

## Introduction

The latest routine international evaluation for females fertility traits took place as scheduled at the Interbull Centre. Data from twentyone (21) countries were included in this evaluation.

International genetic evaluations for female fertility traits of bulls from Australia, Austria, Belgium, Canada, Czech Republic, Denmark-Finland-Sweden, France, Germany, Ireland, Israel, Italy, Netherlands, New Zealand, Norway, Poland, Spain, Switzerland, South Africa, the United Kingdom, Uruguay, Japan and the United States of America were computed. Brown Swiss, Guernsey, Holstein, Jersey, Red Dairy Cattle and Simmental breed data were included in this evaluation.

Based on a decision made by Interbull Steering committee in August 2007, female fertility traits are classified as follows:

- T1 (HC): Maiden (H)eifer's ability to (C)onceive. A measure of confirmed conception, such as conception rate (CR), will be considered for this trait group. In the absence of confirmed conception an alternative measure, such as interval first-last insemination (FL), interval first insemination-conception (FC), number of inseminations (NI), or non-return rate (NR,preferably NR56) can be submitted;
- T2 (CR): Lactating (C)ow's ability to (R)ecycle after calving. The interval calving-first insemination (CF) is an example for this ability. In the absence of such a trait, a measure of the interval calving-conception, such as says oprn (DO) or calving interval (CI) can be submitted;
- T3 (C1): Lactating (C)ow's ability to conceive (1), expressed as a rate trait. Traits like conception rate (CR) and non-return rate (NR, preferably NR56) will be considered for this trait group;
- T4 (C2): Lactating (C)ow's ability to conceive (2), expressed as an interval trait. The interval first insemination-conception (FC) or interval first-last insemination (FL) will be considered for this trait group. As an alternative, number of inseminations (NI) can be submitted. In the absence of any of these traits, a measure of interval calving-conception such as days open (DO), or calving interval (CI) can be submitted. All countries are expected to submit data for this trait group, and as a last resort the trait submitted under T3 can be submitted for T4 as well.
- T5 (IT): Lactating cow's measurements of (I)nterval (T)raits calving-conception, such as days open (DO) and calving interval (CI).

Based on the above trait definitions the following traits have been submitted for international genetic evaluation of female fertility traits.

Country	Traits	Submitted traits and their definitions
AUS	T2=CY T4=C2 T5=IT	Calving interval converted to 42 days pregnancy rate Calving interval converted to 42 days pregnancy rate Calving interval converted to 42 days pregnancy rate
BEL	T2=CY T4=C2 T5=IT	PR=Pregnancy Rate ( $=\frac{21}{(DO-45+11)} \times 100$ , with DO=days open) PR=Pregnancy Rate ( $=\frac{21}{(DO-45+11)} \times 100$ , with DO=days open) PR=Pregnancy Rate ( $=\frac{21}{(DO-45+11)} \times 100$ , with DO=days open)
CAN	T1=HC T2=CY T3=C1 T4=C2 T5=IT	NR=Non Return Rate after 56 Days in heifers (NRR), % CF=Interval from Calving to First Service in cows(CF) NR=Non Return Rate after 56 Days in cows(NRR), % FC=Interval first insemination-conception in cows DO=Days open
CHE	T1=HC T2=CR	CR=Heifers' Conception rate CF=Interval from Calving to First Service (ICF), days

	T3=C1	NR=Non Return Rate after 56 Days (NRR), %
	T4=C2	FL=Interval from first to last insemination cows
CZE	T1=HC	CR=Heifers' Conception rate (pregnant or not after 3 months)
	T3=C1	CR=Cows' Conception rate (pregnant or not after 3 months)
	T4=C2	CR=Cows' Conception rate (pregnant or not after 3 months)
AUT/DEU	T1=HC	NR=Heifers' Non Return Rate after 56 days
	T2=CY	CF=Interval from calving to first insemination cows (days)
	T3=C1	NR=Cows' Non Return Rate after 56 days
	T4=C2	FL=Interval from first to last insemination cows (days)
	T5=IT	DO=Days open (days)
DFS	T1=HC	CR=Heifers' Conception rate for maiden heifers
	T2=CY	CF=Interval from calving to first insemination cows (days)
	T3=C1	CR=Cows' conception rate for cows
	T4=C2	FL=Interval from first to last insemination cows (days)
	T5=IT	DO=Days open (days)
ESP	T2=CY	Days Open
	T4=C2	Days Open
	T5=IT	Days Open
FRA	T1=HC	CR=Heifers' Conception rate (binary trait) for maiden heifers
	T2=CY	Interval between calving and first AI
	T3=C1	CR=Cows' Conception rate (binary trait)
	T4=C2	FL=Interval from first to last insemination cows (days)
	T5=IT	FL=Interval from first to last insemination cows (days)
GBR	T2=CY	CI=days between 1st and 2nd calvings
	T3=C1	NR=1st lactation non return at 56 days
	T4=C2	CI=days between 1st and 2nd calvings
	T5=IT	CI=days between 1st and 2nd calvings
IRL	T2=CY	CI=Calving interval
	T4=C2	CI=Calving interval
	T5=IT	CI=Calving interval
ISR	T3=C1	CR=Inverse of the number of insemination to conception (%)
	T4=C2	CR=Inverse of the number of insemination to conception (%)
ITA	T1=HC	NR= non-return rate 56 days (heifers)
	T2=CY	CF=Days to first service
	T3=C1	NR=Non-return rate at 56 days (%)
	T4=C2	FL=Interval from first to last insemination cows (days)
	T5=IT	DO=days open (days)
ITA(BSW)	T2=CY	CF=Interval calving to first insemination
	T4=C2	Days Open
	T5=IT	CI=Calving interval
NLD	T1=HC	CR=Heifers' Conception rate
	T2=CY	CF=Interval calving to first insemination (days)
	T3=C1	CR=Cows' Conception rate (binary trait) for cows
	T4=C2	FL=Interval from first to last insemination cows (days)
	T5=IT	CI=Calving Interval (days)
NOR	T1=HC	NI=Number of inseminations (heifers)
	T2=CY	CF=Days from calving to first insemination (days)
	T3=C1	NI=Number of inseminations (cows)
	T4=C2	NI=Number of inseminations (cows)
	T5=IT	CF=Days from calving to first insemination (days)
NZL	T2=CY	PM=Lactating cow's ability to start cycling
	T4=C2	PC=Lactating cow's ability to conceive (CR42)
	T5=IT	PC=Lactating cow's ability to conceive (CR42)

POL T1=HC CR=Conception Rate (heifer)  
T2=CR CF=Interval from calving to first insemination  
T3=C1 CR=Conception Rate (cow)  
T4=IT DO=Days open  
T5=IT DO=Days open

URY T4=C2 Days open expressed as Daughter Pregnancy Rate  
T5=IT Days open expressed as Daughter Pregnancy Rate

USA T1=HC CR=Conception rate (heifer)  
T2=CY CF=Interval from calving to first insemination  
T3=C1 CR=Conception rate (cow)  
T4=C2 DP=Daughter Pregnancy Rate  
T5=IT DP=Daughter Pregnancy Rate

ZAF T4=IT CI=Calving Interval  
T5=IT CI=Calving Interval

JPN T1=HC CR=Heifers'Conception rate  
T3=C1 CR=Cows'Conception rate  
T4=C2 DO=Days open  
T5=IT DO=Days open

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CHANGES IN NATIONAL PROCEDURES  
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Changes in the national genetic evaluation of female fertility traits are as follows:

ESP (HOL) Base change  
JPN (HOL) Pedigree verification  
POL (HOL) Decrease in information due to data edits  
AUS (ALL) Wrongly allocated parents or genetic groups have been corrected, causing some bulls to be no longer included in the evaluation as their daughters' count has fell under the minimum treshold of 10 daughters. Correction of a bug in the program generating type of proof.  
DEA (BSW) Decrease in information due to elimination of duplicate inseminations' information.  
CZE (HOL) Decrease in information due to trimm of data before July 2002.  
CHE (ALL) Manual data edits and removal of data errors cause decrease in information. In BSW changes in of herd-year-season assignment causes small decrease in EDC.  
NZL (ALL) Decrease in information due to farmers data updates  
GBR (ALL) Fertility traits are updated at each run this causes some drop of information  
USA (ALL) Fixed of a bug in the determination of the management groups for cows and heifers. Seasonal variations caused drop in information

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INTERBULL CHANGES COMPARED TO THE DECEMBER ROUTINE RUN  
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Subsetting:  
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As decided by the ITC in Orlando, new subsetting was introduced in the september test run. Sub-setting is necessary for operational purposes and restrictions of time scales. To minimize the effect of subsetting, larger subsets with 10-12 countries and with 4 link providing countries have been applied.

Window:  
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According to the decision taken by ITC in Orlando, the following changes have been introduced in regards to the windows used for post processing:

The upper bounds have been set to 0.99 as these were judged to have very little effect on evaluations. The lower values have been set to about the 25% percentile value. The largest changes are for the lower values for conformation traits, with the lowest window being

40% for OFL otherwise it is about 50% for all other confirmation traits.  
It is anticipated that these low values may not have large impact on  
evaluations since there were very few countries combinations whose  
estimated correlations fell between the old limit of 0.30 and these new limits. DATA AND METHOD OF ANALYSIS  
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Data were national genetic evaluations of AI sampled bulls with at least  
10 daughters or 10 EDC (for clinical mastitis and maternal calving traits at least  
50 daughters or 50 EDC, and for direct calving traits at least 50 calvings or 50 EDC) in at  
least 10 herds. Table 1 presents the amount of data included  
in this Interbull evaluation for all breeds.

National proofs were first de-regressed within country and then analysed  
jointly with a linear model including the effects of evaluation country,  
genetic group of bull and bull merit. Heritability estimates used in both  
the de-regression and international evaluation were as in each country's  
national evaluation.

Table 2 presents the date of evaluation as supplied by each country

Estimated genetic parameters and sire standard deviations are shown in APPENDIX I  
and the corresponding number of common bulls are listed in APPENDIX II.

#### SCIENTIFIC LITERATURE

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The international genetic evaluation procedure is based on international work  
described in the following scientific publications:

International genetic evaluation computation:  
Schaeffer. 1994. J. Dairy Sci. 77:2671-2678  
Klei, 1998. Interbull Bulletin 17:3-7

Verification and Genetic trend validation:  
Klei et al., 2002. Interbull Bulletin 29:178-182.  
Boichard et al., 1995. J. Dairy Sci. 78:431-437

Weighting factors:  
Fikse and Banos, 2001. J. Dairy Sci. 84:1759-1767

De-regression:  
Sigurdsson and G. Banos. 1995. Acta Agric. Scand. 45:207-219  
Jairath et al. 1998. J. Dairy Sci. Vol. 81:550-562

Genetic parameter estimation:  
Klei and Weigel, 1998, Interbull Bulletin 17:8-14  
Sullivan, 1999. Interbull Bulletin 22:146-148

Post-processing of estimated genetic correlations:  
Mark et al., 2003, Interbull Bulletin 30:126-135  
Jorjani et al., 2003. J. Dairy Sci. 86:677-679  
<https://wiki.interbull.org/public/rG%20procedure?action=print>

Time edits  
Weigel and Banos. 1997. J. Dairy Sci. 80:3425-3430

International reliability estimation  
Harris and Johnson. 1998. Interbull Bulletin 17:31-36

#### NEXT ROUTINE INTERNATIONAL EVALUATION

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Dates for the next routine evaluation can be found on  
<http://www.interbull.org/ib/servicecalendar>.

NEXT TEST INTERNATIONAL EVALUATION

Dates for the next test run can be found on  
<http://www.interbull.org/ib/servicecalendar>.  
 PUBLICATION OF INTERBULL TEST RUN

Test evaluation results are meant for review purposes only and should not be published.

^LTable 1. National evaluation data considered in the Interbull evaluation for fertility (August Routine Evaluation 2019).  
 Number of records for lactating cow's ability to conceive (cc2) by breed

Country	BSW	GUE	HOL	JER	RDC	SIM
AUS		136	7994	1716	710	
BEL			1810			
CAN	150	44	9036	525	529	
CHE	2753		3287			
CZE			3754			
DEA	5419					
DEU			26644		371	
DFS			15961	2380	9900	
ESP			5278			
EST						
FRA	379		16210			
FRM						
GBR	94	230	6636	550	387	
HUN						
IRL			2832	173	63	
ISR			1390			
ITA	1768		9598			
JPN			5794			
KOR						
LTU						
LVA						
NLD	188		15252	152	79	
NOR					2936	
NZL	56	58	7683	4672	1339	
POL			7384			
PRT						
SVK						
SVN						
URY			1602			
USA	1086	754	38442	4659	697	
ZAF			1235	699	146	
HRV						
MEX						
CAM						
No. Records	11893	1222	187822	15526	17157	
Pub. Proofs	10957	1012	152797	13108	17116	0

^LAPPENDIX I. Sire standard deviations in diagonal and genetic correlations below diagonal

BSW	hco					
	CAN	DEA	FRA	USA	CHE	NLD
CAN	8.62					
DEA	0.84	9.76				
FRA	0.78	0.84	0.90			

USA	0.79	0.80	0.89	2.69		
CHE	0.91	0.95	0.88	0.88	13.06	
NLD	0.78	0.70	0.87	0.88	0.87	3.24

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BSW      crc  
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	CAN	CHE	DEA	NLD	NZL	USA	GBR	FRA	ITA
CAN	7.30								
CHE	0.85	11.29							
DEA	0.85	0.94	14.25						
NLD	0.87	0.88	0.86	3.52					
NZL	0.62	0.65	0.77	0.64	10.86				
USA	0.85	0.86	0.85	0.85	0.62	3.29			
GBR	0.75	0.76	0.75	0.80	0.65	0.83	3.78		
FRA	0.86	0.96	0.94	0.91	0.65	0.86	0.79	1.81	
ITA	0.85	0.85	0.84	0.86	0.69	0.84	0.80	0.87	17.97

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BSW      ccl  
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	CAN	CHE	DEA	NLD	USA	GBR	FRA
CAN	7.87						
CHE	0.79	11.75					
DEA	0.79	0.95	11.03				
NLD	0.75	0.71	0.67	3.85			
USA	0.74	0.67	0.67	0.90	2.81		
GBR	0.73	0.81	0.78	0.70	0.67	0.04	
FRA	0.71	0.69	0.67	0.91	0.92	0.69	0.94

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BSW      cc2  
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	CAN	CHE	DEA	NLD	NZL	USA	GBR	FRA	ITA
CAN	6.54								
CHE	0.73	11.02							
DEA	0.83	0.91	11.73						
NLD	0.88	0.84	0.85	3.20					
NZL	0.64	0.54	0.65	0.64	7.00				
USA	0.85	0.84	0.85	0.87	0.65	2.35			
GBR	0.83	0.78	0.86	0.84	0.70	0.85	3.78		
FRA	0.85	0.86	0.87	0.86	0.64	0.85	0.84	0.94	
ITA	0.85	0.69	0.85	0.85	0.62	0.88	0.84	0.85	23.28

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BSW      int  
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	CAN	DEA	NLD	NZL	USA	GBR	ITA
CAN	7.13						
DEA	0.88	13.60					
NLD	0.89	0.88	3.38				
NZL	0.60	0.65	0.66	6.90			
USA	0.90	0.87	0.87	0.58	2.35		
GBR	0.87	0.88	0.89	0.67	0.87	3.78	
ITA	0.88	0.93	0.88	0.65	0.89	0.88	17.93

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GUE      crc  
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	CAN	GBR	NZL	USA	AUS
CAN	7.60				
GBR	0.75	5.13			
NZL	0.61	0.65	11.61		
USA	0.84	0.87	0.62	3.22	
AUS	0.73	0.87	0.70	0.74	6.96

GUE cc1			
	CAN	GBR	USA
CAN	7.43		
GBR	0.73	0.03	
USA	0.80	0.73	3.36

GUE cc2					
	CAN	GBR	NZL	USA	AUS
CAN	6.96				
GBR	0.84	5.13			
NZL	0.64	0.70	7.36		
USA	0.86	0.85	0.66	2.59	
AUS	0.75	0.73	0.80	0.81	12.83

GUE int					
	CAN	GBR	NZL	USA	AUS
CAN	7.82				
GBR	0.87	5.13			
NZL	0.61	0.66	7.36		
USA	0.91	0.87	0.63	2.59	
AUS	0.87	0.86	0.78	0.87	12.83

HOL hco											
	CAN	CZE	DEU	DFS	FRA	USA	POL	CHE	NLD	ITA	JPN
CAN	7.78										
CZE	0.76	19.31									
DEU	0.93	0.78	15.09								
DFS	0.82	0.87	0.86	13.70							
FRA	0.82	0.88	0.82	0.88	0.84						
USA	0.84	0.88	0.86	0.89	0.90	2.38					
POL	0.71	0.88	0.71	0.85	0.82	0.83	19.59				
CHE	0.95	0.86	0.93	0.86	0.87	0.88	0.80	14.00			
NLD	0.80	0.87	0.79	0.85	0.87	0.88	0.80	0.87	3.81		
ITA	0.84	0.87	0.92	0.88	0.88	0.88	0.87	0.90	0.88	0.04	
JPN	0.83	0.74	0.79	0.75	0.76	0.83	0.68	0.84	0.75	0.73	6.29

HOL crc															
	BEL	CAN	CHE	DEU	DFS	ESP	GBR	IRL	ITA	NLD	NZL	USA	POL	FRA	AUS
BEL	4.74														
CAN	0.72	6.96													
CHE	0.80	0.84	12.42												
DEU	0.72	0.85	0.88	11.17											
DFS	0.79	0.89	0.95	0.90	11.77										
ESP	0.87	0.80	0.83	0.79	0.83	11.20									
GBR	0.89	0.74	0.77	0.74	0.80	0.89	4.65								
IRL	0.86	0.72	0.72	0.72	0.72	0.87	0.87	3.45							
ITA	0.78	0.85	0.88	0.87	0.89	0.86	0.82	0.72	8.28						
NLD	0.81	0.87	0.93	0.90	0.96	0.82	0.80	0.72	0.87	4.53					
NZL	0.65	0.60	0.62	0.60	0.62	0.64	0.64	0.61	0.70	0.60	8.48				
USA	0.84	0.84	0.84	0.84	0.84	0.84	0.88	0.77	0.84	0.84	0.60	3.19			
POL	0.74	0.89	0.89	0.87	0.88	0.82	0.74	0.71	0.92	0.86	0.62	0.84	14.07		
FRA	0.76	0.86	0.94	0.92	0.94	0.84	0.80	0.72	0.91	0.95	0.62	0.84	0.88	1.19	
AUS	0.86	0.72	0.72	0.71	0.72	0.86	0.86	0.87	0.72	0.72	0.61	0.73	0.71	0.72	4.94

HOL cc1	
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	CAN	CHE	CZE	DEU	DFS	FRA	GBR	ISR	ITA	NLD	USA	POL	JPN
CAN	6.71												
CHE	0.92	11.14											
CZE	0.81	0.75	17.81										
DEU	0.90	0.93	0.77	14.39									
DFS	0.74	0.72	0.89	0.73	13.30								
FRA	0.74	0.74	0.89	0.70	0.87	1.02							
GBR	0.73	0.77	0.71	0.78	0.68	0.69	0.03						
ISR	0.76	0.67	0.89	0.73	0.85	0.86	0.74	3.15					
ITA	0.86	0.88	0.74	0.95	0.69	0.68	0.76	0.74	0.05				
NLD	0.76	0.73	0.90	0.72	0.92	0.92	0.69	0.88	0.69	4.71			
USA	0.79	0.71	0.95	0.72	0.87	0.89	0.66	0.91	0.74	0.90	2.76		
POL	0.76	0.75	0.87	0.81	0.81	0.80	0.67	0.78	0.80	0.76	0.80	19.60	
JPN	0.77	0.69	0.90	0.70	0.83	0.79	0.70	0.81	0.70	0.82	0.89	0.68	7.69

HOL cc2

	BEL	CAN	CHE	CZE	DEU	DFS	ESP	FRA	GBR	IRL	ISR	ITA	NLD	NZL	USA	POL	ZAF	AUS	URY	JPN
BEL	4.74																			
CAN	0.83	6.01																		
CHE	0.79	0.86	11.17																	
CZE	0.65	0.84	0.87	17.83																
DEU	0.83	0.92	0.90	0.89	13.04															
DFS	0.84	0.85	0.86	0.80	0.93	12.88														
ESP	0.85	0.86	0.80	0.76	0.87	0.84	11.19													
FRA	0.83	0.87	0.91	0.80	0.90	0.85	0.86	0.98												
GBR	0.89	0.84	0.73	0.65	0.83	0.84	0.87	0.82	4.65											
IRL	0.84	0.83	0.80	0.65	0.83	0.83	0.84	0.83	0.85	3.45										
ISR	0.52	0.62	0.63	0.81	0.74	0.69	0.62	0.65	0.56	0.60	3.14									
ITA	0.75	0.85	0.86	0.90	0.91	0.84	0.86	0.84	0.77	0.78	0.81	15.82								
NLD	0.83	0.90	0.89	0.84	0.94	0.91	0.86	0.88	0.83	0.83	0.71	0.85	4.44							
NZL	0.73	0.64	0.52	0.48	0.63	0.63	0.67	0.62	0.71	0.74	0.46	0.59	0.63	5.36						
USA	0.84	0.85	0.85	0.86	0.90	0.88	0.87	0.85	0.84	0.84	0.74	0.91	0.88	0.65	2.30					
POL	0.83	0.82	0.70	0.62	0.81	0.81	0.84	0.79	0.84	0.81	0.52	0.76	0.81	0.63	0.83	12.96				
ZAF	0.76	0.77	0.80	0.70	0.82	0.77	0.83	0.79	0.80	0.87	0.58	0.84	0.79	0.71	0.87	0.76	15.96			
AUS	0.77	0.77	0.81	0.69	0.77	0.71	0.80	0.78	0.75	0.92	0.60	0.78	0.74	0.74	0.82	0.69	0.90	9.58		
URY	0.84	0.81	0.68	0.59	0.80	0.81	0.82	0.81	0.85	0.84	0.47	0.65	0.81	0.75	0.83	0.85	0.77	0.72	1.43	
JPN	0.83	0.85	0.83	0.74	0.84	0.85	0.89	0.84	0.86	0.84	0.59	0.85	0.84	0.65	0.92	0.90	0.87	0.80	0.82	18.58

HOL int

	BEL	CAN	DEU	DFS	ESP	GBR	IRL	ITA	NLD	NZL	USA	POL	ZAF	AUS	URY	FRA	JPN
BEL	4.74																
CAN	0.87	6.45															
DEU	0.87	0.89	12.23														
DFS	0.90	0.90	0.94	12.82													
ESP	0.88	0.88	0.87	0.88	11.19												
GBR	0.88	0.87	0.87	0.90	0.89	4.65											
IRL	0.87	0.87	0.87	0.87	0.87	0.87	3.45										
ITA	0.87	0.89	0.90	0.90	0.93	0.87	0.87	20.80									
NLD	0.92	0.90	0.91	0.94	0.88	0.90	0.87	0.87	4.52								
NZL	0.73	0.60	0.59	0.59	0.65	0.70	0.71	0.66	0.63	5.36							
USA	0.87	0.92	0.89	0.89	0.89	0.87	0.87	0.93	0.87	0.61	2.30						
POL	0.86	0.87	0.86	0.86	0.86	0.87	0.86	0.89	0.87	0.67	0.87	12.96					
ZAF	0.86	0.87	0.87	0.87	0.87	0.87	0.88	0.89	0.87	0.70	0.88	0.86	15.96				
AUS	0.87	0.87	0.87	0.87	0.87	0.87	0.93	0.87	0.87	0.75	0.87	0.87	0.91	9.58			
URY	0.87	0.86	0.86	0.86	0.86	0.87	0.86	0.87	0.87	0.74	0.87	0.87	0.86	0.87	1.43		
FRA	0.76	0.83	0.77	0.78	0.82	0.70	0.76	0.79	0.76	0.47	0.81	0.65	0.77	0.79	0.61	0.98	
JPN	0.87	0.93	0.90	0.90	0.91	0.87	0.87	0.94	0.87	0.64	0.92	0.92	0.89	0.87	0.87	0.75	18.58

JER hco

	CAN	DFS	USA	NLD
CAN	8.08			
DFS	0.79	17.48		
USA	0.84	0.88	2.74	
NLD	0.79	0.85	0.88	3.62

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JER      crc  
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	CAN	DFS	GBR	NLD	NZL	USA	AUS	IRL
CAN	6.72							
DFS	0.87	13.59						
GBR	0.73	0.85	4.12					
NLD	0.87	0.91	0.78	3.78				
NZL	0.61	0.67	0.67	0.61	6.81			
USA	0.84	0.84	0.84	0.85	0.63	3.70		
AUS	0.72	0.73	0.87	0.73	0.61	0.73	3.68	
IRL	0.74	0.73	0.87	0.73	0.62	0.76	0.88	1.85

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JER      cc1  
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	CAN	DFS	GBR	NLD	USA
CAN	6.71				
DFS	0.72	15.59			
GBR	0.75	0.69	0.03		
NLD	0.75	0.90	0.69	3.79	
USA	0.74	0.88	0.67	0.90	2.90

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JER      cc2  
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	CAN	DFS	GBR	NLD	NZL	USA	ZAF	AUS	IRL
CAN	6.57								
DFS	0.85	15.68							
GBR	0.85	0.84	4.11						
NLD	0.89	0.89	0.84	3.34					
NZL	0.66	0.65	0.74	0.64	4.34				
USA	0.85	0.87	0.85	0.87	0.68	2.57			
ZAF	0.71	0.71	0.77	0.75	0.75	0.86	11.15		
AUS	0.70	0.71	0.70	0.70	0.74	0.77	0.84	7.18	
IRL	0.84	0.85	0.85	0.85	0.68	0.85	0.73	0.77	1.85

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JER      int  
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	CAN	DFS	GBR	NLD	NZL	USA	ZAF	AUS	IRL
CAN	6.38								
DFS	0.88	15.43							
GBR	0.87	0.88	4.11						
NLD	0.88	0.91	0.88	3.51					
NZL	0.64	0.63	0.73	0.61	4.34				
USA	0.89	0.87	0.87	0.87	0.66	2.57			
ZAF	0.87	0.87	0.87	0.86	0.72	0.87	11.15		
AUS	0.87	0.87	0.87	0.87	0.74	0.87	0.88	7.18	
IRL	0.85	0.86	0.85	0.86	0.46	0.86	0.84	0.87	1.85

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RDC      hco  
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	CAN	DEU	DFS	NOR	USA	NLD
CAN	7.46					
DEU	0.91	14.12				
DFS	0.82	0.80	12.35			
NOR	0.87	0.83	0.79	15.65		
USA	0.85	0.84	0.90	0.72	2.60	

NLD 0.79 0.79 0.86 0.72 0.88 4.00

RDC crc

	CAN	DEU	DFS	GBR	NOR	NZL	USA	NLD	AUS	IRL
CAN	6.33									
DEU	0.85	10.09								
DFS	0.87	0.90	12.67							
GBR	0.76	0.74	0.77	4.39						
NOR	0.89	0.87	0.88	0.75	14.00					
NZL	0.61	0.62	0.61	0.65	0.66	10.54				
USA	0.84	0.84	0.84	0.84	0.85	0.70	3.37			
NLD	0.87	0.89	0.93	0.79	0.86	0.61	0.85	3.17		
AUS	0.73	0.73	0.73	0.87	0.75	0.69	0.76	0.73	4.69	
IRL	0.73	0.73	0.74	0.87	0.74	0.63	0.77	0.73	0.88	2.67

RDC cc1

	CAN	DEU	DFS	GBR	NOR	NLD	USA
CAN	7.01						
DEU	0.89	12.96					
DFS	0.77	0.76	13.09				
GBR	0.73	0.78	0.74	0.03			
NOR	0.85	0.82	0.87	0.72	12.54		
NLD	0.77	0.75	0.90	0.71	0.75	3.86	
USA	0.83	0.73	0.86	0.67	0.80	0.90	2.59

RDC cc2

	CAN	DEU	DFS	GBR	NOR	NZL	USA	ZAF	NLD	AUS	IRL
CAN	6.79										
DEU	0.92	10.45									
DFS	0.85	0.94	12.80								
GBR	0.85	0.84	0.85	4.39							
NOR	0.88	0.87	0.85	0.86	11.99						
NZL	0.65	0.64	0.65	0.69	0.66	6.80					
USA	0.87	0.90	0.86	0.85	0.86	0.71	2.32				
ZAF	0.71	0.81	0.74	0.72	0.70	0.72	0.85	17.79			
NLD	0.90	0.95	0.90	0.85	0.86	0.65	0.87	0.78	3.32		
AUS	0.71	0.73	0.67	0.76	0.66	0.78	0.80	0.81	0.72	8.68	
IRL	0.84	0.84	0.85	0.85	0.86	0.73	0.85	0.85	0.84	0.86	2.67

RDC int

	CAN	DEU	DFS	GBR	NOR	NZL	USA	ZAF	NLD	AUS	IRL
CAN	6.70										
DEU	0.89	10.57									
DFS	0.88	0.94	13.10								
GBR	0.87	0.87	0.88	4.39							
NOR	0.90	0.89	0.87	0.88	13.75						
NZL	0.66	0.58	0.59	0.67	0.63	6.80					
USA	0.91	0.89	0.88	0.87	0.88	0.70	2.32				
ZAF	0.87	0.86	0.87	0.87	0.91	0.69	0.88	17.79			
NLD	0.90	0.91	0.92	0.89	0.88	0.62	0.87	0.87	3.31		
AUS	0.87	0.87	0.87	0.87	0.88	0.76	0.87	0.89	0.87	8.68	
IRL	0.86	0.87	0.87	0.87	0.88	0.67	0.87	0.88	0.87	0.92	2.67

^LAPPENDIX II. Number of common bulls

BSW

common bulls below diagonal  
 common three quarter sib group above diagonal

	CAN	DEA	FRA	USA	CHE	NLD
CAN	0	80	47	93	84	28
DEA	65	0	193	168	564	127
FRA	41	141	0	70	154	70
USA	83	126	52	0	191	43
CHE	67	469	114	157	0	82
NLD	25	120	58	39	77	0

BSW

common bulls below diagonal  
 common three quarter sib group above diagonal

	CAN	CHE	DEA	NLD	NZL	USA	GBR	FRA	ITA
CAN	0	103	97	36	19	123	44	65	94
CHE	82	0	545	92	26	255	57	155	399
DEA	80	443	0	140	34	208	56	192	537
NLD	32	84	130	0	25	52	35	76	113
NZL	17	21	27	19	0	21	17	21	27
USA	113	222	158	47	18	0	57	91	158
GBR	38	40	38	27	13	51	0	44	62
FRA	55	114	141	61	17	62	34	0	170
ITA	77	336	415	90	21	110	41	130	0

BSW

common bulls below diagonal  
 common three quarter sib group above diagonal

	CAN	CHE	DEA	NLD	USA	GBR	FRA
CAN	0	103	97	36	124	44	68
CHE	82	0	539	91	255	58	161
DEA	79	437	0	138	208	59	203
NLD	32	84	130	0	52	36	82
USA	114	222	157	47	0	60	94
GBR	39	42	40	27	52	0	48
FRA	58	120	154	68	67	39	0

BSW

common bulls below diagonal  
 common three quarter sib group above diagonal

	CAN	CHE	DEA	NLD	NZL	USA	GBR	FRA	ITA
CAN	0	93	88	34	18	115	41	64	88
CHE	73	0	534	92	26	310	57	161	399
DEA	71	434	0	139	34	303	55	202	528
NLD	30	84	130	0	25	75	35	82	113
NZL	16	21	27	19	0	30	17	22	27
USA	101	288	263	64	26	0	67	114	205
GBR	34	40	38	27	13	61	0	46	62
FRA	55	120	154	68	18	81	37	0	180
ITA	72	336	409	90	21	142	41	141	0

BSW

common bulls below diagonal  
 common three quarter sib group above diagonal

	CAN	DEA	NLD	NZL	USA	GBR	ITA
CAN	0	92	36	19	119	43	93
DEA	74	0	141	34	302	55	638
NLD	33	133	0	25	76	35	119

NZL	17	27	19	0	30	17	27
USA	105	263	67	26	0	67	224
GBR	36	38	27	13	61	0	63
ITA	76	538	98	21	157	41	0

GUE

GUE

common bulls below diagonal  
 common three quarter sib group above diagonal

	CAN	GBR	NZL	USA	AUS
CAN	0	14	3	37	18
GBR	11	0	13	48	27
NZL	2	11	0	9	22
USA	36	45	7	0	19
AUS	13	22	24	16	0

GUE

common bulls below diagonal  
 common three quarter sib group above diagonal

	CAN	GBR	USA
CAN	0	15	37
GBR	12	0	53
USA	36	50	0

GUE

common bulls below diagonal  
 common three quarter sib group above diagonal

	CAN	GBR	NZL	USA	AUS
CAN	0	11	2	35	19
GBR	8	0	13	79	31
NZL	2	11	0	29	22
USA	33	80	28	0	59
AUS	15	26	26	55	0

GUE

common bulls below diagonal  
 common three quarter sib group above diagonal

	CAN	GBR	NZL	USA	AUS
CAN	0	11	2	35	19
GBR	8	0	13	79	31
NZL	2	11	0	29	22
USA	33	80	28	0	59
AUS	15	26	26	55	0

HOL

common bulls below diagonal  
 common three quarter sib group above diagonal

	CAN	CZE	DEU	DFS	FRA	USA	POL	CHE	NLD	ITA	JPN
CAN	0	931	1978	1095	1141	2395	979	761	1135	1526	1010
CZE	658	0	1683	1056	1117	1247	932	453	1277	1157	717
DEU	1457	1226	0	2504	2361	2587	1685	1110	2987	2506	1314
DFS	989	656	1637	0	1522	1378	1049	665	1878	1527	864
FRA	821	659	1279	813	0	1514	1186	644	1787	1695	1059
USA	2677	957	1830	1154	859	0	1385	792	1550	2045	1300
POL	816	687	1355	781	709	1354	0	436	1187	1154	683

CHE	641	299	967	575	575	704	328	0	825	703	427
NLD	1080	1085	2484	1558	1112	1294	989	793	0	1616	938
ITA	1232	776	1595	1120	920	1503	816	626	1269	0	1115
JPN	524	284	490	411	357	627	341	252	434	454	0

HOL

common bulls below diagonal  
common three quarter sib group above diagonal

	BEL	CAN	CHE	DEU	DFS	ESP	GBR	IRL	ITA	NLD	NZL	USA	POL	FRA	AUS
BEL	0	657	543	1104	745	799	774	481	751	1105	464	707	444	859	533
CAN	652	0	778	2062	1177	1333	1361	501	1593	1262	624	2533	878	1234	766
CHE	549	665	0	1108	662	643	673	391	698	845	384	839	386	650	416
DEU	1129	1511	964	0	2562	2043	2021	879	2509	3263	947	2805	1471	2485	1217
DFS	681	1061	578	1668	0	1303	1429	712	1505	1896	774	1519	945	1530	896
ESP	848	1072	588	1755	1068	0	1318	663	1549	1474	672	1560	894	1479	803
GBR	749	1406	605	1456	1054	1173	0	921	1514	1634	878	1694	775	1478	996
IRL	474	496	395	769	587	676	957	0	650	866	702	599	331	726	576
ITA	713	1297	628	1634	1116	1341	1129	567	0	1673	740	2190	1021	1706	851
NLD	1253	1222	819	2895	1621	1498	1387	814	1357	0	984	1782	1053	1885	1062
NZL	381	575	320	722	541	556	749	609	548	890	0	740	367	775	956
USA	665	2821	747	1927	1236	1259	1572	583	1562	1523	667	0	1250	1710	888
POL	356	701	283	1084	679	657	516	241	670	821	265	1156	0	1071	366
FRA	835	898	573	1299	796	1361	918	586	911	1150	455	948	612	0	949
AUS	409	629	338	727	500	589	755	454	525	814	908	710	167	546	0

HOL

common bulls below diagonal  
common three quarter sib group above diagonal

	CAN	CHE	CZE	DEU	DFS	FRA	GBR	ISR	ITA	NLD	USA	POL	JPN
CAN	0	777	964	2062	1181	1235	1422	90	1599	1270	2583	916	1148
CHE	665	0	444	1107	662	654	679	49	698	845	839	412	448
CZE	705	299	0	1633	1033	1103	912	91	1146	1280	1323	906	730
DEU	1504	962	1208	0	2562	2482	2074	133	2495	3252	2785	1598	1444
DFS	1066	578	666	1663	0	1533	1461	119	1507	1897	1525	1008	919
FRA	915	579	659	1299	809	0	1505	108	1706	1889	1705	1126	1181
GBR	1477	615	578	1504	1083	938	0	109	1557	1683	1785	823	1012
ISR	68	32	73	114	95	61	78	0	119	124	114	77	84
ITA	1303	628	788	1621	1115	925	1179	91	0	1673	2187	1073	1167
NLD	1232	819	1104	2880	1620	1161	1446	103	1354	0	1783	1143	1008
USA	2889	747	1006	1908	1236	966	1674	105	1561	1523	0	1304	1486
POL	747	311	658	1264	755	660	563	52	725	939	1218	0	679
JPN	627	285	319	567	472	420	507	39	519	517	764	352	0

HOL

common bulls below diagonal  
common three quarter sib group above diagonal

	BEL	CAN	CHE	CZE	DEU	DFS	ESP	FRA	GBR	IRL	ISR	ITA	NLD	NZL	USA	POL	ZAF	AUS	URY	JPN
BEL	0	647	543	530	1097	746	799	850	774	482	63	750	1105	464	858	437	315	672	308	470
CAN	640	0	764	947	2006	1155	1318	1190	1337	490	85	1563	1231	605	2682	853	425	1113	623	1068
CHE	549	648	0	445	1102	663	643	644	673	391	50	694	846	384	955	375	263	573	278	420
CZE	403	675	299	0	1633	1035	971	1096	903	439	91	1144	1283	504	1450	846	308	715	430	699
DEU	1117	1442	954	1197	0	2546	2051	2451	2014	877	136	2475	3218	942	3525	1434	560	1586	704	1373
DFS	681	1028	579	666	1646	0	1311	1519	1433	712	121	1499	1900	776	1908	924	491	1167	567	869
ESP	848	1045	588	741	1748	1074	0	1478	1320	664	111	1554	1480	674	1878	881	500	1064	577	1000
FRA	823	850	563	644	1254	780	1346	0	1469	729	111	1682	1862	780	2389	1056	467	1203	541	1121
GBR	749	1372	605	566	1445	1054	1173	901	0	921	110	1512	1635	879	2067	764	486	1283	588	956
IRL	474	478	395	309	766	587	676	582	957	0	84	650	867	702	761	321	328	701	337	422
ISR	40	63	32	73	114	95	87	60	77	67	0	119	126	90	139	71	55	86	66	83
ITA	707	1243	619	778	1582	1097	1332	872	1122	563	89	0	1665	738	2540	994	474	1144	627	1109
NLD	1253	1181	819	1104	2815	1622	1501	1115	1387	814	103	1334	0	986	2344	1023	486	1357	583	954

NZL	381	553	320	345	714	542	558	453	749	609	76	545	892	0	1022	357	350	1137	451	521
USA	744	2908	841	1063	2263	1363	1519	1225	1809	681	122	1693	1953	960	0	1263	612	1743	984	1799
POL	345	664	272	583	1034	659	638	590	503	230	45	643	783	256	1130	0	207	587	365	619
ZAF	257	381	211	196	415	350	449	318	416	283	36	361	397	277	575	131	0	456	301	392
AUS	570	1092	499	445	1117	807	828	792	1082	599	57	819	1152	1127	1678	387	387	0	569	809
URY	224	582	202	280	483	379	503	313	467	262	34	438	448	367	1207	274	249	440	0	493
JPN	278	517	246	274	474	407	434	357	429	253	31	437	436	241	656	286	242	393	238	0

HOL

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common bulls below diagonal

common three quarter sib group above diagonal

	BEL	CAN	DEU	DFS	ESP	GBR	IRL	ITA	NLD	NZL	USA	POL	ZAF	AUS	URY	FRA	JPN
BEL	0	650	1095	746	799	774	482	749	1107	464	858	436	315	672	308	850	470
CAN	645	0	2011	1161	1324	1346	496	1572	1247	611	2696	857	427	1120	629	1198	1071
DEU	1116	1450	0	2544	2050	2014	877	2475	3234	942	3522	1429	559	1586	704	2450	1373
DFS	681	1038	1644	0	1310	1432	712	1498	1904	776	1907	924	490	1167	566	1519	869
ESP	848	1061	1748	1074	0	1320	664	1553	1484	674	1875	881	499	1063	577	1477	999
GBR	749	1386	1445	1054	1173	0	921	1512	1643	879	2067	764	485	1283	588	1469	956
IRL	474	486	766	587	676	957	0	650	871	702	761	321	328	701	337	729	422
ITA	707	1258	1582	1097	1331	1122	563	0	1671	738	2540	992	474	1144	627	1682	1109
NLD	1260	1205	2839	1630	1512	1396	817	1343	0	986	2353	1027	486	1359	586	1865	959
NZL	381	558	714	542	558	749	609	545	894	0	1022	357	349	1137	451	780	521
USA	744	2938	2263	1363	1519	1809	681	1693	1964	960	0	1262	611	1743	984	2389	1799
POL	345	669	1032	659	638	503	230	643	790	256	1130	0	207	587	365	1056	619
ZAF	257	387	415	350	449	416	283	361	398	277	575	131	0	455	301	467	391
AUS	570	1097	1117	807	828	1082	599	819	1158	1127	1678	387	387	0	569	1203	809
URY	224	590	483	379	503	467	262	438	450	367	1207	274	249	440	0	541	493
FRA	823	859	1254	780	1346	901	582	872	1120	453	1225	590	318	792	313	0	1121
JPN	278	519	474	407	434	429	253	437	439	241	656	286	242	393	238	357	0

JER

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common bulls below diagonal

common three quarter sib group above diagonal

	CAN	DFS	USA	NLD
CAN	0	58	277	24
DFS	47	0	96	58
USA	259	76	0	51
NLD	18	55	50	0

JER

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common bulls below diagonal

common three quarter sib group above diagonal

	CAN	DFS	GBR	NLD	NZL	USA	AUS	IRL
CAN	0	62	123	28	136	312	116	10
DFS	48	0	131	86	121	112	93	37
GBR	122	120	0	70	188	180	142	63
NLD	22	80	63	0	64	67	48	29
NZL	138	93	192	56	0	246	326	105
USA	310	91	193	69	269	0	233	37
AUS	119	58	150	42	360	237	0	34
IRL	8	32	64	29	117	39	31	0

JER

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common bulls below diagonal

common three quarter sib group above diagonal

	CAN	DFS	GBR	NLD	USA
CAN	0	62	125	28	316
DFS	48	0	130	86	111

GBR	124	119	0	69	182
NLD	22	80	63	0	67
USA	313	91	196	69	0

JER

common bulls below diagonal  
 common three quarter sib group above diagonal

	CAN	DFS	GBR	NLD	NZL	USA	ZAF	AUS	IRL
CAN	0	61	121	28	133	327	120	186	10
DFS	47	0	131	86	122	156	123	119	37
GBR	118	120	0	70	189	207	156	186	63
NLD	21	80	63	0	65	81	67	63	29
NZL	132	93	192	57	0	345	193	409	105
USA	320	122	226	85	417	0	287	447	43
ZAF	118	99	157	62	203	296	0	220	36
AUS	180	85	195	54	448	488	212	0	51
IRL	8	32	64	29	117	45	37	48	0

JER

common bulls below diagonal  
 common three quarter sib group above diagonal

	CAN	DFS	GBR	NLD	NZL	USA	ZAF	AUS	IRL
CAN	0	62	122	28	135	330	122	188	10
DFS	48	0	131	90	122	156	123	119	37
GBR	120	120	0	74	189	207	156	186	63
NLD	23	85	67	0	68	85	70	65	30
NZL	135	93	192	61	0	345	193	409	105
USA	325	122	226	90	417	0	287	447	43
ZAF	120	99	157	66	203	296	0	220	36
AUS	183	85	195	56	448	488	212	0	51
IRL	8	32	64	29	117	45	37	48	0

RDC

common bulls below diagonal  
 common three quarter sib group above diagonal

	CAN	DEU	DFS	NOR	USA	NLD
CAN	0	13	143	6	88	4
DEU	12	0	59	16	18	12
DFS	145	48	0	112	137	47
NOR	5	15	89	0	60	30
USA	84	17	128	60	0	28
NLD	4	12	44	30	26	0

RDC

common bulls below diagonal  
 common three quarter sib group above diagonal

	CAN	DEU	DFS	GBR	NOR	NZL	USA	NLD	AUS	IRL
CAN	0	14	143	65	5	61	123	5	53	4
DEU	13	0	66	19	19	21	25	13	22	6
DFS	146	55	0	93	130	163	153	49	134	18
GBR	66	18	88	0	46	67	82	28	49	20
NOR	5	18	101	48	0	40	67	36	35	52
NZL	61	20	156	63	38	0	87	16	97	12
USA	120	25	147	78	68	89	0	32	52	26
NLD	5	13	47	27	36	16	31	0	12	11
AUS	53	21	117	46	30	104	52	10	0	8
IRL	4	6	13	19	51	12	26	11	7	0

RDC

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common bulls below diagonal  
common three quarter sib group above diagonal  
CAN DEU DFS GBR NOR NLD USA

CAN	0	14	144	67	5	5	123
DEU	13	0	65	19	18	13	25
DFS	147	54	0	94	114	50	153
GBR	67	18	88	0	47	30	86
NOR	5	17	89	49	0	34	67
NLD	5	13	47	29	34	0	32
USA	120	24	146	81	67	31	0

RDC

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common bulls below diagonal  
common three quarter sib group above diagonal  
CAN DEU DFS GBR NOR NZL USA ZAF NLD AUS IRL

CAN	0	13	139	61	5	60	146	69	5	65	4
DEU	12	0	63	19	18	21	25	2	13	43	6
DFS	141	52	0	93	114	163	169	54	50	185	18
GBR	62	18	88	0	45	68	94	39	28	71	20
NOR	5	17	89	47	0	39	68	0	34	56	52
NZL	60	20	156	64	37	0	109	35	16	126	12
USA	149	25	166	92	69	112	0	68	33	108	27
ZAF	73	2	52	37	0	34	63	0	3	38	3
NLD	5	13	47	27	34	16	32	3	0	24	11
AUS	66	42	163	69	46	131	112	40	22	0	14
IRL	4	6	13	19	51	12	27	3	11	13	0

RDC

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common bulls below diagonal  
common three quarter sib group above diagonal  
CAN DEU DFS GBR NOR NZL USA ZAF NLD AUS IRL

CAN	0	13	139	62	5	60	146	69	6	65	4
DEU	12	0	63	19	19	21	25	2	13	43	6
DFS	141	52	0	93	130	163	169	54	50	185	18
GBR	63	18	88	0	46	68	94	39	29	71	20
NOR	5	18	101	48	0	40	68	0	38	60	52
NZL	60	20	156	64	38	0	109	35	16	126	12
USA	149	25	166	92	69	112	0	68	36	108	27
ZAF	73	2	52	37	0	34	63	0	3	38	3
NLD	6	13	47	28	38	16	34	3	0	24	11
AUS	66	42	163	69	50	131	112	40	22	0	14
IRL	4	6	13	19	51	12	27	3	11	13	0

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