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Short communication: Trends for monthly changes in days open in Holsteins

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ABSTRACT

A reaction norm approach was used to estimate trends for days open (DO) with a model that indirectly accounted for heat stress. Data included 3.4 million first-parity records of DO of US Holsteins. A fixed effect model included herd-year, month of calving within region (MOC), age class, and regression on 305-d milk yield. An index calculated from the standardized solutions to MOC derived from the fixed effect model was treated as a proxy for an index on heat stress (SI). The lowest index for any region was set to zero. The highest index was 1.00 for the Southeast, 0.56 for the Northeast, 0.54 for the Midwest, 0.33 for the Northwest, and 0.42 for the Southwest. In all regions except the Northwest, the highest DO and the corresponding highest indices were in March–April. Compared with the fixed model, the reaction norm model also included the effect of an animal and a random regression on the SI; the 2 animal solutions are subsequently referred to as an intercept and a slope. Genetic trends were calculated for cows and sires separately. For cows, the trend for the intercept was −0.1 d/yr, whereas the trend for the slope was 1 d/yr. For sires, the same trends were −0.3 and 1.5, respectively. Official proofs were used to characterize the 100 top and 100 bottom bulls with at least 50 daughters for the intercept and the slope. Compared with the top bulls, the bottom bulls for the intercept gave 56 kg more milk and their type performance index was higher by 212 points. For the slope, the same numbers were −435 kg and −242 points, respectively. Trends for seasonal changes of days open are unfavorable.
Key words: dairy cattle, fertility, days open, heat stress

Decline in fertility traits in many dairy cattle breeds is well documented (Washburn et al., 2002; Rajala-Schultz and Frazer, 2003; de Vries and Risco, 2005) and has a negative effect on the income of dairy farmers (de Vries, 2006). As those traits are lowly heritable, they are difficult to improve by genetic selection. These traits have unfavorable correlations with production (Berger et al., 1981; Abdallah and McDaniel, 2000; Pryce et al., 2004). Therefore, increased selection for production while ignoring fertility results in reduced fertility.

A large fraction of the variability of fertility traits is determined by environmental factors such as herd effect or season of calving (Faust et al., 1988; Ray et al., 1992; Eicker et al., 1996). The variability of days open (**DO**) in the month of calving has been shown by several investigators (Silva et al., 1992; VanRaden et al., 2002; Oseni et al., 2003). According to their results in the United States, DO were longest for spring and shortest for fall calvings. Seasonal trends for DO and for most of the fertility traits were partly attributed to the variation in temperature. High temperature combined with a high level of humidity results in physiological disorders, affecting the digestive system, acid-base chemistry, and blood hormones (Rensis and Scaramuzzi, 2003; West, 2003).

Decreasing heat tolerance may be one of the reasons for decline in fertility. Aguilar et al. (2008) found positive genetic trends for daily milk yield in the first 3 parities when heat stress was absent. However, the rate of decline under heat stress increased, especially in the second and third parities. The sensitivity to heat stress increased with the subsequent number of parities from first to third (Aguilar et al., 2008). García-Ispierto et al. (2006, 2007) reported a similar negative influence of heat stress on fertility. Thus, observed seasonal patterns in fertility traits might be considered a result of the high temperatures in summer months and their negative influence on reproductive performance.

Most high-producing farms in areas where heat stress is present use cooling devices. Although the decline in milk yield over the summer can be greatly reduced under good heat management, the decline in fertility under heat stress is still strong (Her et al., 1988; Flamenbaum and Ezra, 2007). The effect of heat stress on fertility is currently observed not only in the southern US but also as far north as Alberta, Canada (Brouk et al., 2007). One way to counteract this decline is through genetic selection.

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Arguably, the preferable way for genetic evaluation of fertility under heat stress would be the analysis of the nonreturn rate while accounting for temperature conditions at the time of the first insemination (Ravagnolo and Misztal, 2002) or the extension of this technology for outcomes of all inseminations (Averill et al., 2004; Gonzalez-Recio et al., 2005). However, the availability of insemination data in the United States is limited (Huang et al., 2008). An alternative solution is to consider DO that is available from the AIPL/USDA database and is used for US genetic evaluation. Oseni et al. (2004a) estimated the genetic parameters for DO under varying levels of heat stress using a reaction norm model for the southeastern United States. On the one hand, the increase of DO under heat stress was already apparent, and no weather data were necessary for the analysis. On the other hand, changes in DO seemed to be influenced also by management factors and only indirectly related to heat stress. The reaction norm involves an index derived from solutions for the month of calving (**MOC**) effect; rescaling resulted in an index from zero (MOC with lowest DO) to 1 (MOC with highest DO; Oseni et al., 2004a).

The aim of this study was to extend the model of Oseni et al. (2004a) to all regions of the United States and to run the national genetic evaluation of DO with that model to obtain genetic trends.

Production and DO records on 3,401,130 first-parity Holsteins born from 1994 to 2000 in 32,203 herds were extracted from the AIPL/USDA database. The data set included records of 101,764 sires. Days open were precomputed as in VanRaden et al. (2003). Replicates, incorrect records, and DO with values <22 d were removed from the data set. Range for DO was set from 50 to 250 d; values between 22 and 50 d were set to 50 d, and values exceeding 250 d were set to 250 d.

The fixed model to estimate MOC solutions was

$$y_{ijklm} = hy_i + moc_{jk} + age_l + b \times milk + e_{ijklm},$$

where y_{ijklm} is observed DO for mth (m = 1–3,401,130) animal in the herd-year class i (hy; i = 1–34,862), calving in month j (moc; j = 1–12), in region k (k = 1–5), and in age-class l (age; l = 1–6); b is a fixed regression on a 305-d milk yield (milk), and e is the residual term. The standardized solutions for MOC were used to compute a monthly seasonal index (**SI**), using the following formula:

$$SI_{jk} = (sol_{jk} - sol_{\min k})/\alpha,$$

where sol_{jk} is the least square solution for jth MOC (j = 1–12) within kth region (k = 1–5); $sol_{\min k}$ is the minimum solution for the particular region, and α is a constant value that scales the index from 0 to 1.

The genetic evaluation analysis used the following model:

$$y_{ijklm} = hy_i + moc_{jk} + age_l + b \times milk + a_{0m} + a_{1m}SI_{jk} + e_{ijklm},$$

where y_{ijklm}, hy_i, moc_{jk}, age_l, $b \times milk$, and e are defined as in the first model; a_{0m} is the additive effect of animal m at SI equals zero (intercept) (m = 1–3,401,130), and a_{1m} is the random regression coefficient for cow m at a given SI (slope). Variance components were as in Oseni et al. (2004b); residuals among MOC were assumed to be heterogeneous. Additional analysis included a simplified model with the effect due to slope removed. Variance components for the simplified model were reestimated to consider the removal of SI. Estimates from the model were used to calculate genetic trends for the additive effects for cows and proven sires separately. Differences among estimates for group of cows and sires in both analyses were examined using the t-test.

Table 1 shows the distribution of records among the different states and regions; regions were defined as in Figure 1. The largest was the Midwest population, with nearly 1,193,707 cows in 17,528 herds. The smallest number of animals (120,966 in 1,255 herds) was found in the Southeast. Over 50% of all observations were from the following 4 states: California, Wisconsin, New York, and Minnesota (0.8, 0.4, 0.3, and 0.3 million animals, respectively). The average DO was 135 d. The Southeast had the highest mean of all the regions (154 d), whereas the Northwest the lowest mean (131 d).

Figure 2 shows phenotypic changes of DO across MOC with base adjusted so that the lowest estimate of MOC is zero; these changes are rescaled to an index in Figure 3. The highest values were in spring and summer and the lowest in fall and winter (Figure 2). This is similar to findings of Oseni et al. (2003), who attributed the changes to heat stress. Shapes of DO by month were somewhat different among regions. The shape for the Southeast was the most variable. The shape was somewhat different for the Northwest where the peak and the bottom were reached earlier than in the other regions; the Northwest was the region with the smallest magnitude of heat stress.

Figures 4 and 5 show the genetic trends for cows and sires, respectively. Trends were also plotted for the simplified model (with effect due to SI removed). Differences among estimates for cows and sires were highly significant for both models (P < 0.0001). When the index is not in the model, the trends for DO are flat. These findings differ from those presented by VanRaden

Table 1. Distribution of records among the different states and regions

			Days open	
Region/state	Records, n	Herds, n	Mean	SD
Midwest				
Iowa	82,129	1,403	142	67
Illinois	43,326	711	149	69
Indiana	36,377	555	143	68
Kansas	27,979	366	149	73
Kentucky	15,098	295	149	71
Michigan	114,444	1,179	136	66
Minnesota	301,030	4,261	139	66
Missouri	22,969	501	149	71
North Dakota	6,167	90	143	68
Nebraska	23,687	286	149	70
Ohio	96,994	1,152	140	67
South Dakota	16,935	269	144	69
Wisconsin	399,633	6,385	128	64
Wyoming	6,939	75	141	69
Midwest total	1,193,707	17,528	137	66
Northeast				
Connecticut	14,681	127	135	67
Delaware	5,144	33	146	71
Massachusetts	11,154	138	134	65
Maryland	44,806	466	141	68
Maine	13,727	178	134	64
New Hampshire	12,001	121	135	65
New Jersey	8,635	106	143	68
New York	300,067	3,243	132	65
Pennsylvania	298,101	5,161	135	65
Rhode Island	283	6	145	66
Virginia	68,400	610	140	67
Vermont	45,034	545	132	64
Northeast total	822,033	10,734	135	66
Northwest				
Idaho	71,095	232	134	66
Montana	7,179	65	136	63
Oregon	40,028	209	138	65
Washington	83,640	286	136	65
Wyoming	763	6	122	63
Northwest total	202,705	798	135	65
Southeast				
Alabama	4,923	61	153	73
Arkansas	3,252	74	156	71
Florida	19,882	89	161	72
Georgia	20,889	201	154	72
Louisiana	7,506	120	154	73
Mississippi	7,967	97	158	74
North Carolina	27,087	252	151	71
South Carolina	10,858	93	151	71
Tennessee	18,602	268	152	72
Southeast total	120,966	1,255	154	72
Southwest				
Arizona	48,764	53	132	64
California	835,253	1,050	128	67
Colorado	30,798	85	144	68
New Mexico	27,275	42	129	65
Nevada	8,195	21	132	66
Oklahoma	8,135	135	156	72
Texas	68,769	298	149	73
Utah	34,530	204	145	67
Southwest total	1,061,719	1,888	131	67
All United States	3,401,130	32,203	135	67

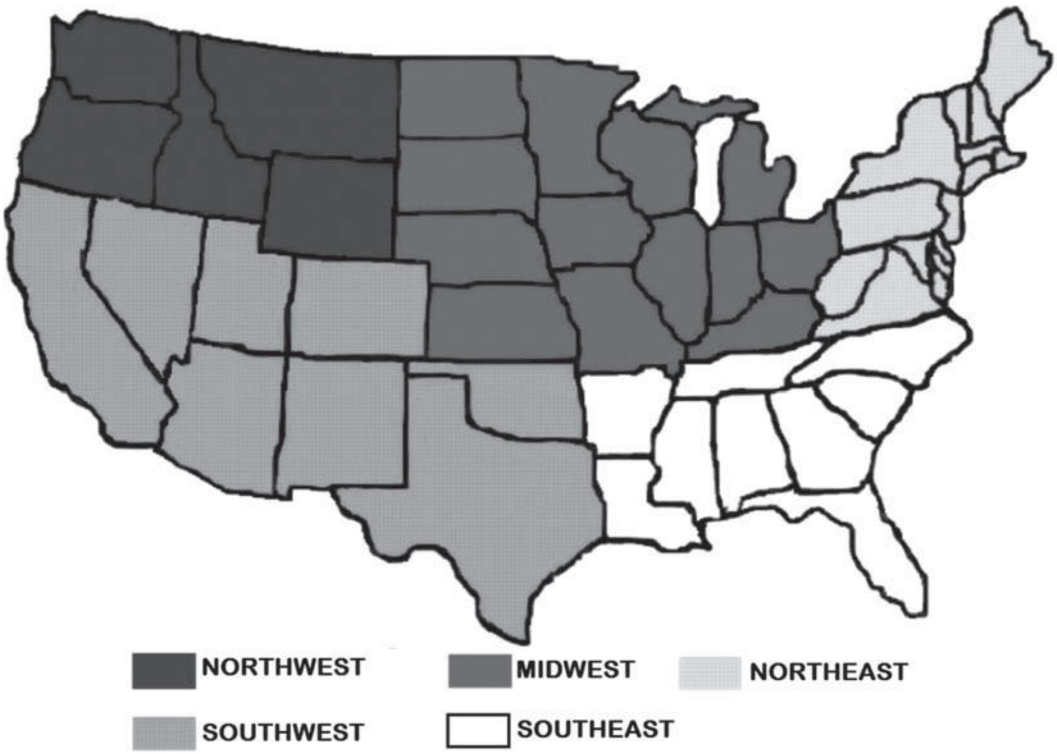

Figure 1. Map of the United States; distribution of states by region.

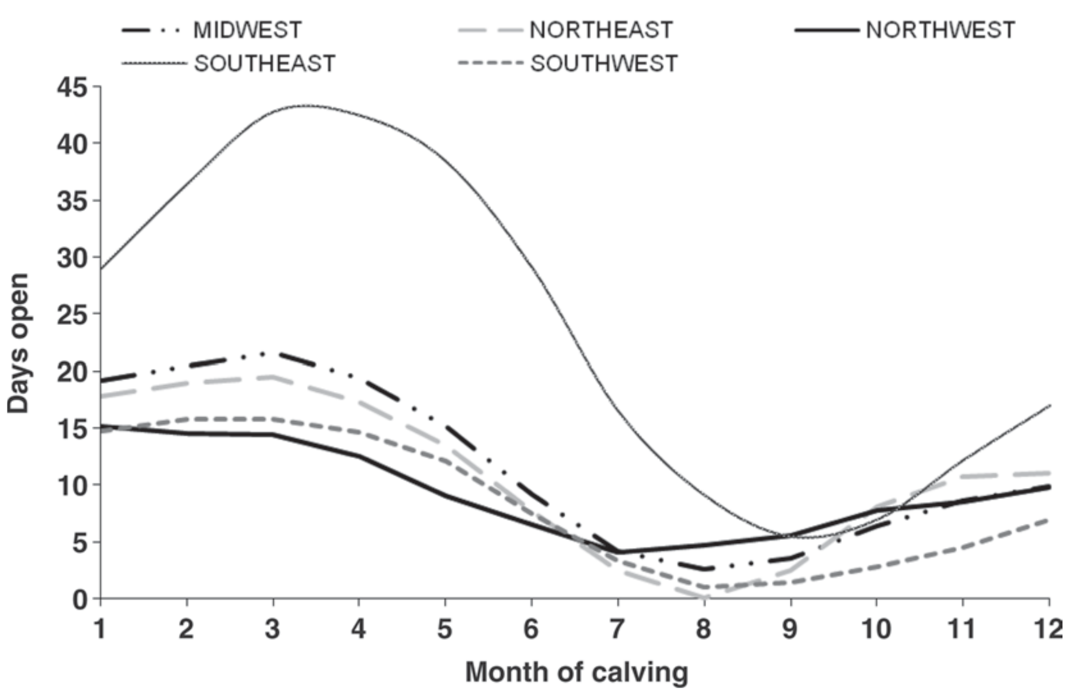

Figure 2. Phenotypic changes of days open across month of calving in different regions of the United States.

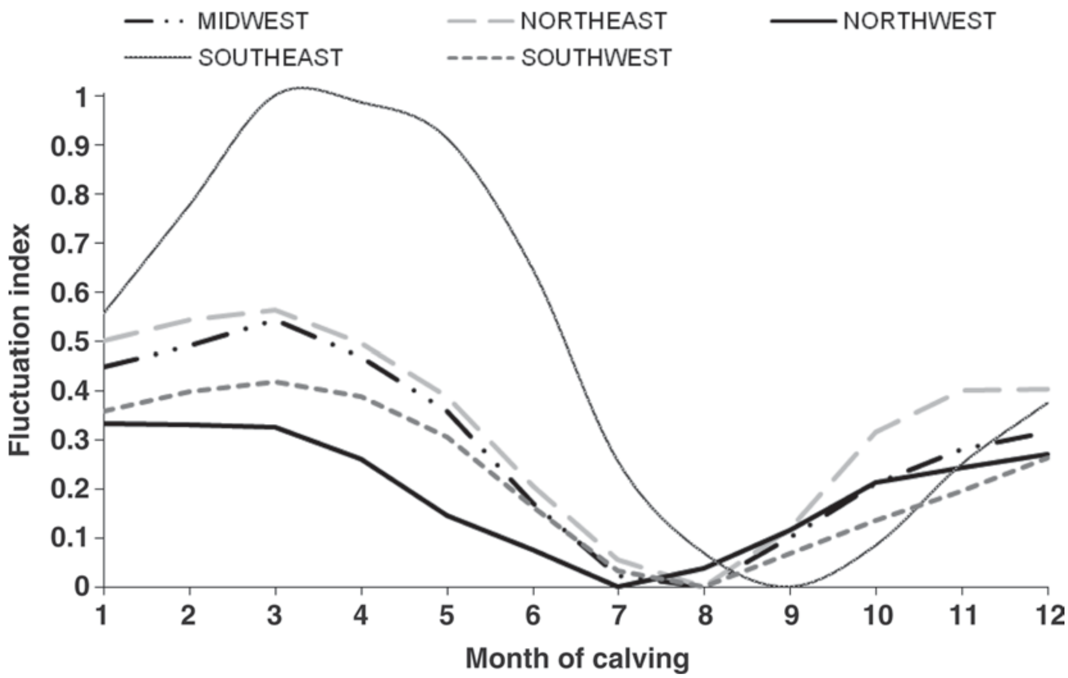

Figure 3. Index of changes of days open across month of calving in different regions of the United States.

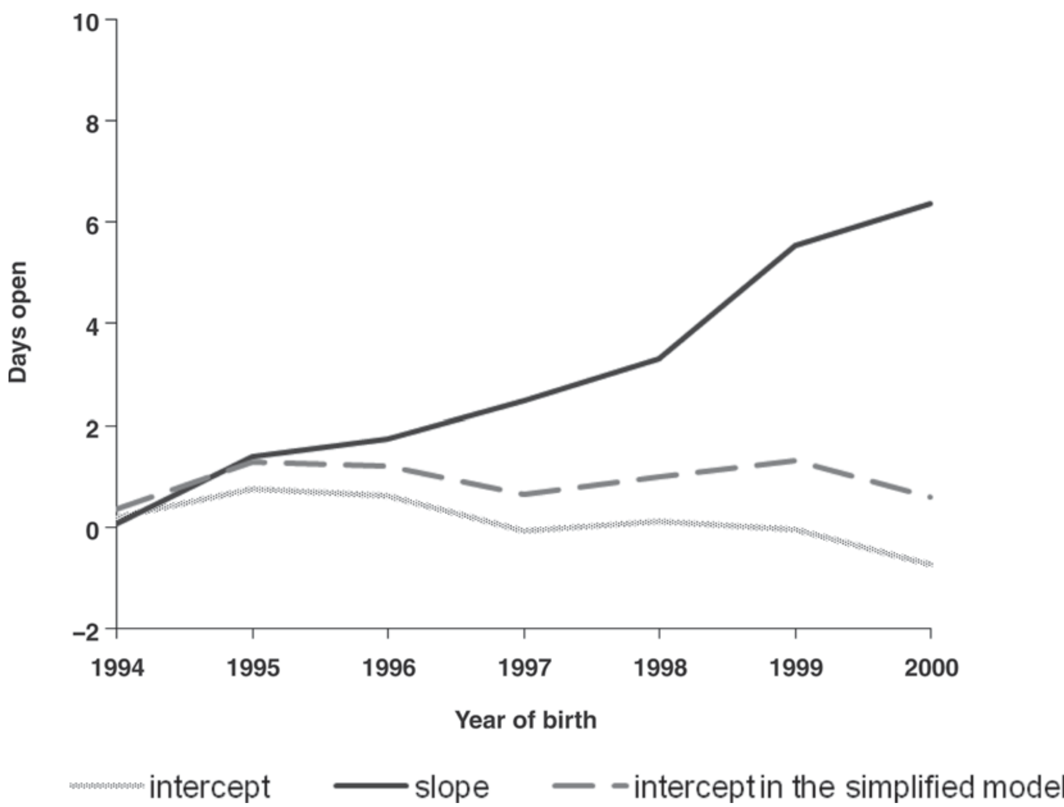

Figure 4. Genetic trends for cows for days open across past years; plotted for the full model with seasonal index (SI) included and simplified model with effect due to SI removed.

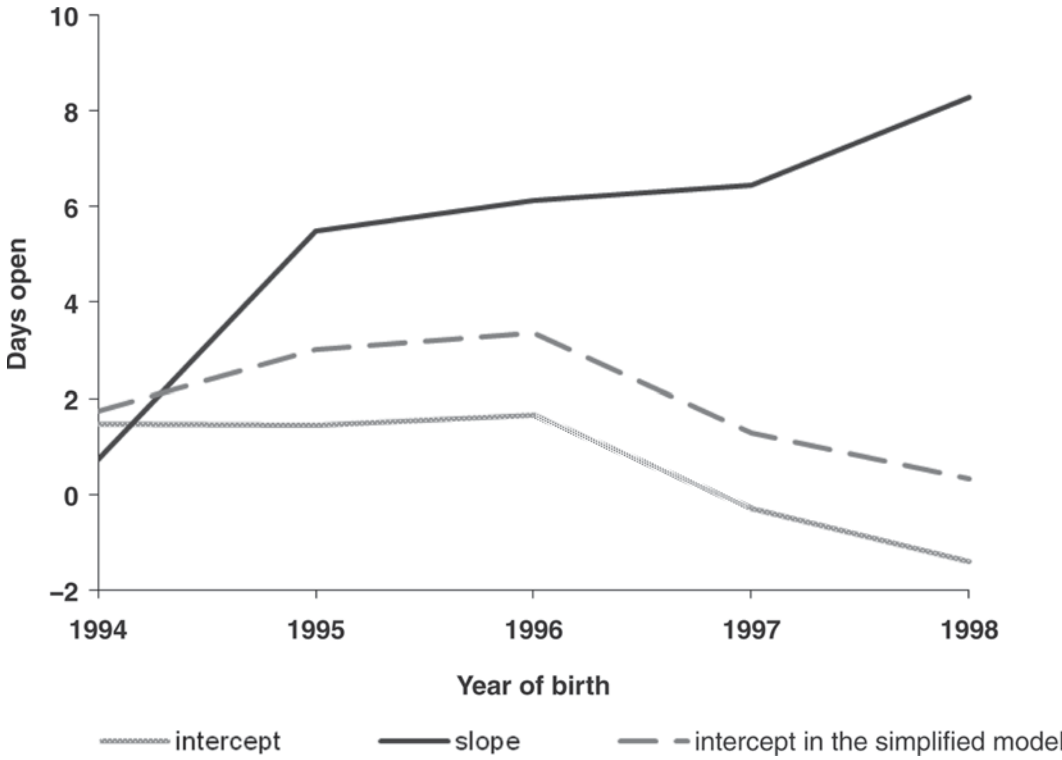

Figure 5. Genetic trends for sires for days open across past years; plotted for the full model with seasonal index (SI) included and simplified model with effect due to SI removed.

et al. (2004). However, in their model, there was no correction for milk yield and 5 parities were included. With the index in the model, the trend for the intercept (called the regular effect) is slightly negative at about −0.1 d/yr, whereas the slope (called changes) is about 1 d/yr. The same trends for sires were −0.3 and 1.5 d, respectively.

To create a profile of top and bottom bulls for selected traits, the top 100 and bottom100 bulls with at least 50 daughters were selected separately for the intercept in the simplified and regular models, and for the changes. For those bulls, official US PTA for February 2005 were obtained (Table 2). Bulls with the smallest changes of DO transmitted much less milk yield (435 kg) and a smaller type performance index (**TPI**; 242 points). It seems that bulls that transmit low changes would be undesirable based on their production and type. Contrary, bulls with the highest changes have, in general, superior characteristics, although their productive life (**PL**) and daughter pregnancy rate (**DPR**) are below average. For the intercept with the full model, the bulls with the lowest DO gave 56 kg of milk and were superior for TPI by 212 points. They were also superior for DPR and PL. In the simplified model, the bulls with the lowest DO had daughters with slightly lower milk, superior TPI, and superior DPR and PL (but slightly lower than with the full model). See Table 2 for a detailed comparison.

Tsuruta et al. (2008) showed that cows kept on large farms had higher milk production and fewer DO. Fewer DO on large farms were due to more timed AI services compared with smaller farms. This is in agreement with the current results. When SI = 0, bulls with fewer DO had higher values for milk yield; similarly, type trait scores were more desirable. Conversely, when SI was greater than zero, bulls with fewer DO had lower values of milk yield and type traits. Therefore, high-producing cows had greater changes of DO due to heat stress. When the conception rate is low, such as during heat stress, there is a tendency to use semen of less expensive bulls. This may explain the unexpectedly low values for both milk and type traits for the top bulls when SI greater than zero.

Although selecting for the intercept would provide positive selection for many desirable traits, selection for reduced changes would greatly reduce milk yield. It seems that high-producing cows adapt to a high level of stress by increasing DO; DO stay flat or even improve during the period of low stress. Therefore, selection to reduce the monthly changes is undesirable. However,

Table 2. Average PTA and type performance index (TPI) from February 2005 US official evaluation for 100 bulls with the longest and 100 bulls with the shortest days open (DO)

			Intercept			
	Slope		Regular model		Simplified model	
Trait	Fewer DO	More DO	Fewer DO	More DO	Fewer DO	More DO
Milk (kg)[1]	−289	146	29	−26	−13	15
Fat (%)[1]	0.02	−0.03	−0.04	0.04	−0.04	0.03
Protein (%)[1]	0.00	0.00	0.00	0.01	0.00	0.01
Type[2]	−1.02	0.06	−0.19	−0.09	−0.30	−0.05
Stature[2]	−0.80	0.15	−0.43	−0.19	−0.47	−0.13
Strength[2]	−0.44	−0.13	−0.24	−0.01	−0.30	0.01
Body depth[2]	−0.62	−0.14	−0.38	0.18	−0.49	0.17
Dairy form[2]	−0.83	0.49	−0.27	0.64	−0.42	0.66
Rump angle[2]	−0.11	0.14	0.28	−0.57	0.23	−0.44
Thurl width[2]	−0.59	−0.12	−0.34	−0.04	−0.36	0.00
Rear leg side view[2]	0.47	−0.48	−0.01	0.13	0.18	0.10
Rear leg rear view[2]	−1.27	0.98	0.01	−0.06	−0.10	0.01
Foot angle[2]	−1.05	0.81	−0.10	−0.10	−0.14	−0.06
Feet and leg score[2]	−0.99	0.44	0.02	−0.27	−0.06	−0.20
Fore udder attachment[2]	−0.98	−0.35	−0.22	−0.21	−0.27	−0.24
Rear udder height[2]	−0.87	−0.33	−0.14	−0.23	−0.26	−0.20
Rear udder width[2]	−0.76	−0.29	−0.06	−0.14	−0.17	−0.12
Udder cleft[2]	−1.10	0.31	−0.15	−0.33	−0.21	−0.23
Udder depth[2]	−0.90	0.00	−0.25	−0.61	−0.18	−0.54
Front teat placement[2]	−1.19	0.15	−0.03	−0.44	−0.12	−0.43
Teat length[2]	0.36	0.47	0.03	0.36	−0.01	0.34
Udder composite[2]	−0.96	−0.09	−0.16	−0.37	−0.20	−0.34
Feet and leg composite[2]	−1.04	0.63	−0.01	−0.18	−0.09	−0.12
Body composite[2]	−0.66	0.01	−0.36	−0.07	−0.42	−0.03
Dairy composite[2]	−0.91	0.26	−0.32	0.41	−0.49	0.45
TPI[1]	801	1,043	1,137	925	1,089	950
Productive life (mo)[1]	0.49	−1.69	1.60	−1.96	1.61	−1.99
Daughter pregnancy rate (%)[1]	1.35	−2.00	1.82	−2.77	1.85	−2.81

[1]Source: Animal Improvement Programs Laboratory, USDA (Beltsville, MD).
[2]Source: Holstein Association, USA Inc. (Brattleboro, VT).

the model that accounts for the changes can improve evaluations for DO compared with the model that ignores the changes.

This study assumed the same genetic control for the changes in all regions and assumed that the changes were mostly due to heat stress. In fact, the reasons for changes can be different; especially for the Northwest. They may include seasonal feed differences, timing of lactations, time on pastures, and so on. Another assumption was that the genetic parameters for all the regions were the same, while the parameters due to the slope were scaled by the index. However, computations with models with different parameters indicated robustness of the model that assumes homogeneous variances for the animal effects. More accurate trends for heat stress might be obtained by analyzing outcomes of successive inseminations. This will be possible when national data sets become more complete and easily available. In addition, such records require extensive editing (Huang et al., 2008).

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