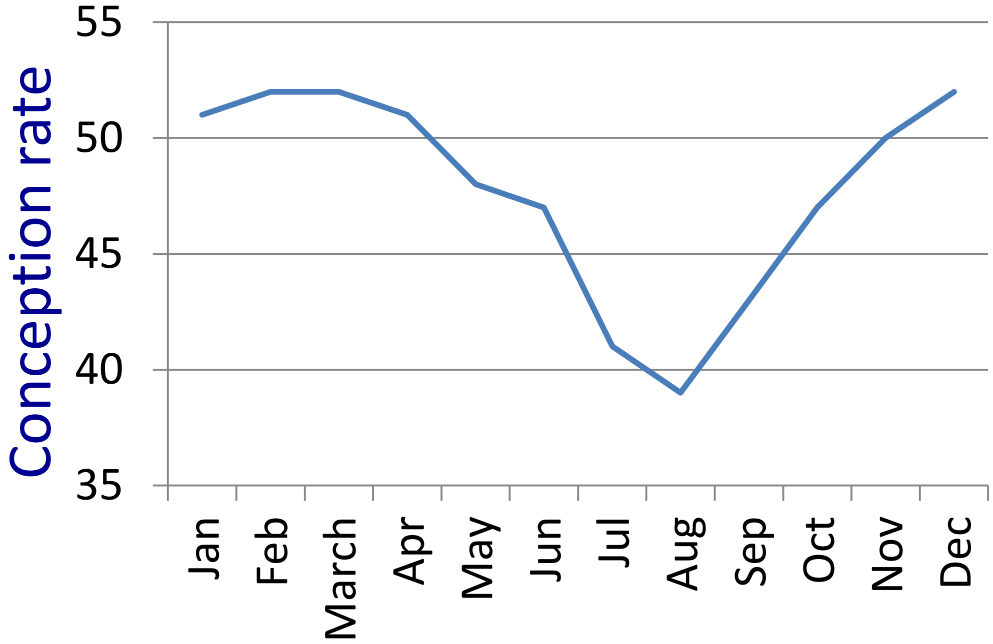
Small effect for milk



Boonkum et al., 2011

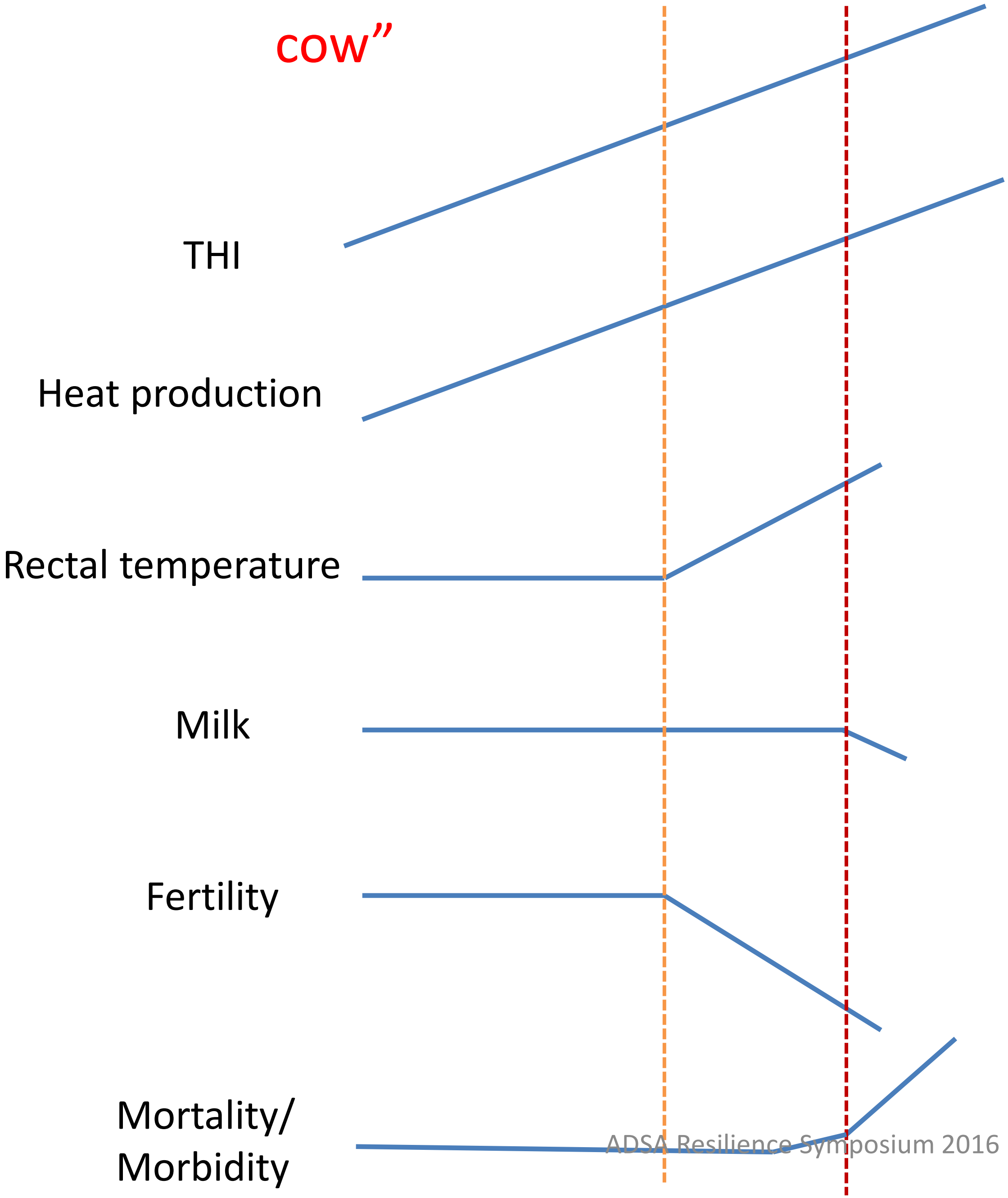
Iranian Holsteins

Small effect for milk



Mokhtar et al, 2012

Profile of a "heat-tolerant cow"



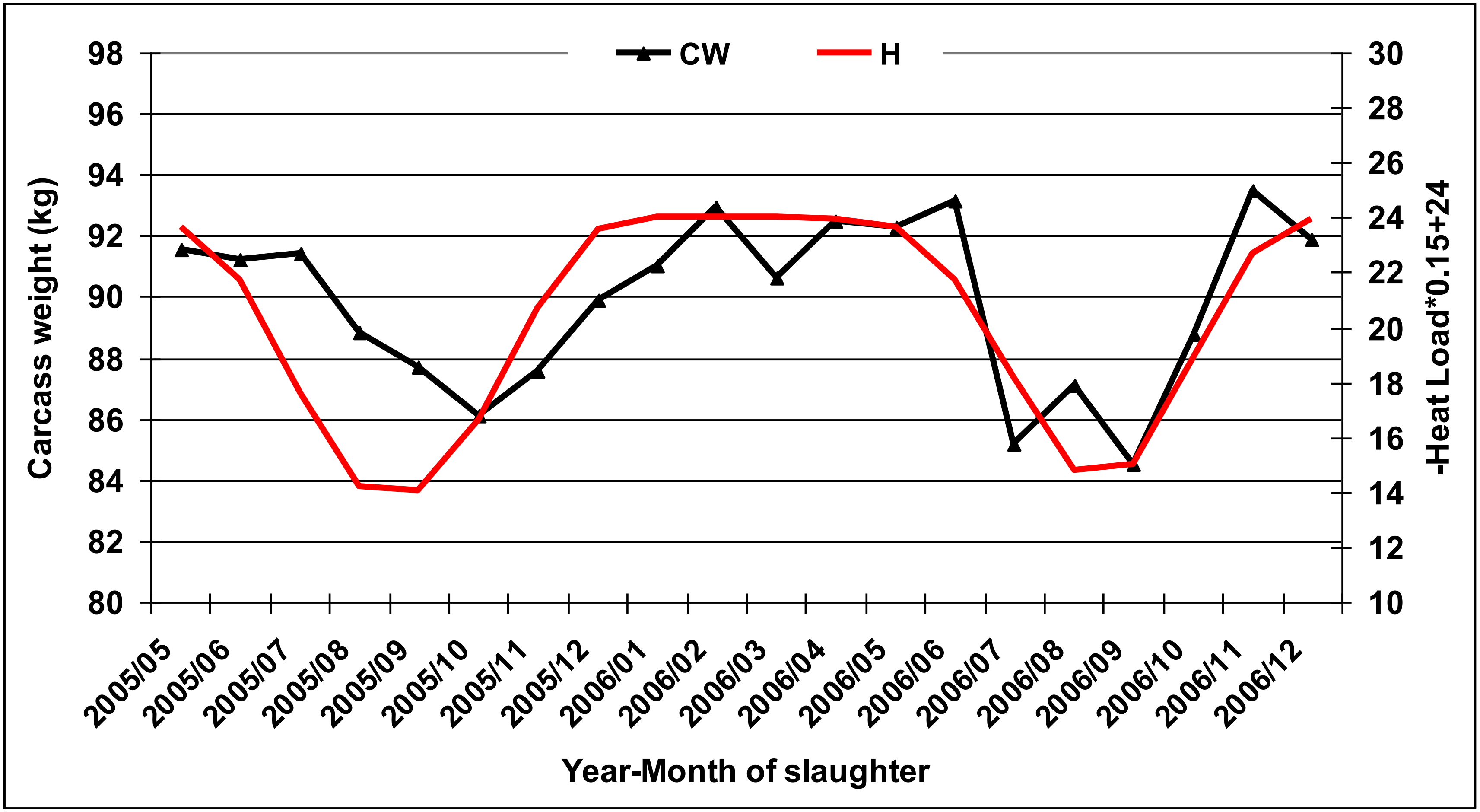
- What is a heat tolerant cow?
  - Milk as long as possible?
  - Reduces production when dangerous?
  - Reduces production early to maintain reproduction
- Thresholds management specific
  - Match genotype to environment

Partially based on Dikmen et al. (2012)

Genetics of growth in pigs under different heat loads (Zumbach et al., 2007)

- Pigs in NC or TX exposed to heat stress
- Heat stress affect growth
- How to model heat stress for growth?

Theoretical and realized heat loads



Zumbach et al., 2007

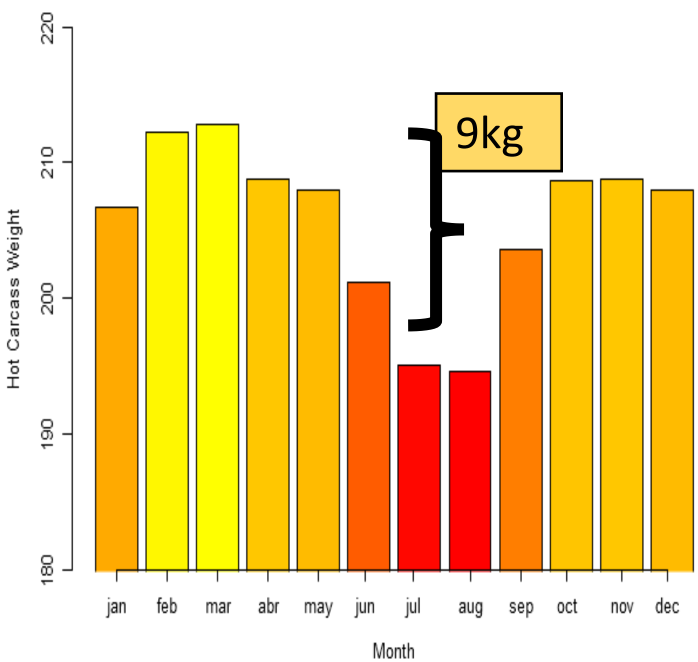
Variances during cold and hot periods

	Genetic	Litter	Error	h^2	$r_{hot,cold}$
Hot	28	17.0	55	0.28	0.42
Cold	14	19.2	66	0.14	

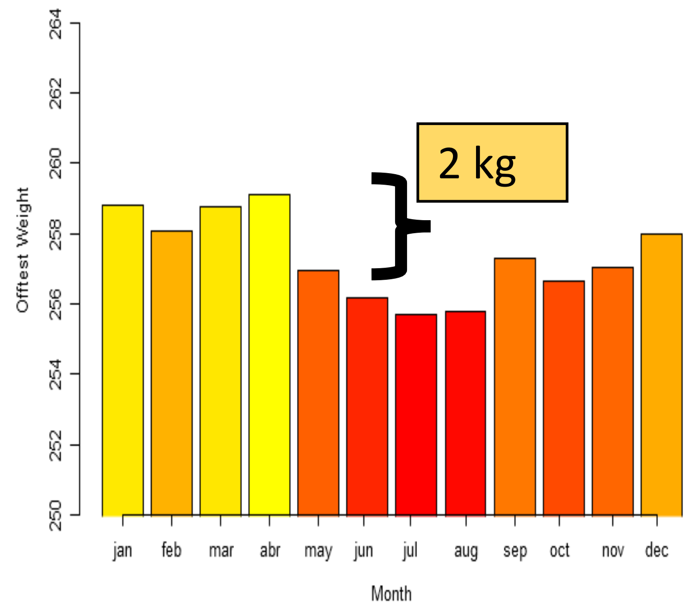
Heat stress in purebred and crossbred pigs

Fragomeni et al., 2016)

Crossbred



Purebred



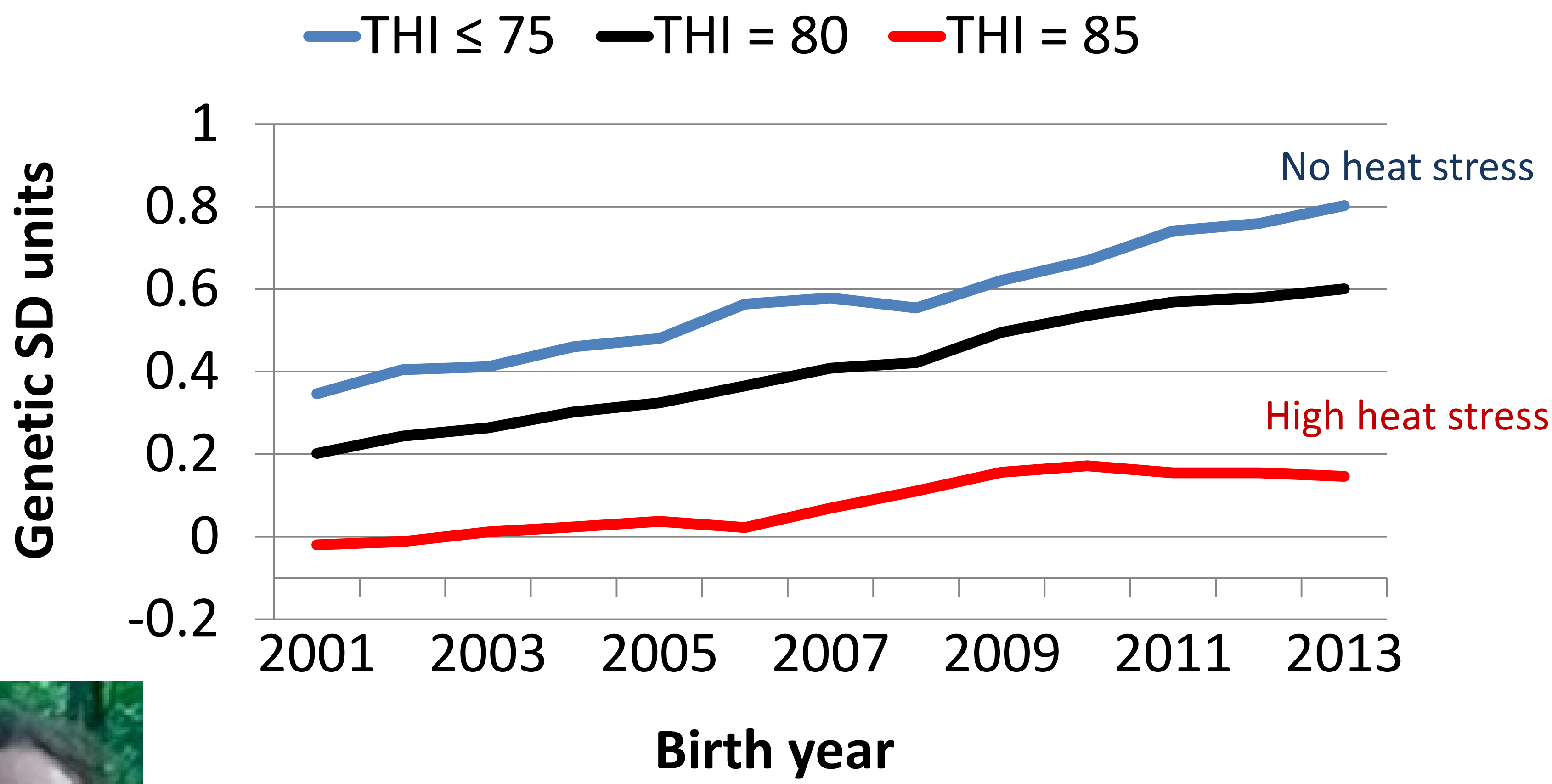
Better environment almost eliminates heat stress

Beef

- Annual economic losses from heat stress (St-Pierre et al., 2003)
  - $87 million for beef cows
  - $282 million for finishing cattle

- Limited quantifiable heat stress for Angus in US (Bradford et al., 2016)
  - Adaptation of beef industry for local condition
    - Timing of breeding
    - Crossbreeding

WW Direct Genetic Trend for Angus in Southeast



ADSA Resilience Symposium 2016

Bradford et al., 2016

Is beef resilient

- Research by Don Spiers (Missouri)
  - 3 days in heat chamber without water
  - Removing hair by torches

QTL for heat stress

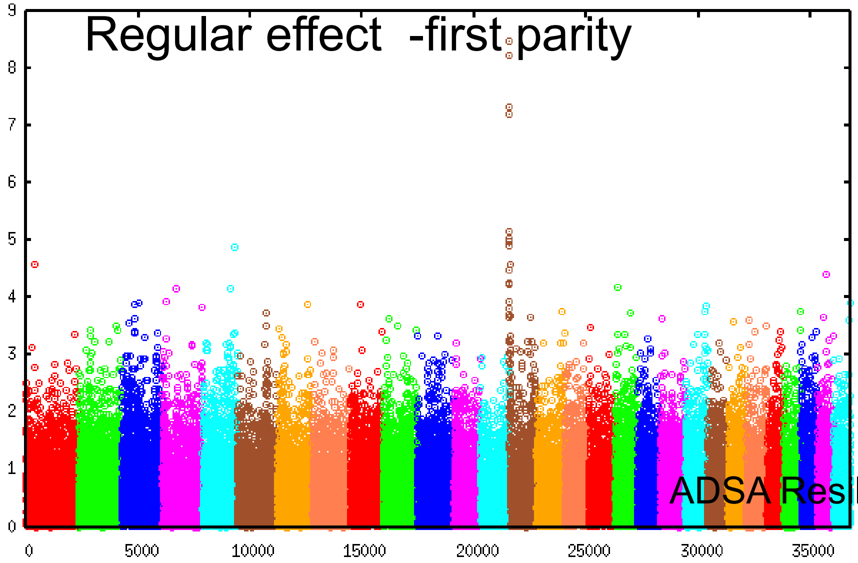
- Slick hair gene (Olsen et al., 2010)
- Gene for spring shedding in beef?

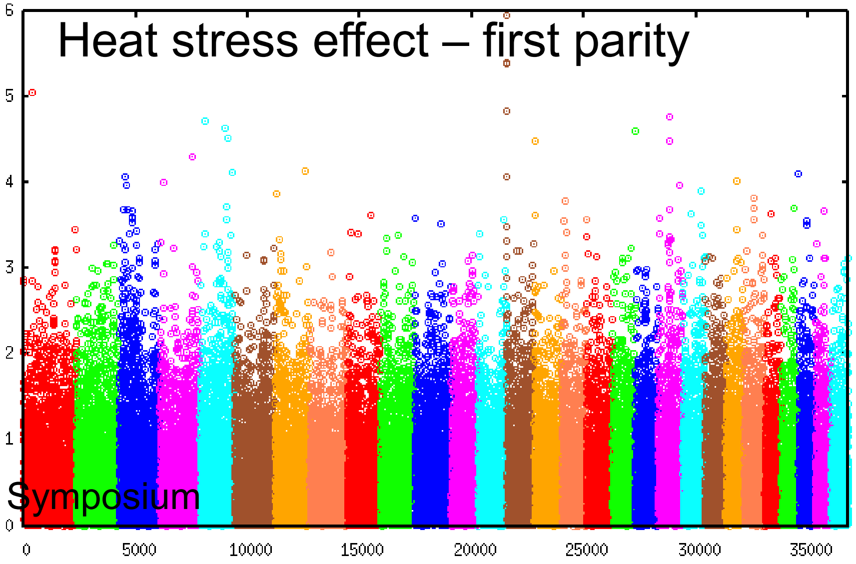
- Markers for rectal temperature (Dikmen et al., 2013)
  - Max 0.44% for 1 Mbase region

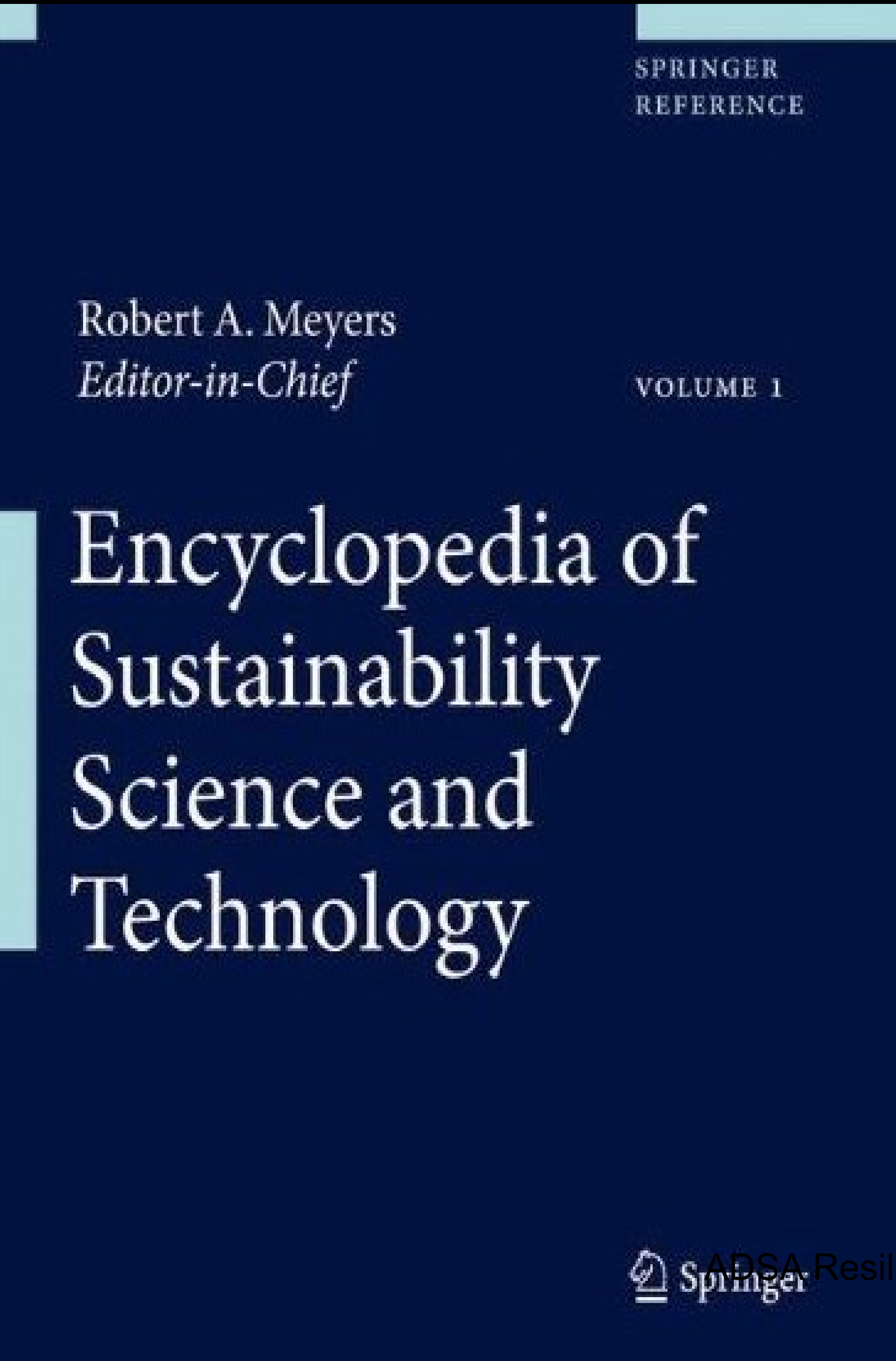
- Studies in AZ (Collier et al., 2012)
  - 500 SNP from microarray studies
  - 500 SNP from GWAS
  - 5 in common

ssGBLUP for Heat Stress in Holsteins (Aguilar, 2011)

- Multiple-Trait Test-Day model, heat stress as random regression
  - ~ 90 millions records, ~ 9 millions pedigrees
  - ~ 3,800 genotyped bulls



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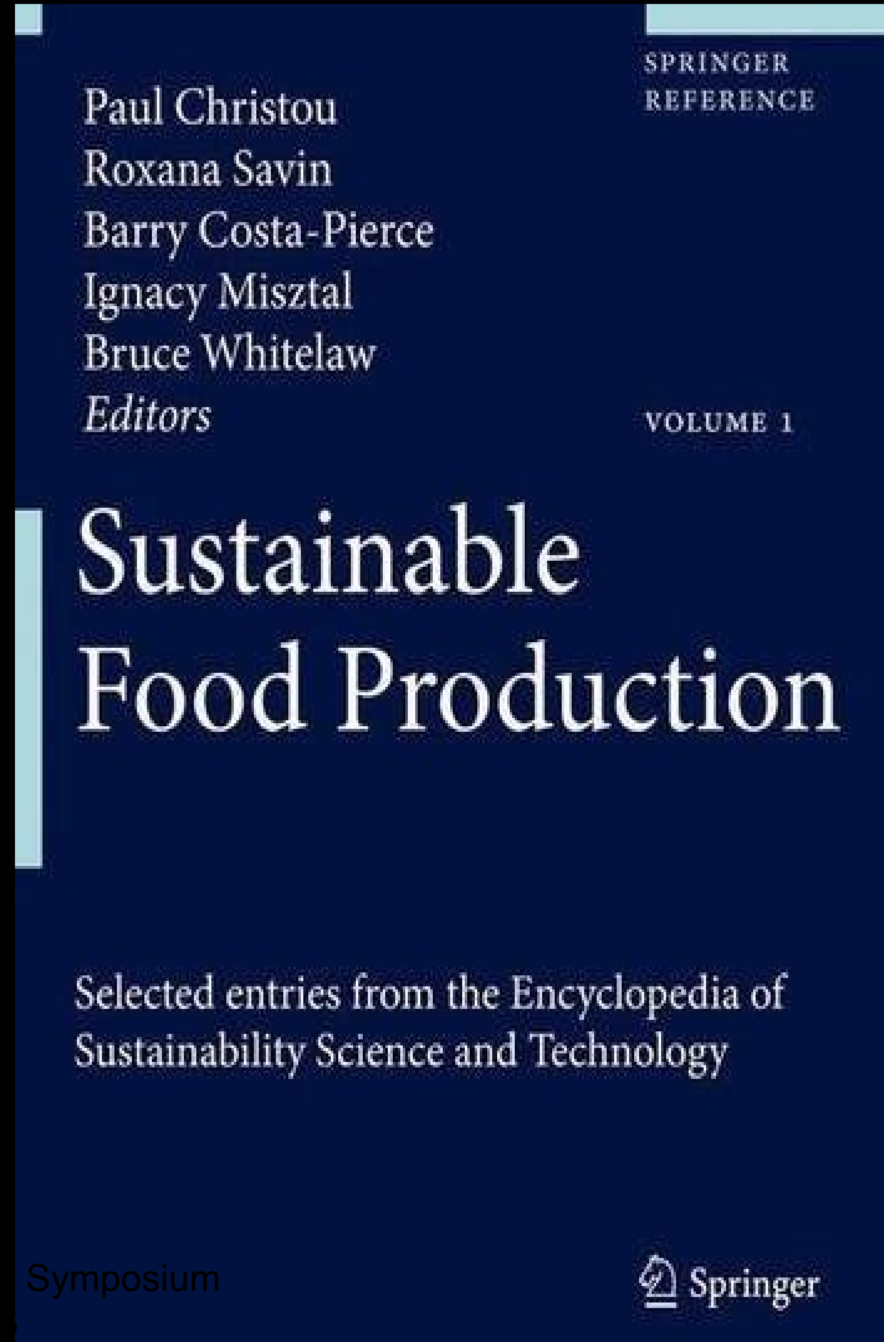
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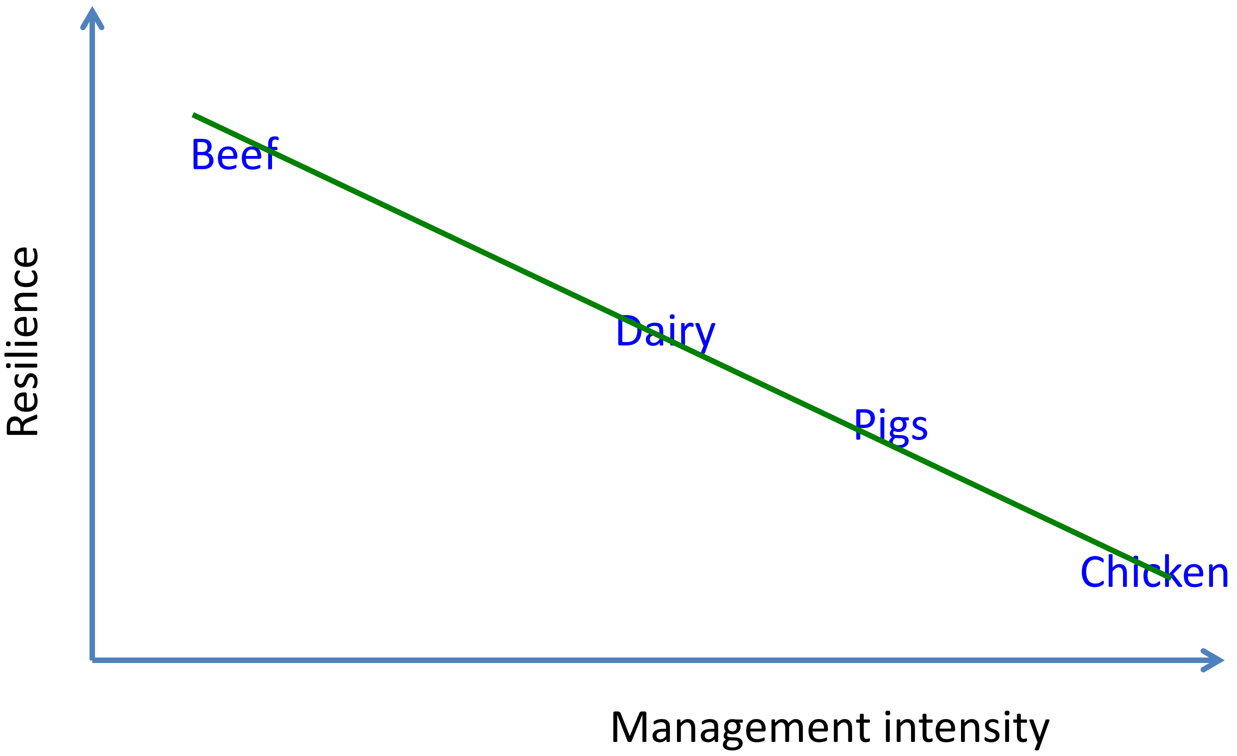
Example – Intensive selection for growth in broiler chicken

- Unlimited appetite / obesity ➔ artificial lightning
- Different maturity rate of males and females ➔ separation of sexes
- Poor survival of males ➔ male supplementation
- Increased susceptibility to diseases ➔ antibiotics
- Low hatchability ➔ alternate heating/cooling of incubators
- …

Selection for main traits with improved management for secondary traits

Eitan and Soller, 2014

Resilience and management intensity



Energy distribution

Pigs and selection for RFI (Dekkers, 2015)

Heat tolerant lines?

- Needs several generations of selection
- Market for heat tolerant animals small
- Improved management simpler

- Selection and production environments
- Interbull and dairy cattle

Conclusions

- Selection as optimization –winner and loser traits
- Management compensates for “losers”
  - Capabilities different by species
- Optimal management for each environment
- Current selection OK if selection and production environments similar