Survey of genetic technology knowledge and use among beef cattle producers

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Contents

Overview/introduction to the data

This survey data comes from a collaboration between the MU Animal Genomics group and the Department of Agricultural Education & Leadership. The survey was designed to evaluate Missouri beef cattle producers' use of and attitude towards genetic (EPDs: "estimated progeny differences" for economically relevant traits calculated based on pedigree relatedness) and genomic (GE-EPDs: EPDs augmented with genomic relatedness data obtained from DNA genotyping) technologies when making selection and breeding decisions. In the first phase of the survey, beef cattle producers across the country who subscribe to BEEF Magazine were surveyed online. In the next phase of the survey, beef cattle producers at 11 sale barns were surveyed over the course of winter 2017. In 2017, Missouri ranked second in the nation for total calf crop and beef cows that have calved, and this survey and the results of these analyses will help to inform future university extension efforts. Questions were as follows:

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1. Out of 100%, when choosing breeding stock how much do you use EPDs and how much do you use visual inspection?
2. How often do you use the following items when selecting breeding animals?
    - EPDs
    - Genomic tests
    - Visual inspections

- Breed association staff
- Breed/semen catalogs
- Semen distributors
- Trusted breeder from whom you've previously purchased stock
- Other producers

3. How often do you use consider the following EPD indexes when selecting breeding stock?
   - CED
   - BW
   - WW
   - YW
   - MILK
   - CEM
   - REA
   - MARB
   - Breed-specific value indexes ($W, $F, $TI, etc.)
   - ACC

Where:

- **CED:** calving ease direct
  - "...expressed as percentage of unassisted births, with a higher value indicating greater calving ease in first-calf heifers. It predicts the average difference in ease with which a sire's calves will be born when he is bred to first-calf heifers." (American Angus Association)
- **CEM:** calving ease maternal
  - "...expressed in percentage unassisted births with a higher value indicating greater calving ease in first-calf daughters. It predicts the average ease with which a sire's daughters will calve as first calf heifers when compared to daughters of other sires." (American Angus Association)
- **BW:** birth weight
- **WW:** weaning weight
- **YW:** yearling weight
- **MILK:** maternal milk yield
- **REA:** ribeye area
  - "Expressed in square inches, [REA] is a predictor of the difference in ribeye area of a sire's progeny compared to progeny of other sires." (American Angus Association)
- **MARB:** marbling
  - MARB is "expressed as a fraction of the difference in USDA marbling score of a sire's progeny compared to progeny of other sires" (American Angus Association), where marbling score is based upon degree of intramuscular fat marbling.
- **Breed specific value indexes:** allow for comparison of animals based upon multiple weighted traits
- **ACC:** accuracy, EPD reliability where 1 indicates higher reliability. "Accuracy is impacted by the number of progeny and ancestral records included in the analysis." (American Angus Association)

4. Which of the following would prevent you from using EPDs?
   - EPDs are difficult to read
   - Inconsistency between breed EPDs
   - Difficult to understand difference between breed baseline and animal reports
   - Too much overlap in composite data
   - Too many bull EPDs to comb through
   - EPDs are not available for the bulls I purchase
   - EPDs have not worked in my situation
   - EPDs don't accurately reflect genetic merit
   - EPDs don't reflect all important factors in selecting breeding animals
5. How important are the following factors in choosing breeding stock for your farm?
   - EPDs
   - Visual inspection

    - Price
    - Previous use of specific animal/genetic line
    - Purebred breeder recommendation
    - Other producers
6. Who makes the breeding decisions on your farm?
    - Me
    - My grandparents
    - My parents
    - My spouse
    - My siblings
    - My sons/daughters
    - My farm manager (not me)
7. How do you learn about new breeding information and new industry technologies?
    - Trade publications/magazines
    - Breed associations
    - Local extension office/agent
    - Local ag teacher
    - Online resources
    - Veterinarian
    - Semen Salesman (ABS, Select Sires, Genex, Cattle Visions, etc.)
    - Other producers
8. How big was your cattle operation (total cows, bulls, calves) in 2016?
9. How old are you?
10. Are you male or female?

Hypotheses

There are 3 main hypotheses which will be tested a number of different ways.

1. Older producers tend to be less progressive and therefore rely more heavily on visual appraisal when making breeding decisions.
2. Size of operation is predictive of EPD/GE-EPD use.
3. There is a relationship between reported EPD usage and reported barriers to EPD usage.

Data import and cleaning

- Surveys with reported age < 18 years were removed.
- Surveys with reported size of operation < 1 were removed.
- In cases where only one of the question 1 (visual appraisal vs. EPD usage) elements was completed, the other element was imputed by subtracting the completed element from 100.
    - Some respondents provided answers to question 1 that totaled to > 100. A new, standardized variable (`epd_usage_stand`) was created by dividing `usage_percent_epd` by the total of `usage_percent_epd` and `usage_percent_visual`.
- Responses that provided a range of numbers for `size_of_operation` were set to NA.
- Responses that fell outside of the appropriate numeric range (i.e., a 7 when only 6 choices were provided) were set to NA

Exploratory data analysis and summarization

How often do you use the following items when selecting breeding animals?

- With possible answers:
  - 1: Never
  - 2: Rarely
  - 3: Occasionally
  - 4: Frequently
  - 5: Often
  - 6: Always

Mean scores were as follows:

Response variable	Mean response	Median response
Visual inspection	5.500000	6
EPDs	4.737527	5
Trusted breeder	4.316239	5
Breed/semen catalogs	3.735484	4
Other producers	3.319613	3
Genomic tests	3.194748	3
Semen distributors	2.949672	3
Breed association staff	2.524229	2

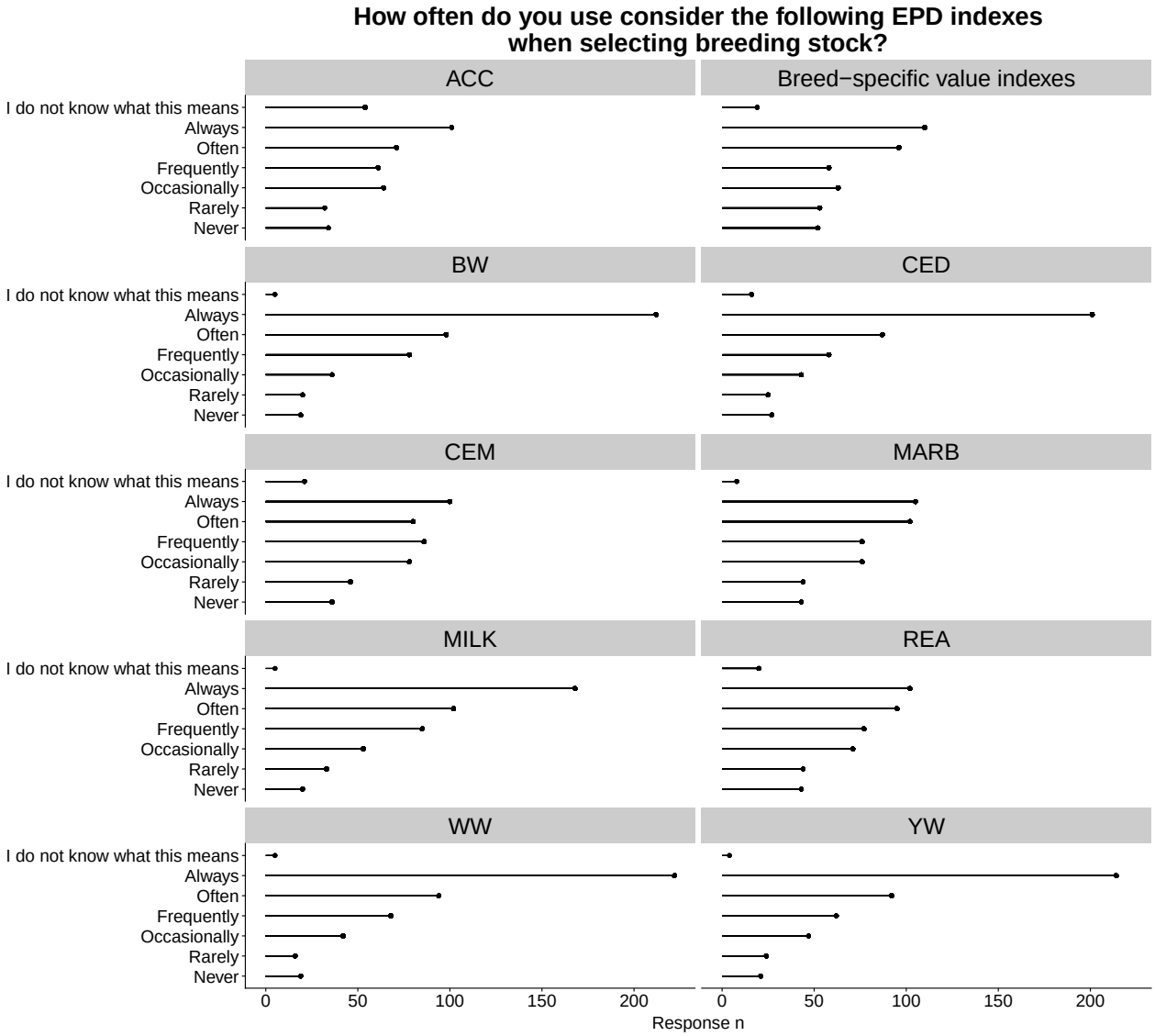
Unsurprisingly, surveyed producers rely most heavily on visual ispection with EPDs in second.

How often do you use consider the following EPD indexes when selecting breeding stock?

- With possible answers:
  - 1: Never
  - 2: Rarely
  - 3: Occasionally
  - 4: Frequently
  - 5: Often
  - 6: Always
  - 7: I do not know what this means

Excluding "7: I do not know what this means", mean scores for each EPD were as follows:

Response variable	Mean response	Median response
WW	4.882863	5
BW	4.840173	5
YW	4.786956	5
CED	4.714286	5
MILK	4.561822	5
ACC	4.118457	4
MARB	4.042601	4
REA	4.025463	4
CEM	4.004695	4
Breed-specific value indexes	3.979167	4



Growth traits (weaning weight, birth weight, and yearling weight) are most often considered when making breeding decisions. This is unsurprising since most of the producers surveyed are likely cow/calf producers that sell cattle at weaning and are paid on the pound.

For each EPD index, what is the distribution of responses? How many responses are 7s ("I do not know what this means")? What percentage of the total responses for each variable are 7s?

Response variable	Total responses	Total "7" responses	Percent "7" responses
ACC	417	54	12.9%
CEM	447	21	4.7%
REA	452	20	4.4%
Breed-specific value indexes	451	19	4.2%
CED	457	16	3.5%
MARB	454	8	1.8%
WW	466	5	1.1%
MILK	466	5	1.1%
BW	468	5	1.1%
YW	464	4	0.9%

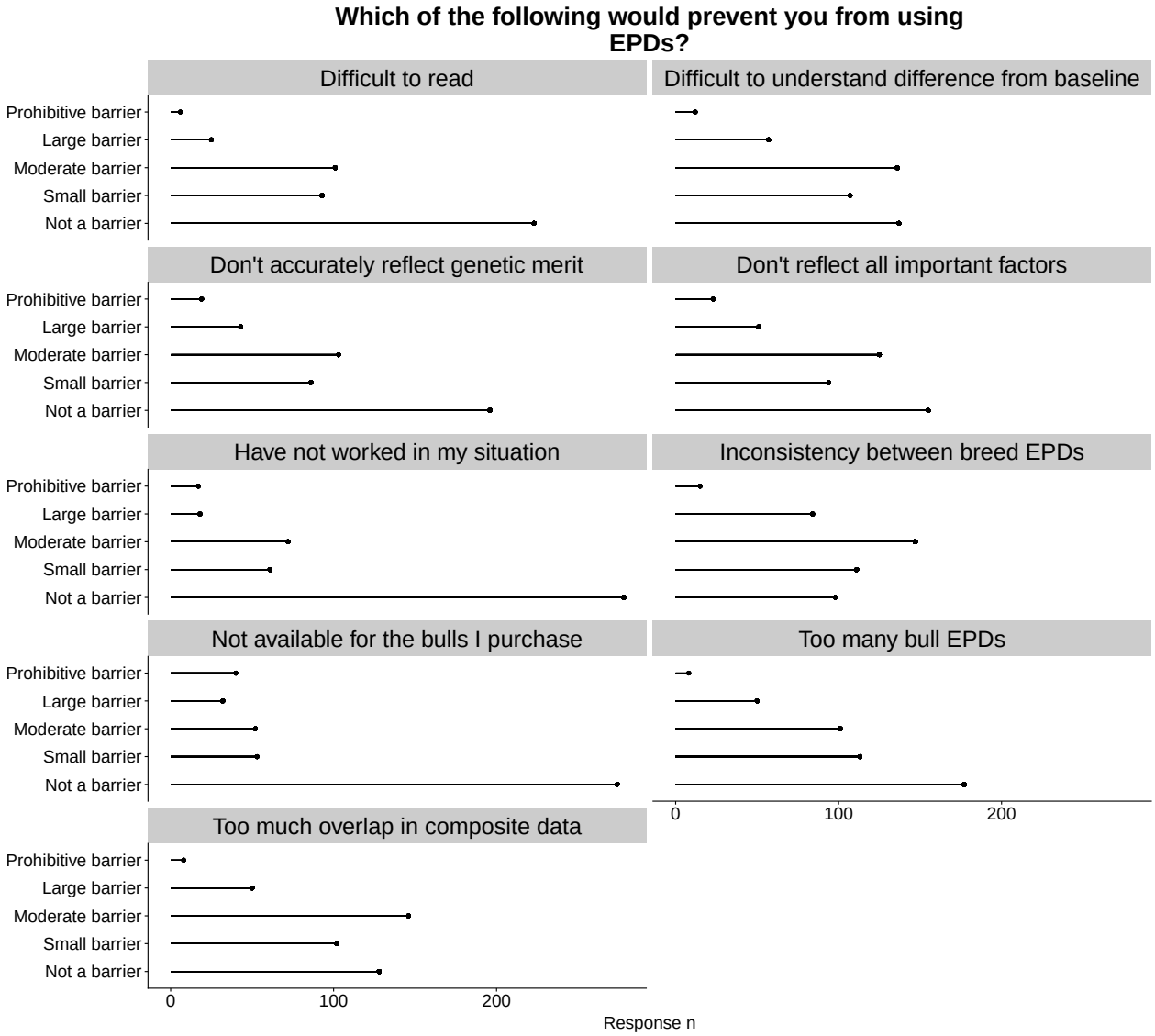
Of the 417 respondents that provided responses for the question about EPD accuracy, ~13% responded with "7: I do not know what this means". However, these results may be underestimated since many fewer people answered the question about accuracy than answered the questions about other EPD idexes. Since accuracy is not actually an EPD itself but a property of EPDs, this question may have been misleading. Still, correctly communicating how accuracy/increased observations affects EPD consistency is vital to dispelling producer mistrust of genetic technology, so this is an important insight.

Which of the following would prevent you from using EPDs?

- With possible answers:
  - 1: Not a barrier
  - 2: Small barrier
  - 3: Moderate barrier
  - 4: Large barrier
  - 5: Prohibitive barrier

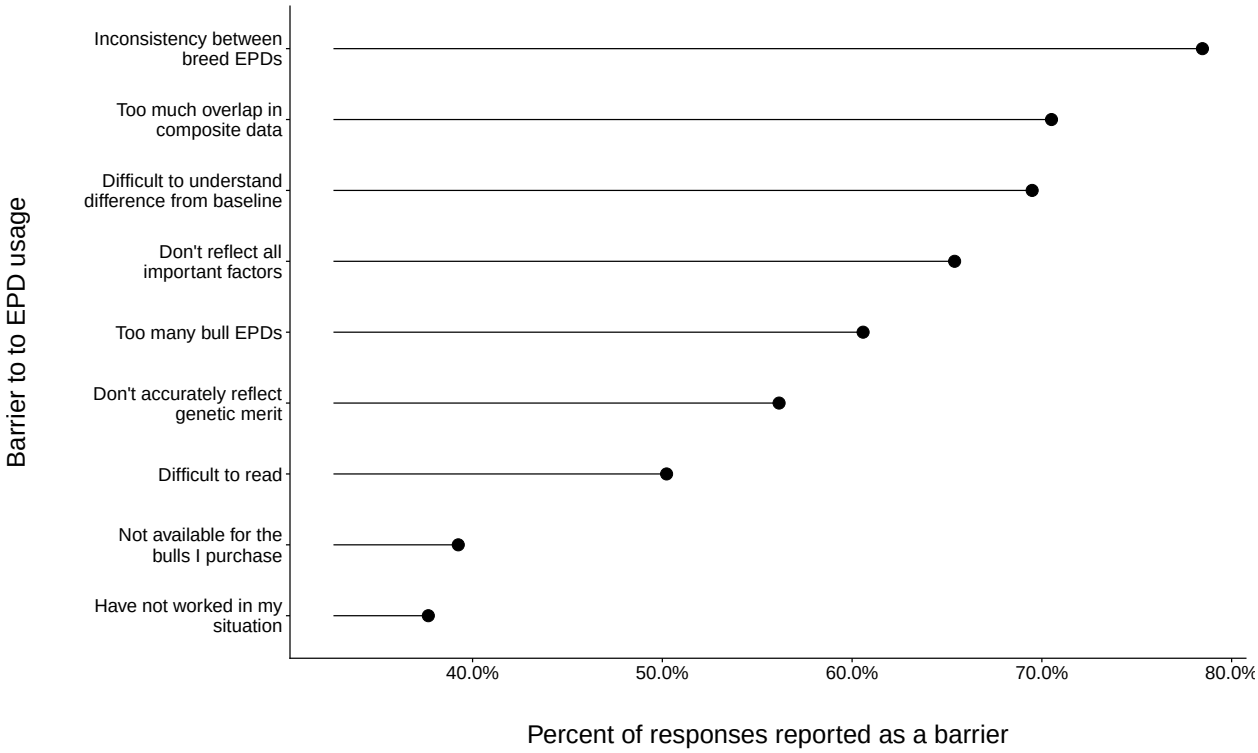
Mean scores were as follows:

Response variable	Mean response	Median response
Inconsistency between breed EPDs	2.575824	3
Difficult to understand difference from baseline	2.331849	2
Too much overlap in composite data	2.327189	2
Don't reflect all important factors	2.314732	2
Don't accurately reflect genetic merit	2.111857	2
Too many bull EPDs	2.106904	2
Not available for the bulls I purchase	1.915743	1
Difficult to read	1.879464	2
Have not worked in my situation	1.733184	1



EPD inconsistency is reported as the largest barrier to EPD usage. However, the range of the mean scores for all barriers is quite small (0.84).

When responses are categorized as not a barrier (1) or a barrier (2, 3, 4, or 5), "inconsistency between breed EPDs", "too much overlap in composite data", and "difficult to understand difference between breed baseline and animal reports" are still reported as the top 3 primary barriers to EPD usage.

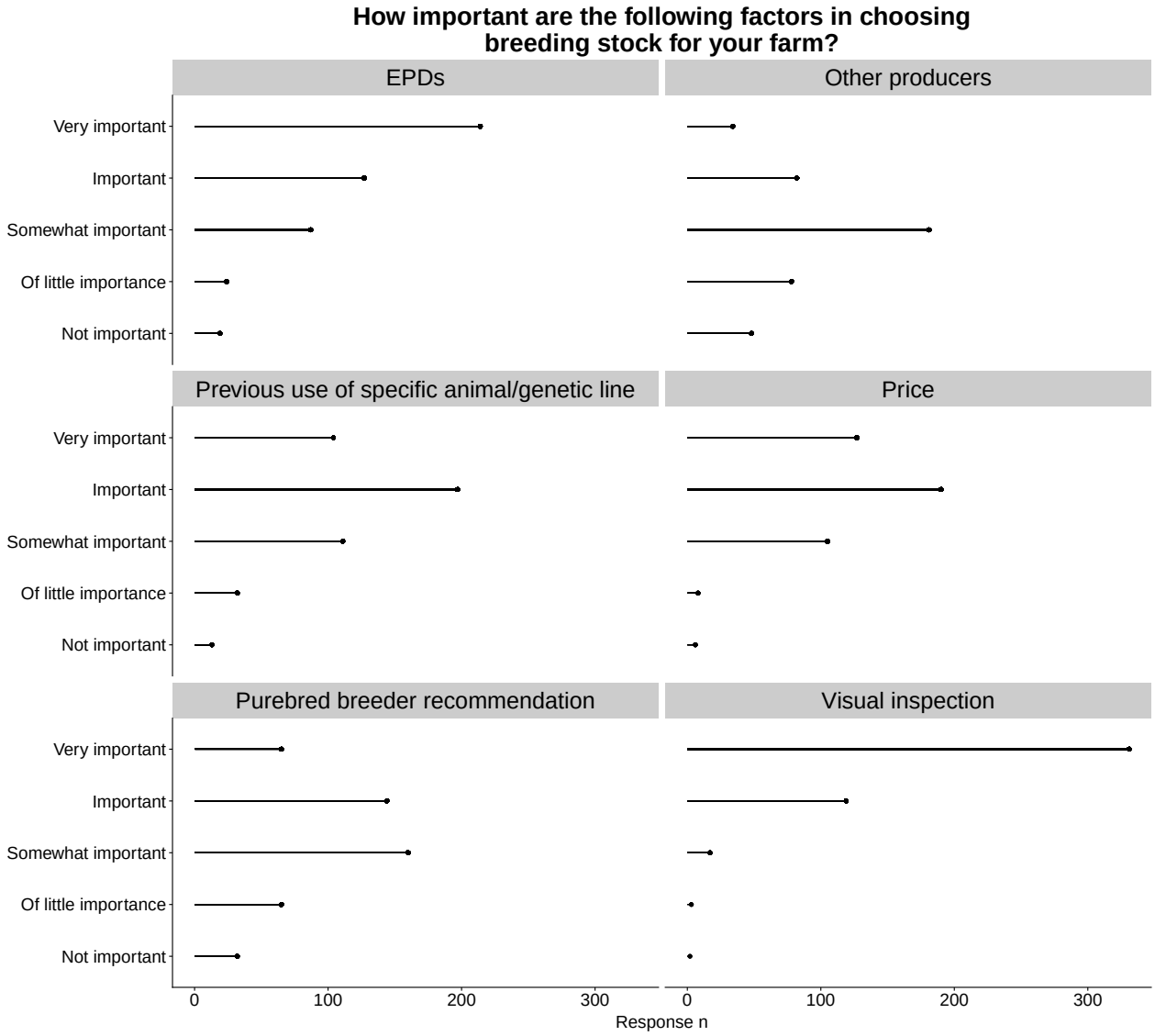


How important are the following factors in choosing breeding stock for your farm?

- With possible answers:
  - 1: Not important
  - 2: Of little importance
  - 3: Somewhat important
  - 4: Important
  - 5: Very important

Mean scores were as follows:

Response variable	Mean response	Median response
Visual inspection	4.639831	5
EPDs	4.046709	4
Price	3.972477	4
Previous use of specific animal/genetic line	3.759300	4
Purebred breeder recommendation	3.311159	3
Other producers	2.943262	3



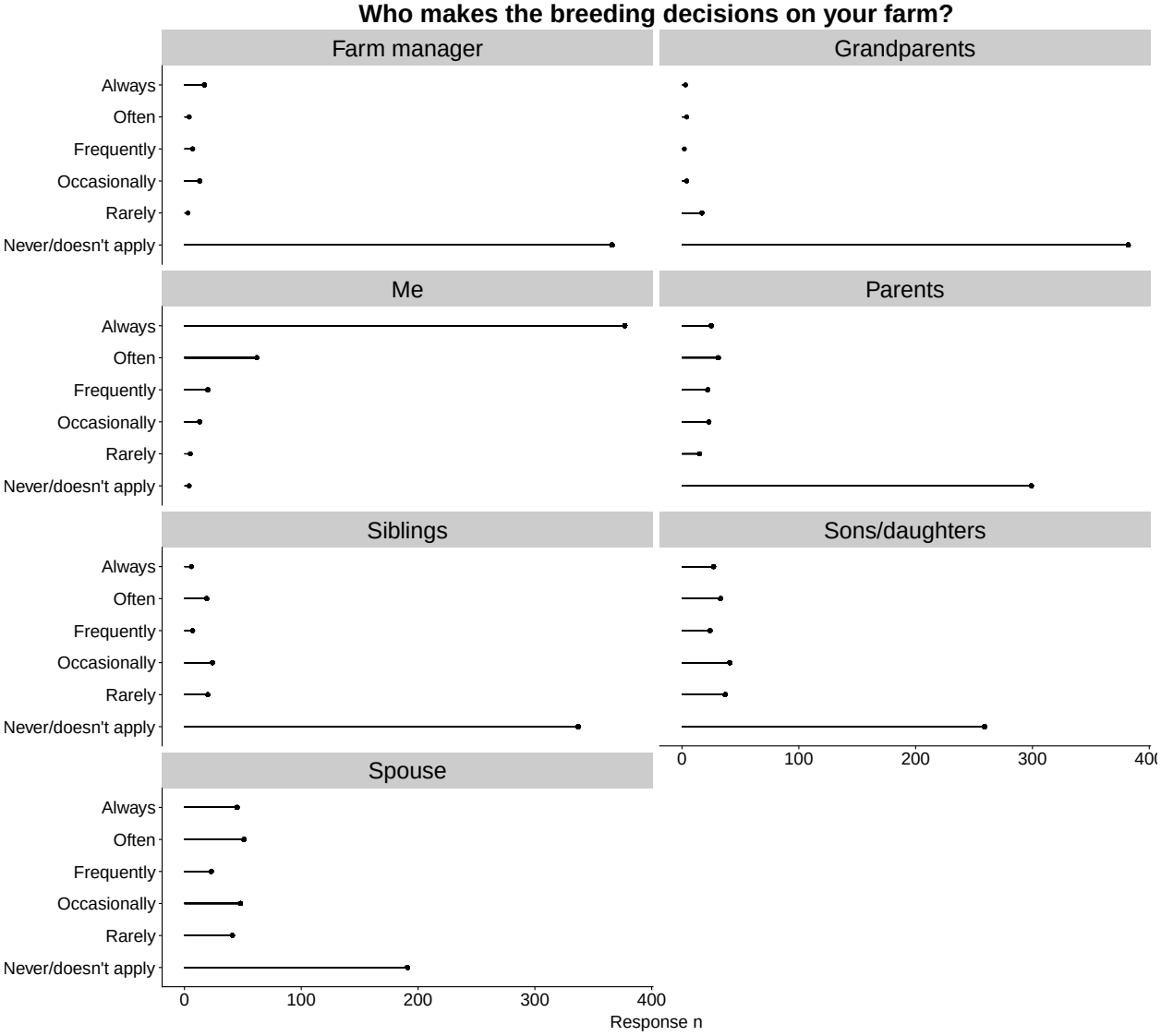
Again, visual inspection and EPDs are reported as the most important factors when making breeding decisions.

Who makes the breeding decisions on your farm?

- With possible answers:
  - 1: Never/doesn't apply
  - 2: Rarely
  - 3: Occasionally
  - 4: Frequently
  - 5: Often
  - 6: Always

Mean scores were as follows:

Response variable	Mean response	Median response
Me	5.623701	6
Spouse	2.591479	2
Sons/daughters	2.087886	1
Parents	1.906024	1
Siblings	1.472155	1
Farm manager	1.368293	1
Grandparents	1.150485	1



Overwhelmingly, surveyed producers list themselves as the main decision makers on their farms.

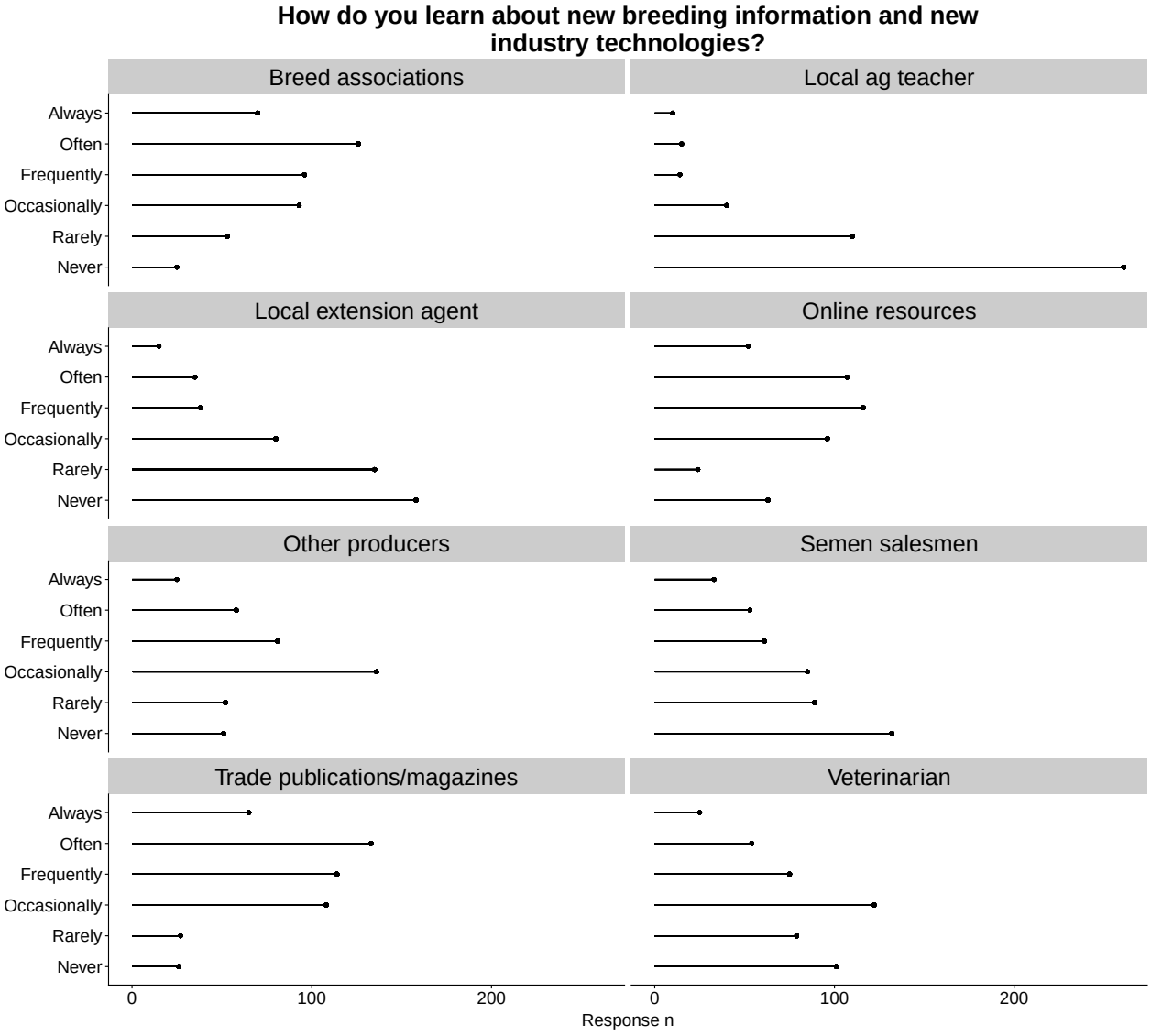
How do you learn about new breeding information and new industry technologies?

- With possible answers:
  - 1: Never

- 2: Rarely
- 3: Occasionally
- 4: Frequently
- 5: Often
- 6: Always

Mean scores were as follows:

Response variable	Mean response	Median response
Trade publications/magazines	4.048626	4
Breed associations	3.982721	4
Online resources	3.733624	4
Other producers	3.292804	3
Veterinarian	2.943107	3
Semen salesmen	2.807947	3
Local extension agent	2.353579	2
Local ag teacher	1.760000	1



On average, producers rely the least on university extension and ag teachers to learn about technologies and the most on maggazines/publications and breed associations. However, these results may be biased as the online phase of the survey was facilitated with the help of BEEF Magazine.

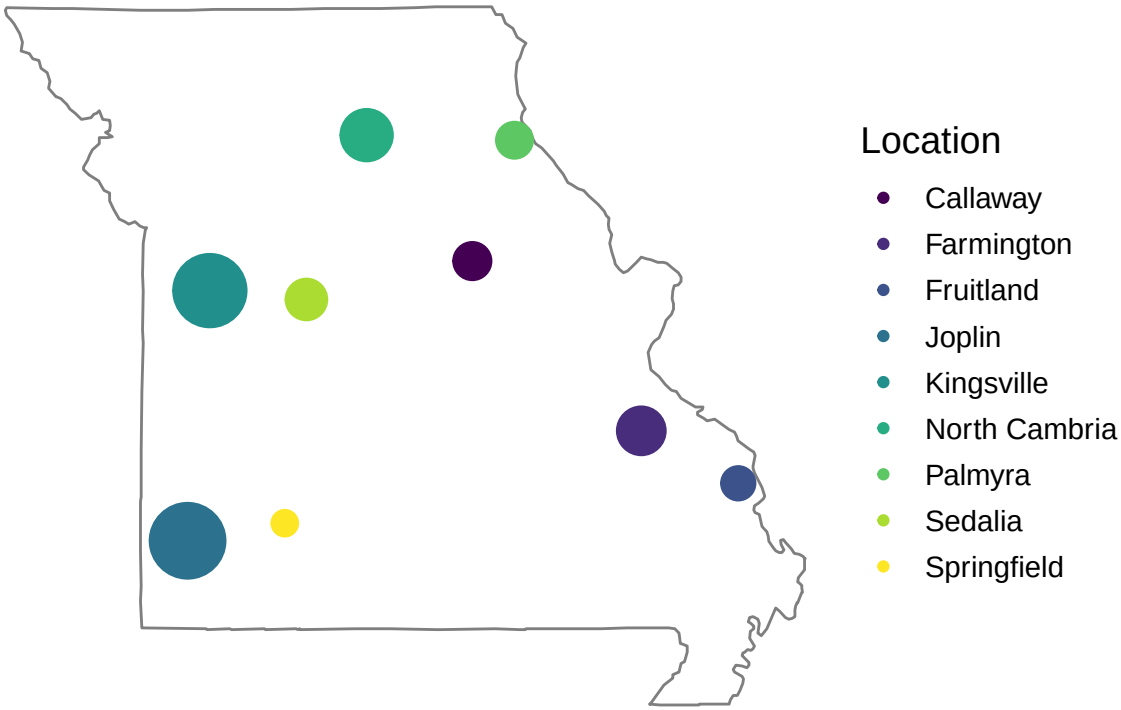
Demographics

Location and medium

After data cleaning, 257 surveys ere collected in person and 249 surveys were collected online. Of surveys collected in person at sale barns, Joplin Regional Stockyards and Kingsville Livestock Auction are the most highly represented.

Medium	Location	n
Online	Online	224
In Person	Joplin	62
In Person	Kingsville	58
In Person	North Cambria	29
In Person	Farmington	25
Online	Pilot	25
In Person	Sedalia	18
In Person	Callaway	15
In Person	Palmyra	14
In Person	Fruitland	12
In Person	Springfield	7

The locations of sale barns used for in-person data collection were as follows:



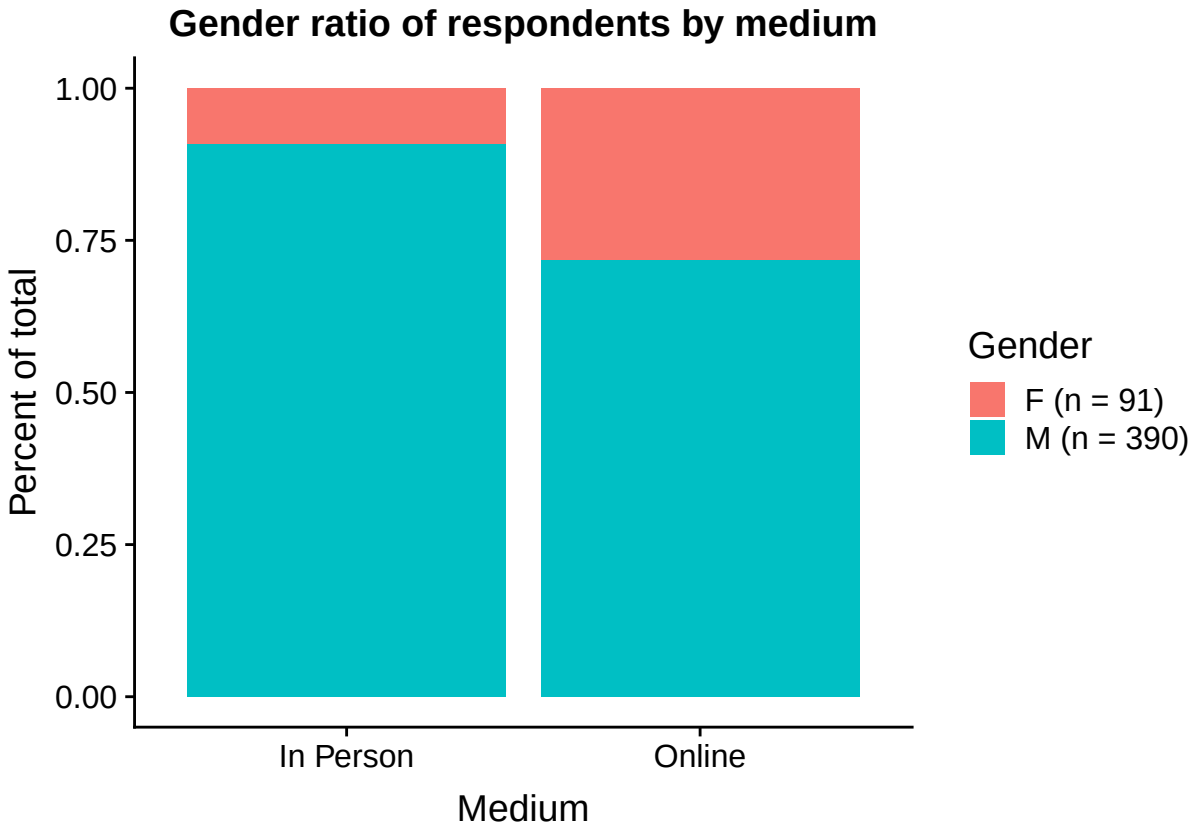
Age and sex

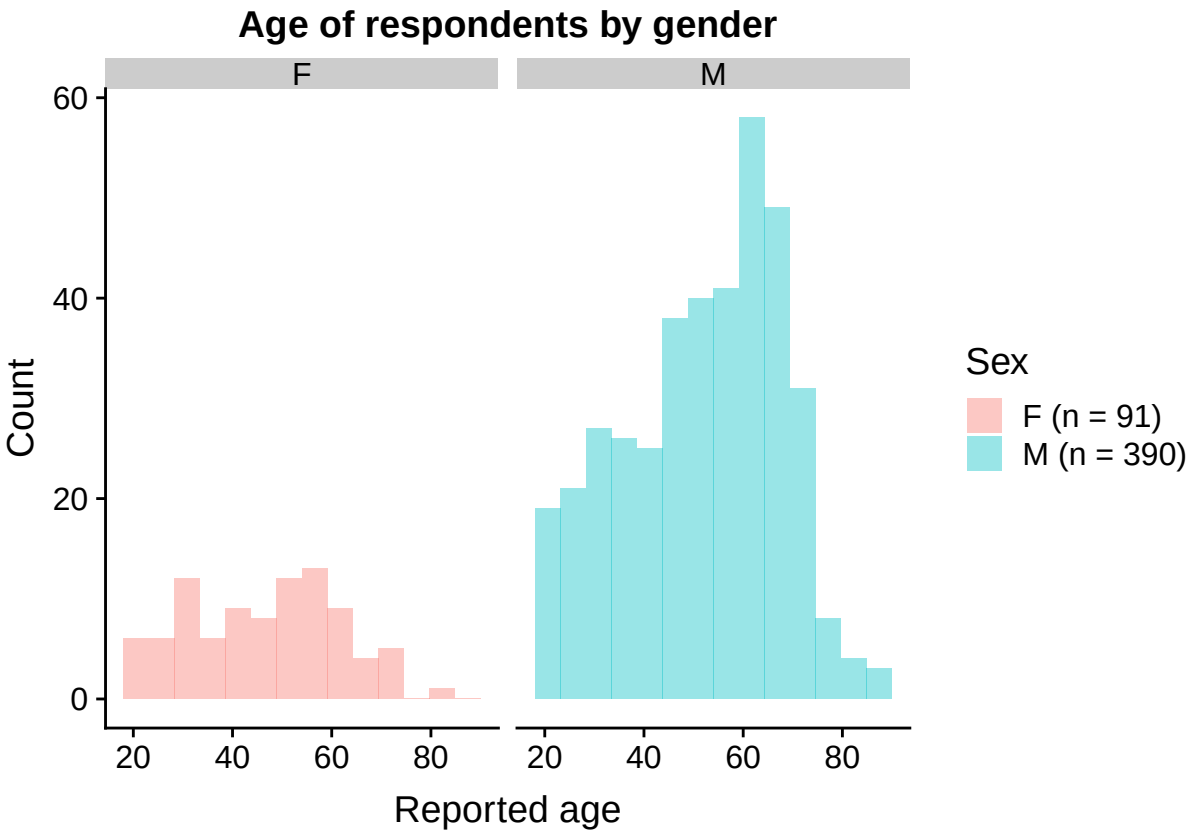
The mean age of all respondents was ~ 51 years and the median age was ~ 53 years. Online respondents were ~ 3 years younger than sale barn respondents on average.

Medium	Mean age	Median age	n
Online	49.12851	50.0	249
In Person	52.90833	56.5	240

Overall, producers that identified as women tended to be slightly younger than producers that identified as men. However, only ~ 19% of total age-reporting respondents identified as women, the majority of which came from online responses. Of in person responses, 9% were women. Of online responses, 28% were women.

Sex	Medium	Mean age	Median age	n
M	In Person	52.84360	57.0	211
M	Online	50.55866	52.0	179
F	Online	45.47143	46.5	70
F	In Person	49.09524	54.0	21





Size of operation

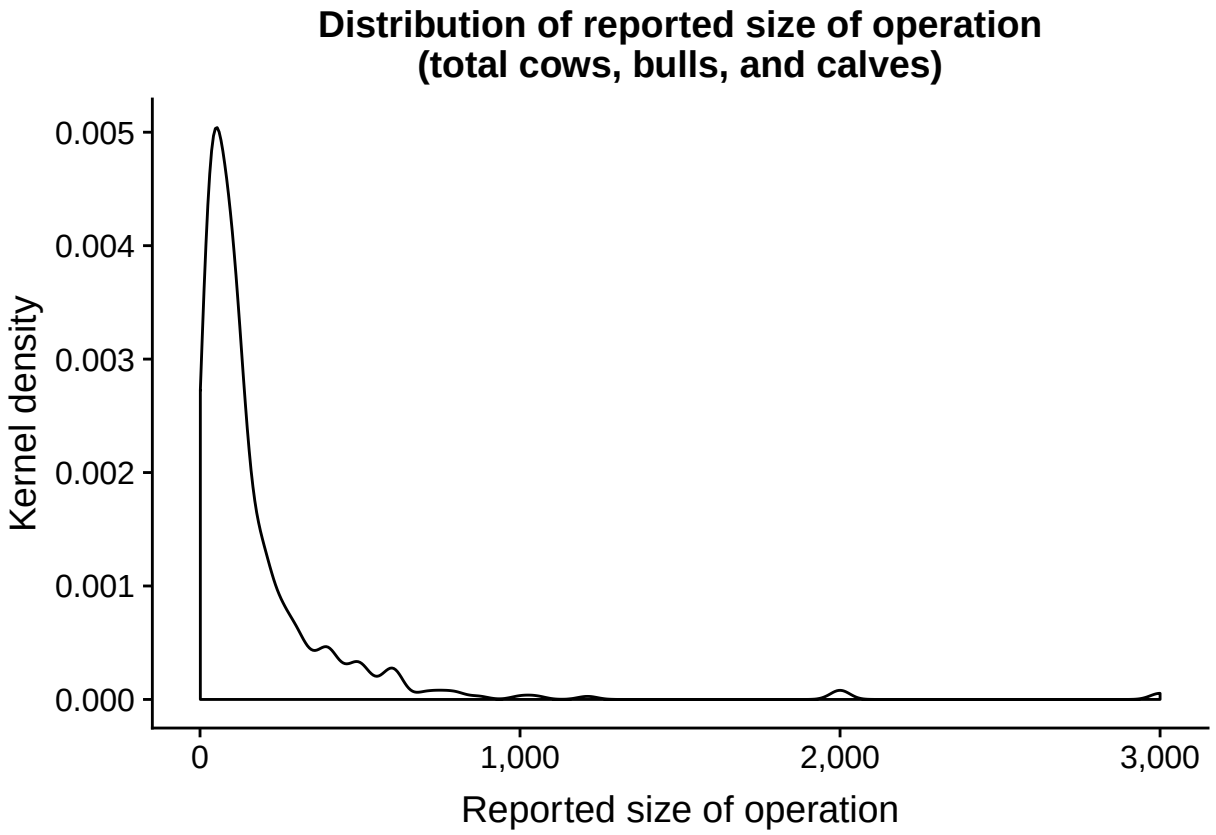
There is a huge spread in reported size of operation. Of all respondents, the median size of operation in 100. This is much higher than USDA ERS estimates of average beef cattle operation size, which may suggest some bias in our results.

Mean size	Median size	Minimum size	Maximum size	SD	n
176.0777	100	1	3000	287.9471	489

Summary statistics broken down by medium and location are as follows:

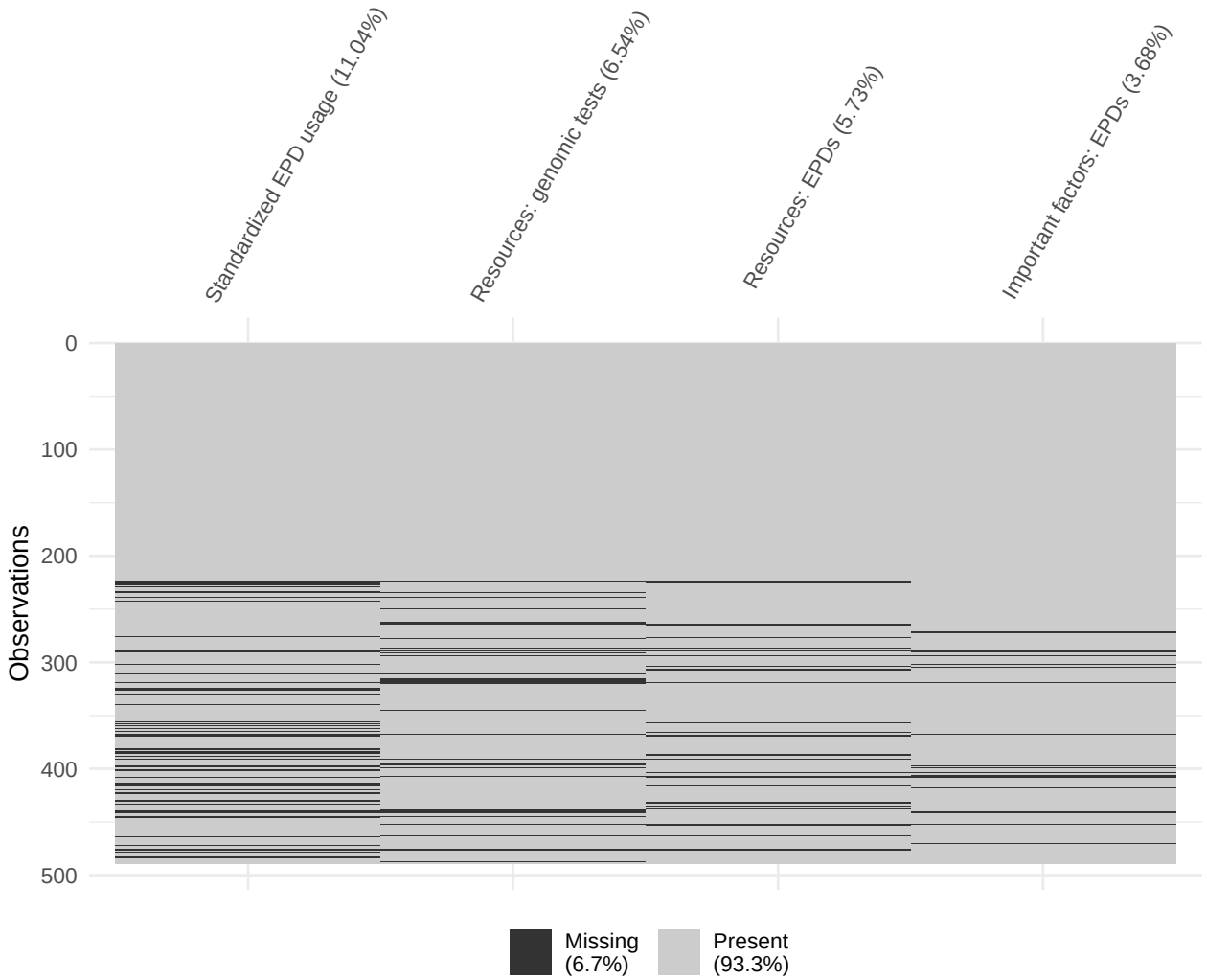
Medium	Location	Mean size	Median size	Minimum size	Maximum size	SD	n
In Person	Farmington	243.3200	125.0	15	1211	284.33515	25
In Person	Joplin	208.7097	122.5	12	3000	382.27882	62
In Person	North Cambria	203.1724	115.0	15	750	233.57089	29
In Person	Kingsville	162.5172	100.0	1	800	171.87391	58
Online	Online	181.2143	100.0	5	3000	327.76688	224
In Person	Fruitland	114.0000	95.5	16	280	78.33146	12
In Person	Sedalia	121.9444	95.0	20	400	109.05340	18
In Person	Callaway	117.4000	80.0	22	400	122.74643	15
In Person	Palmyra	154.5714	70.0	3	600	188.32897	14
Online	Pilot	86.6000	65.0	2	300	75.92924	25
In Person	Springfield	216.5714	60.0	20	1000	358.90661	7

When visualized, reported size of operation is heavily left-skewed.

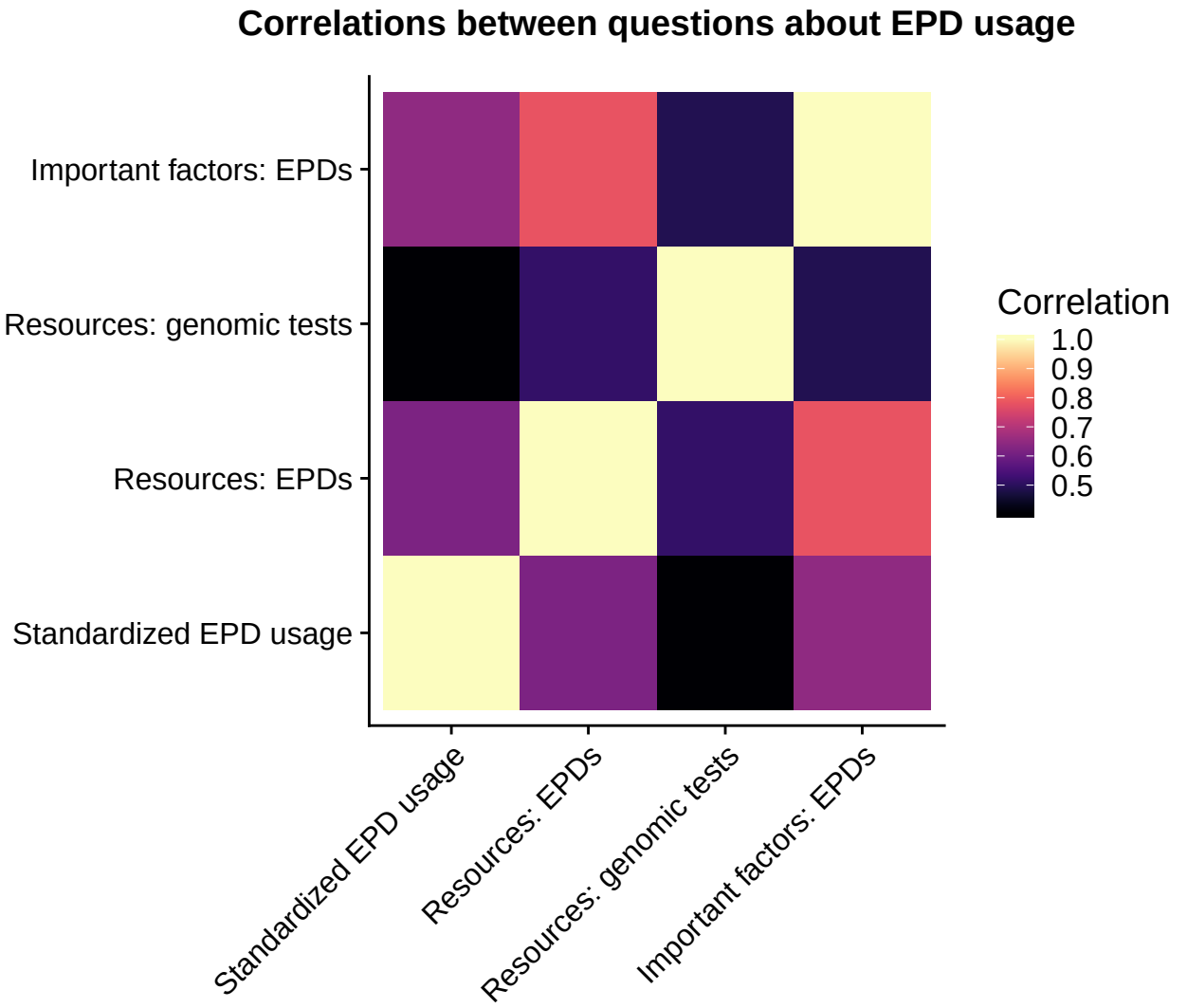


Modelling

In the survey, there are 4 questions that ask about frequency and value of EPD/GE-EPD usage. In the dataset, these questions have various degrees of missingness. Standardized EPD usage (% importance of visual evaluation divided by % importance of EPDs when making breeding decisions) by far has the most missing data (11.04%). This may be because the question was on the front of the survey in the paper version, and therefore overlooked or assumed to be part of the instructions.



Further, reporting a higher % EPD usage requires reporting a lower % visual appraisal usage since the answers can only add up to 100%. Visual appraisal is still a vital part of making breeding decisions, so the responses to this question may not accurately represent EPD usage among respondents. The correlation between the responses to questions about EPD/GE-EPD usage range from 0.406 to 0.782, with GE-EPD usage being the least correlated to other questions.



For this reason, some of the models were run iteratively using each of the four question responses as the Y variable.

1. Older producers tend to be less progressive and therefore rely more heavily on visual appraisal when making breeding decisions.

In order to determine the relationship between EPD usage and age, the following model was tested.

$$Y_{ijk} = \mu + \beta X_i + \gamma_{j(k)} + e_{ijk}$$

Where:

- Y is the scaled EPD usage from question 1

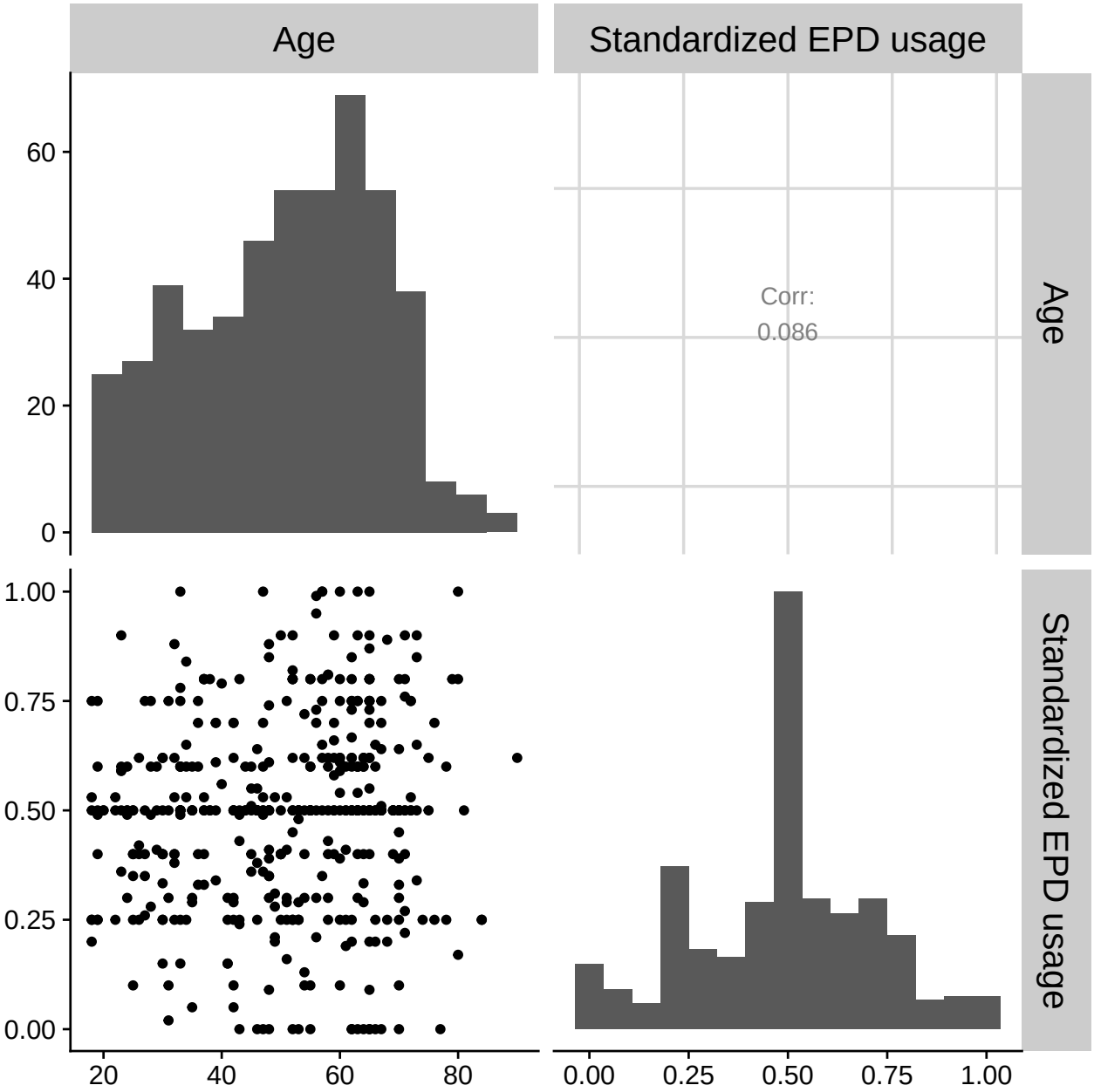
- μ is the mean
- X is the fixed effect of age (continuous)
- γ is the random effect of sale barn nested within medium (survey conducted online vs. in person) for $j = 1, 2$
- e is the residual

```r
set.seed(88)

#Including random effects
car::Anova(lmer(epd_usage_stand ~
                  age +
#https://stats.stackexchange.com/questions/79360/mixed-effects-model-with-nesting
                  (1|medium/sale_barn),
     data = responses),
     type = "III")
```

```
## Analysis of Deviance Table (Type III Wald chisquare tests)
##
## Response: epd_usage_stand
##               Chisq Df Pr(>Chisq)
## (Intercept) 85.2237  1     <2e-16 ***
## age          3.7128  1      0.054 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The model predicting scaled EPD usage from age is not significant at $\alpha = 0.05$ (p = 0.054). When the two variables are visualized, there doesn't appear to be a clear relationship.



2. Size of operation is predictive of EPD/GE-EPD use.

We hypothesized that producers who are more reliant on cattle productuon as their source of income (i.e., producers with reportedly larger operations) would be more data driven, and therefore more likely to implement EPDs. This hypothesis is supported by the USDA ERS assertion that "oerations with 40 or fewer head are largely part of multi-enterprises, or are supplemental to off-farm employment". In order to determine the relationship between size of operation and reported EPD usage, the following model was tested.

$$Y_{ijk} = \mu + \beta X_j + \gamma_{j(k)} + e_{ijk}$$

Where:

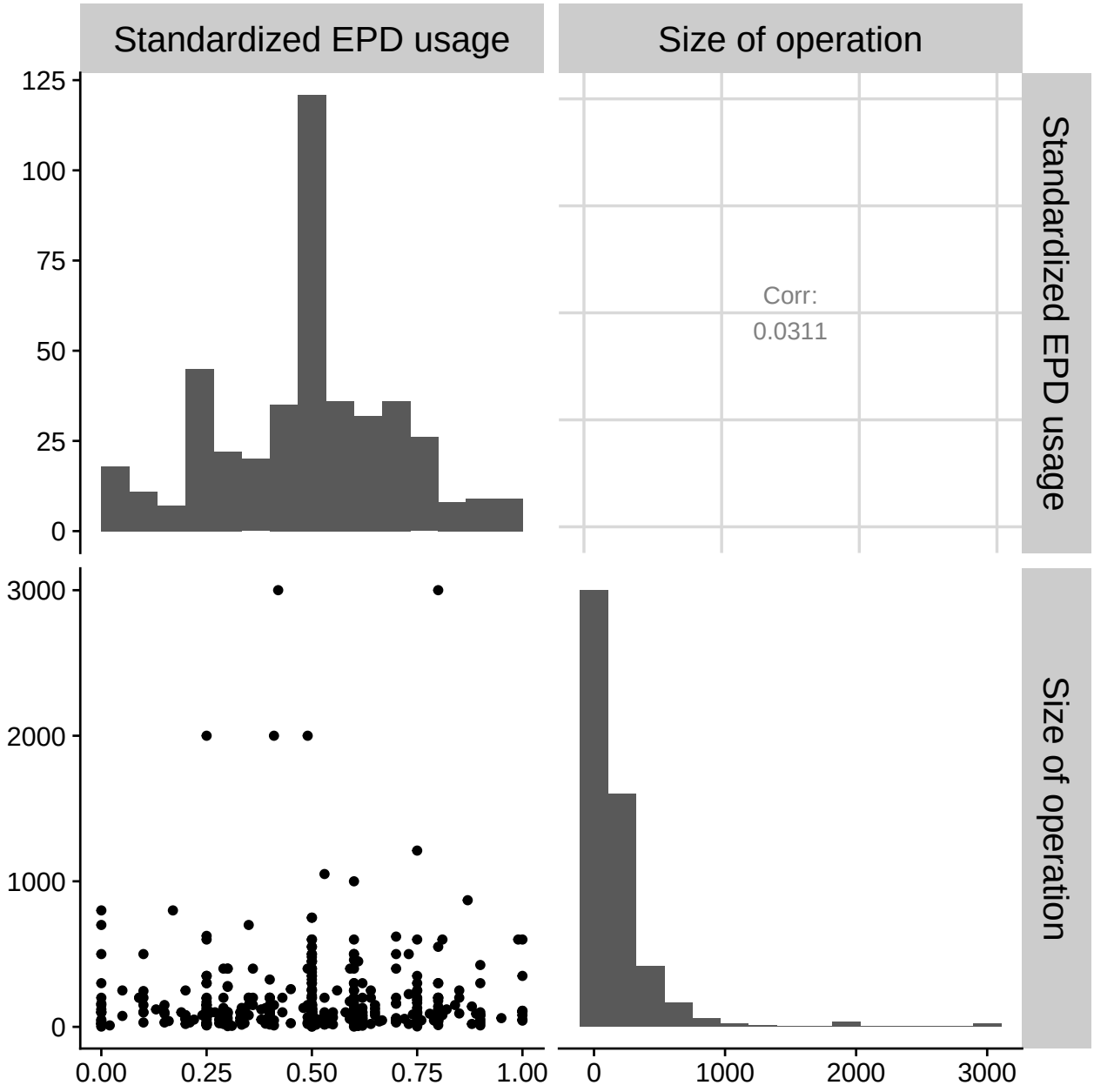
- Y is the scaled EPD usage from question 1

- μ is the mean
- X is the reported operation size reported in question 8 (continuous)
- γ is the random effect of sale barn nested within medium (survey conducted online vs. in person) for $j = 1, 2$
- e is the residual

```
#Including random effects
Anova(lmer(epd_usage_stand ~
                 size_of_operation +
                 #sale barn nested in medium
                 #https://stats.stackexchange.com/questions/79360/mixed-effects-model-with-nesting
                 (1|medium/sale_barn),
     data = responses))
```

```
## Analysis of Deviance Table (Type II Wald chisquare tests)
##
## Response: epd_usage_stand
##                    Chisq Df Pr(>Chisq)
## size_of_operation 0.3465  1     0.5561
```

Surprisingly, size of operation is also not significant in predicting EPD usage than age (p = 0.5561). Again, there is no clear relationship between the two variables when both are visualized.



3. There is a relationship between reported EPD usage and reported barriers to EPD usage.

Simple linear regression

First, a simple linear regression was fit for each of the 4 response variables assaying EPD usage for each of the 9 barriers listed in question 4.

$$Y = \beta_o + \beta_{ij} X_{ij} + E$$

Where:

- Y is one of the four EPD usage responses described above (`epd_usage_stand`, `resources_epds`, `resources_genomic_tests`, or `important_factors_epds`)
- β_o is the intercept
- $\beta_{ij}X_{ij}$ represents for the i^{th} response variable Y, the reported "prohibitiveness" on a scale of 1-5 where 1 is "not a barrier" and 5 is "prohibitive barrier" (see survey question 4) for one of the 9 potential barriers to EPD usage assayed

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The results of all 36 response variable/barrier to EPD usage model combinations were as follows.

Table 1: Summary of all models with all possible response values

Barrier	Response variable	R^2	p-value	AIC	Significance
Don't reflect all important factors	Standardized EPD usage	0.0662124	0.0000001	-100.26894	*
Don't accurately reflect genetic merit	Standardized EPD usage	0.0620408	0.0000003	-93.91424	*
Have not worked in my situation	Standardized EPD usage	0.0496418	0.0000057	-91.69472	*
Too many bull EPDs	Standardized EPD usage	0.0630820	0.0000003	-86.24392	*
Difficult to read	Standardized EPD usage	0.0258348	0.0011225	-79.94505	*
Difficult to understand difference from baseline	Standardized EPD usage	0.0165530	0.0093656	-74.61891	*
Too much overlap in composite data	Standardized EPD usage	0.0177631	0.0079150	-70.15080	*
Not available for the bulls I purchase	Standardized EPD usage	0.0003210	0.7165778	-65.26086	Not significant
Inconsistency between breed EPDs	Standardized EPD usage	0.0032134	0.2509534	-61.36950	Not significant
Too much overlap in composite data	Important factors: EPDs	0.0561707	0.0000007	1277.21453	*
Too many bull EPDs	Important factors: EPDs	0.1072843	0.0000000	1295.07047	*
Difficult to read	Important factors: EPDs	0.0957229	0.0000000	1297.87592	*
Have not worked in my situation	Important factors: EPDs	0.0750547	0.0000000	1302.76258	*
Don't accurately reflect genetic merit	Important factors: EPDs	0.0605293	0.0000002	1314.88434	*
Difficult to understand difference from baseline	Important factors: EPDs	0.0528625	0.0000009	1315.54495	*
Don't reflect all important factors	Important factors: EPDs	0.0557115	0.0000005	1319.18272	*
Not available for the bulls I purchase	Important factors: EPDs	0.0039953	0.1822146	1343.44484	Not significant
Inconsistency between breed EPDs	Important factors: EPDs	0.0131201	0.0150542	1356.95761	*
Too much overlap in composite data	Resources: EPDs	0.0675132	0.0000001	1510.68964	*
Too many bull EPDs	Resources: EPDs	0.1255719	0.0000000	1534.75702	*
Have not worked in my situation	Resources: EPDs	0.0874544	0.0000000	1540.60334	*
Difficult to understand difference from baseline	Resources: EPDs	0.0680766	0.0000000	1557.13802	*

Don't accurately reflect genetic merit	Resources: EPDs	0.0606957	0.0000002	1557.24736	*
Difficult to read	Resources: EPDs	0.1083684	0.0000000	1562.66579	*
Don't reflect all important factors	Resources: EPDs	0.0517250	0.0000018	1563.01964	*
Not available for the bulls I purchase	Resources: EPDs	0.0175308	0.0057352	1583.40212	*
Inconsistency between breed EPDs	Resources: EPDs	0.0118763	0.0223921	1604.66184	*
Too much overlap in composite data	Resources: genomic tests	0.0268701	0.0007348	1620.25533	*
Difficult to read	Resources: genomic tests	0.0656788	0.0000001	1646.30779	*
Have not worked in my situation	Resources: genomic tests	0.0371452	0.0000564	1662.26731	*
Difficult to understand difference from baseline	Resources: genomic tests	0.0272492	0.0005717	1665.70615	*
Too many bull EPDs	Resources: genomic tests	0.0400683	0.0000260	1680.31958	*
Don't reflect all important factors	Resources: genomic tests	0.0078891	0.0645023	1687.48544	Not significant
Not available for the bulls I purchase	Resources: genomic tests	0.0106751	0.0312021	1688.94295	*
Don't accurately reflect genetic merit	Resources: genomic tests	0.0082621	0.0584819	1689.03211	Not significant
Inconsistency between breed EPDs	Resources: genomic tests	0.0020646	0.3427625	1712.68993	Not significant

---

Of the models that used `epd_usage_stand` as the response variable, all barrier models excluding *"EPDs are not available for the bulls I purchase"* and *"Inconsistency between breed EPDs"* were significant. Of significant models, *"EPDs don't reflect all important factors in selecting breeding animals"* had the lowest AIC and lowest p-value. It would be interesting to see if there is a relationship between responses to this barrier and responses to question about selection index usage (which combine multiple selection traits into one EPD index).

Multiple linear regression

Next, all possible subsets selection was performed to choose a model relating EPD usage to reported barriers to EPD usage. The full model was as follows:

$$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + E$$

Where:

- Y represents scaled EPD usage from question 1
- β_o represents the intercept
- $\beta_{1-9} X_{1-9}$ represents for each of the 9 potential barriers to EPD usage assayed, the reported "prohibitiveness" on a scale of 1-5 where 1 is "not a barrier" and 5 is "prohibitive barrier" (see survey question 4)

All possible subset selection using the `leaps` package:

Table 2: Summary of all possible subsets model selection results

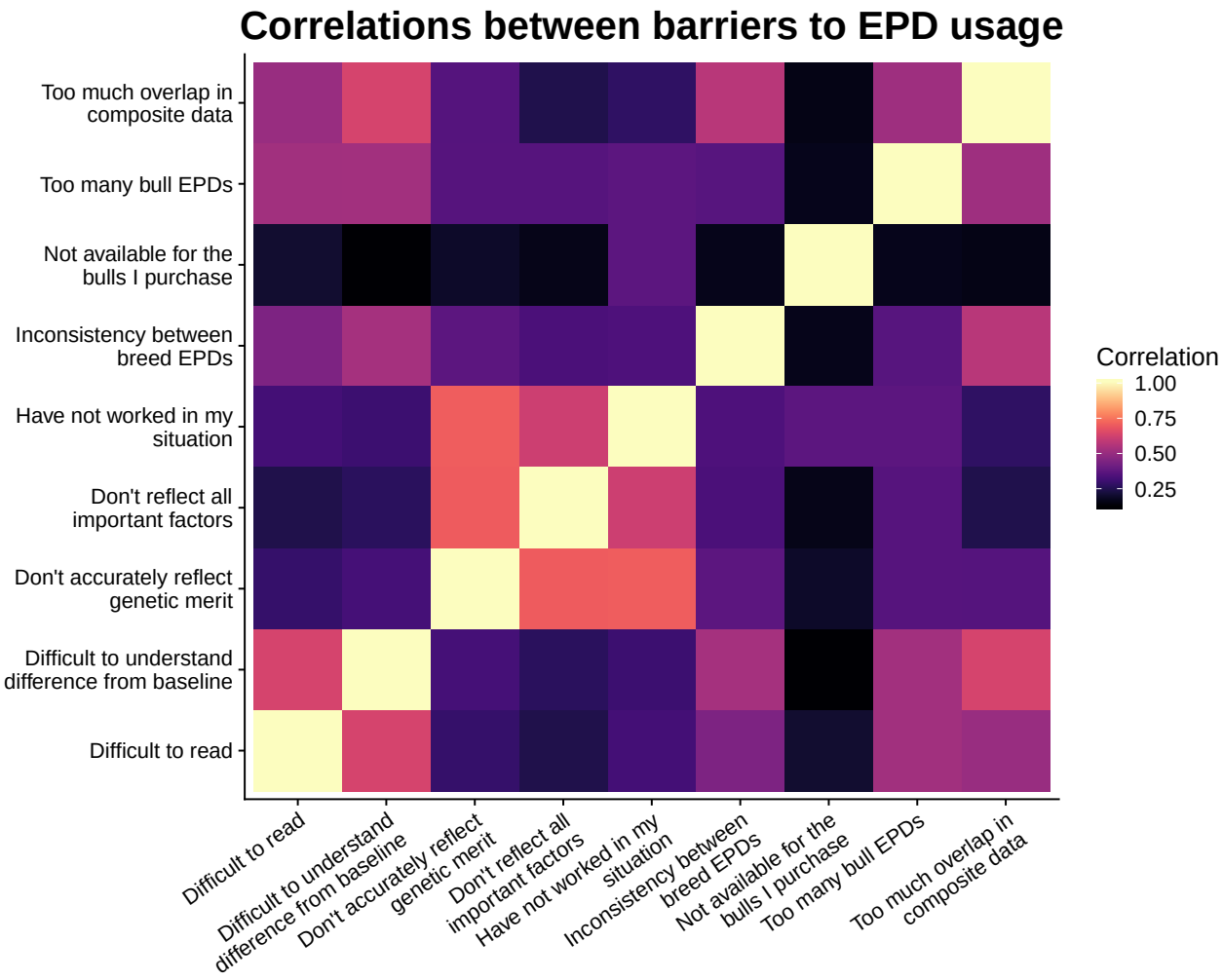
Number of variables	R^2	Adjusted R^2	BIC	Mallow's CP
1	0.0751411	0.0726279	-17.075209	16.985842
2	0.0999431	0.0950381	-21.219477	8.715300
3	0.1097471	0.1024500	-19.358395	6.655413
4	0.1176606	0.1079912	-16.748537	5.378426
5	0.1258145	0.1138064	-14.270169	4.001896
6	0.1282597	0.1138508	-9.393068	4.989316
7	0.1303639	0.1135477	-4.373731	6.117980
8	0.1306479	0.1113825	1.418903	8.000358

```
#https://github.com/alexpghayes/broom/blob/some_cleanup/R/leaps.R
tidy.regsubsets <- function(x, ...) {
  s <- summary(x)
  inclusions <- as_tibble(s$which)
  metrics <- with(
    s,
    tibble(
      r.squared = rsq,
      adj.r.squared = adjr2,
      BIC = bic,
      mallows_cp = cp
    )
  )
  bind_cols(inclusions, metrics)
}
```

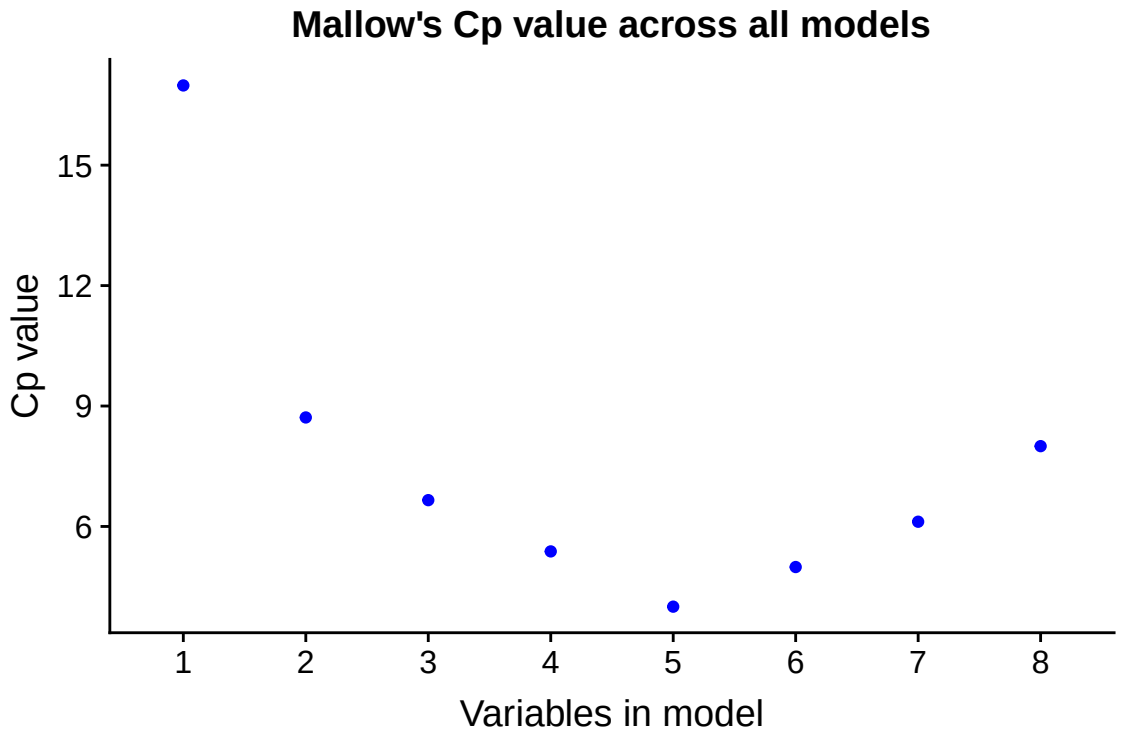
```
#https://rstudio-pubs-static.s3.amazonaws.com/2897_9220b21cfc0c43a396ff9abf122bb351.html
multi_barrier <- responses %>%
  select(epd_usage_stand, starts_with("barrier_"))

barrier_subsets <- regsubsets(epd_usage_stand ~ .,
           data = multi_barrier,
           method = "exhaustive"
           )

tidied_barr <- tidy.regsubsets(barrier_subsets) %>%
  mutate(n_variable = row_number())
```

All models have a very low R^2 and explain very little of the variablility in the data. `barrier_epd_not_accurate` (*"EPDs don't accurately reflect genetic merit"*) is included in all model iterations).

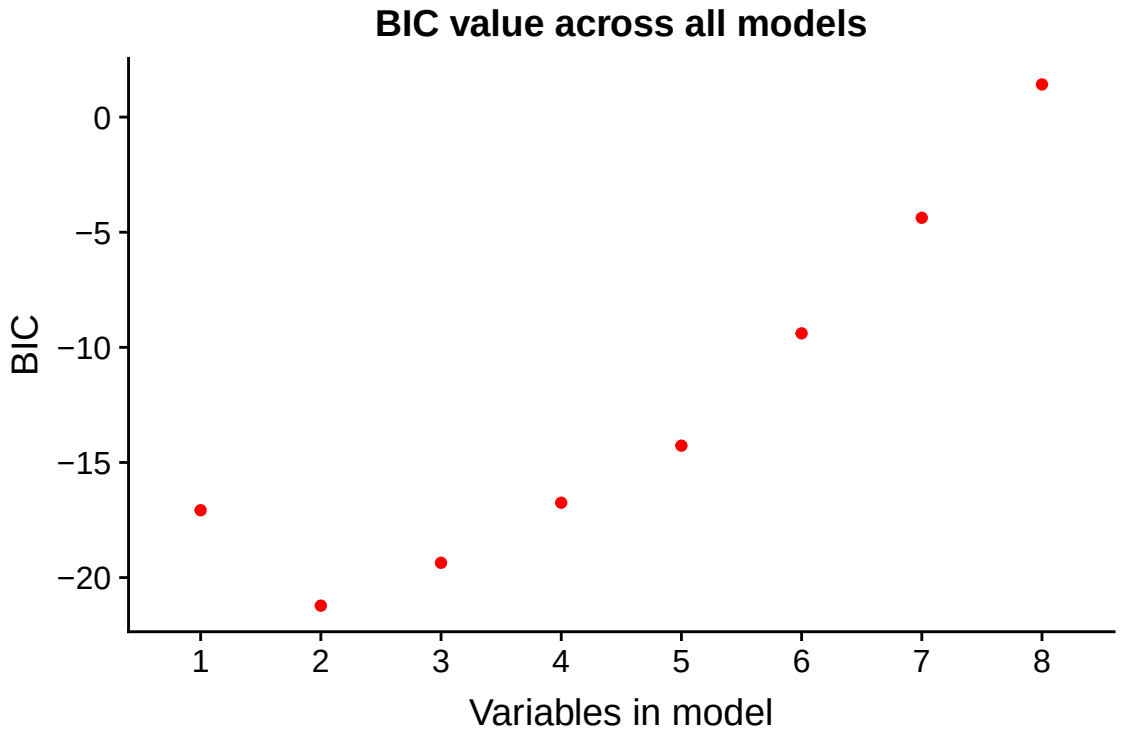
"EPDs don't reflect all important factors in selecting breeding animals" (the most significant model among the simple linear regressions) is not included until the 7 variable case. These 2 variables are probably highly collinear, as evidenced in the pairwise correlation matrix below.



The model with 5 variables (`barrier_epd_inconsistent` + `barrier_epd_too_many_bulls` + `barrier_epd_not_available` + `barrier_epd_have_not_worked` + `barrier_epd_not_accurate`) had the lowest Cp value.



The model with 2 variables (`barrier_epd_too_many_bulls` + `barrier_epd_not_accurate`) had the lowest BIC.



Below are ANOVA results for the selected models with 2-5 variables.

- Five variables:

```
five <- lm(formula = epd_usage_stand ~ barrier_epd_inconsistent +
           barrier_epd_too_many_bulls +
```

```
           barrier_epd_not_available +
           barrier_epd_have_not_worked +
           barrier_epd_not_accurate,
   data = responses)

anova(five)
```

```
## Analysis of Variance Table
##
## Response: epd_usage_stand
##                              Df  Sum Sq Mean Sq F value    Pr(>F)
## barrier_epd_inconsistent      1  0.1140 0.11395  2.6670  0.103258
## barrier_epd_too_many_bulls    1  1.0730 1.07301 25.1131 8.215e-07 ***
## barrier_epd_not_available     1  0.0233 0.02327  0.5445  0.461015
## barrier_epd_have_not_worked   1  0.5933 0.59327 13.8851  0.000223 ***
## barrier_epd_not_accurate      1  0.4644 0.46443 10.8698  0.001067 **
## Residuals                   390 16.6635 0.04273
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

- Four variables:

```
## Analysis of Variance Table
##
## Response: epd_usage_stand
##                              Df  Sum Sq Mean Sq F value    Pr(>F)
## barrier_epd_too_many_bulls    1  1.2049 1.20487 28.2761 1.766e-07 ***
## barrier_epd_not_available     1  0.0253 0.02533  0.5945 0.4411523
## barrier_epd_have_not_worked   1  0.5668 0.56676 13.3008 0.0003009 ***
## barrier_epd_not_accurate      1  0.4131 0.41309  9.6944 0.0019833 **
## Residuals                   394 16.7887 0.04261
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

- Three variables:

```
three <- lm(formula = epd_usage_stand ~ barrier_epd_too_many_bulls +
           barrier_epd_not_available +
           barrier_epd_not_accurate,
   data = responses)

anova(three)
```

```
## Analysis of Variance Table
##
## Response: epd_usage_stand
##                              Df  Sum Sq Mean Sq F value    Pr(>F)
## barrier_epd_too_many_bulls    1  1.2543 1.25431 29.0832 1.193e-07 ***
## barrier_epd_not_available     1  0.0451 0.04512  1.0463     0.307
## barrier_epd_not_accurate      1  0.8356 0.83560 19.3746 1.383e-05 ***
## Residuals                   397 17.1220 0.04313
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

- Two variables:

```
two <- lm(formula = epd_usage_stand ~ barrier_epd_too_many_bulls +
           barrier_epd_not_accurate,
   data = responses)

anova(two)
```

```
## Analysis of Variance Table
##
## Response: epd_usage_stand
##                              Df  Sum Sq Mean Sq F value    Pr(>F)
## barrier_epd_too_many_bulls    1  1.2756 1.27559  28.533 1.546e-07 ***
## barrier_epd_not_accurate      1  0.5758 0.57575  12.879 0.0003734 ***
## Residuals                   402 17.9720 0.04471
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Conclusions

Overall, there is no difference in EPD usage between ages or size of operation. Based on anecdotal evidence, the insignificance of age is unsurprising to me. The insignificance of size of operation is surprising to me, though. However, our data is heavily left skewed and may not be a representative sample of the population. This skewness may be due to medium to large scale producers purchasing cattle by other means than their local sale barn (where half of our data came from). Still, the median size of operation in our data is much larger than the national average.

Taking all results together:

- An overabundance of EPDs to choose from
- A disconnect between the traits EPDs evaluate and the "whole picture" of animal worth

appear to be the biggest barriers to EPD usage. This may provide compelling evidence of the need for EPD indexes that evalueate health traits, structural traits, and environmental compatability.

One major caveat to take into consideration for these results is potential sample bias. Most of the in-person surveys were collected at Show-Me-Select replacement heifer sales, part of an added value marketing program facilitated by the University of Missouri. Therefore, our sample may represent more progressive producers than the population average.