

Analysis of Female Fertility Evaluations (4 traits)

Filippo Miglior^{1,2} and Brian Van Doormaal²

¹Agriculture and Agri-Food Canada and ²Canadian Dairy network
Guelph, Ontario, Canada

Introduction

CGIL has performed genetic evaluations for female fertility using a Multi-Trait Animal Model with four traits: Age at First Service in days (AFS), Non Return Rate at 56 days in heifers (NRRh), Non Return Rate at 56 days in cows (NRRc) and days from Calving To First Service (CTFS). This short report deals with the analysis of fertility proofs in terms of correlations with other proofs for traits of interest, and in terms of combining the four traits into an aggregate index.

Female Fertility Index (FFI)

Two approaches have been used to develop a female fertility index:

(1) Use selection index theory and the known correlation matrix amongst the four traits to calculate the expected genetic progress that would be achieved for each trait over a 10-year period depending on the weights used. This was a bit of a trial and error approach using different pre-selected weights and then determining which was best given how much progress would be expected for each of the four traits. This approach should ideally be done including additional traits of importance (ie: production) but for now was limited to only the four fertility traits to identify how they should be best combined.

(2) Identify a group of bulls (older) that have relatively accurate proof information for Direct Herd Life (DHL) and use regression analysis to identify the relative importance of each fertility trait as they contribute to longevity. The regression analysis would include quadratic terms for at least Age at First Service for heifers and Interval from Calving to First Service for cows since these traits seem to have an intermediate optimum. Extremely young heifers when first inseminated are not the most desirable but neither are the extremely old ones. Similarly, cows bred very late in their lactation are obviously not ideal but perhaps neither are cows bred very early after calving. Anyways, the regression analysis will explain if such quadratic terms are important or not. Using this approach, it will be possible to account for any non-linear relationships that may exist when combining the four traits into the overall FFI.

Selection Index approach

The selection index approach assumed the following:

- Known genetic correlation matrix among traits and trait heritability (Table 1)
- Selection intensities for the 4 selection pathways: 1% for sires and dams of bulls, 5% for sires of cows and 0% for dams of cows
- Generation intervals for the 4 selection pathways: 6 years for sires of bulls (100 daughters), 4 years for dams of bulls and cows (1 lactation) and 5 years for sires of cows (50 daughters)

Table 1. Genetic correlations and heritabilities (diagonal)

	AFS	NRRh	NRRc	CTFS
AFS	.176	.084	.195	.050
NRRh		.030	.223	.050
NRRc			.037	.050
CTFS				.103

Genetic correlations from Table 1 were used in the Multi-Trait animal model evaluation. Genetic correlations between CTFS and other traits were set to .05 as no other previous estimates were available. Genetic correlations among AFS, NRRh and NRRc were from Bethany Muir's PhD thesis (2004).

Selection response was calculated after 10 years and standardized by the genetic SD. Five options of FFI are shown in Table 2.

Table 2. Selection response after 10 years by five different options

Option	Relative emphasis	AFS	NRRh	NRRc	CTFS
FFI1	.25, .25, .25, .25	1.237	0.681	0.835	0.915
FFI2	.20, .30, .30, .20	1.069	0.784	0.926	0.770
FFI3	-.20, .30, .30, -.20	-1.828	1.405	1.277	-1.612
FFI4	-.10, .40, .40, -.10	-0.361	1.303	1.32	-0.429
FFI5	-.05, .47, .46, -.02	0.034	1.199	1.234	0.013

Options 3 and 4 could be chosen if the objective is to decrease AFS and CTFS while increasing Non Return Rate for heifers and cows. Option 5, however, may be the best combination since selection to reduce the two interval traits (AFS & CTFS) is not known to be optimal. This option allows small changes for AFS and CTFS with large increases in NRRh and NRRc. For subsequent analysis it was decided to keep options four and five (FFI4 & FFI5), and for simplicity, the two indexes were standardized and expressed on the type proof scale with mean zero and standard deviation of 5. The base definition used to standardize the fertility proofs included bulls born between 1989 and 1998 that had at least 50 daughters for CTFS.

Relationship with Direct Herd Life approach

A total of 118 bulls were considered in this analysis. Those bulls had at least 50 daughters for CTFS and 20 daughters for Direct Herd Life in 3rd lactation. A regression analysis that maximized the adjusted R-square value was completed. Secondly, the level of significance of each factor included in the analysis was examined in order to obtain the best prediction in terms of the highest level of adjusted R-square and removal of nuisance variables. Quadratic terms for AFS and CTFS were also included.

The best combination included: linear terms for all four traits and the quadratic term for CTFS. The R-Square achieved was .125, which is relatively poor. The relative standardized emphasis for each trait was .05, .05, .12 and .48 for AFS, NRRh, NRRc and CTFS, respectively. When proofs were correlated for those bulls, Direct Herd Life was significantly ($p < .05$) correlated with NRRh (.181), NRRc (.213) and CTFS (-.271), and not significantly ($p = .45$) with AFS (.070). Since Direct Herd Life is specifically observed at the end of a cow's productive life, it is logical to find greater emphasis on the cow fertility traits observed in each lactation compared to the heifer fertility measures observed very early in life.

The prediction equation (Fert) using the regression coefficients was calculated for subsequent analysis. The predicted value was standardized and expressed on the type proof scale.

Correlations with traits of interest

Table 3 reports proof correlations for all bulls in the genetic base (1989-1998) and with at least 50 daughters for CTFS. Overall, fertility proofs and indexes were lowly correlated with most traits: negative with production, SCS, angularity and dairy character; positive with other type traits, LPI and longevity.

Top bull lists

Table 4 reports February Top 100 LPI bull list with the fertility proofs and the selection indexes, together with daughter count for each fertility trait. Table 5 reports a similar list, which includes only bulls that have at least 1000 daughters for CTFS.

Table 3. Proof correlations among bulls with at least 50 daughters for CTFS (N=535)

Fertility

	AFS	NRRh	NRRc	CTFS	FFI4	FFI5	Fert
AFS	1.000	.072 .094	.194 <.0001	.181 <.0001	-.019 .659	.091 .036	.243 <.0001
NRRf	.072 .094	1.000	.360 <.0001	-.054 .208	.822 <.0001	.832 <.0001	.475 <.0001
NRRl	.194 <.0001	.360 <.0001	1.000	.095 .028	.781 <.0001	.812 <.0001	.590 <.0001
CTFS	.181 <.0001	-.054 .208	.095 .028	1.000	-.158 .000	-.015 .727	-.611 <.0001
FFI4	-.019 .659	.822 <.0001	.781 <.0001	-.158 .000	1.000	.986 <.0001	.704 <.0001
FFI5	.091 .036	.832 <.0001	.812 <.0001	-.015 .727	.986 <.0001	1.000	.651 <.0001
Fert	.243 <.0001	.475 <.0001	.590 <.0001	-.611 <.0001	.704 <.0001	.651 <.0001	1.000

Production

	AFS	NRRh	NRRc	CTFS	FFI4	FFI5	Fert
Prot 1	-.230 <.0001	-.061 .131	-.172 <.0001	.152 .000	-.130 .001	-.129 .001	-.271 <.0001
Prot 2	-.178 <.0001	-.035 .388	-.156 <.0001	.100 .012	-.107 .008	-.105 .009	-.211 <.0001
Prot 3	-.140 .001	-.011 .783	-.144 .000	.105 .009	-.091 .024	-.086 .032	-.188 <.0001
Protein	-.193 <.0001	-.037 .352	-.165 <.0001	.126 .002	-.114 .004	-.112 .005	-.235 <.0001
Fat 1	-.122 .002	-.073 .069	-.147 .000	.162 <.0001	-.142 .000	-.128 .001	-.243 <.0001
Fat 2	-.086 .033	-.041 .304	-.122 .002	.101 .012	-.105 .009	-.094 .019	-.172 <.0001
Fat 3	-.047 .240	-.024 .546	-.108 .007	.117 .004	-.094 .018	-.079 .050	-.159 <.0001
Fat	-.089 .027	-.050 .214	-.132 .001	.131 .001	-.120 .003	-.106 .008	-.200 <.0001
Milk 1	-.213 <.0001	-.025 .536	-.139 .001	.190 <.0001	-.097 .016	-.091 .024	-.270 <.0001
Milk 2	-.188 <.0001	-.005 .901	-.136 .001	.121 .003	-.078 .053	-.075 .061	-.210 <.0001
Milk 3	-.153 .000	.005 .909	-.130 .001	.130 .001	-.074 .064	-.069 .087	-.199 <.0001
Milk	-.219 <.0001	-.032 .463	-.160 .000	.099 .021	-.098 .023	-.105 .016	-.227 <.0001
Prot %	.063 .118	-.041 .303	.010 .800	-.093 .021	-.014 .723	-.020 .617	.079 .049
Fat %	.097 .016	-.039 .336	.007 .867	-.020 .620	-.032 .421	-.024 .551	.032 .430
LPI	-.007 .879	.119 .006	.092 .033	-.034 .431	.134 .002	.131 .002	.100 .020

Major Score Card Traits

	AFS	NRRh	NRRc	CTFS	FFI4	FFI5	Fert
Conformation	-.165 <.0001	.073 .069	.001 .986	.047 .240	.063 .118	.058 .151	-.042 .294
Dairy Charcter	-.143 .000	-.027 .505	-.090 .025	.235 <.0001	-.084 .037	-.063 .116	-.225 <.0001
Capacity	-.335 <.0001	.004 .925	-.008 .834	.043 .289	.043 .282	.019 .639	-.097 .016
Rump	-.046 .250	-.021 .593	.037 .360	.139 .001	-.005 .904	.009 .823	-.095 .018
Feet & Legs	.080 .047	.073 .068	.023 .560	.005 .897	.044 .272	.058 .148	.052 .198
Fore Udder	-.095 .017	.078 .053	-.063 .115	-.074 .063	.034 .397	.018 .648	.010 .799
Rear Udder	.002 .967	.033 .405	.078 .052	.066 .100	.058 .152	.066 .102	.018 .658
Mammary Sys.	-.057 .155	.065 .105	-.002 .964	-.006 .887	.048 .232	.044 .278	.014 .728
Angularity	-.131 .001	-.045 .251	-.137 .000	.277 <.0001	-.132 .001	-.106 .007	-.283 <.0001

Body Traits

	AFS	NRRh	NRRc	CTFS	FFI4	FFI5	Fert
Size	-.366 <.0001	-.009 .815	-.029 .466	-.025 .537	.038 .349	.000 .996	-.080 .046
Stature	-.450 <.0001	.028 .486	-.050 .216	.070 .079	.047 .241	.016 .696	-.161 <.0001
Height Front End	-.069 .085	.100 .012	.154 .000	.000 .999	.163 <.0001	.163 <.0001	.094 .019
Chest Width	-.254 <.0001	-.042 .298	-.027 .509	-.084 .035	.011 .783	-.026 .523	-.013 .754
Body Depth	-.036 .369	-.039 .330	-.064 .111	.085 .034	-.069 .087	-.061 .125	-.103 .010
Loin Strength	-.015 .710	-.032 .419	.030 .448	.239 <.0001	-.035 .377	-.004 .912	-.157 <.0001
Pin Width	-.149 .000	-.070 .079	-.085 .033	.042 .290	-.078 .053	-.085 .035	-.121 .002
Rump Angle	-.035 .377	-.011 .781	.034 .398	.078 .051	.010 .800	.013 .743	-.049 .226

Table 3. Proof correlations among bulls with at least 50 daughters for CTFS (N=535)

Feet & Legs Traits

	AFS	NRRh	NRRc	CTFS	FFI4	FFI5	Fert
Bone Quality	.175 <.0001	.107 .008	.093 .020	.085 .034	.080 .046	.114 .005	.073 .069
Foot Angle	-.074 .066	-.017 .673	-.056 .160	.142 .000	-.054 .182	-.042 .301	-.157 <.0001
Heel Depth	-.109 .006	-.059 .139	-.074 .064	.161 <.0001	-.086 .031	-.076 .060	-.191 <.0001
Rear Leg Side View	.074 .064	-.054 .177	-.063 .116	.047 .242	-.091 .024	-.079 .049	-.059 .144
Rear Leg Rear View	-.029 .466	.112 .005	-.019 .641	-.092 .022	.072 .074	.062 .120	.085 .035

Mammary Traits

	AFS	NRRh	NRRc	CTFS	FFI4	FFI5	Fert
Udder Depth	-.028 .483	.107 .008	.010 .811	-.134 .001	.094 .018	.078 .052	.119 .003
Udder Texture	-.050 .214	.039 .327	-.023 .567	.076 .057	.007 .859	.015 .716	-.037 .352
Median Suspensory	-.072 .073	-.080 .046	-.120 .003	.125 .002	-.127 .002	-.118 .003	-.159 <.0001
Fore Attachment	-.090 .024	.107 .007	.018 .662	-.131 .001	.108 .007	.085 .034	.098 .014
Fore Teat Placement	-.065 .103	-.017 .679	-.186 <.0001	-.003 .946	-.111 .005	-.118 .003	-.117 .004
Fore Teat Length	-.020 .623	-.008 .845	.105 .009	.048 .230	.054 .182	.060 .134	.017 .675
Rear Attch. Height	.089 .026	.036 .376	.105 .009	.088 .028	.056 .160	.076 .058	.030 .456
Rear Attch. Width	-.072 .074	-.054 .180	.059 .139	.094 .019	.001 .978	.002 .951	-.054 .179
Rear Teat Placement	-.085 .033	-.061 .130	-.171 <.0001	.055 .172	-.135 .001	-.135 .001	-.152 .000

Functional Traits

	AFS	NRRh	NRRc	CTFS	FFI4	FFI5	Fert
SCS 1	-.060 .137	-.086 .032	.045 .264	.207 <.0001	-.045 .263	-.028 .486	-.145 .000
SCS 2	-.098 .015	-.095 .018	.009 .828	.163 <.0001	-.057 .155	-.051 .200	-.145 .000
SCS 3	-.099 .013	-.107 .008	.024 .548	.122 .002	-.050 .213	-.048 .232	-.112 .005
SCS	-.094 .019	-.104 .009	.028 .488	.174 <.0001	-.055 .173	-.046 .249	-.144 .000
Persistency 1	.079 .049	-.063 .116	-.040 .319	.143 .000	-.094 .019	-.072 .074	-.124 .002
Persistency 2	.103 .010	-.055 .170	-.024 .547	.143 .000	-.084 .036	-.058 .145	-.106 .008
Persistency 3	.114 .005	-.027 .508	.001 .990	.124 .002	-.050 .213	-.026 .521	-.069 .087
Persistency	.111 .005	-.059 .140	-.023 .567	.142 .000	-.087 .031	-.061 .129	-.103 .010
Calving Ease	.065 .144	.045 .308	.091 .040	-.202 <.0001	.103 .019	.083 .059	.197 <.0001
Maternal CE	.079 .078	.082 .067	.089 .047	-.106 .017	.108 .015	.102 .022	.164 .000
Herd Life	.135 .002	.140 .001	.101 .020	-.213 <.0001	.159 .000	.145 .001	.276 <.0001
Milking Speed	.016 .704	-.044 .313	-.071 .102	.025 .567	-.076 .080	-.072 .098	-.053 .221
Milking Temperament	.048 .291	-.024 .586	.031 .490	.130 .004	-.023 .604	-.003 .951	-.050 .263

Table 4. February 2004 Top 100 LPI list with fertility proofs

Obs	Bull ID	Name	Year	LPI	AFS	NRRh	NRRc	CTFS	FFI4	FFI5	Fert	d_prot	d_afs	d_nrrh	d_nrrc	d_ctfs
1	HOCANM6961162	CALBRETT-I H H CHAMPION	1997	2571	-14.63	-2.12	-0.66	-2.92	-1	-2	-1	73	59	59	26	26
2	HOCANM6947936	COMESTAR STORMATIC	1997	2464	-0.86	4.48	0.75	3.96	4	5	-2	132	97	97	75	75
3	HOUSAM2249055	WA-DEL CONVINCER-ET	1994	2444	-12.19	-4.69	-6.41	1.08	-8	-9	-8	459	636	636	246	246
4	HOCANM9052013	CLAYNOOK AFFINITY	1998	2367	-15.51	0.73	-4.80	-3.18	-1	-2	-3	94	80	80	64	64
5	HOUSAM2271271	RICECREST EMERSON-ET	1994	2298	-5.27	-0.42	-1.80	9.20	-3	-2	-6	236	959	959	264	264
6	HOUSAM17151983	REGANCREST CELCIUS BRANT-ET	1996	2205	9.30	4.03	-3.64	5.35	-1	0	-4	45	17	17	14	14
7	HOCANM6483076	SUMMERSHADE INQUIRER	1995	2180	-4.63	-5.10	-6.98	-0.41	-10	-10	-7	60	7752	7752	60	60
8	HOCANM6790237	BRAEDALE GOODLUCK	1997	2154	-12.03	-3.61	1.43	4.31	-2	-2	-5	97	90	90	72	72
9	HOUSAM121066224	KICK-IT-UP AMO-ET	1997	2120	-15.10	-0.60	0.50	-0.59	1	0	-2	87	84	84	49	49
10	HOCANM6778295	LA PRESENTATION DIGNATOR	1997	2095	-7.28	-8.14	-3.63	-1.23	-10	-10	-5	85	87	87	52	52
11	HOCANM6834617	CHERRY CREST CLIMATE	1997	2068	-4.30	4.03	-5.73	-0.21	0	0	-4	96	60	60	44	44
12	HONLDM780180664	ETAZON LORD LILY	1991	2061	-7.83	-0.54	-10.37	6.28	-9	-9	-11	228	152	152	70	70
13	HOCANM6813835	COVISTA TY	1997	2043	8.27	-7.91	0.70	-4.59	-7	-7	3	80	66	66	48	48
14	HOCANM6812634	COMESTAR EXPORT	1997	2036	-2.31	-3.15	-7.01	-2.58	-8	-8	-4	119	62	62	46	46
15	HOCANM6663935	COMESTAR LHEROS	1996	2016	-10.45	-2.85	-1.80	-0.77	-3	-4	-4	99	75	75	58	58
16	HOCANM6780909	BOSSIDE RONALD	1997	2011	-1.46	-0.23	1.95	-6.99	3	2	7	56	61	61	33	33
17	HOCANM6684184	COMESTAR LAUGAN	1997	1970	-3.64	-0.23	-3.11	-6.03	-1	-2	3	186	113	113	80	80
18	HOCANM6682654	BENNER AEROWOOD	1996	1950	-8.00	-1.63	4.10	-0.64	2	2	0	43	5	5	3	3
19	HOCANM6595344	BOSSIDE RUBEN	1996	1944	-15.06	0.49	-0.10	5.28	1	1	-6	74	36	36	2	2
20	HOUSAM17256762	HENKESEEN EMPEROR-ET	1996	1944	-8.89	0.59	0.88	-1.92	2	2	0	76	217	217	55	55
21	HOUSAM18030591	SULLY ANGLE-ET	1997	1937	-16.88	-1.93	-8.99	-4.11	-7	-8	-5	66	28	28	23	23
22	HOUSAM2301353	RICECREST MONDAY-ET	1996	1921	1.40	0.22	2.22	-0.45	2	2	1	104	855	855	61	61
23	HOCANM6830327	PENNVIEW INCOME	1997	1914	-0.39	2.39	7.00	0.13	8	8	3	99	85	85	66	66
24	HOCANM6853353	LA PRESENTATION JENUS	1997	1884	3.27	4.90	3.20	0.31	7	7	2	110	62	62	35	35
25	HOCANM5844883	STBVQ RUBENS	1993	1862	4.25	-1.62	-6.94	1.17	-7	-7	-6	2345	2972	2972	1419	1419
26	HOCANM6802397	CLOVIO ROYAL	1997	1862	11.75	5.00	5.50	12.89	6	8	3	74	49	49	28	28
27	HOUSAM122651023	MARKWELL RAINE-ET	1998	1862	10.28	-1.32	1.99	-5.70	1	0	7	67	68	68	35	35
28	HOUSAM121479202	CLOVER-MIST RA KASSIDEY-ET	1998	1857	-5.25	-3.51	-5.69	0.39	-7	-8	-6	62	61	61	31	31
29	HOCANM6846348	LA PRESENTATION AEROCERF	1997	1837	0.70	-10.03	-3.83	-3.00	-12	-13	-3	100	43	43	31	31
30	HOCANM6906786	BRAEDALE FREEMAN	1997	1837	-2.57	-1.77	-2.19	11.25	-5	-4	-6	76	75	75	43	43
31	HOUSAM17085075	BLOK-BROS LOUIS-ET	1995	1835	0.06	-8.13	-2.39	-0.51	-9	-10	-4	73	186	186	17	17
32	HOCANM6817117	STEEPLEHIGH-I C C RIDLER	1997	1833	0.53	0.59	1.83	0.15	2	2	0	92	67	67	39	39
33	HOUSAM2216459	RIDGE-STAR JUSTY-ET	1992	1827	6.70	-5.99	-2.67	-2.31	-8	-8	-1	293	196	196	137	137
34	HOCANM5757117	COMESTAR LEE	1992	1824	0.59	-1.02	-8.53	3.61	-8	-8	-8	16563	17579	17579	9716	9716
35	HOCANM6806471	BENNER JUSTIN	1997	1820	-9.71	4.48	-6.27	-5.58	1	0	1	82	47	47	34	34
36	HOCANM6845021	DONNANDALE PROTOCOL	1997	1819	-15.65	-3.98	-6.03	-6.67	-6	-8	0	58	26	26	21	21
37	HOCANM6239888	DOHBELL AMAZON	1994	1816	16.49	-0.11	-1.35	-10.27	-1	-1	13	80	58	58	35	35
38	HOCANM6264421	RICHESS STONEHAM	1994	1801	-11.29	-4.40	-0.10	3.40	-4	-4	-6	1525	5057	5057	2329	2329
39	HOCANM6781798	BLONDIN CINCINNATI	1997	1796	-0.62	-1.20	-6.80	-2.57	-6	-6	-3	105	88	88	63	63
40	HOUSAM17361734	OUR-FAVORITE MELVILLE-ET	1997	1795	-13.81	2.81	-8.39	-7.61	-1	-3	2	108	107	107	86	86
41	HOUSAM2128554	EASTVIEW MEADOWLORD-ET	1990	1792	-5.33	3.51	2.38	-2.78	6	6	3	607	334	334	151	151
42	HOCANM6508943	RICHESS STRAUSS	1996	1791	8.43	8.11	0.66	-3.91	8	8	6	94	76	76	54	54
43	HOUSAM2265005	DIXIE-LEE AARON-ET	1994	1790	-11.48	-5.94	-4.93	-0.18	-8	-9	-7	739	968	968	451	451
44	HOCANM6858231	RAYPEL SCIENTIFIQUE	1997	1787	-0.46	3.55	8.61	-9.99	12	11	17	108	57	57	46	46
45	HOCANM6880709	BLONDIN COURAGE	1997	1785	-9.80	-2.44	-4.61	-1.61	-5	-6	-4	81	51	51	33	33
46	HOCANM5470579	STARTMORE RUDOLPH	1991	1784	-7.94	5.24	2.85	-2.21	8	8	3	41436	29274	29274	18791	18791
47	HOCANM6754099	WALKERBRAE LOGISTIC	1997	1784	4.48	0.78	6.02	5.55	4	5	0	120	84	84	69	69
48	HOCANM6903539	BRILEA LM FINNIGAN	1997	1777	2.46	-5.01	1.26	4.51	-5	-4	-4	96	99	99	59	59
49	HOUSAM17129288	CANYON-BREEZE ALLEN-ET	1995	1773	-6.07	-0.54	-2.99	0.84	-2	-3	-4	52	1043	1043	1	1
50	HOCANM6830350	GRASSHILL GERONIMO	1997	1766	-5.74	-6.13	-2.65	0.15	-7	-8	-5	93	78	78	55	55

Table 4. February 2004 Top 100 LPI list with fertility proofs

Obs	Bull ID	Name	Year	LPI	AFS	NRRh	NRRc	CTFS	FFI4	FFI5	Fert d	prot	d afs	d nrroh	d nrroc	d ctf
51	HOCANM6215479	SILKY GIBSON	1994	1753	3.54	3.08	-0.04	5.94	1	3	-3	1226	3136	3136	1306	1306
52	HOCANM6583776	CALBRETT-I STRAUSS	1996	1752	-27.99	-0.16	-3.70	4.38	-1	-2	-9	99	79	79	59	59
53	HOCANM6666474	LYSTEL BARCLAY	1997	1750	-18.39	1.39	-7.37	-3.34	-2	-4	-4	100	47	47	36	36
54	HOCANM6843785	BAUVREUIL R LEGER	1997	1743	-6.68	4.68	1.74	0.27	6	6	0	85	40	40	32	32
55	HOCANM6026421	COMESTAR OUTSIDE	1994	1738	-10.58	2.21	0.85	1.65	3	3	-2	8731	13795	13795	7122	7122
56	HOCANM6844277	TAILOR MADE ICON	1997	1738	10.72	-1.48	0.15	0.62	-2	-2	-1	112	90	90	58	58
57	HOCANM6945990	CEDARWAL RAIDER	1998	1734	16.40	7.56	7.15	10.52	9	12	4	78	48	48	35	35
58	HOCANM6588867	WILLSONA STARDEL	1996	1729	5.87	3.17	0.93	-2.36	4	4	3	69	169	169	41	41
59	HOCANM6602666	TWILITE-I DARTER	1996	1717	5.45	-3.66	1.00	7.30	-4	-3	-4	74	63	63	47	47
60	HOCANM6873798	GRANDUC TRIBUTE	1997	1715	17.26	0.81	-4.67	7.75	-6	-4	-5	105	65	65	43	43
61	HOCANM6928149	LA PRESENTATION DOMINO	1998	1705	7.50	3.10	-0.68	-0.94	2	2	1	101	76	76	47	47
62	HOCANM6387868	BROAD COVE GOLDENGATE	1995	1695	5.32	2.42	3.50	1.17	4	5	1	75	510	510	5	5
63	HOCANM7053450	GLENHAVEN COSMO	1996	1688	22.28	5.91	9.77	-0.92	11	13	9	96	77	77	55	55
64	HOCANM5925716	MAPEL WOOD ESTIMATE	1993	1677	-12.97	0.39	-3.33	2.48	-2	-2	-6	1401	3509	3509	1506	1506
65	HOCANM6793639	SHOREMAR LASER	1997	1674	-3.76	2.84	-3.72	-0.91	0	0	-2	122	99	99	65	65
66	HOCANM6929629	REDAMA LUIGI	1997	1673	-12.53	1.36	-4.04	-0.41	-1	-1	-4	107	95	95	69	69
67	HOCANM6839262	DESLACS STARWORD	1997	1672	-14.22	4.28	6.70	-0.29	10	10	2	104	69	69	41	41
68	HOUSAM2183007	HA-HO CUBBY MANFRED-ET	1991	1669	-1.00	1.19	-0.49	-6.01	2	1	5	193	55	55	40	40
69	HOCANM6988440	DOHBELL CURIUS	1997	1668	-1.08	-0.12	11.14	-4.72	10	9	10	98	90	90	74	74
70	HOCANM6820212	GLOREMI LORQUI	1997	1664	-1.96	-4.33	5.88	1.93	0	1	0	111	99	99	71	71
71	HOCANM6913459	NIPPONIA SYMBOL	1997	1663	-12.78	-1.50	-5.25	-5.68	-3	-5	0	100	88	88	48	48
72	HONLDM311651443	SKALSUMER SUNNY BOY	1985	1661	-4.38	-2.48	1.19	-5.20	0	-1	4	302	28	28	18	18
73	HOCANM6855451	BOFRAN LASSO	1997	1660	-3.11	-0.53	-0.89	-0.32	-1	-1	-2	92	90	90	48	48
74	HOUSAM17335394	COOKS-VALLEY BENEDICT-ET	1997	1660	-3.55	-7.59	-7.48	-2.12	-12	-13	-6	87	80	80	54	54
75	HOCANM6833573	DERIANNE STEPHANE	1997	1652	10.67	3.11	1.68	-2.78	4	4	4	75	73	73	43	43
76	HOUSAM17310469	VEEDMAN-DAIRY SECURITY-ET	1997	1652	14.01	6.74	7.09	4.17	10	11	4	96	47	47	36	36
77	HOCANM6649200	HANDREY SUTTON	1996	1642	-19.49	-1.63	-5.23	-0.49	-4	-5	-6	59	59	59	43	43
78	HOCANM6951659	GEN-I-BEQ CLINTON	1998	1634	7.68	-0.90	-1.38	-1.13	-2	-2	0	95	91	91	60	60
79	HOCANM6821048	BEAUCOISE NISSAN	1997	1628	11.44	3.88	0.22	14.59	0	3	0	95	90	90	70	70
80	HOCANM8041770	GARONNE PRET	1997	1627	-26.55	-2.34	-3.74	-9.84	-1	-4	5	105	72	72	56	56
81	HOFRAM4494059987	JELTAN JAB	1994	1625	-20.57	-5.89	-7.28	-5.14	-8	-11	-4	58	13	13	4	4
82	HOUSAM2160458	BRABANT STAR PATRON-ET	1991	1614	-9.75	-1.12	-1.91	-12.32	1	-2	13	156	24	24	15	15
83	HOUSAM2149849	SECOND-LOOK JOLT	1990	1613	-8.85	-2.09	2.95	0.25	1	1	-1	2208	2098	2098	786	786
84	HOCANM6694439	RAYLUC PHILL	1996	1610	-5.51	2.04	0.71	-2.96	3	3	2	132	78	78	55	55
85	HOCANM7053435	GLENHAVEN ACRE MAN	1998	1607	0.86	0.81	-0.12	-5.76	2	1	5	120	108	108	80	80
86	HOUSAM17129511	REGANCREST DREAM-ET	1996	1602	9.72	1.16	-0.53	-5.02	1	0	5	132	77	77	39	39
87	HOUSAM17271204	ART-ACRES CABIN-ET	1997	1600	15.49	-0.75	-1.54	2.07	-4	-3	-2	80	75	75	55	55
88	HOCANM6827076	SHOREMAR LOUVER	1997	1596	-1.81	-2.44	-0.29	4.45	-3	-3	-5	108	89	89	64	64
89	HOUSAM2236057	HANOVER-HILL PREMIER-ET	1993	1593	-3.42	-0.84	1.30	-2.60	1	0	1	94	72	72	34	34
90	HOCANM6831072	GRANDUC SIR SOUTER	1997	1592	5.05	-2.66	3.67	2.59	-1	0	-1	90	33	33	28	28
91	HOUSAM2203292	SIR ROCKIE AARON-ET	1992	1590	6.73	3.56	1.08	-2.78	4	4	4	1003	673	673	448	448
92	HOUSAM2231562	RICECREST MARTY-ET	1993	1590	0.61	2.44	6.71	4.04	7	8	1	1912	1100	1100	705	705
93	HOCANM7057207	INDEPENDENT LUNAR	1997	1585	6.24	3.01	-4.25	2.70	-2	-1	-4	73	28	28	22	22
94	HOUSAM17139633	WHITTIER-FARMS CEDRIC-ET	1996	1585	4.93	0.84	-5.65	2.40	-4	-4	-5	80	71	71	51	51
95	HOUSAM2228954	CALBRETT MAYERS DUSTY	1993	1582	14.56	0.22	-4.05	-0.77	-4	-4	-1	1557	1518	1518	1008	1008
96	HOCANM6143035	PEARTOME DOCTOR	1994	1576	6.33	0.74	1.14	-6.78	2	2	8	32	2	2	1	1
97	HOCANM6466625	SUMMERSHADE IGNITER	1995	1572	-4.01	-1.62	-0.42	9.51	-3	-2	-5	123	5580	5580	99	99
98	HOCANM6505247	GLEN DRUMMOND INTENSIFIER	1996	1571	-1.88	-2.80	2.01	1.77	-1	-1	-2	91	122	122	37	37
99	HOUSAM2283419	CLOVER-MIST LUXURY-ET	1995	1571	-3.82	-1.51	2.55	-8.37	2	1	9	60	272	272	30	30
100	HOCANM5457798	MAUGHLIN STORM	1991	1566	7.82	2.28	-0.31	6.67	0	1	-3	34154	24875	24875	14445	14445

Table 5. February 2004 LPI list with fertility proofs for bulls with at least 1000 daughters for CTFS

Obs	Bull ID	Name	Year	LPI	AFS	NRRh	NRRc	CTFS	FFI4	FFI5	Fert	d_prot	d_afs	d_nrrh	d_nrrc	d_ctfs
1	HOCANM5844883	STBVQ RUBENS	1993	1862	4.25	-1.62	-6.94	1.17	-7	-7	-6	2345	2972	2972	1419	1419
2	HOCANM5757117	COMESTAR LEE	1992	1824	0.59	-1.02	-8.53	3.61	-8	-8	-8	16563	17579	17579	9716	9716
3	HOCANM6264421	RICHESSE STONEHAM	1994	1801	-11.29	-4.40	-0.10	3.40	-4	-4	-6	1525	5057	5057	2329	2329
4	HOCANM5470579	STARTMORE RUDOLPH	1991	1784	-7.94	5.24	2.85	-2.21	8	8	3	41436	29274	29274	18791	18791
5	HOCANM6215479	SILKY GIBSON	1994	1753	3.54	3.08	-0.04	5.94	1	3	-3	1226	3136	3136	1306	1306
6	HOCANM6026421	COMESTAR OUTSIDE	1994	1738	-10.58	2.21	0.85	1.65	3	3	-2	8731	13795	13795	7122	7122
7	HOCANM5925716	MAPEL WOOD ESTIMATE	1993	1677	-12.97	0.39	-3.33	2.48	-2	-2	-6	1401	3509	3509	1506	1506
8	HOUSAM2228954	CALBRETT MAYERS DUSTY	1993	1582	14.56	0.22	-4.05	-0.77	-4	-4	-1	1557	1518	1518	1008	1008
9	HOCANM5457798	MAUGHLIN STORM	1991	1566	7.82	2.28	-0.31	6.67	0	1	-3	34154	24875	24875	14445	14445
10	HOCANM6215489	SILKY COUSTEAU	1994	1525	10.48	-0.89	-1.14	10.15	-4	-2	-4	3340	3875	3875	2026	2026
11	HOCANM5902195	SHOREMAR JAMES	1993	1519	-3.58	-4.03	-7.66	1.03	-10	-10	-8	9586	12910	12910	6771	6771
12	HOCANM5429693	OLIVEHOLME AEROLINE	1991	1456	-0.16	-6.31	-0.96	0.43	-7	-7	-4	24843	21620	21620	12670	12670
13	HOCANM6130765	MEADOW BRIDGE MARKEM	1994	1448	-1.41	0.88	-1.36	6.09	-1	0	-5	1469	3628	3628	1682	1682
14	HOCANM5319769	COMESTAR LEADER	1990	1437	3.42	0.52	-0.99	-6.84	1	0	6	16249	11148	11148	6271	6271
15	HOCANM5662554	SILVERRIDGE NICOLAS	1992	1411	8.83	-1.22	0.33	4.94	-3	-1	-3	2447	2278	2278	1562	1562
16	HOCANM5364343	BEAUCOISE BLACK KING	1991	1367	12.95	4.43	-1.37	-8.02	3	3	10	6620	2206	2206	1277	1277
17	HOCANM5574544	STARTMORE LEADMASTER	1991	1182	6.66	5.25	3.41	0.24	7	8	3	5045	3252	3252	2062	2062
18	HOCANM397763	HALDREY LEADERSHIP	1987	1012	12.59	-1.24	-3.80	0.98	-5	-5	-3	16768	5317	5317	3640	3640
19	HOCANM5335690	DIXELLEN DESIGN	1991	983	-5.23	-5.68	-1.15	-6.00	-5	-6	2	5200	1740	1740	1160	1160
20	HOCANM5808350	COMESTAR TOP GUN	1993	976	-7.53	-1.23	-11.81	-8.31	-8	-10	1	6245	5515	5515	3663	3663
21	HOCANM5406271	KARNVILLA RATIO	1991	965	-4.63	5.14	5.47	-4.24	10	10	7	2762	2823	2823	1291	1291
22	HOUSAM2204207	CAERNARVON JAY-ET	1992	914	-12.37	-1.07	-4.44	2.17	-4	-4	-7	3494	2822	2822	1903	1903
23	HOUSAM2234121	DUNCAN PROGRESS-ET	1993	849	-8.84	0.13	3.90	-0.79	4	4	1	12178	14900	14900	8273	8273
24	HOCANM5524122	MALOYA LEO	1991	840	-2.07	3.88	5.24	-5.38	9	8	8	4065	2830	2830	2028	2028
25	HOUSAM2201168	HANOVER-HILL MIRAGE-ET	1992	765	9.48	-3.51	-0.14	3.63	-5	-4	-3	2611	1923	1923	1261	1261
26	HOCANM392405	DUREGAL ASTRE STARBUCK ET	1986	721	11.17	3.11	2.38	10.74	2	4	0	43189	1907	1907	1190	1190
27	HOCANM5279989	SHOREMAR MASON	1990	673	-1.63	-4.26	1.94	6.42	-3	-3	-4	26077	12477	12477	8151	8151
28	HOCANM382748	A TOWNSON LINDY ET	1984	607	7.75	0.70	0.84	0.22	1	1	0	33311	2122	2122	1315	1315
29	HOCANM5610317	GILLETTE CARLTON	1992	459	6.36	-0.65	-1.31	10.54	-4	-2	-4	5398	2928	2928	1968	1968
30	HOCANM395671	BOULET CHARLES ET	1988	295	5.44	6.38	2.45	-2.97	8	8	5	20748	2075	2075	1077	1077
31	HOCANM5402550	SHOREMAR MILAN	1991	265	-3.11	-4.23	-2.44	-3.63	-5	-6	-1	9027	2798	2798	1759	1759