How might DNA-based information generate value in the beef cattle sector?

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Overview

- Where might DNA-information generate value?
- Value Proposition for each sector
  - Seedstock breeder
    - ❖Nucleus –> stud bulls to breed bulls
    - ❖Multiplier –> "stock" bull to go to commercial sector
  - Commercial cow/calf producers
  - Feedlot
  - Processor/Retailer
- "Next Generation" value if can solve structural and technological/logistical issues

US cattle numbers (x 10^6)

# US Beef operations	766,350
Million Cows	31.4
Average herd size	122

Breeder

1.1

Seedstock Cows

Commercial cow/calf producer

35.7

"Suckling herd"
Commercial Cows + replacements

Feedlot

13.6 (on feed at any one time)

25.6 (cattle fed per year in 2009)

Processing

43.2

Retailer

Other Beef Animals (calves, steers, heifers and bulls)

Potential uses of genomic information for beef sectors

ONLY THESE SECTORS PRODUCE NEW ANIMALS

Use	Seedstock	Commercial	Feedlot	Processor
DNA-assisted selection	X	X		
Parentage	X	X		
Recessive allele testing	X	X		
Control of Inbreeding	X	X		
Mate selection	X	X		
DNA-assisted management	X	X	X	
DNA-based purchasing			X	X
Product differentiation				X
Traceability				X

Lead Today with 50K

- Calving ease direct
- Birth weight
- Weaning weight
- Yearling weight
- Yearling height
- Mature weight
- Mature height
- Dry matter intake
- Residual feed intake
- Scrotal circumference
- Docility
- Calving ease maternal
- Milking ability
- Carcass weight
- Fat thickness
- Ribeye area
- Marbling score
- Tenderness

Pfizer Animal Health
Animal Genetics

50K SNP chip assays
50,000 SNPs spread
throughout genome

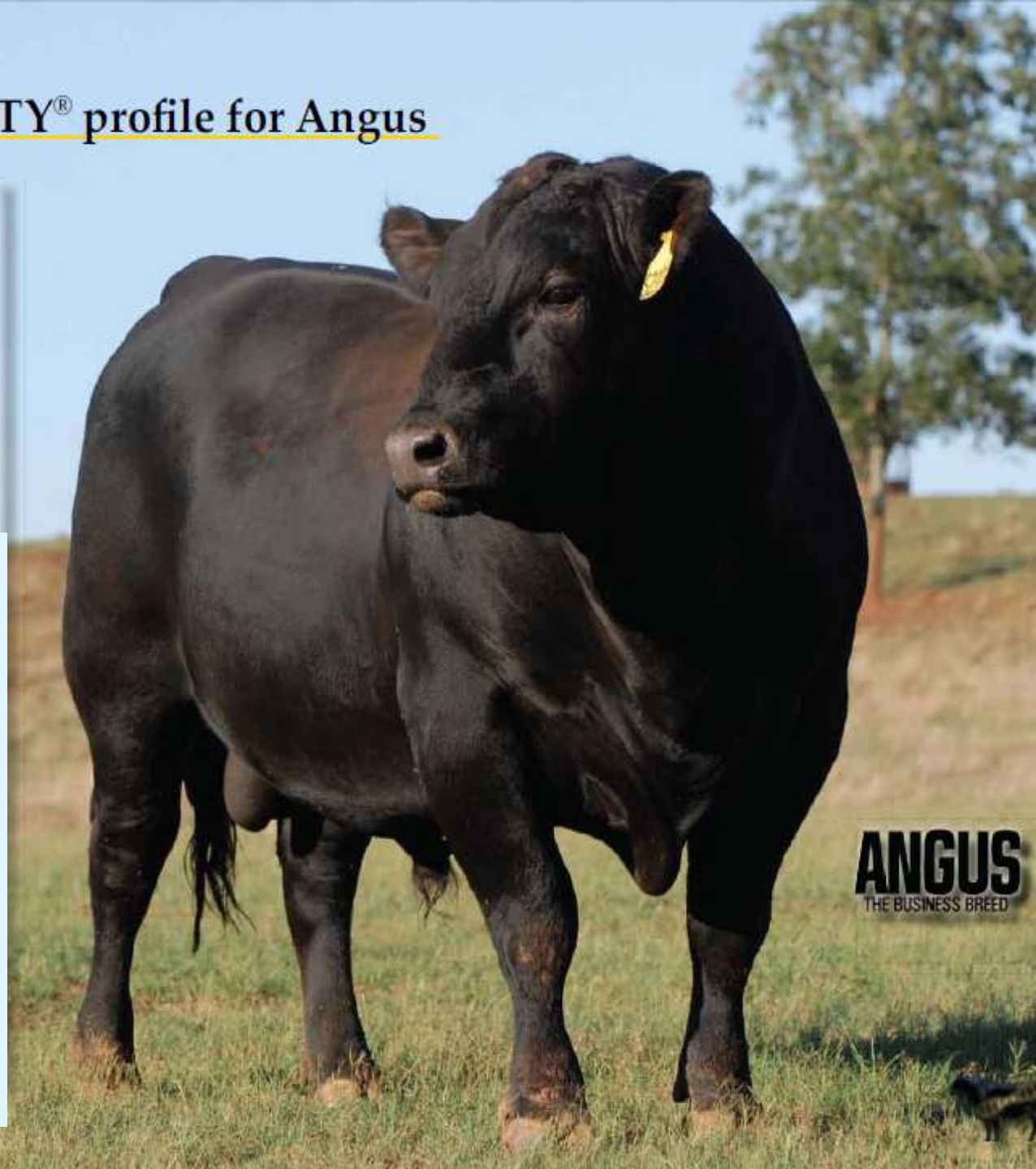
The Power of the IGENITY® profile for Angus

The American Angus Association® through its subsidiary, Angus Genetics Inc.® (AGI), has a vision to provide Angus breeders with the most advanced solutions to their genetic selection and management needs.

Genomic-enhanced Expected Progeny Differences (EPDs) can now be calculated for your animals using the highly predictable American Angus Association database along with IGENITY® profile results to provide a more thorough characterization of economically important traits and improved accuracy on young animals.

Using the IGENITY profile for Angus, breeders receive comprehensive genomic results for multiple, economically important traits.

1. **Dry Matter Intake**
2. **Birth Weight**
3. **Mature Height**
4. **Mature Weight**
5. **Milk**
6. **Scrotal Circumference**
7. **Weaning Weight**
8. **Yearling Weight**
9. **Marbling**
10. **Ribeye Area**
11. **Fat Thickness**
12. **Carcass Weight**
13. **Tenderness**
14. **Percent Choice (quality grade)**
15. **Heifer Pregnancy**
16. **Maternal Calving Ease**
17. **Direct Calving Ease**
18. **Docility**
19. **Average Daily Gain**
20. **Feed Efficiency**
21. **Yearling Height**



American Angus Association performs weekly evaluations with genomic data – recently updated to include new traits

	Igenity	Pfizer
Calving ease (CED)	✓	✓
Growth (BW WW YW Milk)	✓	✓
Residual Average Daily Gain (RADG)	✓	✓
Docility (DOC)	✓	✓
Yearling Scrotal/Height (SC,YH)	✓	✓
Mature Weight (MW)	✓	✓
Carcass (CWT MARB RIB FAT)	✓	✓

http://www.angus.org/AGI/GenomicChoice11102011.pdf (updated 11/18/2011)

Potential Value of DNA information to the seedstock sector

Estimate the value of using DNA test information to increase the accuracy of beef bull selection in a seedstock breeding program

- The expected returns from using a commercial sire sourced from a seedstock herd using DNA testing
- Additionally, the value of marker information in the selection of replacement stud males to be mated in a seedstock breeding program was also estimated.

Van Eenennaam, A. L., J.H. van der Werf, and M.E. Goddard. 2011. The economics of using DNA markers for beef bull selection in the seedstock sector. Journal of Animal Science. 89:307-320.

"Feedlot" $Index (Whole Industry Good index)

Suitable for a self-replacing commercial herd in temperate Australia targeting the production of steers for the long-fed markets that value marbling and 600 day growth.

TRAIT	"FEEDLOT" $INDEX PROFIT DRIVERS
Calving ease direct	14%
Calving ease daughters	9%
Birth weight	1%
600 day weight	26%
Mature cow weight	-12%
Milk	1%
Days to calving	-1%
Eye muscle area	7%
Retail beef yield (%)	5%
Intramuscular Fat %	19%

High (h^2) and **intermediate** (½ h^2) accuracy DNA tests explaining genetic variation in all of selection criteria and traits in the breeding objective were used to test all male progeny from one calf crop

Objective Trait	h^2
Sale liveweight – direct	0.31
Sale liveweight – maternal	0.04
Cow weaning rate	0.05
Cow survival rate	0.03
Cow weight	0.41
Calving ease – direct	0.10
Calving ease – maternal	0.10
Dressing Percentage	0.33
Saleable meat Percentage	0.56
Fat depth (rump)	0.41
Marbling score	0.38

Selection criteria	h^2
Birth weight	0.39
200 d Weight	0.18
400 d Weight	0.25
600 d Weight	0.31
Scrotal Size	0.39
Days to Calving	0.07
Mature Cow Weight	0.41
P8 fat	0.41
RIB fat	0.34
Eye Muscle Area	0.26
Intramuscular Fat	0.25

Currently no selection criteria for many economically-important traits: Feed efficiency, feedlot performance, feedlot health, stayability/longevity, fertility, etc.

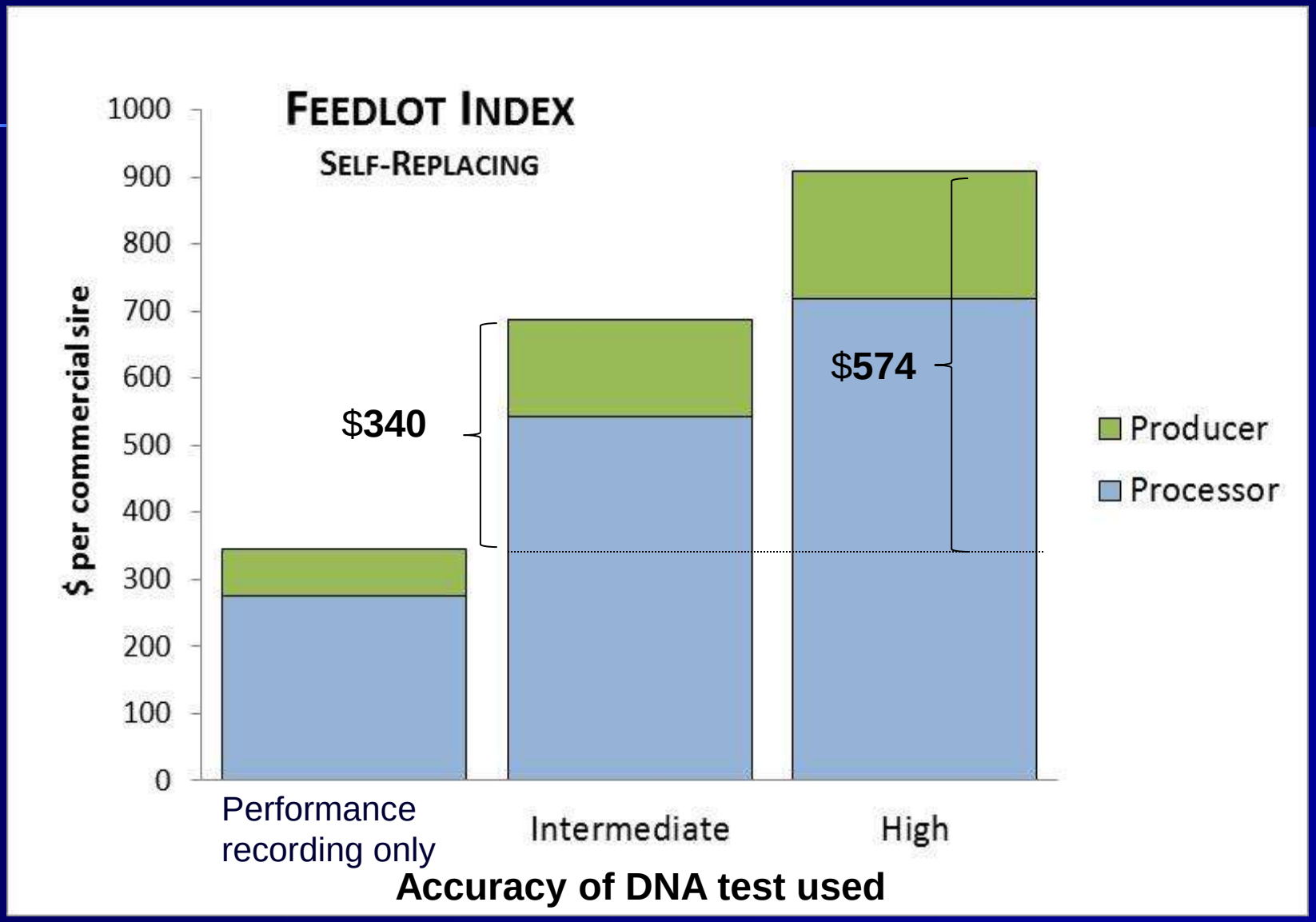
Value of improved selection response for stud bulls due to DNA-test increase in Long Fed / CAAB $Index accuracy

Variable	Unit	Accuracy of DNA test used	Long Fed / CAAB $Index
Increased value derived from ΔG in commercial sires	AU$/ bull	Intermediate	16,882
		High	27,901

Value of improved selection response for commercial bulls due to DNA-test increase in Long Fed / CAAB $Index accuracy

Variable	Unit	Accuracy of DNA test used	Long Fed / CAAB $Index
Increased value derived from ΔG in commercial sires	AU$/ Bull	Intermediate	340
		High	574

Where are returns from genetic gain (ΔG) in commercial bulls realized?



Results: Value of genetic improvement (ΔG) per DNA test in commercial and stud sires

Variable	Unit	Accuracy of DNA test used	Long Fed / CAAB $Index
Increased value derived from ΔG in stud sires	AU$/ test	Intermediate	506
		High	836
Increased value derived from ΔG in commercial sires	AU$/ test	Intermediate	170
		High	282

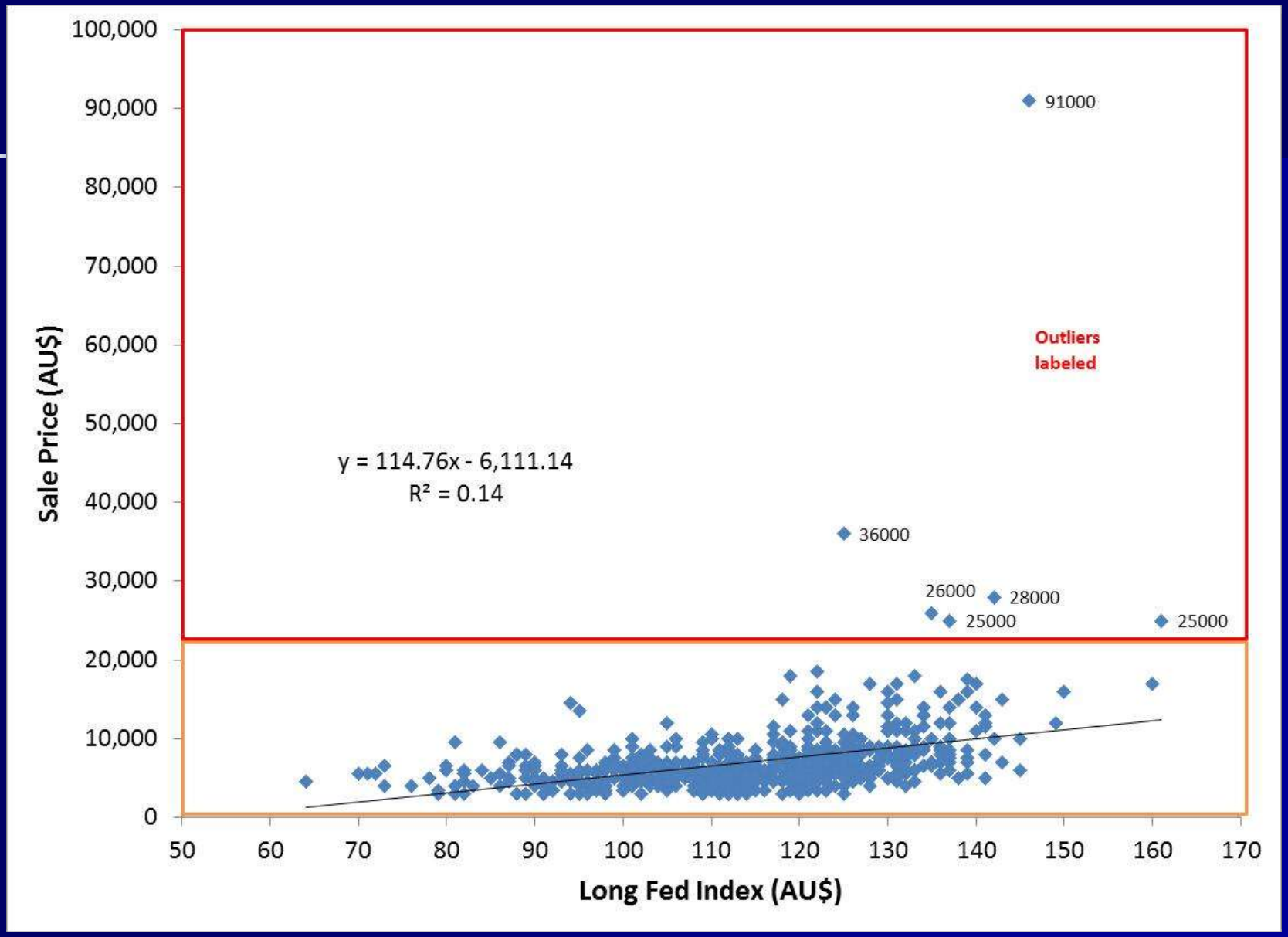
Are bull buyers willing to pay more for high indexing bulls?

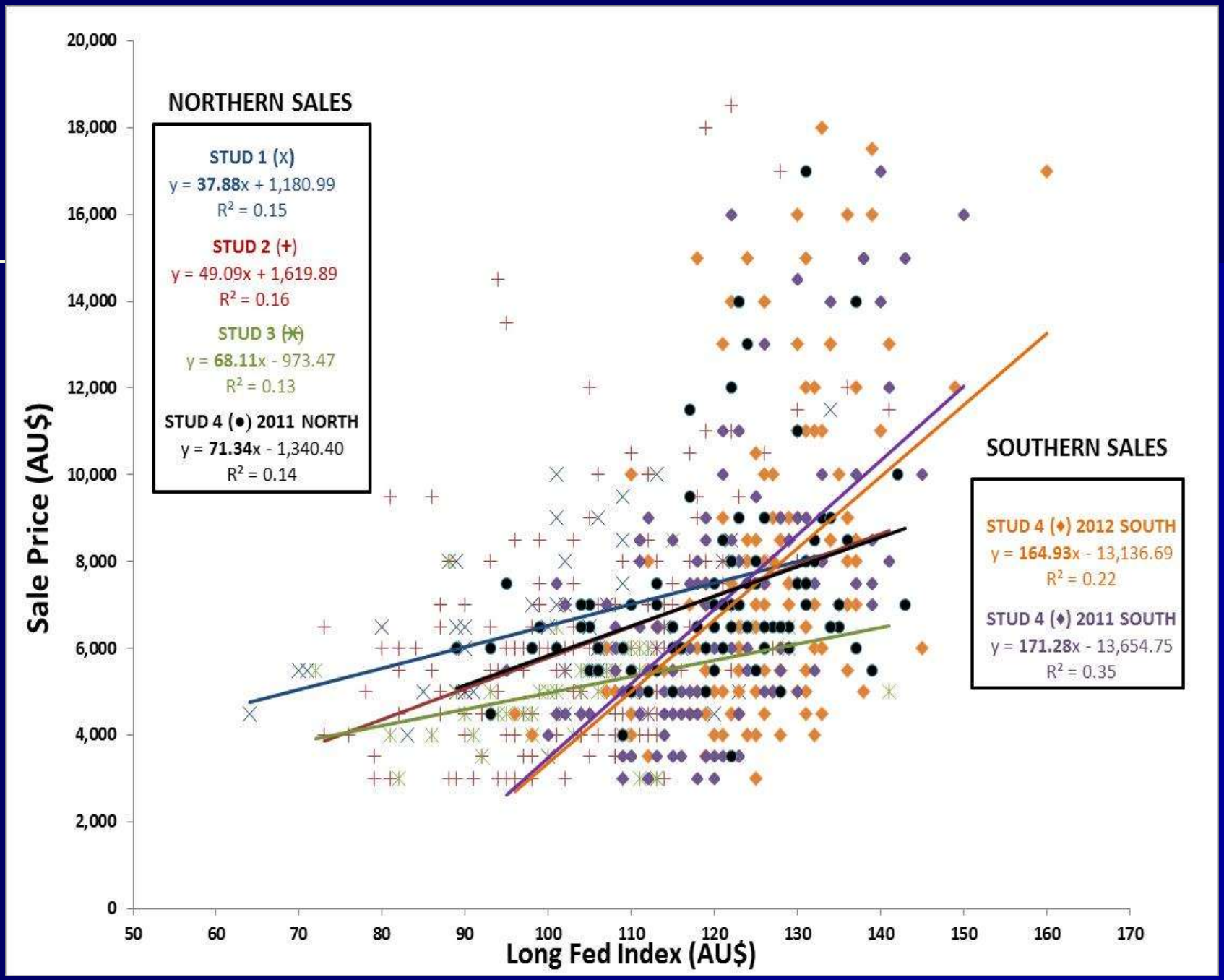
Long Fed/CAAB $Index* value was compared to bull purchase price from 645 bulls sold in Australia in 2011/2012. Six sales were examined – four studs were included stud 1 (n=44), stud 2 (n=200), stud 3 (n=45); and stud 4 with 3 sales represented Southern 2011 (n=115), Northern 2011 (n=96), and Southern 2012 (n=145) – 2/29/2012

Removed outlier bulls (>3 sd from average price)

* http://breedplan.une.edu.au/tips/Interpreting%20Australian%20Angus%20Selection%20Indexes.pdf

All bulls included




NORTHERN SALES
STUD 1 (x)
y = 37.88x + 1,180.99
R² = 0.15
STUD 2 (+)
y = 49.09x + 1,619.89
R² = 0.16
STUD 3 (✳)
y = 68.11x - 973.47
R² = 0.13
STUD 4 (●) 2011 NORTH
y = 71.34x - 1,340.40
R² = 0.14
SOUTHERN SALES
STUD 4 (♦) 2012 SOUTH
y = 164.93x - 13,136.69
R² = 0.22
STUD 4 (♦) 2011 SOUTH
y = 171.28x - 13,654.75
R² = 0.35
Sale Price (AU$)
Long Fed Index (AU$)
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
50
60
70
80
90
100
110
120
130
140
150
160
170

Value of genomic information for recessive genetic defects

- **Arthrogryposis multiplex (AM) is a lethal recessive deletion for which a DNA test was developed in 2008**
- In the 11 months following the release of the test, the American Angus Association posted the results of tests for AM on about 96,247 cattle.
- **@$25/test this amounts to $2.4 million in tests**
- Of these, 20% (19,529) were carriers of AM. **That leaves 23,638 bulls and more than 53,000 heifers which tested as free of AM.**
- **At $4K/bull and $2K/heifer ~$200 million**

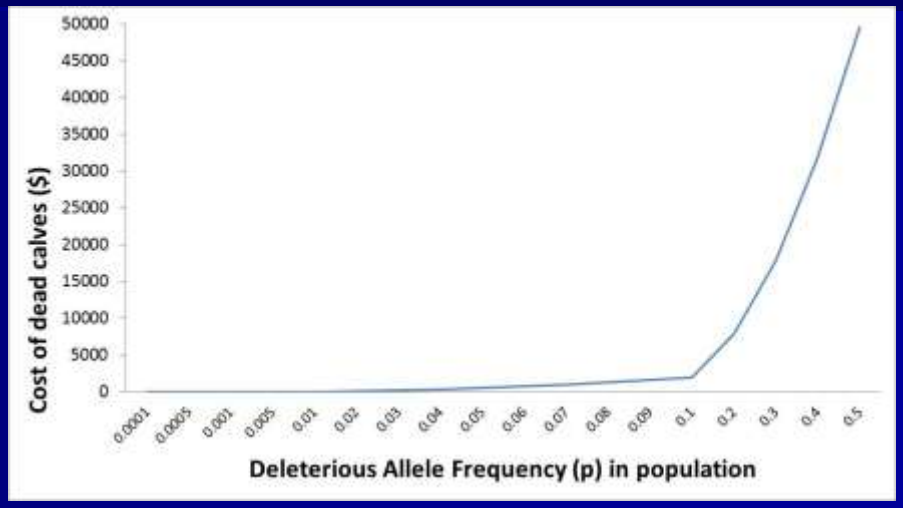
Estimates of US and Australia genetic testing costs (Angus)

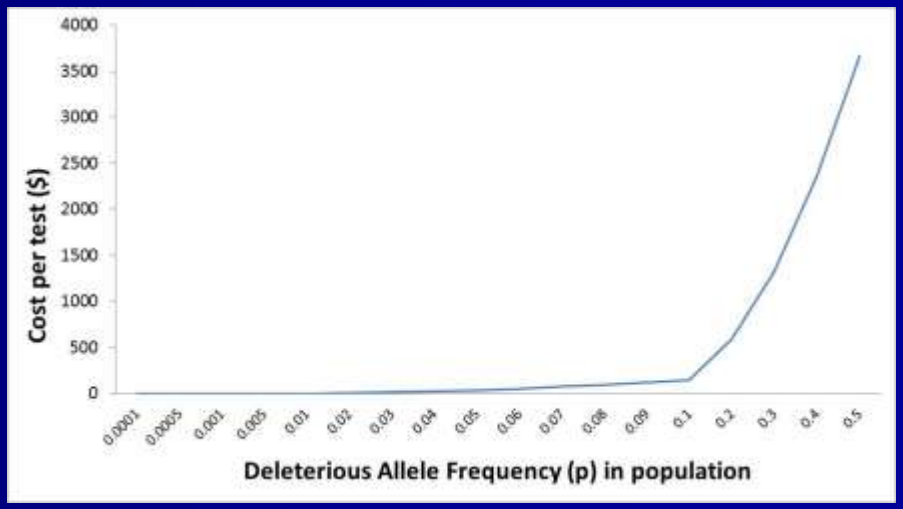
	US	AUSTRALIA
AMF (Arthrogryposis multiplex)	113,526	12,021
NHF (Neuropathic Hydrocephalus)	77,067	9,936
CAF (Congenital Contractural Arachnodactyly)	28,837	2,532
TOTAL NUMBER	294,054	34,991
COST (@ $25/test)	$7,351,350	$874,775

Numbers kindly shared by Bryce Schumann, American Angus Association; and Carel Teseling, Angus Australia; current as of 5/2011

Break even cost of DNA testing to eliminate randomly selected carrier sires from entering a herd over a range allele frequencies (p) for a recessive lethal allele (*assuming herd frequency of allele is also p*). The value increases substantially if the sire is very likely to be a carrier.

Allele frequency (p)	Cost of calf loss if DNA testing of yearling bulls not performed (US$)	Breakeven cost DNA test if testing yearling bulls entering herd (US$)	
		All bulls tested	Carrier bull
0.0001	<0.01	<0.01	213
0.0005	0.05	<0.01	216
0.001	0.20	0.01	219
0.005	5	0.37	247
0.01	20	1	281
0.02	79	6	350
0.03	178	13	419
0.04	317	23	488
0.05	495	37	557
0.06	713	53	626
0.07	971	72	695
0.08	1268	94	764
0.09	1605	119	833
0.1	1981	147	902
0.2	7924	586	1593
0.3	17828	1319	2283
0.4	31695	2344	2973
0.5	49523	3663	3663





Cost of commercially-available DNA tests for US beef cattle

- **Seedstock producers are using DNA information for pedigree verification, genetic defect testing, and genomic enhanced EBVs. Sometimes these analyses are sent to three different laboratories, and costs can be in excess of $200 per animal.**
- **At the current time the costs of DNA extraction and genomic analyses tend to exceed the value that is returned to any single sector.**

Type/Purpose of DNA Test	Species	Cost ($US)
Microsatellite or SNP-based parentage test	Cattle	~$ 10-25
Genetic Defects/Single gene tests	Cattle	~$ 15-100
Illumina Bovine 3K (just genotypes - no prediction equation)/Research	Cattle	~$ 38
Illumina Bovine 50K (just genotypes)/Research	Cattle	~$ 80
Affymetrix Bovine 650K (just genotypes)/Research	Cattle	~$200
Illumina Bovine 770K (HD) SNP Test (just genotypes)/Research	Cattle	~$210
384 SNP Angus Profile (Igenity US/AGI)/Selection	Beef Cattle	~$ 65
Illumina Bovine 50K (Pfizer Animal Genetics US/AGI)/Selection	Beef Cattle	~$139

Extracting DNA multiple times in different labs for different applications makes about as much sense as simultaneously paying to have access to all of the following communication devices

New genotyping platforms and technologies will mean a single DNA sample can be assayed for multiple purposes

(Parentage, genetic defects, disease diagnostics, imputation to high density for predictions of genetic merit estimates, mate selection decisions to avoid inbreeding, and minimize matings between heterozygote "carriers" for deleterious recessive alleles, product traceback, differentiation, traceability).

SEEKSIRE™

Parentage and Sire Identification Program for Cattle

SeekSire is created for breeders, breeders and breed associations who need to manage their herd's pedigrees in a highly accurate and cost-effective manner. SeekSire can help maintain herd books, facilitate retrospective genetic improvement, and manage herd performance and quality. Additionally, when all sires and dams used in a herd are known and identified through DNA, it is possible to identify all progeny, thereby creating full traceability as well. GeneSeek's newest technology platforms make SeekSire very affordable!

SEEKTRACE™

Traceability Program for Beef

SeekTrace can address traceability needs across the entire production to consumer pipeline. SeekTrace enables management of the origin, movement and identity of each animal through the entire supply, demand and consumption chain. A powerful set of DNA markers are used to identify a unique sample, and in conjunction with date of processing, facility or premise ID, any animal can be traced with the help of custom informatics solutions. While traceability has been a desirable solution for many years, high DNA testing costs have limited widespread adoption. But now, for the first time, new advances in DNA technology allow us to provide SeekTrace for a fraction of the end value of each animal.

SNP Profiling and Illumina® Services

Available Illumina Genotyping Assays

- NEW GeneSeek Genomic Profiler for dairy and beef - Custom low density bead chip featuring 10,000 SNP markers
- Bovine SNP50 BeadChip – 54,609 informative SNP markers.
- BovineHD – High density genotyping with greater than 800,000 SNP markers

SNP Genotyping Panels

- Sequenom® MassARRAY® spectrometry-based detection system for sensitive, accurate, and rapid genotyping
- 384 and 96-well options for high- and low-throughput applications
- Easy-to-use multiplexed assay design and optimization software saves research time and helps maximize efficiency
- Flexible SNP numbers allows for economical marker assisted selection

BVDV Diagnostics

- PCR screening/ELISA confirmation
- Diagnostic testing can now be performed from hair follicle submissions
- BVDV and genomic testing all from the same sample
- International samples accepted

GENESEEK Europe

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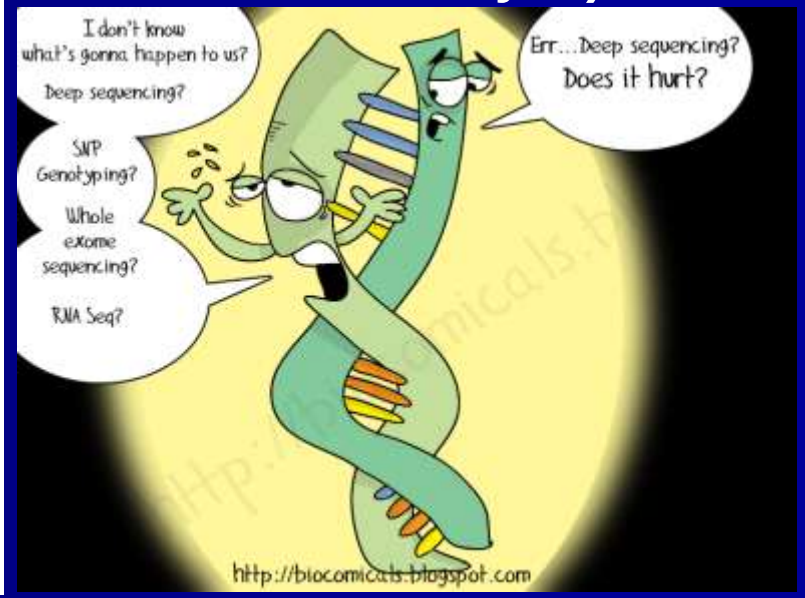
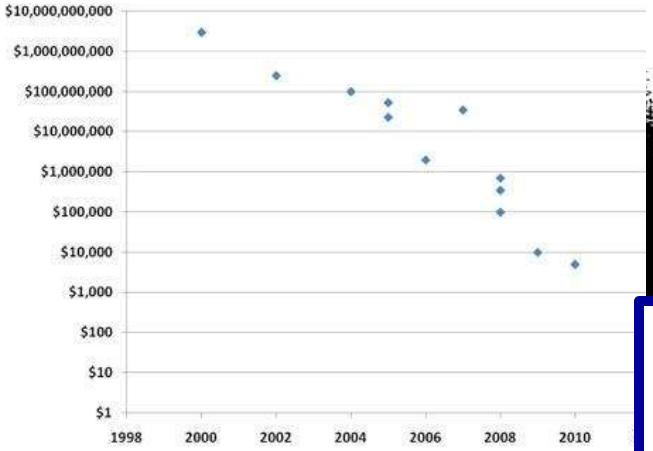
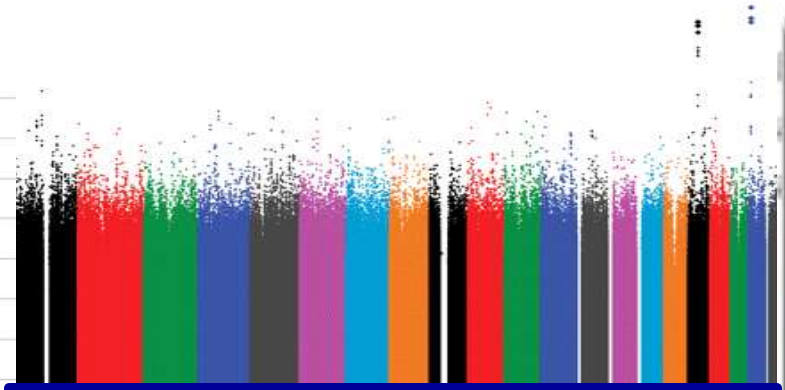
All in one LD plus product from GeneSeek "Genomic Profiler" ~ US$35-40

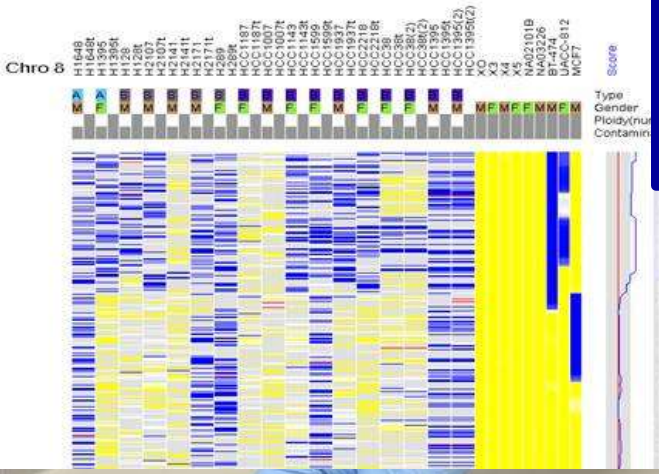
(+ recessive lethal royalty fees if assayed).



Cost of sequencing a genome







What will happen when next generation sequencing meets next generation technology?

Next generation VALUE derived from DNA testing

TECHNOLOGICAL CHALLENGE: How do we collect phenotypes and DNA on all animals and make genotype information available to all sectors?

ONLY THESE SECTORS PRODUCE NEW ANIMALS

Use	Seedstock	Commercial	Feedlot	Processor
DNA-assisted selection	XXXX	X	XXXX	XXXX
Parentage	XX	X		
Recessive allele testing	XX	X		
Control of Inbreeding	XX	X		
Mate selection	XX	X		
DNA-assisted management/purchasing		X	XX	XX
Product differentiation				XXXX
Traceability				XX

Ideally cattle would be genotyped ONCE early in life and genotypes shared with downstream production sectors to derive the maximum value from the fixed DNA collection and extraction costs

Cattle industry Sector	Mobile Device// Data Access Plan	Type of DNA product // DNA information access required	Cost? (US$)
Nucleus seedstock/AI bulls	ipad	Full genome sequence	$250
Seedstock/bull multiplier	iphone	HD 770 K genotype	$50
Registered females and stock bulls for commercial sector	Talk and text smart phone	50K genotype + parentage + single gene traits/recessives	$25
Commercial cattle – Marker-assisted management (MAM), replacement heifer selection	Prepaid cellular phone	Imputation LD chip + parentage + single gene traits/recessives	$10
Feedlot cattle purchasing, sorting and marker-assisted management (MAM)	Pay as you go contract	Access genotypes from supplier (subset of LD imputation chip).	<$1
Traceability for voluntary labelling e.g. Angus beef	Friends and family plan	Access genotypes from supplier (subset of LD imputation chip).	<$1
Traceability for disease outbreak/contaminated meat	Emergency only phone (911 calls)	Access genotypes from supplier (subset of LD imputation chip).	<$1

Crystalyx
Brand Supplements
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Manage Pastures
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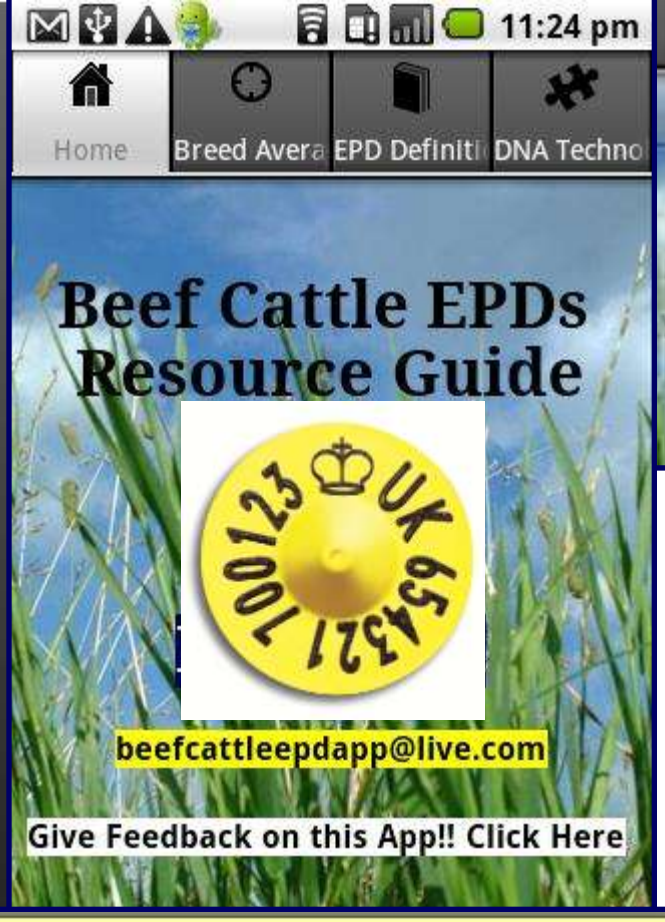
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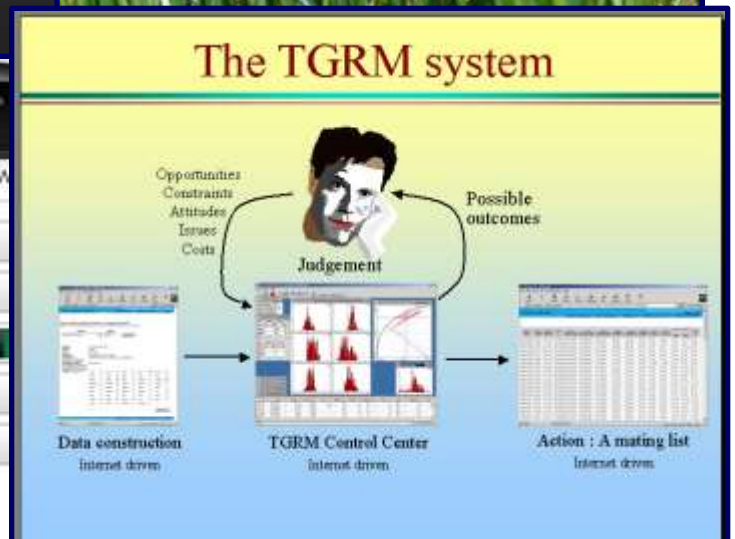
BREEDING MANAGER
BREEDING SUMMARY


The TGRM system
Opportunities
Constraints
Attitudes
Issues
Costs
Judgement
Possible outcomes
Data construction
Internet driven
TGRM Control Center
Internet driven
Action : A mating list
Internet driven

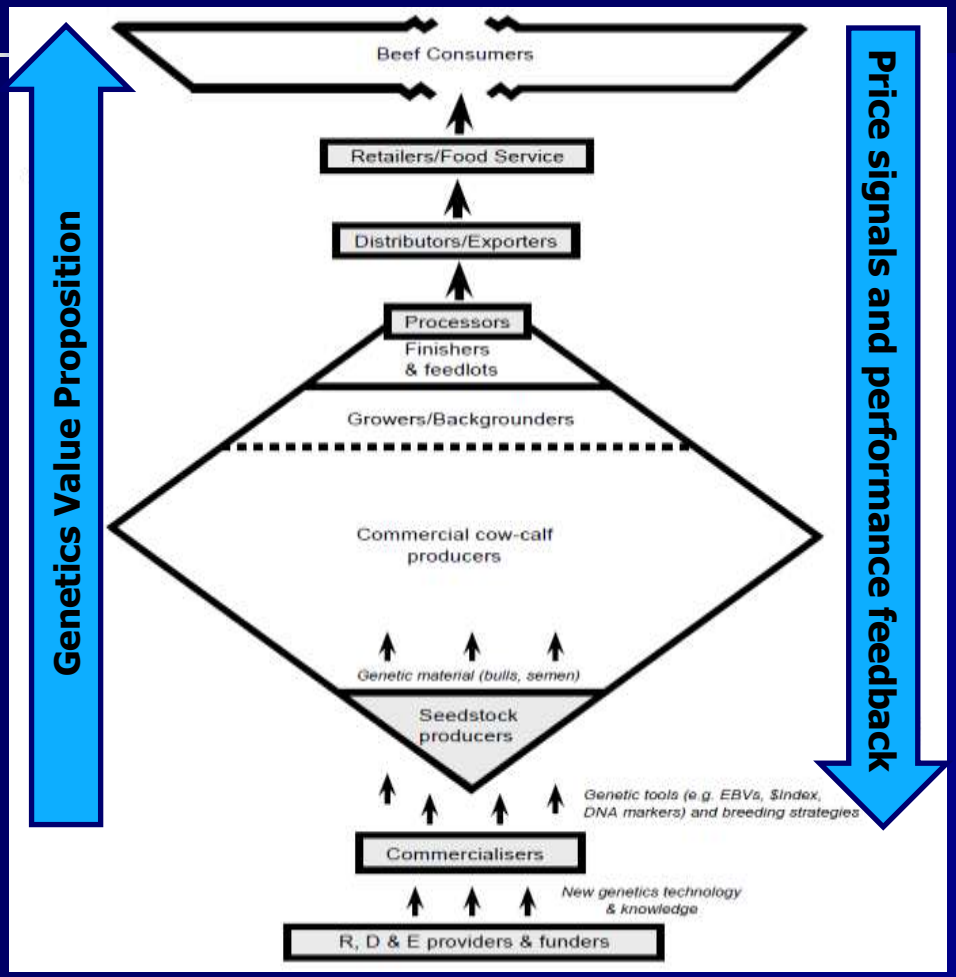
4:20 PM
SICK COW
ABOUT
HOW SICK?

STRUCTURAL CHALLENGE : Many cattle operations have fewer than 100 head, and most sell their cattle at auction prior to feedlot entry

Whole industry selection indexes are developed to maximize the profitability of the whole supply chain

- In reality most producers' financial returns are tied very closely to the number of calves, a function of reproduction, and less if at all to feedlot performance (e.g. feed efficiency) and carcass traits, and even less to feedlot health (e.g. respiratory) and mortalities.
- To incentivize the inclusion of traits that provide value in downstream sectors in selection decisions, a mechanism to equitably share some of the value derived from improved feedlot performance and carcass quality is needed to compensate breeders and producers for collecting DNA and genomic information to improve these traits, and for including them in their breeding objectives with concomitant decreased selection pressure on production traits that return value directly to producers.

Industry structure may evolve to enable the exchange of information and value between the different sectors.



For widespread technology adoption, breeders need to be adequately rewarded for making DNA investments and selection decisions for traits that benefit the different sectors of the beef industry.

Parnell, P.F. 2007. Effective value chain partnerships are essential for rapid adoption of beef genetics technology. Association for the Advancement of Animal Breeding and Genetics. 18. 167-174 .

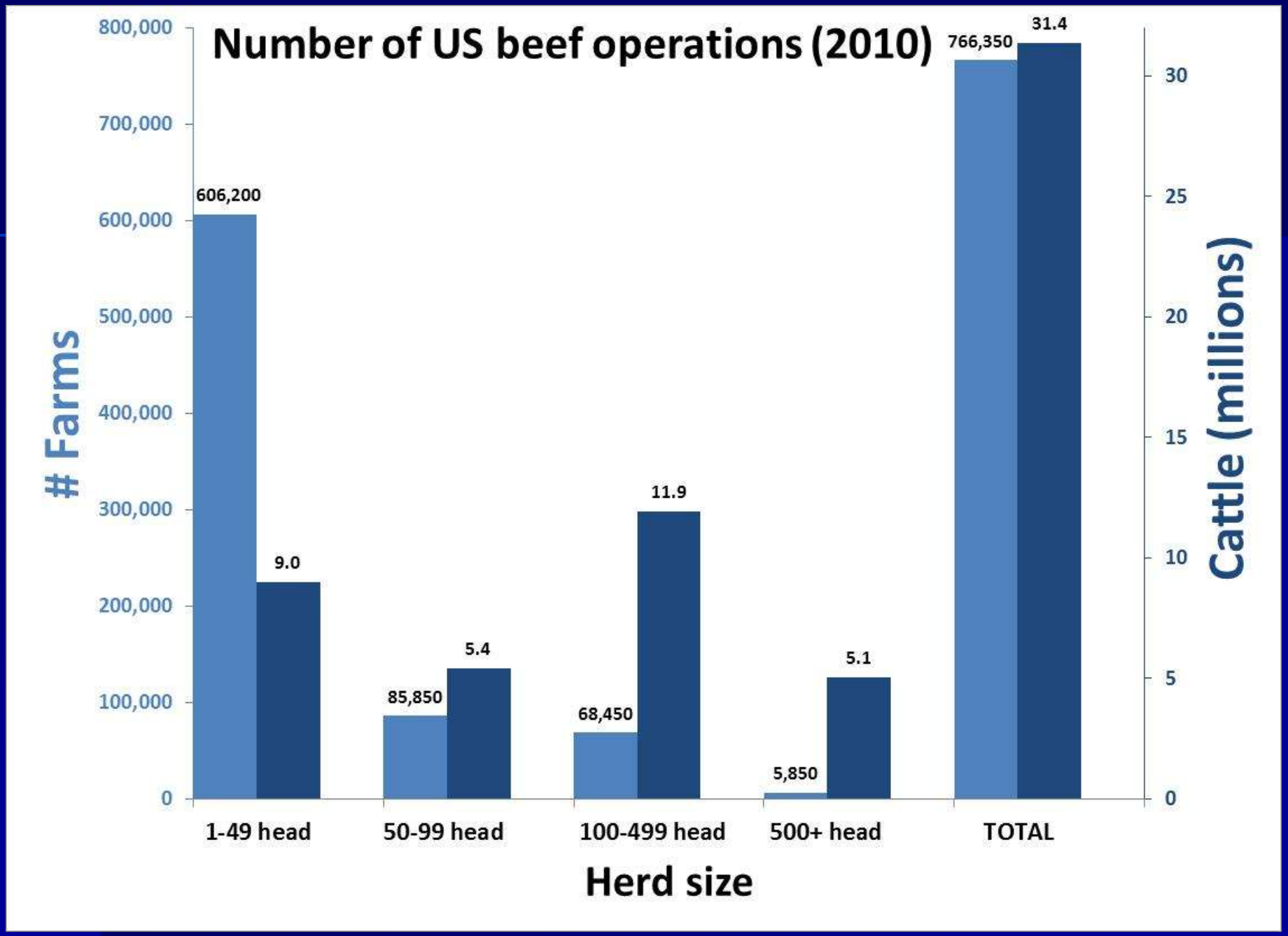
Concluding thought….

Breeds/groups that can organize themselves and **technologically** and **structurally** to seamlessly obtain and marry entire supply chain phenotypes and genotypes and take advantage of the rapidly-declining cost of genotyping to capture the cumulative value derived from using genomic information for multiple purposes (selection, parentage, genetic defects, marker-assisted management, product differentiation, traceability) will be ideally positioned to fully realize the nascent potential of genomic information.

Thanks for inviting me!

Value proposition work supported by National Research Initiative competitive grant no. 2009-55205-05057 ("Integrating DNA information into beef cattle production systems") from the USDA National Institute of Food and Agriculture Animal Genome Program.

USDA
United States Department of Agriculture
National Institute of Food and Agriculture


Number of US beef operations (2010)
Farms
Cattle (millions)
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
30
25
20
15
10
5
0
606,200
9.0
85,850
5.4
68,450
11.9
5,850
5.1
766,350
31.4
1-49 head
50-99 head
100-499 head
500+ head
TOTAL
Herd size

There are 260 feedlots with a one time capacity of >16,000 cattle

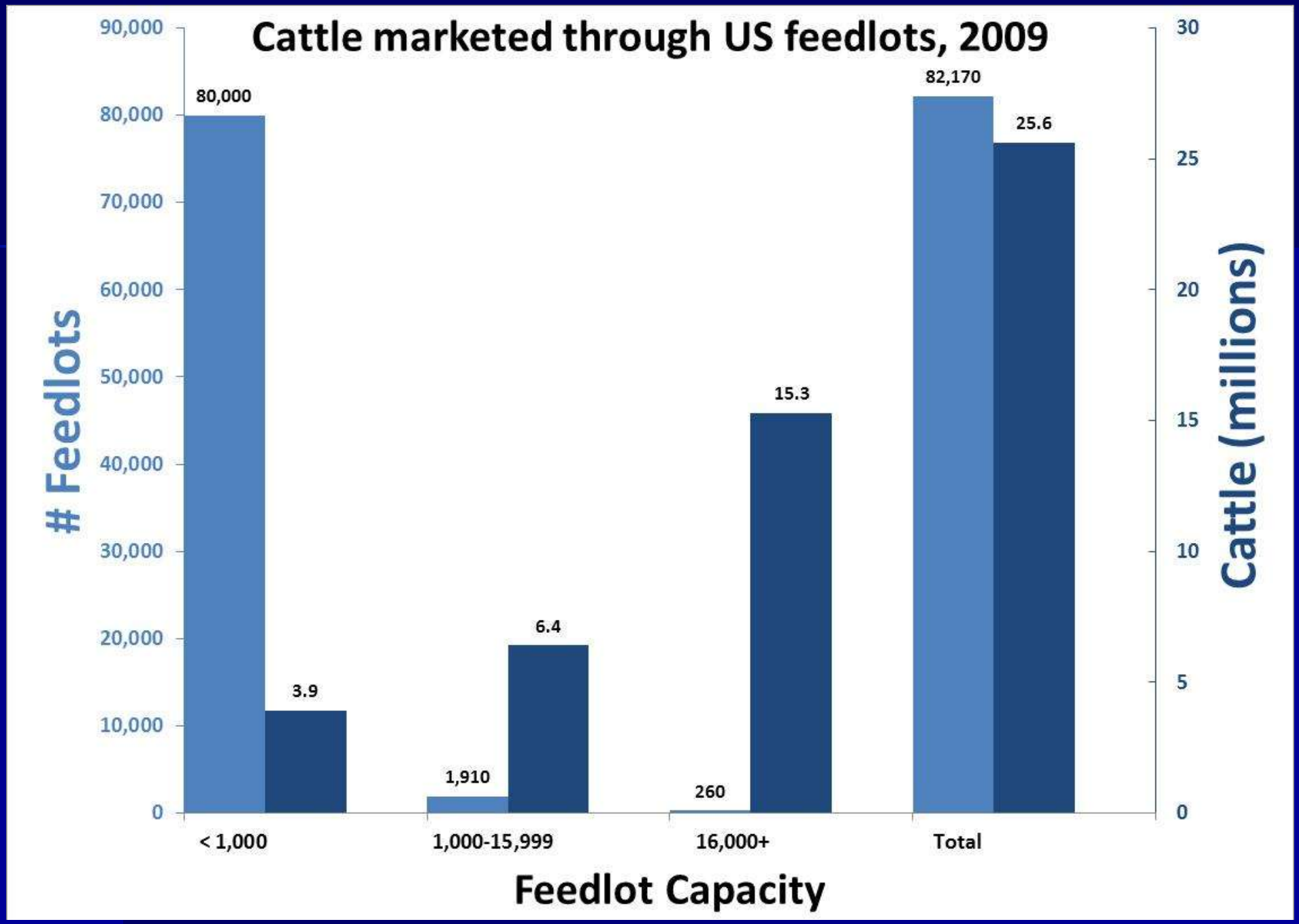
Capacity of large cattle feeding operations in the U.S. – 2009 (Source: web sites of the companies listed and personal communication)

Rank	Company	One-time capacity
1.	JBS Five Rivers Cattle Feeding LLC, Greeley, CO	839,000
2.	Cactus Feeders, Inc., Amarillo, TX	520,000
3.	Cargill Cattle Feeders LLC, Wichita, KS	335,000
4.	Friona Industries LP, Amarillo, TX	275,000
5.	AzTx Cattle Co., Hereford, TX	265,000
6.	J. R. Simplot Co., Grand View, ID	230,000
7.	Irisk and Doll, Cimarron, KS	200,000
8.	Four States Feedyards, Lamar, CO	195,000[1]
9.	Agri Beef Co., Boise, ID	175,000
10.	Pinal Feeding Company, Maricopa, AZ	150,000[2]

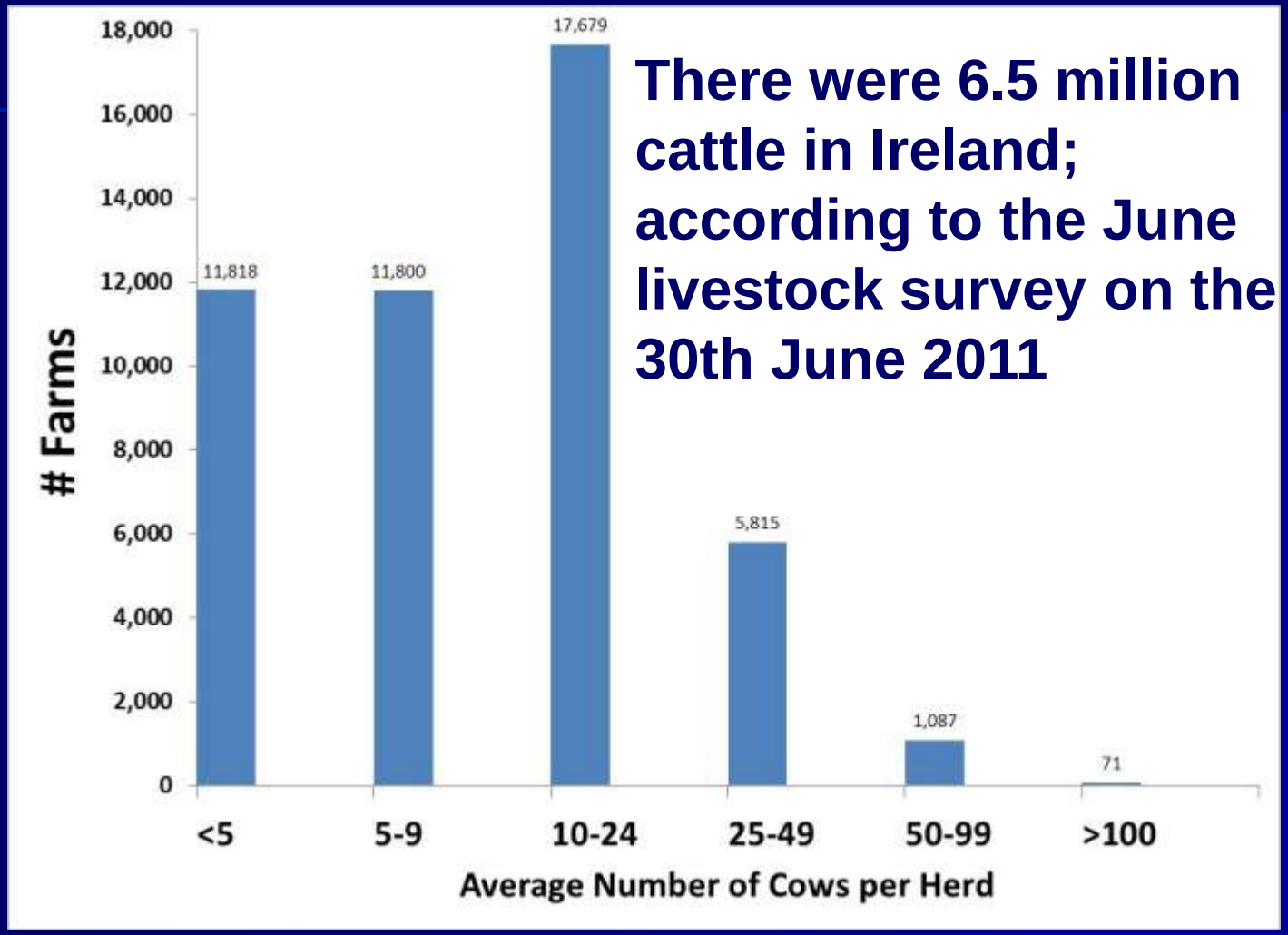
[1]Value for 2006 obtained from: http://agr.wa.gov/fof/docs/feedlot.pdf.

[2]Reported as "capacity for over 150,000 head of cattle" on the company web site.

http://ag.arizona.edu/ANS/swnmc/Proceedings/2010/06_Galyean_2010.pdf


Cattle marketed through US feedlots, 2009
Feedlots
Cattle (millions)
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
30
25
20
15
10
5
0
80,000
3.9
1,910
6.4
260
15.3
82,170
25.6
< 1,000
1,000-15,999
16,000+
Total
Feedlot Capacity

Count of calving beef cows in various categories of cow size on the ICBF database and with at least one cow calving record in the period May 2007 to May 2008.



There were 6.5 million cattle in Ireland; according to the June livestock survey on the 30th June 2011

Evans et al. 2008. Developments in National and International beef evaluations; some experiences from Ireland. INTERBULL Meeting Niagara Falls, NY, June 16th -19th, 2008

Different herd classifications based on type of beef cows calved for herds with at least one cow calving record in the period May 2007 to May 2008 in ICBF database.

Type of herd on ICBF database	Count of herds	Count of cows calved	Average number of cows per type of herd	
			Pedigree	Crossbred
Crossbred beef cows only	40,482	503,270	0	12
Pedigree beef & crossbred beef cows	5,905	126, 512	4	17
Pedigree beef, crossbred beef & dairy cows	967	17,712	4	14
Pedigree beef cows only	702	5,028	7	0
Pedigree beef and dairy cows	5	1,061	5	0
TOTAL	48,061	527,071	5	10

Evans et al. 2008. Developments in National and International beef evaluations; some experiences from Ireland. INTERBULL Meeting Niagara Falls, NY, June 16th -19th, 2008