

PRODUCTION AND MANAGEMENT: *Original Research*

Assessing best management practice adoption by pasture-based beef producers: The Whole Herd Beef Risk Index

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ABSTRACT

Objective: The objectives of this research were to develop an adaptable index of herd-level risk, the Whole Herd Beef Risk Index (WHBRI), based on implementation of 14 selected best management practices (BMP) for the management of cows and calves on an operation and to pilot it using an online survey of beef producers.

Materials and Methods: We developed the WHBRI by assigning weights to each BMP, indicating high, medium, and low effects on reducing risk of a major herd event that could affect some or all herd members negatively, animal welfare, and animal performance and may carry implications for operation viability. We employed the WHBRI with a sample of US cattle producers in an online survey. We estimated Tobit models to test relationships between WHBRI scores and demographics of the operation and primary operator.

Results and Discussion: Our sample consisted of 58% mid-risk, 24% low-risk, and 19% high-risk producers. We found that riskier WHBRI scores occurred when an operation had a primary operator 65+ yr old ($P < 0.05$), had a herd of <50 head ($P < 0.01$), marketed cattle with only conventional claims ($P < 0.01$), or sold primarily at local auctions ($P < 0.01$). Less risky WHBRI scores occurred when primary operators had 35+ yr of experience ($P < 0.05$) or the operation included a seed stock enterprise ($P < 0.05$).

Implications and Applications: The WHBRI is a guide for extension personnel and producers for evaluating herd-level risk and will empower managers to assess and implement BMP. The index is customizable to reflect differences in BMP from unique regional or operational characteristics.

Key words: cattle, Tobit model, survey

INTRODUCTION

Over the last 20 yr there has been significant focus on best management practice (BMP) implementation in the production and management of livestock and poultry. In the beef cattle industry, the Beef Quality Assurance Program (BQA) serves as the common national standard and BMP for beef cattle care. Other private labeling and certification programs for beef cattle exist, with many focusing on the assessment and auditing of animal welfare against published standards or guidelines. Regardless of the type of program a beef producer chooses, it is important to know whether they are implementing required or recommended BMP and to assess the risk of a major herd-level event when BMP are not practiced. We define a herd-level event to be an event that could affect some or all herd members negatively, animal welfare, and animal performance and may carry implications for operation viability.

Previous studies of beef producers' implementation of BMP focused on cattle management, handling, animal health, use of technologies, and financial health. Some have reported low implementation of BMP. Low rates of BMP implementation by cow-calf producers have been reported in Canada and the United States (Murray et al., 2016; Schumacher et al., 2017; Wilson et al., 2017). These studies focused on BMP related to managing calves. Murray et al. (2016) surveyed Canadian cow-calf producers to establish relationships between calf BMP practiced and herd mortality and morbidity. Schumacher et al. (2017) surveyed Oklahoma cow-calf producers to elucidate the demographic influences affecting BMP implementation related to the management and marketing of preweaned calves. In a review of BMP recommended for newly weaned calves, Wilson et al. (2017) noted BMP may differ based on factors such as calf genetics, preconditioning programs, and the time of year calves are marketed. They used a risk assessment classification system (high, medi-

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um, or low risk) based on the probability of calves developing bovine respiratory disease due to BMP practiced on the farm. However, Simon et al. (2016a) reported >50% implementation of health-related BMP in their 41-question survey of 30 California cow-calf producers. Therefore, these producers may have perceived the implementation of health-related BMP as essential to lowering herd-level risk. Furthermore, Sitienei et al. (2018) reported larger-scale grass-fed beef producers engaged in producing grass-fed meat and maintained a cow herd were more likely to adopt the 14 BMP used in their survey.

Several indices exist to measure the use of farm-level management practices. For example, Colditz et al. (2014) proposed the Unified Field Index to measure farm animal welfare performance of enterprises. However, the Unified Field Index and other indices are complicated to use and do not measure the level of risk. At present, we know of no tool developed to help beef cattle producers estimate their risk of experiencing a herd-level event when BMP are not implemented. Moreover, the index we developed is flexible and should be customized to account for regional differences in beef management.

The objectives of this research was to develop an adaptable index of herd-level risk, the Whole Herd Beef Risk Index (**WHBRI**), based on implementation of selected BMP for the management of cows and calves on a beef operation and then to pilot it using an online survey of beef producers.

MATERIALS AND METHODS

In this section, we describe the WHBRI development, the survey used to pilot this index with cattle producers,

and the models used to test relationships between demographics and index score.

WHBRI Development

To develop the WHBRI, we consulted with the literature, including the studies by Simon et al. (2016a) and Sitienei et al. (2018), and animal welfare and production experts to identify a list of 14 common BMP for pasture-based beef operations. We chose these practices to represent practices that put operations at varying levels of risk of a herd-level event if not implemented. A “herd-level event” is defined as an event that could affect some or all herd members negatively and carry potential implications for producer viability. The selected BMP focused on animal health, general cow herd management, and the educational aspects of managing cattle that were common across most cow-calf operations. Further, many of the BMP used in our index can also be found in the BQA certification and other standards for cattle care and health.

Next, consulting with extension beef experts, we classified the 14 management practices selected as high-, mid-, or low-level risks based on their potential to affect the herd (Table 1). For example, the lack of a vaccination program likely poses a higher risk to the herd than a producer not obtaining BQA certification for their cattle. To create the WHBRI, which describes an operation’s risk of having a major herd-level event, we assigned index weights of 5 (high), 3 (mid), and 1 (low) to each of the 14 practices used in our survey.

“High risk,” if not implemented, refers to practices that are essential to minimizing challenges to animal health, maintaining animals in a good nutritional state, and mini-

Table 1. Classes and index weights of management practices for the Whole Herd Beef Risk Index

Production practice and risk level	Referred to in manuscript as	Index weight
High level		
Maintain a herd health program that includes vaccinations for cows and calves	Herd health program	5
Written or computer health records for the herd	Written health records	5
Method of animal identification (e.g., ear tag)	Animal identification method	5
Quarantine new cattle at least 30 d after arrival at ranch	Quarantine new cattle	5
Mid level		
Perform a visual health check of your herd at least twice per week	Visual health checks	3
Have an established client relationship with veterinarian	Established veterinary relationship	3
Ability to safely restrain cattle	Cattle restraining system	3
Training your employees on low-stress cattle handling and care	Employee training	3
Planned breeding and calving season	Planned calving season	3
BCS cattle to gauge nutritional state during production cycle	BCS	3
Use a low-stress weaning program	Low stress weaning	3
Low level		
Castrate bull calves within the first 3 mo of age	Castration	1
Beef Quality Assurance (BQA) certified	Beef Quality Assurance (BQA)	1
Written or computer financial records	Written financial records	1

mizing stress to the animals while helping animals reach their performance potential. Practices within the high-level category received a weight of 5 if not implemented on an operation. “Mid risk,” if not implemented, refers to practices that are still important for maintaining a low-risk operation but not as important as those in the high-level category. Mid-level practices received a weight of 3 if not implemented. “Low risk,” if not implemented, refers to practices that are the least essential for maintaining a low-risk operation but still ideal management practices. Practices within the low-level category received a weight of one. For example, although attaining BQA certification is recommended for producers, a producer could attain the same results without being BQA certified.

Based on the previous work of Pruitt et al. (2012) and others, real local and regional differences exist in BMP implementation that may affect the assignment of risk level. Thus, the BMP included in the index as well as the determination of high, medium, or low risk associated with each BMP is customizable to local and regional conditions.

If operators indicated the production practice was not used or not applicable in their beef operation, they received the respective weight for that practice toward their overall risk index score. If they indicated they did use the practice in their operation, they did not receive the respective weight toward their overall index score. Next, the weights from the 14 management practices were summed to arrive at a final WHBRI value, which ranges from 0 (all BMP implemented) to 44 (no BMP implemented). Thus, lower WHBRI values indicate lower risk operations, and greater values indicate higher risk operations.

We classified operations with index scores less than 5 as “low-risk” operations. To receive an index score less than 5, an operation had to practice almost all the 14 management practices analyzed. The WHBRI does provide lenience for not practicing one high-level practice or a combination of mid- and low-level practices. We classified “mid-risk” operations as having index scores between 5 and 15. Here we provide more lenience for operations to not practice a combination of the practices analyzed but still required implementation of most practices. Index scores above 15 were considered “high-risk” operations. Note that a greater index value does not mean the operation is a “bad” operation. The operation may produce high-quality cattle and be profitable. A greater index value simply means that the operation could adopt new BMP to reduce their risk of a herd-level event.

Data Collection

To operationalize the WHBRI, 14 questions relating to herd management were included on a beef producer survey about BMP adoption. The instrument was exempt under 45 CFR 46.104(d) 2(ii) by the Michigan State University Institutional Review Board (STUDY 00003111). In September 2019, *BEEF Magazine* administered the survey in 2 iterations to their United States email listserv of cow-calf

producers who owned at least 25 head. The first email was delivered to 52,202 email addresses and opened by 2,160 individuals. A follow-up email was delivered 3 wk later and opened by 1,582 individuals. The 2 emails received 351 responses, providing a 0.7% response rate from total delivered emails and a 9.4% response rate from opened emails. Emails came from a newly created email by *BEEF Magazine* for this survey distribution rather than their daily newsletter email. Thus, we expect many emails were delivered to spam or junk folders.

Next, to increase sample size, cattlemen’s associations for the 11 states holding the most beef cows that calved January 1, 2019, and the Michigan Cattlemen’s Association were contacted for collaboration (LMIC 2020). The Arkansas Cattlemen’s Association, Kansas Livestock Association, Michigan Cattlemen’s Association, Oklahoma Cattlemen’s Association, South Dakota Cattlemen’s Association, and Pharo Cattle Company, a listserv of regenerative grazers, agreed to send the survey to their listservs, adding 108 responses. The response rate to this effort is unknown because we did not have access to email listservs for the associations due to privacy restrictions.

From the combined 459 responses, 40 responses were dismissed from the survey for answering “no” to at least 1 of the 3 qualifying questions: “Do you voluntarily agree to participate in this research study?”; “Are you a primary operator on a beef cattle operation?”; and “Does your operation graze beef cattle?” Of the remaining 419 respondents, we removed 83 unfinished responses, 23 responses from respondents whose primary enterprise was a feedlot (more than 50% feedlot) as the index is for pasture-based systems, 2 outliers, and 9 responses from respondents who did not answer at least one of the relevant WHBRI questions. Thus, we had a final sample of 302 responses.

Tobit Models

We used a Tobit model because the dependent variable (WHBRI value) is censored between 0 and 44, with 18 observations at the lower limit. Greene (2003) notes that in a model in which some of the dependent variable observations are 0, ordinary least squares estimates tend to be biased, and so a censored Tobit regression is preferred. Indeed, many past studies on producers’ adoption of technology or management practices employ censored Tobit models to handle data with lower or upper limit observations (Norris and Batie 1987; Ransom et al., 2003; Chiputwa et al., 2010). We used this method to estimate coefficient values to identify whether relationships existed between herd-level event risk mitigation and demographics of the operator and operation. Due to the nonlinear nature of Tobit models, marginal effects were then calculated and used for interpretation of the results. The latent variable of interest (indicated with a * superscript) was the WHBRI variable (riskiness_i^*), modeled as follows:

$$\text{riskiness}_i^* = \mathbf{X}_i' \beta + \varepsilon_i, \quad [1]$$

where the relationship between the latent variable and the observed variables is as follows:

$$\text{riskiness}_i = \begin{cases} \text{riskiness}_i^* & \text{if } 0 \leq \text{riskiness}_i^* \leq 44 \\ 0 & \text{if } \text{riskiness}_i^* < 0 \\ 44 & \text{if } \text{riskiness}_i^* > 44 \end{cases} .$$

In Equation 1, \mathbf{X}'_i is a vector of explanatory variables for each operation i and an intercept; β are the coefficients of interest, corresponding to the variables in \mathbf{X}'_i . $\varepsilon_i \sim N(0, \sigma^2)$ is the error term, where σ is the SD of ε . Regressions were conducted using the *Tobit* command in Stata (StataCorp 2019).

RESULTS AND DISCUSSION

Operator Demographics

Respondents' demographic information is summarized in Table 2. The average age of respondents was 58 yr old, with 18% under the age of 45 and 29% over 65. These numbers are on par with the national average of 57.4 yr old for principal beef cattle producers (NCBA, 2019). All operators in our sample received at least a high school diploma, with 43% obtaining a bachelor's degree and 23% obtaining a graduate degree. While our sample is more educated than the general US population, past studies also found that respondents in agricultural producer surveys were more educated than the public (Ward et al., 2008; McKendree et al., 2018; Thompson et al., 2019). Annual pretax household income for producers in our sample also reflects findings of previous studies (McKendree et al., 2018). Thirty-two percent of respondents reported less than \$50,000 in annual pretax household income, whereas 35% had a pretax income of over \$100,000. Fifty percent of respondents indicated that 25% or less of their total household income came from their beef operation, and 30% reported that their beef operation accounted for over 50% of their household income. Thirty-two percent of our sample had full-time off-farm jobs. Nationally, 40% of primary beef operators identified the beef operation to be their primary occupation, and 60% had other primary occupations (USDA 2019). Finally, 57% of responding producers identified as Republican, and 8% identified as Democrat.

Operation Demographics

We asked producers about the beef enterprises included in their operation. Operation demographics are included in Table 3. Most of our sample, 93%, indicated their beef operation included a cow-calf enterprise. Twenty percent reported having a seed stock enterprise, 65% backgrounding and stocking, 10% feedlot, and 18% had a grass finishing enterprise.

Table 2. Primary operator demographics (n = 302)

Demographic variable	%
Average age (yr)	58
Under 45 yr	18
45 to 65 yr	53
Over 65 yr	29
Education level	
No high school diploma	0
High school graduate	12
Some college	13
Technical training	9
Bachelor's degree	43
Graduate or professional degree	23
Annual pretax household income	
Less than \$25,000	16
\$25,000 to \$49,999	16
\$50,000 to \$74,999	18
\$75,000 to \$99,999	15
\$100,000 to \$124,999	13
\$125,000 or more	22
Household income from beef operation	
0%	6
Less than 25%	44
26 to 50%	20
51 to 75%	29
Over 75%	1
Full-time off-farm job	32
Political affiliation	
Democrat	8
Republican	57
Independent	19
Other	16

On average, respondents' beef cow herd size was 162 head, including lactating, gestating, and replacement heifers as of January 1, 2019, with a median of 87 head. Operations with less than 50 head composed 28% of our sample, whereas 43% were operations with over 100 head. According to the 2017 Census of Agriculture, the average beef cow herd is 43.5 head, and operations with 100 or more beef cows make up 9.9% of beef operations, making the operations in our sample larger than the national average (USDA, 2019).

Respondents' operations on average had been established for 34 yr at the time of the survey, with a median of 35 yr. Thirty percent of our sample's operations were less than 15 yr old, and 40% had been established for over 35 yr. Primary operators in our sample tended to have more experience than those nationally, as 32% had over 35 yr of experience, 45% had between 8 and 34 yr, and 23% had less than 8 yr. Nationally, 73% of beef operators have operated a farm 11 or more years, 13% have operated between 6 and 10 yr, and 15% for 5 or fewer years (USDA, 2019).

Table 3. Operation summary statistics (n = 302)

Variable	%
Operation enterprises	
Seed stock	20
Cow-calf	93
Background or stocker	65
Feedlot	10
Grass finisher	18
Other	3
Beef cow herd size ¹	
Less than 50 head	28
50 to 100 head	29
Over 100 head	43
Average	162
Median	87
Years established	
Less than 15 yr	30
15 to 35 yr	30
More than 35 yr	40
Average	34
Median	35
Primary operator experience	
Less than 8 yr	23
8 to 34 yr	45
More than 35 yr	32
Region	
Midwest	52
Northeast	2
South	28
West	18
Marketing claims	
None (conventional)	21
Age and source verified (ASV/SAV)	24
Natural (no hormones/antibiotics)	35
Organic	3
Humanely raised	20
NHTC (nonhormone treated)	19
Preconditioned (weaning or vaccination claims)	58
Grass fed	24
Other	8
Marketing outlets	
Local auction	50
Video or internet auction	6
Direct to background/stocker operation	6
Direct to feedlot operation	10
Direct to processor	3
Direct to consumers	14
Retain ownership	4
Other	7

¹Herd size includes lactating, gestating, and replacement heifers.

Most of our sample, 52%, resided in the Midwest, followed by 28% in the South, 18% in the West, and 2% in the Northeast [regions assigned following the US census (US Census Bureau, 2020). West included WA, OR,

ID, MT, WY, CO, UT, NV, CA, AZ, and NM. Midwest included ND, SD, NE, KS, MN, IA, MO, WI, IL, IN, MI, and OH. South included TX, OK, AR, LA, MS, AL, TN, KY, GA, FL, SC, NC, VA, WV, MD, DC, and DE. Northeast included PA, NJ, NY, RI, CT, MA, VT, NH, and ME.] Operations in our sample are more concentrated in the Midwest and West than that nationally. The larger portion of respondents in the Midwest is likely due to targeting South Dakota, Kansas, and Michigan producers via their cattlemen's and livestock associations. Additionally, Midwest producers, especially those in Michigan, may have been more likely to respond to the survey due to Michigan State University's name recognition.

When marketing their cattle, 21% of operations in our sample did not use additional claims; that is, they marketed their cattle as conventionally raised. Twenty-four percent used age and source verified (ASV/SAV) claims, 35% used natural (no hormones or antibiotics) claims, and 3% used organic claims. Further, 20% of operations marketed their cattle as humanely raised, 19% marketed cattle as nonhormone treated (NHTC), 58% used some type of preconditioning claims, and 24% marketed their cattle as grass fed. Finally, 8% of operations in our sample indicated that they used some other type of marketing claim when selling their cattle.

Operations in this study also used a variety of marketing outlets to sell their cattle. Fifty percent indicated that they sold cattle at local auctions, whereas only 6% sold at video or Internet auctions. Many operations sold directly to downstream actors in the beef supply chain; 6% sold directly to background/stocker operations, 10% sold directly to feedlots, 3% sold directly to processors and packing plants, and 14% sold directly to consumers. Last, 4% of the operations retained ownership of their cattle, and another 7% used some other marketing outlet to sell their cattle.

BMP Implementation and the WHBRI

Figure 1 provides the percentage of respondents who practiced each of the 14 BMP. Practices are given in order of most to least widely practiced, with the use of an animal identification system being the most common practice implemented, whereas quarantining new cattle was the least practiced. At least 90% of producers used an animal identification method, cattle restraining system, and had an established relationship with their veterinarian. At least 80% had a planned calving season, conducted visual health checks, kept written financial records, and maintained a herd health program. Additionally, at least 70% of respondents used a low stress weaning program, trained employees in proper handling of animals, and kept written health records, and over 50% used a BCS, castrated bull calves at 3 mo of age, and were Beef Quality Assurance certified. Finally, about one-third—33.8%—of producers quarantined new cattle, though 31.8% indicated this was not applicable to their operation.

These findings are on par with results from previous studies. Simon et al. (2016a) found that 100% of their sample used some form of animal identification method; 96% of our sample used an animal identification method. Many of our producers also had an established veterinary relationship (92.7%), performed visual herd health checks (88.1%), and kept written herd health records (84.4%), again in line with results of Simon et al. (2016a). Like Mulenga et al. (2020), who found that 71% of operations castrated bull calves at 3 mo of age, 67.9% of our sample castrated at 3 mo.

Table 4 shows the percentage of producers classified into each of the riskiness levels of the WHBRI. Most producers, 58%, were classified as mid risk, 24% as low risk, and 19% as high risk. However, this simple classification does not detail the relationship between a producer's index score and operation characteristics. In the next subsection, we use a Tobit model to investigate these relationships.

Exploring Relationships Between Index Scores and Producer Characteristics

The coefficients from the Tobit model exploring the relationship between WHBRI score and operation and operator characteristics are in Appendix Table A1. The resulting average marginal effects are displayed in Table 5. The interpretation of the average marginal effects is relatively straightforward, as all the data are coded as dichotomous, or dummy, (0/1) variables. The average marginal effect value for a given characteristic represents the difference in the WHBRI score for producers identifying with that

Table 4. Frequency table for Whole Herd Beef Risk Index risk levels (n = 302)

Risk level	Producers	
	No.	%
Low risk (score <5)	72	23.84
Mid risk (score 5–15)	174	57.62
High risk (score >15)	56	18.54

characteristic and producers that are in the base group, all else being equal. For instance, if a primary operator was over 65 yr old, they were on average predicted to have a WHBRI score 1.74 points greater than if they were between the ages of 46 and 65.

Statistically significant predictors for an operation's WHBRI score included primary operator age, herd size, operation type, types of marketing, and higher education. [We include a 10% statistical significance level due to the highly nonlinear nature of Tobit models, which have wide confidence intervals and therefore allow us to be more flexible with interpreting *P*-values. Other studies that have used 10% *P*-values for Tobit models include those by Norris and Batie (1987), Ransom et al. (2003), and Chiputwa et al. (2010).] Operations with primary operators over 65 yr old were at higher risk for a herd-level event, with expected index scores 1.74 points greater than those with operators between 46 and 65 yr old ($P < 0.05$). In contrast

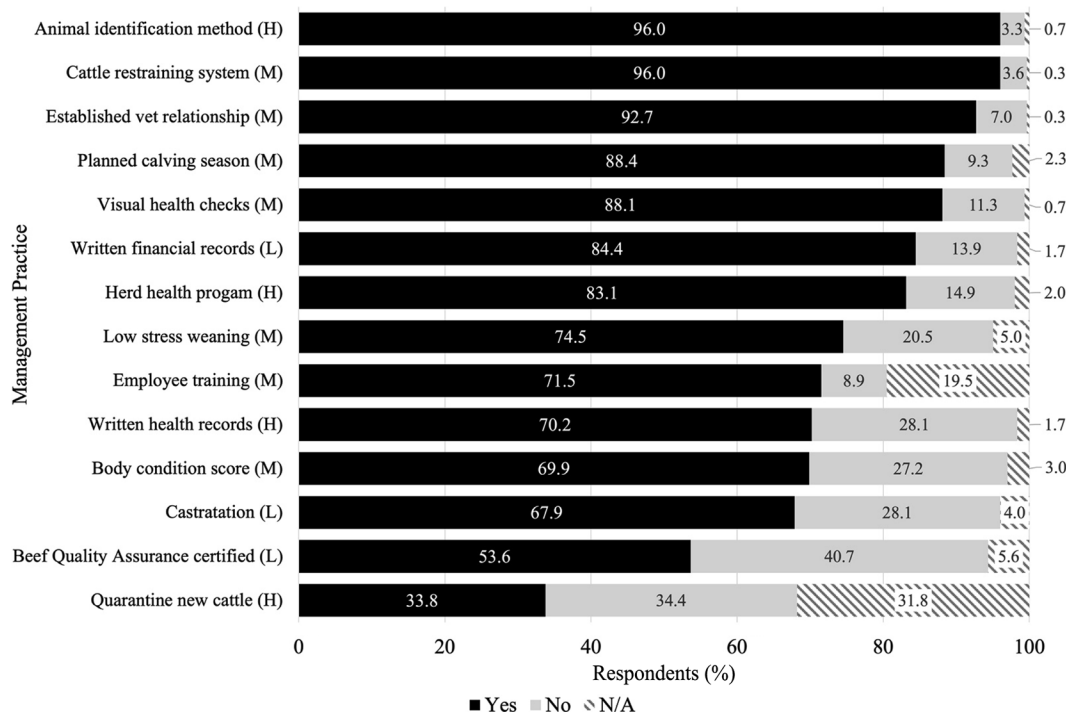


Figure 1. Percentage of producers implementing management practices (n = 302). The abbreviations (H), (M), and (L) indicate high-, mid-, and low-risk practices, respectively. N/A = not applicable (the management practice was not relevant to a producer's operation).

Table 5. Tobit regression average marginal effects

Variables	Average marginal effects ¹
Primary operator under 45 yr ²	0.57 (1.00)
Primary operator over 65 yr ²	1.74** (0.88)
Primary operator experience more than 35 yr ³	-1.93** (0.93)
Less than 50 head ⁴	2.97*** (0.89)
50 to 100 head ⁴	0.56 (0.85)
Seed stock ⁵	-2.21** (0.94)
Cow-calf ⁵	-2.61* (1.46)
No marketing claims ⁶	4.05*** (0.88)
Local auction marketing outlet ⁶	2.59*** (0.74)
Bachelor's degree ⁷	0.38 (0.81)
Graduate degree ⁷	-1.74* (0.98)
Established less than 15 yr ⁸	-1.56 (0.97)
Established more than 35 yr ⁸	0.49 (0.86)
Northeast ⁹	-0.66 (2.48)
Midwest ⁹	1.34 (0.99)
South ⁹	1.10 (1.08)
Republican ¹⁰	-0.63 (0.70)
Full-time off-farm job ¹¹	0.90 (0.84)
Observations (no.)	302

¹Standard errors are given in parentheses. The average marginal effect value for a given characteristic represents the difference in the Whole Herd Beef Risk Index score for producers identifying with that characteristic and the producers who are in the base group, all else equal.

²Base case is primary operator between 46 and 65 yr old.

³Base case is primary operator with 35 yr or less experience.

⁴Base case is herd size between 50 and 100 head.

⁵Base case is grass finishing or background stocking operation.

⁶Base case using marketing claims such as organic, natural, humanely raised, and so on and using marketing outlets such as direct to buyer, video or internet auction, or retaining ownership.

⁷Base case is lower education levels including no high school or a 2-yr college degree.

⁸Base case is established between 15 and 35 yr.

⁹Base case is western region (WA, OR, ID, MT, WY, CO, UT, NV, CA, AZ, and NM).

¹⁰Base case is democrat, independent, or other.

¹¹Base case is part-time or no off-farm job.

*** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$.

to the positive effect of operator age on index scores, we found that an operation's riskiness score will decrease on average by 1.93 points if the primary operator had at least 35 yr of experience. Pruitt et al. (2012) also found that operations with older primary operators were more likely to adopt more BMP; however, other studies, including Ward et al. (2008) and Johnson et al. (2010), found that older producers are less likely to adopt most BMP. These mixed age results match our findings for primary operator age and years of experience, which had conflicting effects on predicted riskiness.

Operations with less than 50 head were also riskier, with an expected score increase of 2.97 points over herds with more than 100 head ($P < 0.01$). These results align with findings from previous studies (Ward et al., 2008; Johnson et al., 2010; Pruitt et al., 2012). Seed stock operations had on average an index score that was 2.21 points lower than other operation types, meaning these operations were expected to be less risky. Similarly, cow-calf operations had an average index score 2.61 points lower than other operations, which aligns with Pruitt et al. (2012), who found that cow-calf operations that were more integrated with downstream beef segments were more likely to adopt BMP and, therefore, were less risky.

Operations that marketed conventionally, with no added claims, saw an average WHBRI score increase of 4.05 points and were considered higher risk for a herd-level event. This result is not surprising, as many marketing programs require the use of at least some of the BMP defined in our study. Additionally, operations that primarily sold at local auctions saw an average WHBRI score increase of 2.59 points; again, this is intuitive, as other marketing outlets likely require use of at least some of the BMP defined in our study.

We find conflicting effects of education on WHBRI scores. Producers holding a graduate degree—23% of our sample—have a 1.74-point lower index score than those holding less than a bachelor's degree. Conversely, the index score of those who hold a BS degree—43% of our sample—is not statistically different from those with lower education levels. The limited variation in the sample for bachelor's degree holders relative to graduate degree holders may explain the conflicting education effects in our Tobit model. Previous work in the use of environmental BMP (Baumgart-Getz et al., 2012) found that higher formal education levels were correlated with lower adoption of BMP and animal welfare practices. However, Pruitt et al. (2012) found that operations with primary operators who had at least a 4-yr degree were more likely to adopt BMP.

Though not statistically significant, we found that operations established over 35 yr had on average an expected WHBRI score increase of 0.49 points. Likewise, Simon et al. (2016b) found that older operations—those that were established longer—were more likely to have thin cattle, which decreases animal welfare and can increase the risk of a major health event. Finally, though insignificant in

our model, attention should be paid to regional effects. Pruitt et al. (2012) found that Midwestern operations in general adopted more BMP, whereas our study found that midwestern operations were more likely to have riskier operations, correlating to use of fewer BMP. However, Pruitt et al. (2012) also found that southeastern operations adopted fewer BMP, which matches our results. The authors recognize there are differences in production practices across regions. Thus, when considering these results, one should note that the WHBRI should be modified to reflect regional BMP.

APPLICATIONS

The Whole Herd Beef Risk Index (WHBRI) is a simple and flexible tool based on implementation of BMP that can be used to measure and help producers to understand the risk to their operations of a major herd-level event. Extension professionals and producers can use the WHBRI when evaluating herd-level event risk and to empower managers to assess and implement BMP in their operations. The index is customizable; the BMP used in the index and their assigned risk levels can be changed to reflect differences in recommended BMP due to beef production methods, management techniques, herd size, and health risks unique to their region. The WHBRI may also be used to benchmark BMP adoption by first surveying state or regional producers to determine BMP adoption rates and then to target programming to improve producer adoption or to compare progress within an operation. Additionally, our producer survey results can be used to develop targeted extension programming to groups with greater index scores, such as those with smaller herd sizes and those marketing conventional cattle.

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APPENDIX

Table A1. Tobit regression coefficients

Variable	Tobit regression coefficients ¹
Bachelor's degree	0.41 (0.88)
Graduate degree	-1.89* (1.07)
Full-time off-farm job	0.98 (0.91)
Primary operator under 45 yr	0.62 (1.09)
Primary operator over 65 yr	1.89** (0.96)
Republican	-0.68 (0.76)
Northeast	-0.71 (2.70)
Midwest	1.45 (1.08)
South	1.20 (1.17)
Established less than 15 yr	-1.69 (1.06)
Established more than 35 yr	0.53 (0.94)
Less than 50 head	3.22*** (0.97)
50 to 100 head	0.61 (0.92)
Seed stock	-2.40** (1.03)
Cow-calf	-2.84* (1.59)
Primary operator experience more than 35 yr	-2.09** (1.01)
No marketing	4.40*** (0.97)
Local marketing	2.82*** (0.81)
var(e._Riskiness2) ²	39.83 (3.40)
Constant	9.52*** (2.13)
Observations (no.)	302

¹Standard errors are given in parentheses.

²var(e._Riskiness2) is the ancillary statistic (sigma), which is analogous to the square root of the residual variance in ordinary least squares regression.

*** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$.