VALUE OF PREGNANCY TESTING

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An earlier article in this Ranchers' Guide investigated optimal culling decisions for range cows given cow age, pregnancy status, and market prices (i.e., Optimal Economic Range Cow Culling Decisions: Biological and Market Factors Combined by Tronstad and Gum). The analysis found conditions where it was optimal to keep a sound cow even if the cow was open. This result indicates that pregnancy testing doesn't always have economic merit. The economic value of pregnancy testing is quantified in this article for different biological and market conditions.

Biological, market, and cost information on which these pregnancy test and culling alternatives are evaluated include: cow age, recent history of calf fertility, replacement cost of bred heifers, calf prices, cull cow values, and the cost differential (feed and/or performance cost) between spring and fall calving. Biological productivity estimates were taken from a prior article in this Guide entitled, "Range Cow Culling: Herd Performance." Market price relationships estimated in the prior article of "Market Impacts on Culling Decisions" were updated to reflect more recent prices and to categorize prices in narrower intervals. The cost differential between spring and fall calving is considered since the analysis has allowed for spring and fall calving. Biannual calving was found to be an important factor for culling decisions since a cow has the potential to be productive six months earlier than under a strict annual calving system.

Management Alternatives

Range cow culling and replacement decisions are driven by future cow productivity, feed costs, and the market value of replacements, calves, and slaughter cows. As the spread between market prices changes through time the value of pregnancy testing and optimal culling decisions also change. To simultaneously evaluate the dynamics of physical productivity, market prices, and production costs a computer model is used to evaluate the culling decision. The model incorporates statistical price relationships while evaluating the long-term economic implications of decision alternatives. Decision alternatives evaluated are:

1. Whether to keep or cull a cow without a pregnancy test? Economics may conclude that older cows should be replaced or younger cows should be kept, irrespective of pregnancy status. If young cows are open, should they be bred immediately or at a later period?

2. If pregnancy testing has economic justification, what should be done with cows that are open? Should they be culled and replaced with a bred heifer now or at a later time in the future? Do market factors justify maintaining, expanding, or contracting herd size?

Table 1. Fertility Rates for Cows with Sale Calf at Side.

Cow Age	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5
					%						
Pregnant	86.20	85.73	85.13	84.41	83.57	82.61	81.54	80.34	79.02	77.59	76.03
Open	13.80	14.27	14.87	15.59	16.43	17.39	18.46	19.66	20.98	22.41	23.97

Table 2. Fertility Rates for Cows with No Calf at Side.

Cow Age	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5
					%						
Pregnant	74.03	74.03	74.03	74.03	74.03	74.03	74.03	74.03	74.03	74.03	74.03
Open	25.97	25.97	25.97	25.97	25.97	25.97	25.97	25.97	25.97	25.97	25.97

Comparing Alternatives

In order to assess the value of pregnancy testing, the economic returns from making decisions with pregnancy test information is compared to returns generated without pregnancy test information. Without pregnancy test information, the likelihood that a cow is open or pregnant is made solely on the basis of cow age and recent calving history. These estimates were made from data collected on the San Carlos Apache Experimental Research Registered Herd, located at Arsenic Tubs, AZ. The odds that a cow was pregnant or open with a sale calf at side were found to be influenced by cow age (see Table 1). If a cow had no calf at her side because she was previously open or lost her calf, cow age was not found to be a factor that influenced whether the cow would be open or pregnant (see Table 2).

In calculating the value of pregnancy testing, the economic value associated with applying the same culling decision to all cows of a given age and calf status was first obtained. Say the decision under consideration is to keep and allow for immediate breeding of all cows 7.5 years of age that have a sale calf at their side. Given the information in Tables 1 and 2, 83.57% are expected to be pregnant and 16.43% open. The economic value of making a keep decision is made by multiplying the value of keeping a pregnant cow by 83.57% and adding the value of keeping an open cow by 16.43%. Four non-pregnancy test alternatives for a given cow age and calf status are compared: (a) keep all and allow for immediate breeding, (b) replacing all with a bred heifer, (c) keep all cows but don't allow for breeding any open cows until 6 months from now, and (d) cull all cows and don't replace with a bred heifer this period. The highest value from the four non-pregnancy testing alternatives is the best decision one can make without any information regarding pregnancy status. This value is compared to the best decision possible with pregnancy testing. Two economically viable options under pregnancy testing are; (a) keep all pregnant cows and replace open cows with a bred heifer, or (b) keep all pregnant cows and cull the open cows without replacing them with a bred heifer. The optimal decision is the highest value attained from evaluating all options. The model assumes a cost of $2 per head for pregnancy testing.

Table 3. Long-term Probability Price Levels Estimated for May.

Replacement	Calf Prices ($/cwt.)						
Prices ($/head)	**< 64**	**64-72**	**72-80**	**80-88**	**88-96**	**96-104**	**> 104**
< 465	0.0507	0.0345	0.0248	0.0138	0.0065	0.0025	0.0008
465 - 555	0.0234	0.0324	0.0358	0.0267	0.0158	0.0076	0.0035
555 - 645	0.0148	0.0276	0.0406	0.0403	0.0300	0.0176	0.0109
645 - 735	0.0070	0.0168	0.0313	0.0400	0.0383	0.0283	0.0234
735 - 825	0.0024	0.0074	0.0172	0.0277	0.0338	0.0319	0.0370
825 - 915	0.0006	0.0023	0.0066	0.0132	0.0201	0.0243	0.0428
> 915	0.0001	0.0005	0.0019	0.0050	0.0096	0.0151	0.0547

Table 4. Long-term Probability Price Levels Estimated for November.

Replacement	Calf Prices ($/cwt.)						
Prices ($/head)	**< 64**	**64-72**	**72-80**	**80-88**	**88-96**	**96-104**	**> 104**
< 465	0.0863	0.0227	0.0139	0.0069	0.0026	0.0007	0.0001
465 - 555	0.0592	0.0325	0.0259	0.0164	0.0080	0.0027	0.0007
555 - 645	0.0451	0.0381	0.0389	0.0307	0.0186	0.0079	0.0026
645 - 735	0.0250	0.0298	0.0390	0.0392	0.0298	0.0159	0.0066
735 - 825	0.0103	0.0164	0.0270	0.0348	0.0340	0.0228	0.0124
825 - 915	0.0030	0.0063	0.0127	0.0206	0.0266	0.0235	0.0171
> 915	0.0006	0.0018	0.0047	0.0096	0.0164	0.0219	0.0318

The value of pregnancy testing is determined by subtracting the best uniform culling decision from the highest of the two pregnancy test alternatives. The value of pregnancy testing varies depending on market prices, cow age, calving season (spring or fall), the cost differential between spring and fall calving, and recent cow fertility. Whether a cow has a sale calf at her side or no calf at side is the information used for recent cow fertility. Cows that were sound with a newborn calf at side were automatically kept in the herd and thus not pregnancy tested.

Market Prices

Market prices for replacements (2.5 year old bred heifers), calves, and slaughter values are considered in the analysis. Table 3 gives long-term price probabilities of replacement and calf prices for May based on biannual prices from 1971 through 1991. These probabilities are for a range of prices rather than for an exact price. For example, historical prices indicate that for any year in May the odds that calf prices are between $80 to $88 per cwt. while replacement prices are between $555 to $645 per head is 4.03 percent. However, as shown in Table 4 for the month of November, the odds of this price combination are lower at 3.07%. Historical prices show sale calves to be lower for November than in May. On average, $6.66/cwt. lower in the fall than spring using long-term price probabilities.

Prices have been observed to follow predictable patterns from one period to the next for shorter time intervals. These patterns are highly dependent on the level of current

Table 5. Six Month Transition Probabilities Given November Calf Price<$64 per cwt. and Replacement Price Between $555-$645 per Head.

Replacement Prices in May ($/head)	**May Calf Prices ($/cwt.)** < 64	**64-72**	**72-80**	**80-88**	**88-96**	**96-104**	**> 104**
< 465	0.1272	0.0221	0.0053	0.0006	0.0000	0.0000	0.0000
465 - 555	0.1120	0.0615	0.0266	0.0054	0.0005	0.0000	0.0000
555 - 645	0.0776	0.0887	0.0651	0.0227	0.0037	0.0003	0.0000
645 - 735	0.0264	0.0580	0.0721	0.0426	0.0119	0.0016	0.0001
735 - 825	0.0042	0.0171	0.0362	0.0363	0.0172	0.0039	0.0004
825 - 915	0.0003	0.0023	0.0082	0.0140	0.0113	0.0043	0.0008
> 915	0.0000	0.0001	0.0009	0.0026	0.0038	0.0027	0.0012

prices. Table 5 illustrates how price levels in November influence where prices will be in the following May. Given a November calf price less than $64 per cwt. and replacement costs between $555 - $645 per head, the odds of going to the price category described above (calf prices of $80 to $88 per cwt. and replacement prices between $555 to $645) is only 2.27 percent rather than the long-term odds of 4.03 percent. The odds are lower because current calf prices are low. The value of pregnancy testing is based most heavily on current price levels since the impact of distant prices is reduced by a discount rate. Future returns are discounted at a real discount rate of 6 percent. Because current prices play the biggest role in determining the value of pregnancy testing, the value of pregnancy testing and optimal culling decisions are not very sensitive up to a 4 point increase or decrease in the discount rate.

Costs of Production

Costs directly influence the bottom line of profitability and the differential in feed costs for a replacement versus an older cow impacts the culling decision. Added feed costs of a first calving replacement heifer need to be evaluated against the performance of an older cow with lower feed costs. The model uses a feed cost of $100 per head every six months except for replacements during their first year. An additional feed cost of $25 per head every six months was added for replacements in the period that they gave birth and the following nursing period.

Costs of production are allowed to vary for spring versus fall calving. In general, spring calving is the norm since most areas can better match their forage availability with nutritional demands associated with a spring calving season. Lower calf prices in the fall than spring reflect this seasonal phenomena. In total, 11 different cost differentials of $0.0, $10, $20, $30, $40, $55, $75, $100, $130, $165, and $205 were evaluated. A cost differential of $30 implies that it costs $30 more to calve a cow in the fall than the spring. The highest cost differential implies a spring only calving system. The cost differential can be associated with more feed requirements, more labor, lower fertility, and/or lower calf weights.

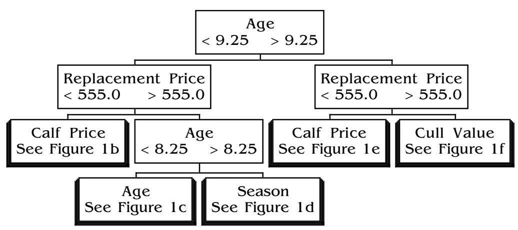
Culling Decisions and Value of Pregnancy Testing

The number of possible price combinations (49, 7•7), age (20), calf or no calf at side (2), spring or fall (2), and cost differentials (11) considered for evaluating culling decisions number 43,120 possibilities. Because this number is unduly large, these decisions have been categorized into a decision tree framework. Figures 1a through 1f describe the 43,120 different possibilities into 110 categories or terminal nodes. The six possible culling decisions are defined as: 1) K - keep and breed immediately, 2) R - replace with a bred heifer, 3) K6 - keep and breed in 6 months, 4) RN - cull and don't replace, 5) PR - pregnancy test cows, keep pregnant cows and replace open cows with a bred heifer, and 6) PN - pregnancy test cows, keep pregnant cows and don't replace open cows that are culled at this time.

Condensing 43,120 decisions into 110 general categories comes with a cost since most of the nodes are not classed 100% correctly. In technical terms they have some "node impurity." In order to assess how much node impurity exists, average one period cost of mistake

Figure 1. Culling Rule Recommendations of Decision Tree by Terminal Nodes.

Figure 1a.



Legend

K - Keep and breed immediately
R - Replace with a bred heifer
K6 - Keep and breed in 6 months
RN - Cull and don't replace
PR - Pregnancy test cows replace open cows with a bred heifer
PN - Pregnancy test cows, don't replace open cows that are culled.

Figure 1b.

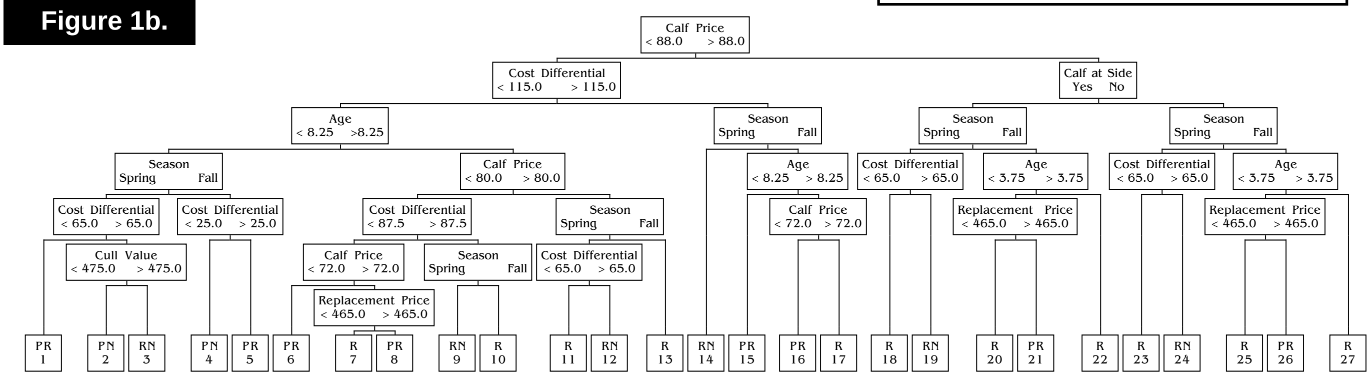


Figure 1c.

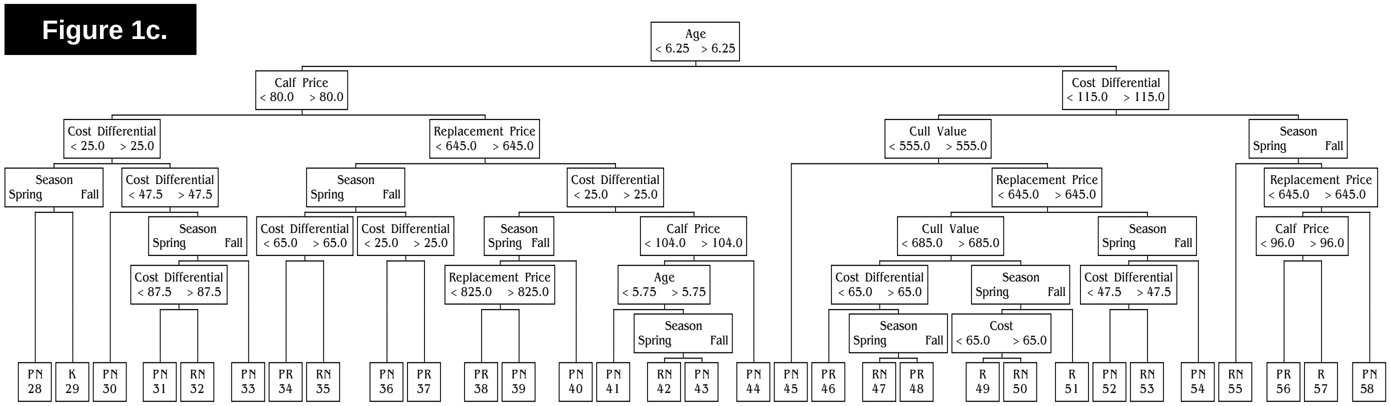
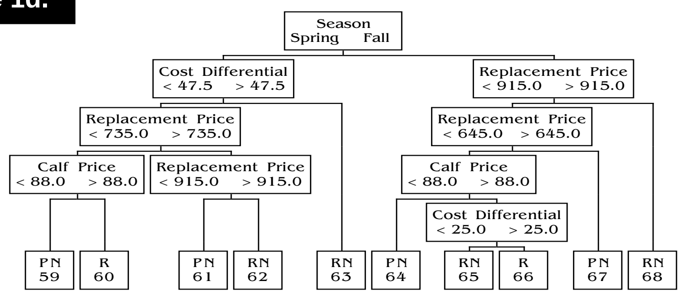


Figure 1 (cont.)

Figure 1d.



Legend

K - Keep and breed immediately

R - Replace with a bred heifer

K6 - Keep and breed in 6 months

RN - Cull and don't replace

PR - Pregnancy test cows replace open cows with a bred heifer

PN - Pregnancy test cows, don't replace open cows that are culled.

Figure 1e.

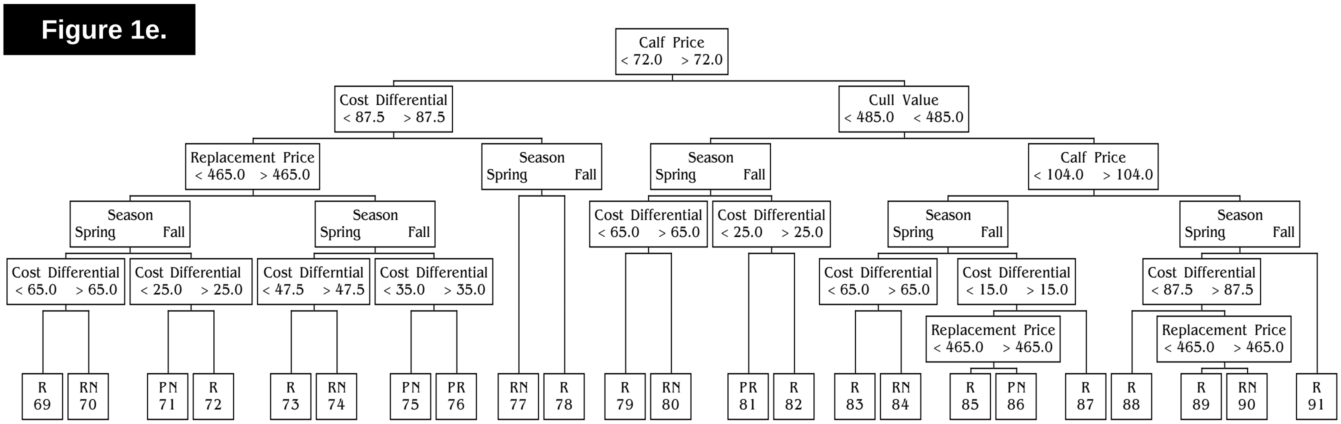
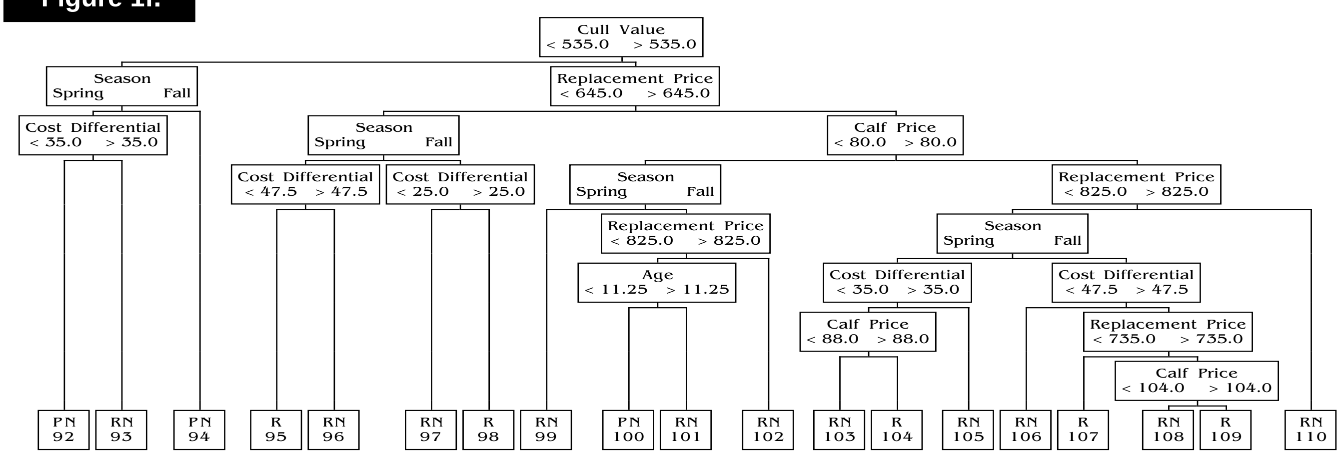


Figure 1f.



values are given in Table 6. One period cost of mistake values are determined by comparing a non-optimal decision one period followed by optimal culling decisions to a continuous stream of optimal culling decisions. All splits and categories were selected on the basis of minimizing average one period cost of mistakes for each category. For example, the first split at the top of Figure 1a was selected on the basis of splitting all decisions into two categories or nodes so that the average cost of mistake for all decisions is minimized. All variables and levels were numerically searched. Cow age of 9.25 years is the variable and level identified that splits all 43,120 culling decisions into two groups so that the average cost of mistake is minimized. Subsequent splits were

Table 6. Value of Pregnancy Testing, Present Value, and Cost of Mistake Values for Terminal Nodes in Figure 1.

Terminal Node Number	Recommended CART Decision	Average Value of Preg Testing by Node	Average Present Value by Node	Average Cost of Mistake Values For Different Decisions* K Decision 1	R Decision 2	K6 Decision 3	RN Decision 4	PR Decision 5	PN Decision 6
1	PR	$31.8	$1965.2	-$35.9	-$46.5	-$46.0	-$135.3	-$4.2	-$22.4
2	PN	$6.4	$1403.2	-$9.1	-$106.9	-$23.2	-$21.6	-$20.2	-$2.7
3	RN	-$10.3	$1447.4	-$33.8	-$79.2	-$42.6	-$3.5	-$29.5	-$13.8
4	PN	$2.5	$1897.1	-$5.0	-$75.1	-$9.1	-$53.3	-$7.0	-$2.5
5	PR	$23.5	$1645.2	-$34.6	-$49.8	-$26.3	-$131.9	-$2.8	-$19.7
6	PR	$23.9	$1723.8	-$31.8	-$33.0	-$30.6	-$66.7	-$6.7	-$14.1
7	R	-$20.1	$1834.5	-$68.0	-$8.4	-$65.9	-$92.0	-$28.5	-$46.9
8	PR	$8.8	$1779.1	-$44.0	-$20.8	-$42.1	-$51.5	-$12.0	-$18.8
9	RN	-$21.9	$1335.0	-$47.2	-$112.6	-$49.7	-$0.1	-$46.8	-$22.0
10	R	-$2.9	$1439.8	-$64.6	-$9.0	-$42.5	-$110.0	-$11.9	-$34.2
11	R	-$46.3	$1958.6	-$105.0	$0.0	-$107.6	-$117.4	-$46.3	-$72.2
12	RN	-$42.2	$1440.8	-$76.6	-$55.8	-$77.6	$0.0	-$54.6	-$42.2
13	R	-$13.1	$1886.5	-$58.6	-$9.8	-$49.5	-$79.9	-$22.9	-$38.4
14	RN	-$33.0	$1446.8	-$48.2	-$127.0	-$58.5	-$0.4	-$59.8	-$33.4
15	PR	$30.1	$1573.2	-$67.8	-$48.1	-$33.4	-$162.6	-$3.3	-$26.9
16	PR	$8.3	$1319.2	-$69.0	-$13.6	-$32.2	-$101.6	-$5.3	-$24.7
17	R	-$34.9	$1565.9	-$113.3	$0.0	-$76.5	-$141.0	-$34.9	-$66.0
18	R	-$48.4	$2361.8	-$97.6	-$2.1	-$100.4	-$163.4	-$50.4	-$75.7
19	RN	-$57.1	$1822.9	-$83.4	-$37.5	-$86.0	-$4.1	-$66.5	-$61.2
20	R	-$31.7	$2179.6	-$71.3	-$0.6	-$62.0	-$157.0	-$32.4	-$53.8
21	PR	$13.8	$2100.2	-$37.5	-$18.7	-$29.1	-$120.5	-$4.8	-$18.8
22	R	-$39.7	$2246.3	-$84.9	-$2.9	-$73.1	-$132.0	-$42.6	-$63.2
23	R	-$43.1	$1849.7	-$123.9	-$1.7	-$128.8	-$163.1	-$44.9	-$86.8
24	RN	-$50.6	$1310.8	-$92.0	-$37.5	-$96.8	-$4.1	-$63.3	-$54.7
25	R	-$27.5	$1688.5	-$103.6	-$0.5	-$85.9	-$156.9	-$28.0	-$68.6
26	PR	$11.6	$1609.1	-$68.2	-$16.0	-$52.3	-$117.8	-$4.4	-$30.8
27	R	-$35.5	$1733.6	-$107.8	-$2.5	-$88.7	-$131.7	-$38.1	-$71.6
28	PN	$17.1	$1804.7	-$18.1	-$226.4	-$28.7	-$125.2	-$21.5	-$1.1
29	K	-$1.5	$1734.2	-$1.9	-$263.1	-$16.9	-$76.4	-$41.2	-$3.5
30	PN	$11.2	$1517.4	-$11.4	-$244.8	-$21.9	-$91.0	-$31.3	-$0.2
31	PN	$13.1	$1407.6	-$15.0	-$275.6	-$32.1	-$35.2	-$50.6	-$2.0
32	RN	-$41.8	$1401.4	-$55.7	-$349.8	-$72.9	-$0.9	-$113.3	-$42.7
33	PN	$13.3	$1436.4	-$36.5	-$243.6	-$13.7	-$107.4	-$28.0	-$0.4
34	PR	$39.8	$2233.1	-$41.9	-$42.0	-$51.5	-$118.6	-$2.1	-$17.6
35	RN	-$38.4	$1742.8	-$62.1	-$126.2	-$74.3	-$1.7	-$65.3	-$40.1
36	PN	$11.5	$2126.2	-$12.1	-$67.6	-$16.0	-$29.4	-$8.4	-$0.6
37	PR	$31.2	$1872.8	-$50.5	-$47.4	-$32.4	-$125.9	-$1.2	-$17.0
38	PR	$34.3	$2177.0	-$35.7	-$94.4	-$44.7	-$127.6	-$1.3	-$8.1
39	PN	$32.3	$2132.2	-$32.3	-$187.4	-$41.7	-$98.1	-$18.1	-$0.1
40	PN	$9.2	$2090.2	-$9.6	-$180.0	-$20.2	-$51.8	-$26.2	-$0.3
41	PN	$27.3	$1791.2	-$40.7	-$214.6	-$41.5	-$70.4	-$42.4	-$13.4
42	RN	-$21.2	$1789.8	-$66.8	-$227.8	-$76.4	-$12.5	-$78.3	-$33.7
43	PN	$18.6	$1766.5	-$39.2	-$140.7	-$19.9	-$67.7	-$16.3	-$1.2
44	PN	$33.3	$1888.1	-$51.6	-$145.6	-$49.5	-$55.9	-$34.3	-$16.2
45	PN	$17.5	$1731.4	-$19.1	-$130.2	-$18.6	-$55.5	-$17.0	-$1.1
46	PR	$22.2	$2113.5	-$38.1	-$28.1	-$38.5	-$51.4	-$5.9	-$10.9
47	RN	-$24.9	$1641.6	-$57.3	-$116.2	-$63.0	$0.0	-$49.7	-$24.9
48	PR	$4.2	$1702.3	-$59.8	-$10.9	-$41.1	-$99.9	-$6.6	-$25.6
49	R	-$37.5	$2240.1	-$101.8	$0.0	-$103.3	-$104.8	-$37.5	-$59.9
50	RN	-$48.5	$1749.8	-$90.4	-$65.5	-$91.9	$0.0	-$62.5	-$48.5
51	R	-$22.6	$2131.0	-$71.5	-$7.8	-$62.9	-$55.1	-$30.4	-$40.5
52	PN	$30.6	$2179.3	-$44.4	-$128.4	-$47.9	-$34.8	-$24.1	-$4.1

* See Figure 1 for a description of decisions.

Table 6. (cont.)

Term-inal Node Number	Recommended CART Decision	Average Value of Preg Testing by Node	Average Present Value by Node	Average Cost of Mistake Values For Different Decisions* K Decision 1	R Decision 2	K6 Decision 3	RN Decision 4	PR Decision 5	PN Decision 6
53	RN	-$26.8	$1743.3	-$66.6	-$237.3	-$71.8	-$1.1	-$78.3	-$27.9
54	PN	$20.4	$2095.4	-$29.3	-$158.3	-$22.4	-$24.3	-$30.6	-$2.0
55	RN	-$79.1	$1749.2	-$115.6	-$305.1	-$121.0	$0.0	-$144.2	-$79.1
56	PR	$19.0	$1602.2	-$56.0	-$52.9	-$20.5	-$84.8	-$1.5	-$8.3
57	R	-$29.5	$1805.3	-$111.2	$0.0	-$75.7	-$121.8	-$29.5	-$55.5
58	PN	$19.7	$1748.6	-$57.3	-$142.3	-$21.8	-$38.5	-$24.2	-$2.1
59	PN	$33.2	$1844.9	-$37.1	-$53.0	-$40.5	-$42.3	-$6.3	-$3.9
60	R	-$32.1	$2231.5	-$96.3	-$0.7	-$97.5	-$83.2	-$32.8	-$51.0
61	PN	$7.3	$2111.4	-$50.4	-$102.2	-$51.9	-$12.8	-$25.2	-$5.5
62	RN	-$20.7	$2054.7	-$72.5	-$194.9	-$73.2	-$0.6	-$64.2	-$21.3
63	RN	-$65.4	$1766.9	-$108.8	-$256.5	-$111.0	-$0.3	-$122.3	-$65.7
64	PN	$13.7	$1818.4	-$32.8	-$57.7	-$16.7	-$40.5	-$6.8	-$3.0
65	RN	$8.4	$2121.5	-$33.1	-$33.0	-$30.9	-$1.3	-$16.7	-$9.7
66	R	-$36.5	$1868.1	-$99.7	-$0.3	-$77.6	-$89.1	-$36.7	-$56.3
67	PN	$11.9	$2085.9	-$42.0	-$108.4	-$25.8	-$16.6	-$25.0	-$4.7
68	RN	-$15.1	$2022.3	-$58.2	-$222.9	-$41.9	$0.0	-$64.3	-$15.1
69	R	-$34.1	$1712.3	-$81.3	-$0.2	-$84.0	-$101.9	-$34.3	-$58.0
70	RN	-$14.4	$1228.7	-$40.0	-$46.9	-$40.6	-$0.2	-$25.5	-$14.6
71	PN	$9.4	$1653.5	-$12.3	-$47.1	-$10.0	-$33.7	-$3.8	-$0.6
72	R	-$21.5	$1386.3	-$64.1	-$1.8	-$52.5	-$86.4	-$23.4	-$43.1
73	R	-$6.9	$1657.3	-$52.9	-$4.8	-$55.6	-$61.6	-$11.7	-$24.9
74	RN	-$18.2	$1235.2	-$48.3	-$69.9	-$49.4	-$0.6	-$34.9	-$18.8
75	PN	$13.6	$1625.2	-$16.9	-$66.1	-$13.6	-$20.6	-$10.6	$0.0
76	PR	$1.3	$1295.4	-$42.0	-$7.3	-$28.8	-$46.9	-$6.0	-$15.2
77	RN	-$29.4	$1229.0	-$56.9	-$138.6	-$57.7	$0.0	-$61.8	-$29.4
78	R	-$20.4	$1308.5	-$90.1	-$2.6	-$55.1	-$90.7	-$23.1	-$43.6
79	R	-$74.2	$1876.8	-$136.1	$0.0	-$138.0	-$127.3	-$74.2	-$104.1
80	RN	-$45.1	$1359.0	-$78.9	-$69.4	-$79.1	$0.0	-$61.4	-$45.1
81	PR	$14.8	$1831.7	-$20.1	-$21.5	-$17.8	-$24.0	-$3.0	-$3.5
82	R	-$62.7	$1592.5	-$131.1	$0.0	-$107.5	-$129.9	-$62.7	-$93.3
83	R	-$85.5	$2208.3	-$155.3	-$0.4	-$156.4	-$129.7	-$85.9	-$116.0
84	RN	-$64.8	$1670.1	-$105.7	-$68.5	-$105.9	-$0.7	-$81.3	-$65.5
85	R	-$18.0	$2111.8	-$47.2	-$2.4	-$46.0	-$43.4	-$20.3	-$29.9
86	PN	$3.6	$2039.8	-$23.5	-$28.6	-$22.3	-$6.6	-$8.1	-$3.0
87	R	-$67.2	$1934.5	-$136.7	-$0.8	-$115.6	-$127.9	-$68.0	-$97.5
88	R	-$127.6	$2335.6	-$209.8	-$0.6	-$210.0	-$157.7	-$128.1	-$164.8
89	R	-$85.9	$1779.6	-$132.2	$0.0	-$132.2	-$15.0	-$85.9	-$89.4
90	RN	-$88.4	$1745.4	-$136.0	-$48.7	-$136.0	$0.0	-$99.7	-$88.4
91	R	-$102.3	$2220.3	-$178.9	$0.0	-$161.3	-$142.5	-$102.3	-$135.5
92	PN	$20.9	$1642.0	-$38.9	-$41.1	-$40.9	-$26.9	-$9.3	-$6.0
93	RN	-$35.9	$1285.3	-$70.3	-$195.7	-$71.6	-$0.8	-$82.3	-$36.7
94	PN	$11.9	$1669.3	-$37.8	-$83.5	-$20.3	-$13.7	-$18.2	-$1.8
95	R	-$56.2	$2213.0	-$121.5	-$0.6	-$122.5	-$82.4	-$56.8	-$75.9
96	RN	-$74.1	$1748.5	-$121.2	-$116.6	-$121.5	-$0.8	-$101.9	-$75.0
97	RN	-$11.3	$2104.1	-$39.3	-$42.1	-$36.9	-$1.2	-$22.0	-$12.5
98	R	-$47.1	$1850.7	-$113.5	-$1.4	-$90.2	-$75.2	-$48.5	-$65.8
99	RN	-$51.3	$1685.6	-$96.7	-$268.2	-$97.5	-$1.0	-$114.6	-$52.3
100	PN	$5.2	$1661.1	-$38.2	-$121.1	-$21.1	-$6.4	-$27.5	-$1.2
101	RN	-$8.9	$1609.3	-$52.4	-$106.8	-$34.3	$0.0	-$34.6	-$8.9
102	RN	-$16.2	$1654.1	-$60.2	-$253.5	-$42.8	-$0.1	-$75.5	-$16.3
103	RN	-$11.0	$1777.6	-$66.1	-$29.0	-$66.9	-$7.1	-$23.2	-$18.1
104	R	-$38.5	$2151.9	-$104.4	-$3.5	-$104.7	-$44.6	-$42.0	-$51.6
105	RN	-$76.3	$1778.2	-$129.1	-$157.6	-$129.5	-$1.2	-$113.9	-$77.4
106	RN	-$19.8	$2068.1	-$54.3	-$63.3	-$49.7	-$1.3	-$35.6	-$21.1
107	R	$30.5	$1726.6	-$97.6	-$1.8	-$69.3	-$43.0	-$32.2	-$41.8
108	RN	-$8.0	$1578.3	-$65.8	-$31.5	-$37.5	-$1.8	-$16.7	-$9.7
109	R	-$35.0	$1669.7	-$102.6	$0.0	-$74.3	-$16.6	-$35.0	-$38.9
110	RN	-$55.6	$2034.4	-$110.8	-$176.4	-$102.1	$0.0	-$96.8	-$55.7

* See Figure 1 for a description of decisions.

made below each category until the average cost of mistake for a node was less than $5 or a split could not be found such that the number of cases in the smaller branch was at least 10 percent of the number of cases to be split at this point in the tree.

Terminal node 1 gives a culling recommendation of pregnancy test and replace open cows with a bred heifer. This category describes cows that are less than 8.25 years in age, replacement prices less than $555/head, calf prices less than $88/cwt., spring decision period, and a cost differential for spring calving that is $65/head less than fall calving. The amount of node impurity associated with this decision is identified by looking at the cost of mistake value for the recommended decision. This value is $4.17 (cost of mistake value for PR), about $17 less than the next best decision of pregnancy test and not replacing open cows (PN). Under the conditions described, the decision of cull all and don't replace (RN) is the worst decision one could make. The average cost of mistake for RN is $135.30, significantly more than all the other possible decisions. Terminal node 17 has an average cost of mistake of $0.00 for the decision R since none of the decisions are incorrectly classified.

Table 6 also gives the present value for an animal unit that is classed into each terminal node (20 year planning horizon). The category with the highest present value is node 18, at $2,362. This node represents the following; a cow less than 9.25 years of age with a sale calf at side, spring season, an operation where the cost of fall calving is not $65/head more than spring calving, calf price is greater than $88/cwt. and replacement prices less than $555/head. This cow and calf are not worth $2,362 but expected future returns from this starting point and subsequent optimal replacement decisions for a 20 year planning horizon yield a present value of $2,362 (6% real discount rate utilized).

The value of pregnancy testing for one period is determined by subtracting the lowest cost of mistake value for pregnancy testing (i.e., PR, or PN) from the lowest uniform culling decision (i.e., K, R, K6, or RN) cost of mistake. For example, for node 1 the lowest uniform cost of mistake value is K at $35.93. The lowest pregnancy test cost of mistake is PR at $4.17. Subtracting $4.17 from $35.93 yields a value of pregnancy testing of $31.76. Node 11 has a value of pregnancy testing equal to -$46.28. The value of pregnancy testing can go much lower than -$2/head or the assumed cost of pregnancy testing each cow. This is because cows that test open are always culled from the herd even if market prices and age indicate that these cows should be maintained in the herd. And pregnant cows are always maintained in the herd, even if market prices and biological factors are conducive to replacing these cows with a bred heifer or culling them and not replacing them in the current period. The lower limit of -$2/head would only occur if cows that tested open or pregnant were kept or culled according to optimal culling decisions.

Figure 2 compares the long run economic merits that accrue to (i.e., present

Figure 2. Present Value of Selected Culling Strategies.

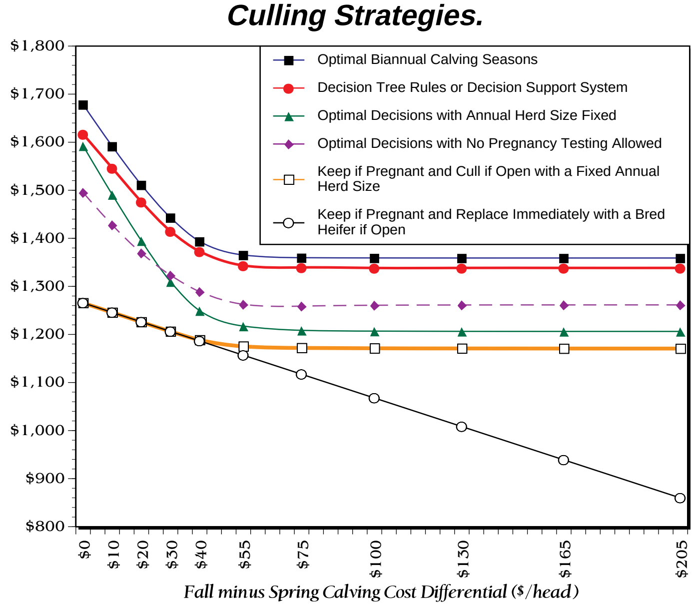
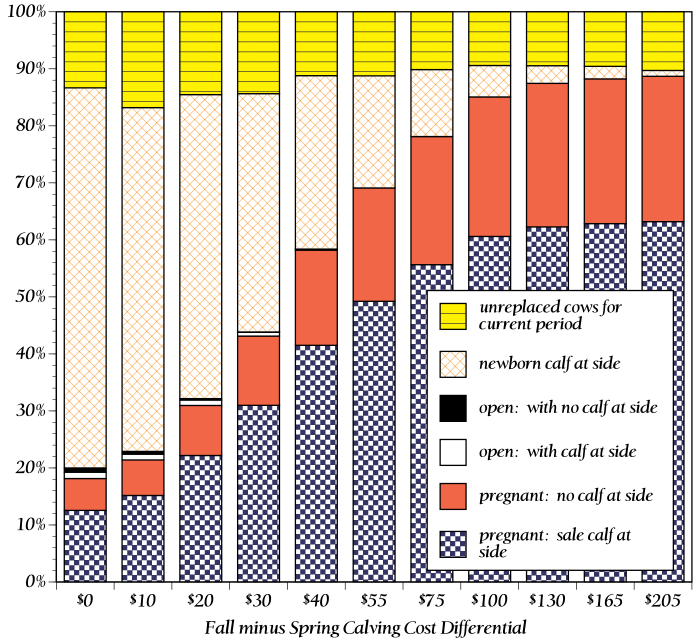


Figure 3. Long Term Status of Herd in the Fall for Different Calving Cost Differentials.



value of a 20 year planning horizon) six different culling strategies. The strategies considered are: 1) optimal culling decisions with pregnancy testing allowed and herd size variable, 2) decision tree rule presented in Figure 1 that simplifies the 43,120 decisions from the dynamic programming model (decisions used to obtain 1), 3) optimal culling decisions with a fixed annual herd size, 4) optimal culling decisions made with herd size variable and no pregnancy test information, 5) keep if pregnant and cull if open culling decisions with a fixed annual herd size, and 6) keep if pregnant and replace open cows immediately with a bred heifer. The present value of a slot in the herd is at a maximum of $1,678 if the cost differential between spring and fall calving is $0.0 and optimal culling decisions are made with a variable herd size and pregnancy testing is allowed. The present value falls quite rapidly as the cost differential increases to $55 and then levels off to a value of $1,359 with a spring only calving season. A biannual calving season has an expected net worth of $319 ($1,678-$1,359) more than a spring only calving season when the cost of spring and fall calving are equal. Two items contribute to this increase in profitability. First, sale calf prices have been historically higher in the spring than fall. As described in Figure 3, on average around 70% of the herd should have a newborn calf at side in the fall. These calves will be sold in the spring at a relatively higher price than if they were sold in the fall. Second, open cows can be brought back into production six months earlier (by allowing the cow to switch calving seasons) than with a spring only calving system. As described in Figure 3, a small percentage of open cows are maintained in the herd when the cost differential of fall minus spring calving is less than $40 or when biannual calving seasons are viable. Figure 3 indicates that about half of the calves should be born in the spring and the other half in the fall if the cost of fall calving is $30 to $40 greater than spring calving.

The decision tree culling rules shown in Figure 1 capture anywhere from 96.4% of the optimal returns with a $0.0/head calving cost differential to 98.5% with a calving cost differential above $40/head. The third management alternative evaluated is a biannual calving season with a fixed herd size. As shown in Figure 3, around 10% of the slots in a herd are not replaced immediately in the current period. This means that on average price conditions are often not conducive for immediately bringing a replacement into the herd. The impact of not allowing herd size to vary can be seen by comparing the present value of optimal decisions with herd size variable (strategy 1) and annual herd size fixed (strategy 3). The fixed herd size is 5% less profitable over the long run than optimal culling decisions with a $0.0/head calving cost differential and decreases to over 13% less cumulative profit with a calving cost differential greater than $75/head. Size is fixed in an annual sense because replacements are not forced to take the place of a cow that may die or be determined physically unfit in the spring. That is, replacements are not forced into the herd to calve in the fall when the cost of fall calving is not economically viable.

Table 6 describes the value of pregnancy testing for one season. Figure 2 quantifies the long run value of pregnancy testing by comparing the optimal returns generated when pregnancy testing is allowed (strategy 1) to those when pregnancy testing is not allowed (strategy 4). The fourth management strategy considered allows for biannual calving and a variable herd size, but optimal culling decisions are made on the basis of not having the ability to obtain any pregnancy test information. The long run value of pregnancy testing is estimated at $183 when the differential is $0.0/head. This value falls to $105 with a $40/head calving cost differential and levels off at around $98 with a cost differential above $100/head. Although pregnancy testing is not always profitable, having the technology to obtain pregnancy status information at $2/head allows for increasing long term ranch profitability from 7% to 11%.

The fifth management strategy keeps all cows that are pregnant and culls all open cows. Open cows must be replaced within a year since annual herd size is fixed. As seen in Figure 2, this strategy yields $413 less expected wealth with a $0 cost differential than optimal biannual calving seasons. As the calving cost differential increases above $55, expected wealth is $188 or about 13% less than optimal biannual calving seasons. Clearly, pregnancy testing alone is not the answer to increasing ranch profitability. In fact the more traditional management strategy of pregnancy testing all cows and culling all open cows (strategy 5) results in anywhere from 8% to 18% less profit than optimal culling decisions made without any pregnancy test information. The last management strategy considered forces open cows to be replaced with a bred heifer immediately. Plus cows that test pregnant must be maintained in the herd. Cows that die or are determined to be unfit in the spring, must be replaced with a bred heifer even if the cost of fall calving is $100/head greater than spring calving. This strategy illustrates the impact that bringing cows into the herd to calve in the fall has when the cost of fall calving escalates. As the cost of fall calving exceeds spring calving costs by over $55, profits plummet in almost direct proportion to the increase in the cost of fall calving.

Age Distribution

Figures 4 and 5 give the anticipated age distribution in the fall under optimal biannual culling decisions (strategy 1). Panel b gives a cumulative age distribution from the percentages in panel a.

Figure 4. Long Term Age Distribution in the Fall with a $0 Cost Differential.

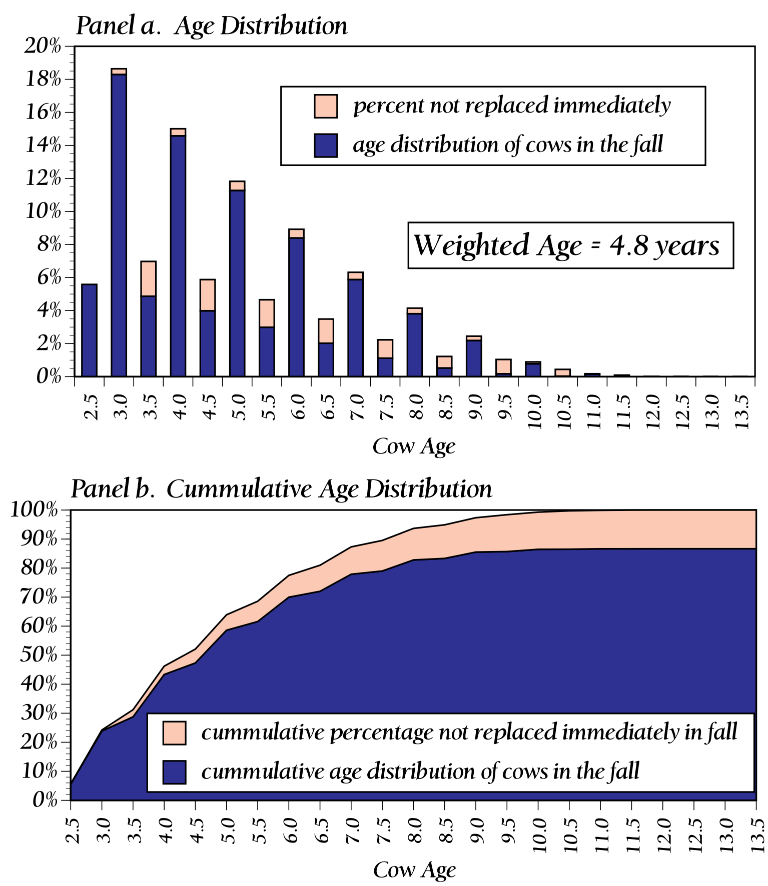
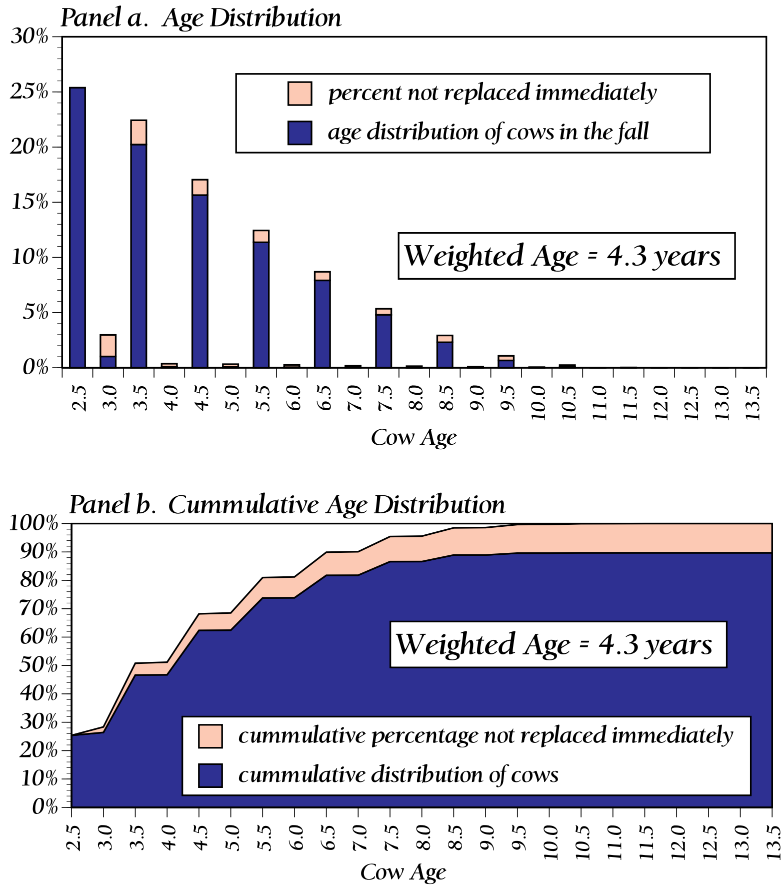


Figure 5. Long Term Age Distribution in the Fall with a $250 Cost Differential.



The cost of spring and fall calving are equal in Figure 4, whereas the cost of fall calving exceeds spring calving costs by $205 in Figure 5. Cow age is slightly higher for the $0 than $205 calving cost differential. In the fall, an average cow age of 4.8 years is expected with a $0 cost differential, one-half a year more than when fall calving costs exceed spring calving by $205. Cow age is determined after replacement decisions have been made. With essentially a spring only calving season, about 25% of the herd is expected to be composed of 2.5 year old bred heifers after culling decisions have been made. This greatly contributes to a relatively young cow age.

A $205 calving cost differential implies that essentially all bred heifers will enter the herd in the fall to coincide with a spring calving cycle. Whereas with a $0 cost differential, bred heifers are more likely to enter the herd in the spring so that sale calves can be sold at a relatively higher spring market the subsequent spring. During the spring season, the average age for a $0 and $205 cost differential is 4.5 and 4.6, respectively. When averaging age across seasons, $0 and $205 cost differentials have a combined fall-spring average age of 4.65 and 4.45 years, respectively. Biannual calving with no cost penalty for fall calving increases the optimal age of the herd by about 1/5 of a year. All cows are culled by 12 years of age with a $0 calving cost differential. When the calving cost differential increases to $205, essentially all cows are culled before they reach 11 years of age.

The analysis assumes that the cost of bringing a bred heifer replacement on the ranch is the market price plus $10/head for veterinary costs and $10/head for trucking costs. Feed and/or management costs were increased by $50/head over older cows for bred heifers during their first year of ownership. A 4% shrink, 1.5% sale commission and $.01/lb. in trucking costs were deducted from the revenues obtained from selling cull cows. Any increase in these transaction costs of replacing culled cows with replacements would increase the long term age of the herd. Also, replacement prices may be relatively high for some remote local areas. If this were true, this would also increase the long term age distribution of the herd. However, results suggest that a relatively young and thrifty herd is the most economically viable management strategy.

Conclusions

A good culling strategy has the potential to increase your long run ranch profitability to the tune of 7 to 10 percent over many of the simple strategies used in the past. The following questions are critical to ask about your culling strategy:

1. Should I preg test. If so which cows?
2. Should I maintain a constant herd size?
3. Should I calve in the spring, fall or both?

These are not simple questions. The results presented for our biological data suggest that in general you should preg test, not maintain a constant herd size, and depending on your cost differential between fall and spring calving, calve part of your herd in spring and fall. The specific recommendations change as market conditions change. This reaction to market conditions is in one of the keys to increasing profits by using our culling strategy system.

To simplify the development of culling recommendations for situations similar to our baseline herd we have set up a World Wide Web (WWW) site with an interactive version of our decision tree that will give you culling recommendations for specific market conditions. Check it out at http://ag.arizona.edu/AREC/cull/culling.html.

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