

Bison Genetics Results & Analysis: Bison Genetic Value Index Update for the Crane Trust Bison Herd – 3 Dec. 2021

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Photo Credit: Brad Mellema

Objectives – The Crane Trust primarily reintroduced Plains Bison (*Bison bison bison*; hereafter “bison”) at its Shoemaker Island properties along the Platte River in Hall County, Nebraska, to improve ecosystem function for the benefit of migratory birds and other species of conservation concern. However, our organization is also committed to supporting the cultural and genetic recovery of bison in North America, within our capacity, as a secondary objective. To that end, the Crane Trust collected genetic samples from most bison as they were introduced into the herd through purchase or birth during our annual fall “working” period. Samples were sent to the DNA Technologies Laboratory at Texas A&M University for processing from 2015-2016 and to the Veterinary Genetics Laboratory at the University of California–Davis from 2018-2020. Bison face a number of genetic issues resulting from an extreme population bottleneck in the late 1800s driven by overhunting, as well as their currently fragmented distribution across artificially restricted ranges, which eliminates opportunities for natural dispersal and population connectivity. Most conservation organizations have limited acreage available to their bison herds, necessitating the regular removal of individuals to avoid exceeding habitat carrying capacity. This also limits opportunities for herds to grow large enough to support genetically self-sustaining populations. Therefore, it is important to translocate bison between herds, but this is a cost and labor-intensive process. It can be made more efficient, however, through the targeted retention and dissemination of specific genetic resources. Our goal is to not only maintain genetic purity and eliminate cattle (*Bos taurus*) introgression within our herd by current measures, but also to improve genetic diversity and fitness (heterozygosity; Hz) as well as retain and increase the number of unique and potentially adaptive genetic traits within our herd (allelic richness). However, the direct results of genetics investigations can be highly complex and challenging for many bison managers to interpret and act upon. For instance, some bison may have high genetic diversity (i.e., Hz) but very few unique alleles relative to the herd as a whole. Similarly, Crane Trust bison do not demonstrate cattle introgression regarding mitochondrial DNA analyses but cattle alleles have been irregularly detected via nuclear DNA analyses. Given the multifaceted and occasionally contradictory implications of genetic results for individual bison, we have developed tabular and graphical reporting methods to improve data actionability for the Crane Trust bison management staff. The most novel analytical tool our team developed was the Bison Genetic Value Index (BGVI), which is a weighted scale considering a bison’s genetic diversity and uniqueness relative to the herd that is penalized for the presence of cattle alleles. This report contains aforementioned tabular and graphic evaluations of individual bison and the herd as a whole which can be used to support bison genetic management decisions.

Figure 1. Sire Records – From 2017 to 2020 across 105 calves tested for parentage A10 sired 43 (41.0%), Thunder, Crazy Horns, and other unknown males with uncollected genetics sired 16 (15.2%), A6 sired 14 (13.3%), A11 and B88 both sired 10 (9.5%), and A12, A8, and B89 each sired 3 (2.9%). The rest of the breeding males sired just a single calf. In all, we have detected a minimum of 11 sires.

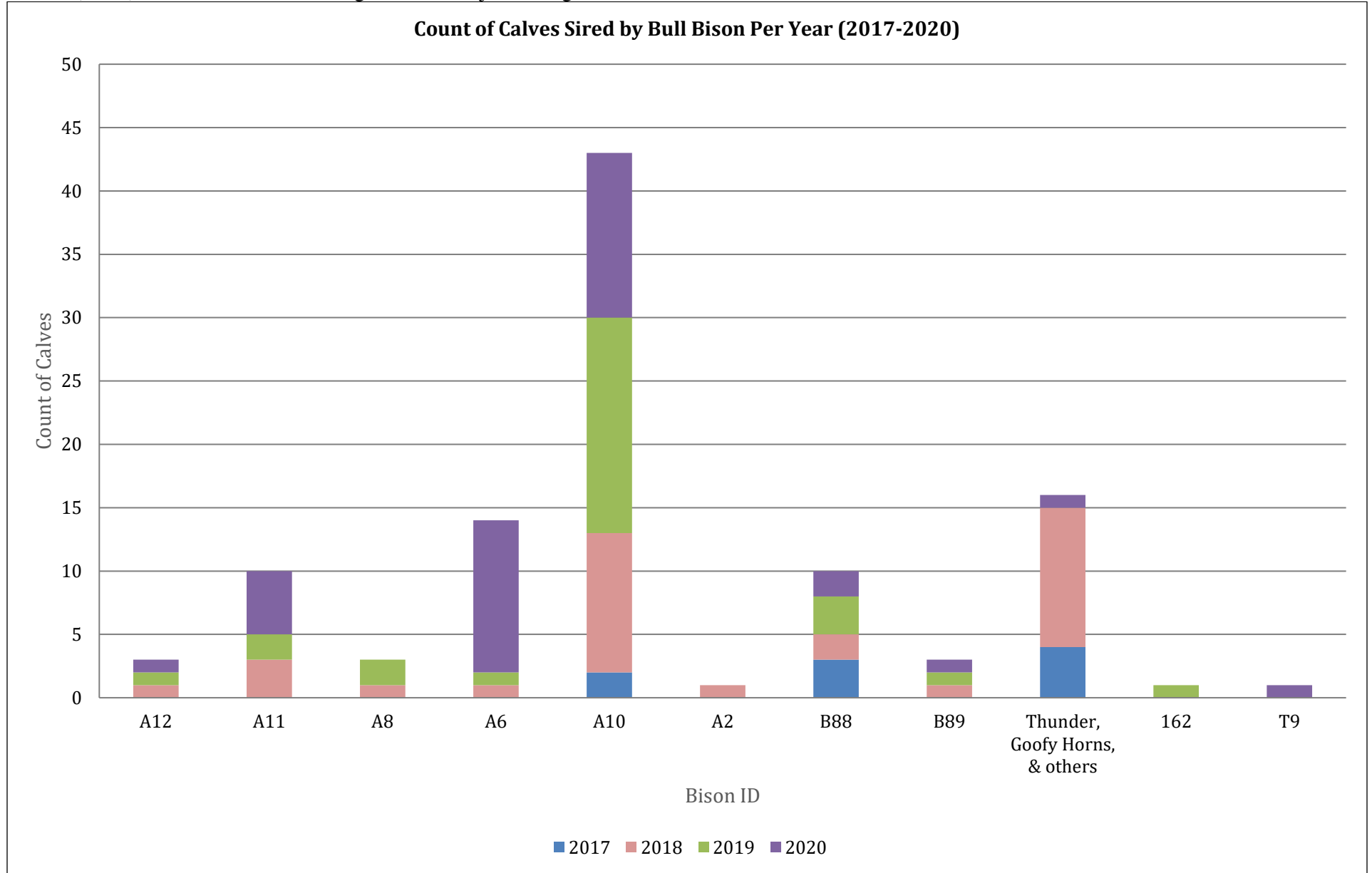


Figure 2a. Genetic Diversity by Sire – Below we present the mean calf heterozygosity (Hz) per sire with error bars representing 1 standard error. A12 calves had the highest mean Hz 0.75 ± 0.04 of those bison siring more than 1 calf. Additionally, A2, A11, A6, A8, and B88 sired calves with mean Hz scores >0.70 . This analysis included 105 individual calves.

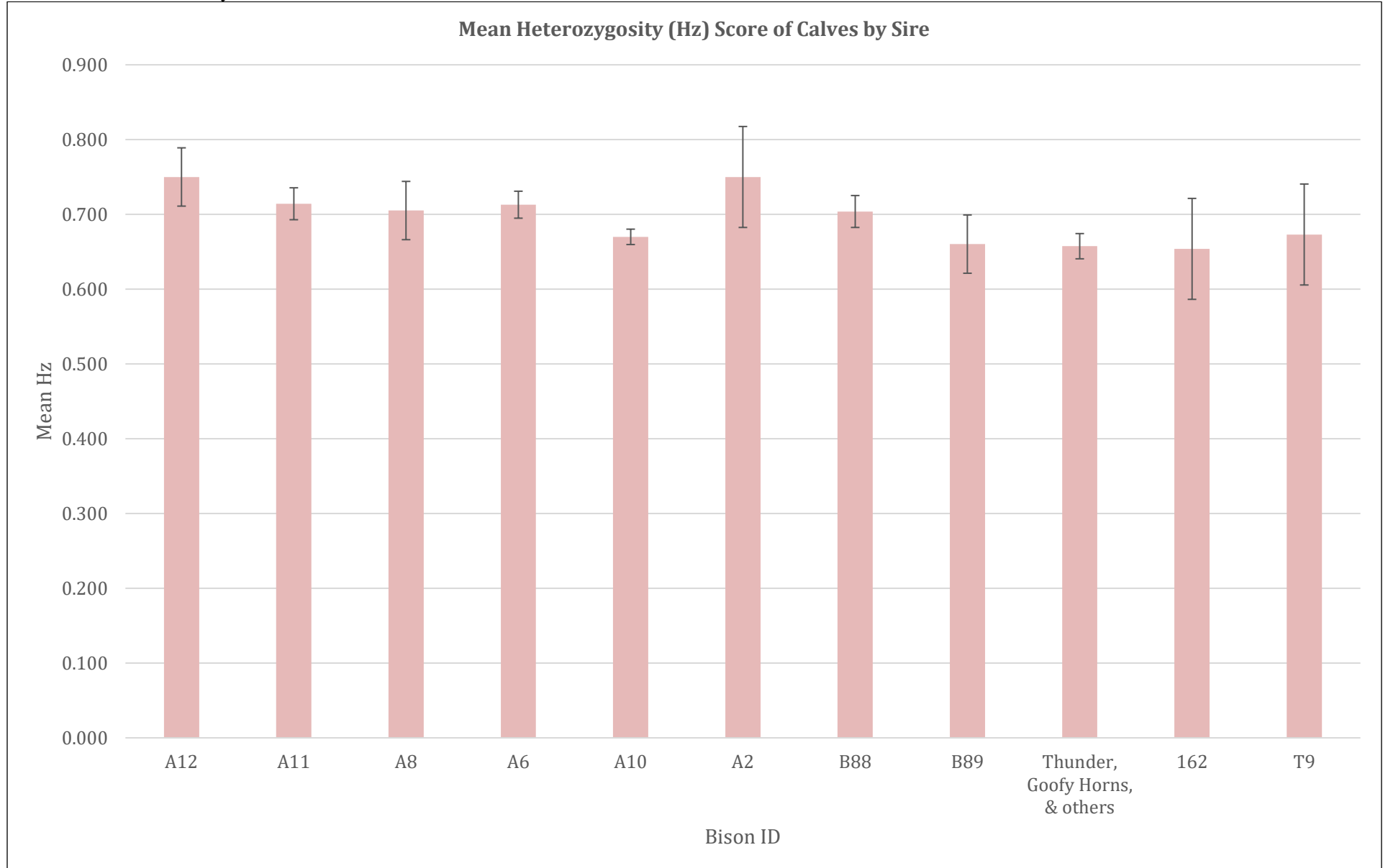


Figure 2b. Genetic Uniqueness by Sire – Below we present the mean calf Genetic Uniqueness Index (GUI) per sire, which quantifies the amount of genetic heritage attributed to underrepresented herds. The lone calf sired by T9 had 53.0% of its genetic heritage associated with underrepresented herds. For those bison siring 3 or more calves, mean GUI was highest for B89 (41.6%), and calves sired by A11 and A8 also averaged >20% on the GUI (22.0% and 25.9%, respectively). This analysis included 105 individual calves.

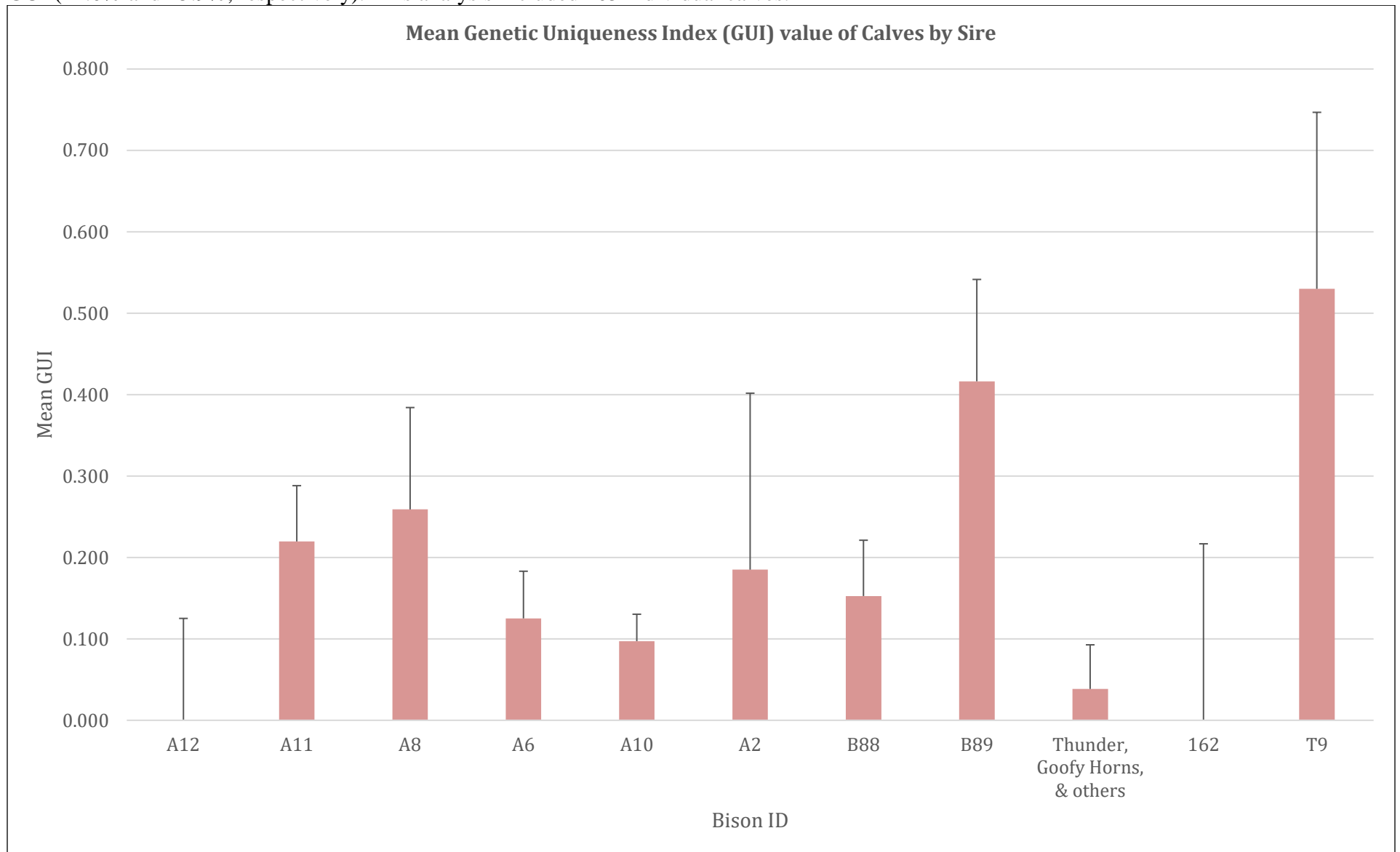


Figure 2c. Genetic Value by Sire – Below we present the Bison Genetic Value Index (BGVI) by sire. This measure is a composite index that considers both genetic uniqueness and diversity and provides an applied tool to help the Crane Trust Bison Coordinator and associates make herd management decisions that continue to improve genetic diversity and purity. For male bison siring 3 or more calves, A11’s calves averaged the highest BGVI (3.1), which ranges from -1 to 6, with higher values equating to better genetics. Bison managers should consider retaining or promoting bison with scores of ≥ 3 within the herd. However, bison scoring ≥ 2 are above, but within 1 standard deviation of average. A8, B89, A12, and B88 all produced calves that averaged ≥ 2.0 . Of course, calves sired by A2 and T9 scored well on the BGVI (≥ 3), but these individuals only sired a single calf each. This analysis included 105 individual calves.

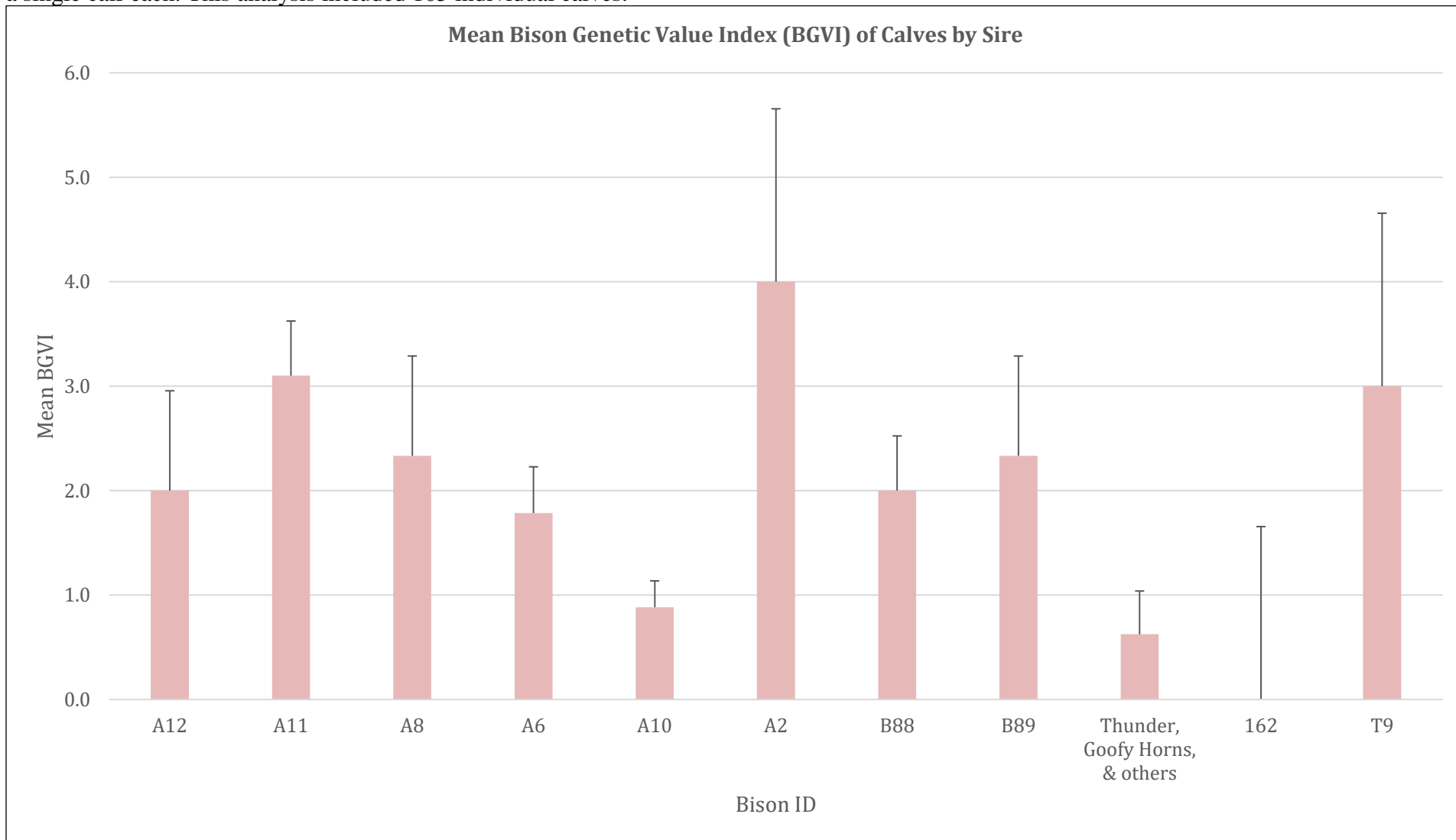


Figure 3. Herd Genetic Diversity Trends – The below blue line represents the weighted average genetic diversity (Heterozygosity – Hz) of all animals tested within our herd from 2015 to 2019 (2015-2016 tests from DNA Technologies Laboratory (DTL) at TAMU, and 2018-2020 from Veterinary Genetics Laboratory (VGL) at UC-Davis). The green line represents the mean Hz from the founding herd. The black line represents the annual mean Hz of all new animals added to our herd through birth or purchase; the associated gray lines represent a one standard deviation confidence interval. Our weighted average herd Hz was 0.655 from 2015-2019 and the mean of new animals added to the herd annually ranged from a low of 0.616 in 2015 to high of 0.690 in 2020. However, results from 2018 (0.682), 2019 (0.686), and 2020 (0.690) are statistically similar, suggesting our upward trend may be slowing. Table 1 provides further information on individual bison Hz.

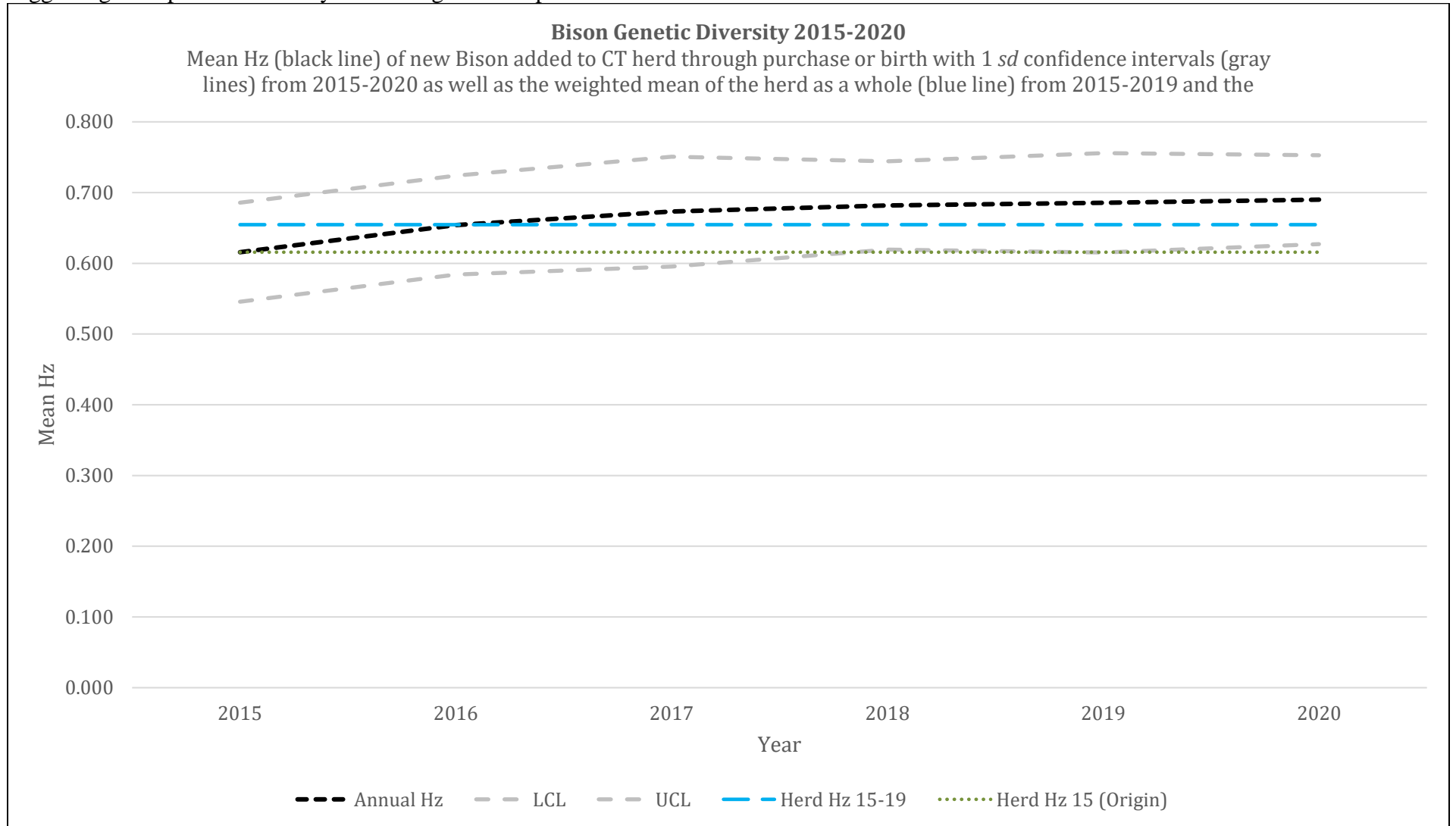


Figure 4. Individual Genetic Diversity Figure– Individual Hz data from all bison tested at the University of California-Davis Veterinary Genetics Laboratory (VGL, n = 117). Mean Hz for all animals tested at VGL (predominantly calves (born 2017 to 2020) was 0.683 with a low of 0.519 and a high of 0.827. Below individual animals are plotted with reference to several lines: black (mean), orange (lower confidence interval – 1 sd), red (lower confidence interval – 2 sd), green (upper confidence interval – 1 sd), blue (upper confidence interval – 2 sd). Bison above the green line can be considered to have “great” genetic diversity while those above the blue line can be considered to have the “best”. Similarly, those animals below the orange line can be considered to have “bad” genetic diversity and those below the red line the “worst”. Table 1 provides further information on individual bison Hz.

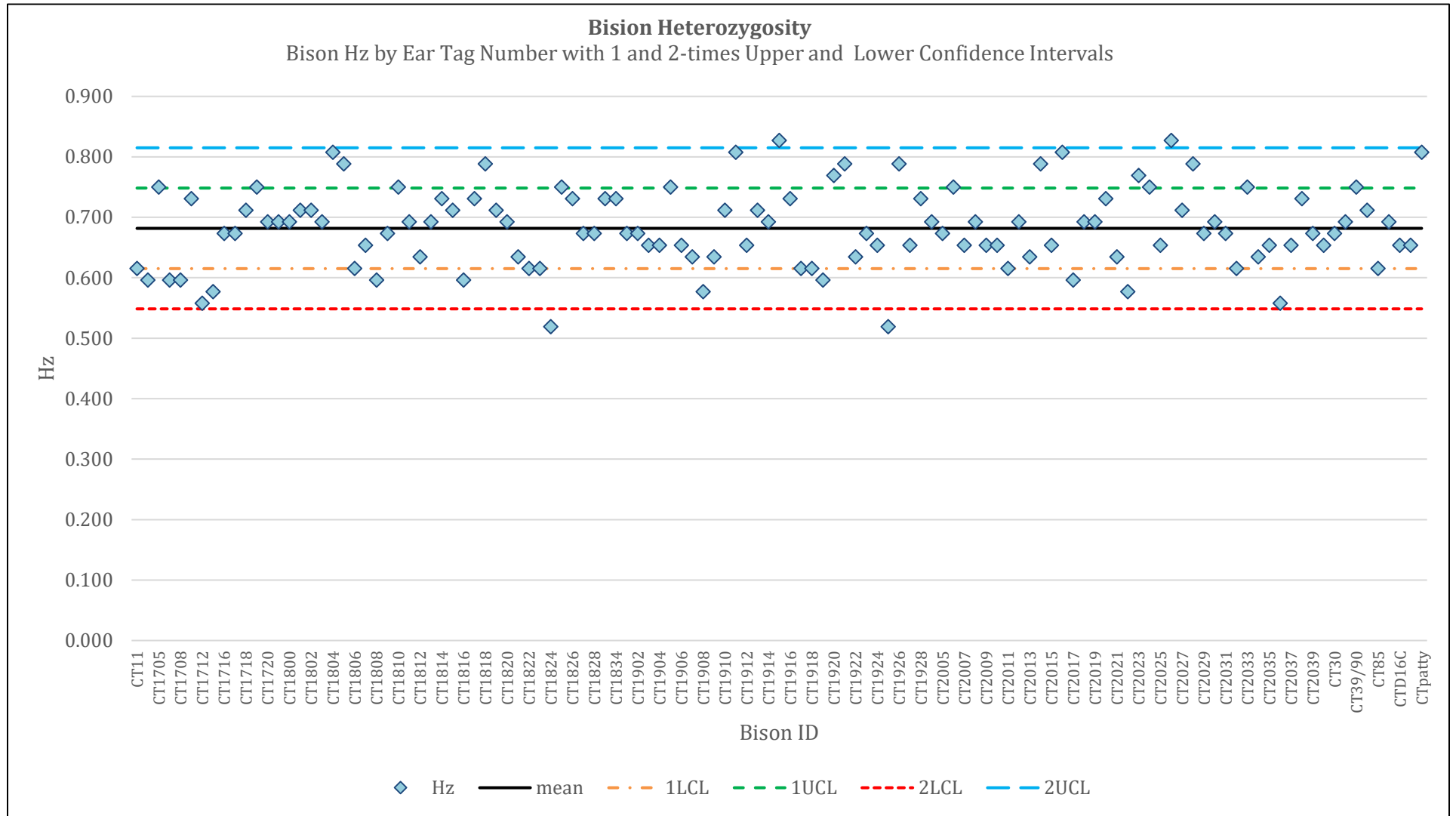


Figure 5. Individual Genetic Uniqueness Results – The genetic uniqueness index is a result of totaling the percent heritage derived per bison from conservation bison herds underrepresented genetically within ours. This comprised all herds that had genetic representation in less than 15% of tested Crane Trust bison (i.e., ≤ 17 individuals), and included 8 of the 12 conservation herds tested by VGL. Our herd contained no genetic heritage from only the National Elk Refuge (NER) and Fort Niobrara National Wildlife Refuge (FTN), which presents regional opportunities for valuable bison exchange. The mean genetic uniqueness index (GUI) was 0.16 ± 0.24 within our herd, with a minimum of 0 and a maximum of 0.91 (91% of genetics coming from underrepresented herds) considering all genetics data processed by VGL from 2018-2020 ($n = 117$). Below, the green line represents the mean GUI per animal and the blue line represents the upper confidence level (1 *sd*) using VGL data from 2018-2019. Only 27 (23.1%) of 117 bison tested by VGL from 2018-2020 had 30% or more heritage from underrepresented herds and only 20 (17.1%) exceeded the 1 standard deviation confidence internal limit of 41.3%. Table 1 provides further information on individual bison GUI.

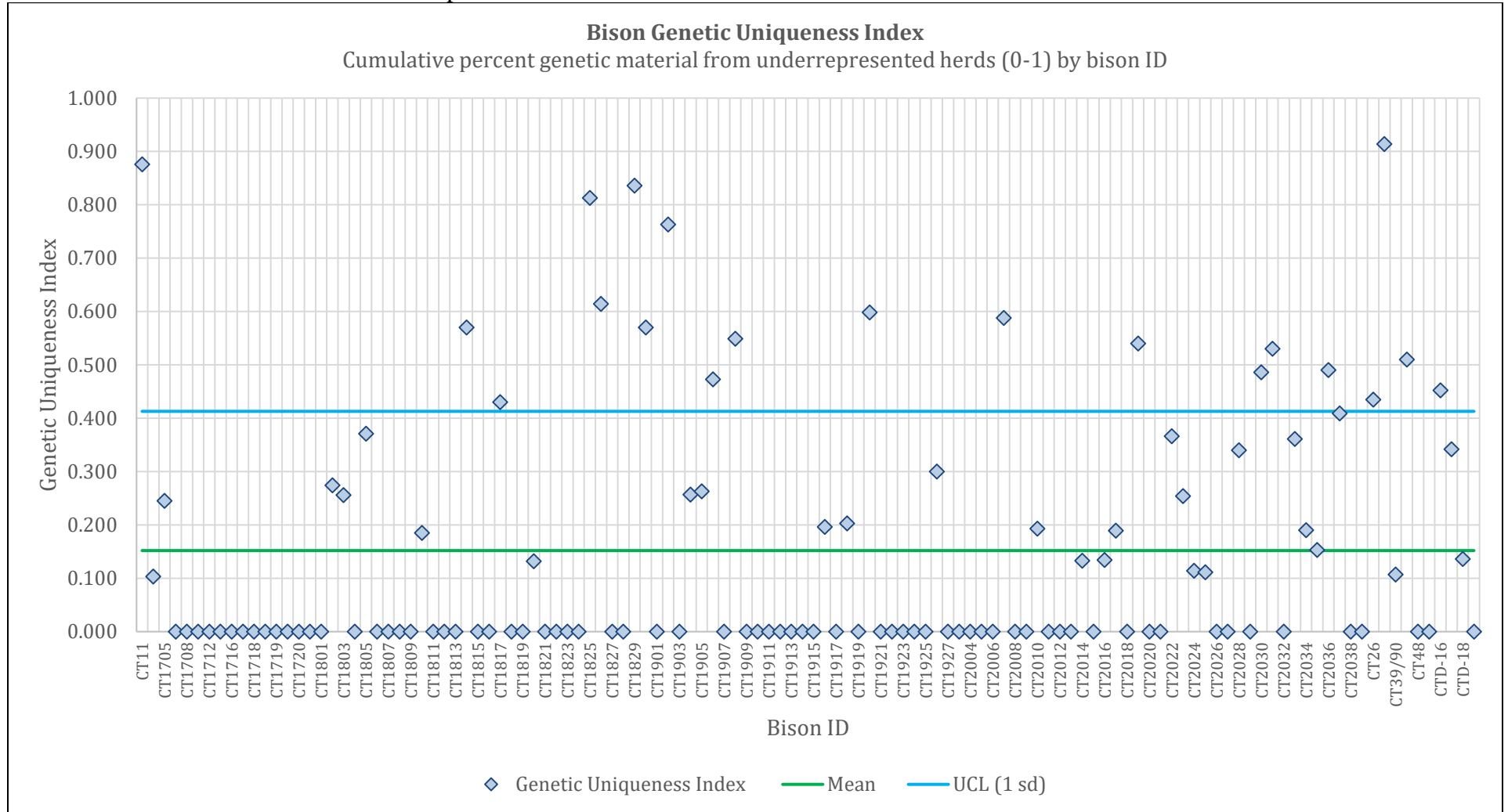


Figure 6. Bison Genetic Value Index Scores – The Bison Genetic Value Index (BGVI) is a weighted composite score including information from above figures. Bison are given +1 point (pt.) for having a better than average Hz and an additional +2 pts. for better than 1 *sd* above the mean. Similarly, individual bison are given +1 pt. for above average genetic uniqueness (GUI) and +2 pts. for being more than 1 *sd* above mean genetic uniqueness. Finally, bison are penalized -1 pt. for each cattle allele detected in evaluations of nuclear DNA. All Crane Trust Bison are pure in terms of mitochondrial DNA. The score ranges from a potential of -1 to +6. We considered all bison at 2 or above to be of “good” value, those at 3 or above to be of “great” value, and those scoring 4 or more to be of “excellent” value. Operationally, keeping individuals of high BGVI in our herd, particularly the cows, and selling, culling, or trading animals with below average BGVI (particularly bison scoring -1 and 0) would allow us to continue to improve our genetics with minimal additional genetic inputs (occasionally adding new breeding bulls – every 5-7 years, Hartway 2019 ABS). A low BGVI score does not mean that the individuals in question are not of “high” genetic value. All these measures are relative to our own herd. For instance, bison genetics that are common in our herd may be rare in others. Additionally, calves with an Hz score of 0.62 would be below average in our herd but above averaged regarding conservation herds nationally (mean = 0.60, range = 0.53 – 0.66, UC Davis). Table 1 provides further information on individual BGVI scores.

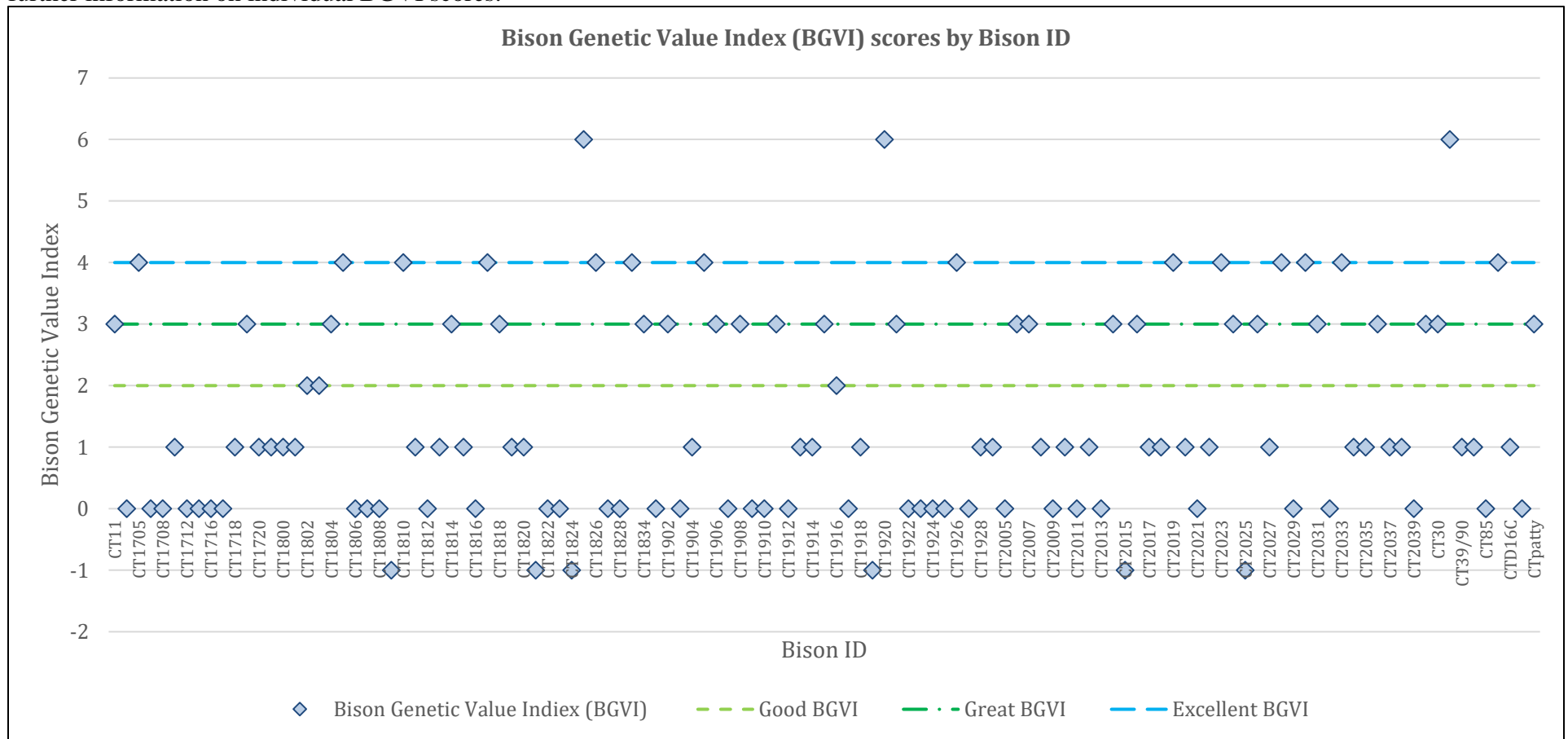


Table 1. Results from All Models by Bison ID – Data is color coded to make interpretation of results straightforward. Some metrics (Hz) include a 6-point scale and related color-coding for all responses, while others (GUI, Cattle Alleles) include fewer categories and therefore use a reduced number of color indicators. However, all span from the yellow-red spectrum (somewhat problematic) to the green-blue spectrum (acceptable or above average in some manner). We utilized these aggregated indices to make some recommendations for which bison to sell and retain, both to reduce the number of breeding adults and calves within our herd. Bison for which no recommendation has been made are indicated with a “*”.

<i>Legend</i>						
Scale		BGVI (-1-6)	Hz (0-1)	GUI (0-1)	Cattle Alleles (0,-1)	
Best		>=4	>0.815	>0.413	*	
Great		4>=3	0.815>0.748	0.413>0.152	*	
Average +		3>=2	0.748>0.682	0.152>0	0	
Average -		2>=1	0.682>0.615	0	*	
Bad		1>=0	0.615>0.549	*	*	
Worst		-1	0.549>	*	-1	
<i>Data</i>						
ID	Sex	BGVI (-1-6)	Hz (0-1)	GUI (0-1)	Cattle Alleles (0,-1)	Recommendations
CT11	M	3	0.615	0.876	0	*
CT1702	F	0	0.596	0.103	0	Sell
CT1705	F	4	0.750	0.245	0	Retain
CT1706	M	0	0.596	0.000	0	*
CT1708	M	0	0.596	0.000	0	*
CT1709	F	1	0.731	0.000	0	Retain
CT1712	M	0	0.558	0.000	0	*
CT1714	F	0	0.577	0.000	0	Sell
CT1716	F	0	0.673	0.000	0	Sell
CT1718	M	1	0.712	0.000	0	*
CT1719	F	3	0.750	0.000	0	Retain
CT1720	F	1	0.692	0.000	0	Optional
CT1800	F	1	0.692	0.000	0	*
CT1801	M	1	0.712	0.000	0	*
CT1802	M	2	0.712	0.274	0	*
CT1803	F	2	0.692	0.256	0	Retain
CT1804	F	3	0.808	0.000	0	Retain
CT1805	F	4	0.788	0.371	0	Retain
CT1806	M	0	0.615	0.000	0	*
CT1807	M	0	0.654	0.000	0	*
CT1808	M	0	0.596	0.000	0	*
CT1809	F	-1	0.673	0.000	-1	*
CT1810	F	4	0.750	0.185	0	Retain
CT1811	M	1	0.692	0.000	0	*
CT1812	F	0	0.635	0.000	0	*
CT1813	F	1	0.692	0.000	0	*
CT1814	F	3	0.731	0.570	-1	*
CT1815	F	1	0.712	0.000	0	*
CT1816	M	0	0.596	0.000	0	*

CT1817	M	4	0.731	0.430	0	*
CT1818	F	3	0.788	0.000	0	Retain
CT1819	F	1	0.712	0.000	0	*
CT1820	F	1	0.692	0.132	0	*
CT1821	M	-1	0.635	0.000	-1	*
CT1822	M	0	0.615	0.000	0	*
CT1823	M	0	0.615	0.000	0	*
CT1824	M	-1	0.519	0.000	-1	*
CT1825	F	6	0.750	0.813	0	Retain
CT1826	M	4	0.731	0.614	0	Retain
CT1827	M	0	0.673	0.000	0	*
CT1828	M	0	0.673	0.000	0	*
CT1829	M	4	0.731	0.836	0	*
CT1834	F	3	0.731	0.570	-1	*
CT1901	F	0	0.673	0.000	0	*
CT1902	F	3	0.673	0.763	0	*
CT1903	F	0	0.654	0.000	0	*
CT1904	F	1	0.654	0.257	0	*
CT1905	F	4	0.750	0.263	0	Retain
CT1906	M	3	0.654	0.473	0	*
CT1907	M	0	0.635	0.000	0	*
CT1908	F	3	0.577	0.549	0	Retain
CT1909	M	0	0.635	0.000	0	*
CT1910	F	0	0.712	0.000	-1	Sell
CT1911	F	3	0.808	0.000	0	Retain
CT1912	F	0	0.654	0.000	0	*
CT1913	F	1	0.712	0.000	0	*
CT1914	M	1	0.692	0.000	0	*
CT1915	F	3	0.827	0.000	0	Retain
CT1916	M	2	0.731	0.196	0	*
CT1917	M	0	0.615	0.000	0	*
CT1918	M	1	0.615	0.203	0	*
CT1919	M	-1	0.596	0.000	-1	Sell
CT1920	M	6	0.769	0.598	0	Retain
CT1921	F	3	0.788	0.000	0	Retain
CT1922	M	0	0.635	0.000	0	*
CT1923	M	0	0.673	0.000	0	*
CT1924	M	0	0.654	0.000	0	*
CT1925	M	0	0.519	0.000	0	*
CT1926	F	4	0.788	0.300	0	Retain
CT1927	F	0	0.654	0.000	0	*
CT1928	F	1	0.731	0.000	0	*
CT2004	F	1	0.692	0.000	0	Sell
CT2005	F	0	0.673	0.000	0	Sell
CT2006	F	3	0.750	0.000	0	Retain
CT2007	F	3	0.654	0.588	0	Retain
CT2008	F	1	0.692	0.000	0	Sell

CT2009	M	0	0.654	0.000	0	Sell
CT2010	M	1	0.654	0.193	0	Sell
CT2011	M	0	0.615	0.000	0	Sell
CT2012	F	1	0.692	0.000	0	Sell
CT2013	M	0	0.635	0.000	0	Sell
CT2014	M	3	0.788	0.133	0	Sell
CT2015	M	-1	0.654	0.000	-1	Sell
CT2016	M	3	0.808	0.134	0	Retain
CT2017	U/M	1	0.596	0.189	0	Sell
CT2018	F	1	0.692	0.000	0	Sell
CT2019	M	4	0.692	0.540	0	Optional
CT2020	F	1	0.731	0.000	0	Sell
CT2021	M	0	0.635	0.000	0	Sell
CT2022	U/M	1	0.577	0.366	0	Sell
CT2023	F	4	0.769	0.254	0	Retain
CT2024	M	3	0.750	0.114	0	Sell
CT2025	F	-1	0.654	0.111	-1	Sell
CT2026	F	3	0.827	0.000	0	Retain
CT2027	F	1	0.712	0.000	0	Sell
CT2028	F	4	0.788	0.340	0	Retain
CT2029	M	0	0.673	0.000	0	Sell
CT2030	M	4	0.692	0.486	0	Optional
CT2031	M	3	0.673	0.530	0	Sell
CT2032	F	0	0.615	0.000	0	Sell
CT2033	M	4	0.750	0.361	0	Optional
CT2034	F	1	0.635	0.190	0	Sell
CT2035	F	1	0.654	0.153	0	Sell
CT2036	M	3	0.558	0.490	0	Sell
CT2037	M	1	0.654	0.409	0	Sell
CT2038	M	1	0.731	0.000	0	Sell
CT2039	F	0	0.673	0.000	0	Sell
CT26	F	3	0.654	0.435	0	*
CT30	M	3	0.673	0.914	0	*
CT39/90	F	6	0.750	0.510	0	*
CT39/90	F	1	0.692	0.107	0	*
CT48	F	1	0.712	0.000	0	*
CT85	F	0	0.615	0.000	0	*
CTD-16	F	4	0.692	0.452	0	*
CTD16C	M	1	0.654	0.342	0	*
CTD-18	F	0	0.654	0.136	0	Optional
CT-Patty	F	3	0.808	0.000	0	Retain
MEAN		1.5	0.68	0.16	-0.1	
MEDIAN		1.0	0.67	0.00	0.0	
SD		1.7	0.07	0.24	0.3	
SE		0.2	0.01	0.02	0.0	
MAX		6.0	0.83	0.91	0.0	
MIN		-1.0	0.52	0.00	-1.0	