

## 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 and Slovenia 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 days open (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	T4=C2 T5=IT	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 T3=C1 T4=C2	CR=Heifers' Conception rate CF=Interval from Calving to First Service (ICF), days NR=Non Return Rate after 56 Days (NRR), % 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	Interval from Calving to First Service (ICF)
	T3=C1	Conception rate
	T4=C2	Interval first insemination to conception
	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=Days Open
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	CR= Cow's conception rate at 42 days
	T5=IT	CR= Cow's conception rate at 42 days
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
SVN	T5=IT	CI=Calving interval (days)

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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:

CHE (HOL)	Drops in information due to manual edits
NOR (RDC)	The rolling definition of effects redistribute the daughters and some bulls loose EDC.
ISR (HOL)	Drops in information due to pedigree corrections and edits.
DFS (ALL)	Quality check editing on data causing drops in information
AUS (HOL, JER, RDC)	Decreasing in information due to pedigree changes, changes in status of bull which leads to a good number of bulls no longer being qualified
JPN (HOL)	Some changes in proofs caused by additional records and in EDCs caused by modification of pedigree.
POL (HOL)	Drops in information due to data edits.
ITA (HOL)	Drops in information for some bulls due to data edits.
USA (ALL)	Drops in information for most traits are due to pedigree corrections and herd-year minimum edits.
NZL (BSW, GUE, HOL, JER, RDC)	Continuous DNA parentage testing affected daughter counts, herd count, EDCs, and reliabilities.
DEU (HOL)	Decrease in number of daughters, herds, EDCs and bulls changing publish status because of checking in the data.
SVN (BSW, HOL, SIM)	Some bulls losing information (herds/daughters/EDC), due to changes in data base, related to the pedigree completeness as well as phenotypic data improvement.
CZE (HOL)	Trimmed old data for ccl and cc2 . Therefore decrease in older bulls is expected.
ESP (HOL)	Change in base definition. Some Bulls lost some EDC, due to some daughters that were assigned as culled but did contribute more information now.
ITA (BSW)	For some traits, new information cause low correlation with previous evaluation for some years.
FRA (HOL)	The reliability from the singlestep is now used as a factor of the publication.

INTERBULL CHANGES COMPARED TO THE PREVIOUS ROUTINE RUN  
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Post-processing Windows:  
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According to the decision taken by ITC in Orlando (2015) to review the post-processing windows every 5 years, during the 2020 the relative working group has been re-activated and new windows have been identified.

As before, the upper bounds have been set to 0.99 as these were judged to have very little effect on evaluations while the lower values have been reduced to the 10th percentile. This reduction would provide post-processed correlations to be closer to the real estimated ones. Over the past five years, in fact, the previous adopted lower value (25th percentile) had been found too high causing estimated and post-processed correlations to differ significantly from each other. The new lower values have been applied to all breeds and traits.

The weight assigned to the magnitude of the changes tested by each country has also been revised. The new weight will allow post-processed correlations to take more in consideration the value of the new estimated ones even when no changes are applied by the countries.

The new weights are as follows:

No changes	:: 2
Small changes	:: 1
Big changes	:: 0

More information can be read on [https://interbull.org/ib/rg\\_procedure](https://interbull.org/ib/rg_procedure)

#### 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

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

PUBLICATION OF INTERBULL ROUTINE RUN  
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Results were distributed by the Interbull Centre to designated representatives in each country. The international evaluation file comprised international proofs expressed on the base and unit of each country included in the analysis. Such records readily provide more information on bull performance in various countries, thereby minimizing the need to resort to conversions.

At the same time, all recipients of Interbull results are expected to honor the agreed code of practice, decided by the Interbull Steering Committee, and only publish international evaluations on their own country scale. Evaluations expressed on another country scale are confidential and may only be used internally for research and review purposes.

PUBLICATION OF INTERBULL TEST RUN  
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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 2022).  
 Number of records for lactating cow's ability to conceive (cc2) by breed

Country	BSW	GUE	HOL	JER	RDC	SIM
AUS		145	8580	1833	771	
BEL			2040			
CAN	182	48	10018	618	580	
CHE	2946		3189			
CZE			3710			
DEA	4838					
DEU			25065		303	
DFS			17036	2469	10427	
ESP			6252			
EST						
FRA	423		17025			
FRM						
GBR	107	246	7409	602	439	
HUN						
IRL			3184	227	71	
ISR			1598			
ITA	1909		9416			
JPN			6416			
KOR						
LTU						
LVA						
NLD	213		16326	222	92	
NOR					3069	
NZL	53	49	8184	4760	1301	
POL			8612			
PRT						
SVK						
SVN						
URY			1882			
USA	1170	788	41390	5192	777	
ZAF			1274	740	154	
HRV						
CAM						
No. Records	11841	1276	198606	16663	17984	

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

BSW hco

	CAN	DEA	FRA	USA	CHE	NLD
CAN	9.49					
DEA	0.86	9.91				
FRA	0.77	0.86	0.89			
USA	0.78	0.78	0.88	2.66		
CHE	0.91	0.94	0.87	0.81	13.27	
NLD	0.77	0.63	0.72	0.74	0.63	4.49

BSW crc

	CAN	CHE	DEA	NLD	NZL	USA	GBR	FRA	ITA
CAN	6.82								
CHE	0.83	11.36							
DEA	0.79	0.95	14.95						
NLD	0.85	0.89	0.89	3.88					
NZL	0.60	0.62	0.73	0.62	0.12				
USA	0.78	0.84	0.82	0.81	0.61	8.03			
GBR	0.71	0.71	0.64	0.77	0.63	0.73	3.83		
FRA	0.82	0.96	0.95	0.91	0.64	0.84	0.74	1.78	
ITA	0.82	0.79	0.79	0.82	0.66	0.79	0.75	0.82	16.51

BSW cc1

	CAN	CHE	DEA	NLD	USA	GBR	FRA
CAN	7.68						
CHE	0.82	11.82					
DEA	0.78	0.94	11.42				
NLD	0.77	0.71	0.67	4.10			
USA	0.75	0.68	0.67	0.85	2.87		
GBR	0.76	0.80	0.78	0.73	0.67	0.03	
FRA	0.73	0.69	0.67	0.87	0.89	0.71	0.96

BSW cc2

	CAN	CHE	DEA	NLD	NZL	USA	GBR	FRA	ITA
CAN	6.64								
CHE	0.77	11.11							
DEA	0.78	0.93	12.21						
NLD	0.85	0.84	0.83	3.42					
NZL	0.70	0.66	0.73	0.70	5.93				
USA	0.82	0.83	0.84	0.82	0.70	2.46			
GBR	0.73	0.81	0.83	0.76	0.70	0.82	3.83		
FRA	0.84	0.87	0.88	0.86	0.70	0.83	0.79	0.96	
ITA	0.81	0.70	0.79	0.82	0.67	0.82	0.77	0.78	21.72

BSW int

	CAN	DEA	NLD	NZL	USA	GBR	ITA	SVN
CAN	7.17							
DEA	0.81	14.22						
NLD	0.87	0.91	3.36					
NZL	0.68	0.80	0.69	5.93				
USA	0.91	0.85	0.83	0.67	2.46			
GBR	0.83	0.79	0.86	0.67	0.84	3.83		
ITA	0.85	0.92	0.88	0.68	0.82	0.83	17.57	
SVN	0.70	0.68	0.71	0.72	0.69	0.72	0.69	20.55

GUE crc					
	CAN	GBR	NZL	USA	AUS
CAN	7.98				
GBR	0.74	5.06			
NZL	0.61	0.63	0.12		
USA	0.78	0.77	0.61	6.87	
AUS	0.68	0.79	0.89	0.66	6.97

GUE cc1			
	CAN	GBR	USA
CAN	7.50		
GBR	0.76	0.03	
USA	0.80	0.72	3.45

GUE cc2					
	CAN	GBR	NZL	USA	AUS
CAN	6.95				
GBR	0.72	5.06			
NZL	0.69	0.70	5.85		
USA	0.85	0.81	0.70	2.76	
AUS	0.68	0.68	0.69	0.73	9.93

GUE int					
	CAN	GBR	NZL	USA	AUS
CAN	7.78				
GBR	0.83	5.06			
NZL	0.67	0.67	5.85		
USA	0.91	0.81	0.67	2.76	
AUS	0.75	0.72	0.72	0.75	9.93

HOL hco											
	CAN	CZE	DEU	DFS	FRA	USA	POL	CHE	NLD	ITA	JPN
CAN	7.79										
CZE	0.77	17.96									
DEU	0.91	0.80	15.19								
DFS	0.79	0.85	0.84	13.54							
FRA	0.81	0.82	0.81	0.88	0.84						
USA	0.84	0.86	0.84	0.87	0.89	2.37					
POL	0.64	0.59	0.64	0.59	0.61	19.66					
CHE	0.96	0.82	0.93	0.80	0.85	0.87	0.61	13.70			
NLD	0.78	0.77	0.81	0.85	0.83	0.83	0.57	0.80	5.08		
ITA	0.81	0.79	0.92	0.76	0.77	0.81	0.69	0.88	0.74	0.04	
JPN	0.85	0.72	0.83	0.72	0.78	0.84	0.64	0.85	0.74	0.74	6.25

HOL crc														
	BEL	CAN	CHE	DEU	DFS	ESP	GBR	IRL	ITA	NLD	NZL	USA	POL	FRA
BEL	4.71													
CAN	0.75	7.26												
CHE	0.81	0.83	12.29											
DEU	0.72	0.84	0.87	10.94										
DFS	0.79	0.87	0.94	0.92	11.61									
ESP	0.86	0.84	0.87	0.85	0.87	11.06								
GBR	0.90	0.74	0.77	0.72	0.79	0.86	4.59							
IRL	0.85	0.62	0.67	0.61	0.63	0.77	0.82	3.55						
ITA	0.80	0.86	0.87	0.87	0.86	0.91	0.81	0.67	7.76					
NLD	0.82	0.87	0.93	0.90	0.96	0.87	0.79	0.63	0.85	4.88				

NZL	0.61	0.60	0.61	0.58	0.62	0.63	0.63	0.55	0.70	0.59	0.09			
USA	0.73	0.78	0.82	0.81	0.86	0.82	0.78	0.59	0.80	0.82	0.60	6.81		
POL	0.76	0.89	0.89	0.85	0.84	0.89	0.75	0.68	0.95	0.84	0.68	0.76	13.38	
FRA	0.78	0.85	0.94	0.92	0.94	0.88	0.79	0.66	0.90	0.94	0.62	0.82	0.88	1.18

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HOL      cc1  
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	CAN	CHE	CZE	DEU	DFS	FRA	GBR	ISR	ITA	NLD	USA	POL	JPN						
CAN	6.63																		
CHE	0.92	10.90																	
CZE	0.83	0.75	17.49																
DEU	0.91	0.92	0.80	14.73															
DFS	0.75	0.70	0.88	0.77	13.16														
FRA	0.78	0.75	0.90	0.75	0.88	1.02													
GBR	0.76	0.77	0.70	0.78	0.66	0.72	0.03												
ISR	0.77	0.67	0.91	0.75	0.86	0.87	0.74	3.24											
ITA	0.87	0.86	0.79	0.95	0.70	0.73	0.78	0.76	0.05										
NLD	0.79	0.76	0.90	0.79	0.92	0.94	0.73	0.88	0.74	4.81									
USA	0.80	0.71	0.95	0.74	0.85	0.87	0.67	0.92	0.77	0.87	2.80								
POL	0.72	0.75	0.73	0.76	0.64	0.65	0.66	0.68	0.80	0.67	0.67	19.68							
JPN	0.77	0.74	0.89	0.75	0.83	0.81	0.75	0.83	0.75	0.82	0.91	0.67	7.59						

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HOL      cc2  
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	BEL	CAN	CHE	CZE	DEU	DFS	ESP	FRA	GBR	IRL	ISR	ITA	NLD	NZL	USA	POL	ZAF	AUS	URY	JPN
BEL	4.71																			
CAN	0.77	6.05																		
CHE	0.82	0.90	10.96																	
CZE	0.66	0.87	0.86	17.49																
DEU	0.80	0.93	0.92	0.91	13.49															
DFS	0.82	0.85	0.88	0.82	0.94	12.82														
ESP	0.84	0.83	0.86	0.86	0.89	0.84	11.05													
FRA	0.82	0.88	0.93	0.84	0.92	0.86	0.88	0.97												
GBR	0.89	0.73	0.74	0.66	0.78	0.81	0.81	0.76	4.58											
IRL	0.84	0.78	0.83	0.69	0.81	0.78	0.83	0.82	0.83	3.55										
ISR	0.65	0.74	0.74	0.88	0.83	0.78	0.82	0.77	0.64	0.69	3.24									
ITA	0.76	0.86	0.86	0.90	0.92	0.84	0.89	0.85	0.78	0.79	0.88	15.17								
NLD	0.82	0.89	0.90	0.86	0.96	0.92	0.87	0.92	0.77	0.81	0.80	0.86	4.46							
NZL	0.70	0.69	0.63	0.63	0.69	0.69	0.65	0.69	0.69	0.69	0.62	0.63	0.69	4.61						
USA	0.81	0.86	0.85	0.88	0.90	0.87	0.87	0.81	0.83	0.82	0.82	0.92	0.84	0.69	2.33					
POL	0.82	0.74	0.73	0.63	0.73	0.74	0.76	0.73	0.82	0.79	0.64	0.80	0.73	0.69	0.79	12.85				
ZAF	0.77	0.78	0.83	0.72	0.82	0.76	0.82	0.79	0.79	0.87	0.67	0.84	0.76	0.63	0.87	0.82	15.42			
AUS	0.69	0.68	0.73	0.63	0.70	0.64	0.71	0.71	0.69	0.85	0.63	0.70	0.66	0.62	0.73	0.62	0.80	8.39		
URY	0.74	0.72	0.66	0.62	0.72	0.72	0.68	0.72	0.74	0.74	0.57	0.64	0.72	0.72	0.75	0.78	0.67	1.40		
JPN	0.84	0.82	0.85	0.77	0.84	0.85	0.85	0.81	0.87	0.85	0.71	0.87	0.81	0.69	0.92	0.90	0.88	0.72	0.75	18.36

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HOL      int  
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	BEL	CAN	DEU	DFS	ESP	GBR	IRL	ITA	NLD	NZL	USA	POL	ZAF	AUS	URY	FRA	JPN	SVN		
BEL	4.71																			
CAN	0.88	6.53																		
DEU	0.86	0.91	12.30																	
DFS	0.90	0.91	0.95	12.74																
ESP	0.90	0.88	0.88	0.88	11.05															
GBR	0.89	0.84	0.86	0.89	0.88	4.58														
IRL	0.85	0.84	0.83	0.81	0.87	0.83	3.55													
ITA	0.86	0.89	0.90	0.89	0.93	0.87	0.84	19.80												
NLD	0.93	0.91	0.92	0.96	0.89	0.88	0.83	0.88	4.56											
NZL	0.71	0.66	0.66	0.66	0.67	0.66	0.66	0.66	0.66	4.61										
USA	0.83	0.93	0.91	0.88	0.90	0.84	0.83	0.92	0.86	0.66	2.33									
POL	0.82	0.87	0.81	0.83	0.84	0.83	0.80	0.91	0.83	0.68	0.81	12.86								
ZAF	0.80	0.85	0.85	0.82	0.87	0.82	0.87	0.87	0.82	0.66	0.88	0.85	15.42							
AUS	0.75	0.76	0.74	0.72	0.76	0.74	0.85	0.74	0.71	0.66	0.75	0.72	0.82	8.39						
URY	0.75	0.72	0.72	0.72	0.72	0.73	0.76	0.75	0.71	0.73	0.71	0.76	0.82	0.73	1.40					
FRA	0.81	0.87	0.81	0.81	0.85	0.73	0.80	0.81	0.82	0.66	0.81	0.71	0.79	0.72	0.65	0.97				
JPN	0.86	0.93	0.90	0.90	0.90	0.87	0.85	0.94	0.88	0.66	0.92	0.91	0.89	0.76	0.77	0.80	18.36			



SVN 0.84 0.69 0.70 0.79 0.78 0.72 0.73 0.77 0.80 0.67 0.68 0.66 0.67 0.67 0.67 0.76 0.72 17.92

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JER hco  
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	CAN	DFS	USA	NLD
CAN	7.87			
DFS	0.74	17.19		
USA	0.80	0.84	2.72	
NLD	0.82	0.84	0.75	4.74

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JER crc  
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	CAN	DFS	GBR	NLD	NZL	USA	IRL
CAN	6.71						
DFS	0.82	13.43					
GBR	0.67	0.84	3.99				
NLD	0.85	0.87	0.73	3.82			
NZL	0.55	0.70	0.67	0.57	0.07		
USA	0.77	0.83	0.79	0.80	0.66	8.19	
IRL	0.64	0.63	0.81	0.63	0.56	0.60	2.33

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JER cc1  
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	CAN	DFS	GBR	NLD	USA
CAN	7.07				
DFS	0.72	15.32			
GBR	0.78	0.67	0.03		
NLD	0.77	0.85	0.71	3.73	
USA	0.75	0.84	0.67	0.79	2.90

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JER cc2  
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	CAN	DFS	GBR	NLD	NZL	USA	ZAF	AUS	IRL
CAN	6.81								
DFS	0.82	15.55							
GBR	0.74	0.77	4.00						
NLD	0.86	0.88	0.76	3.23					
NZL	0.70	0.70	0.69	0.70	3.98				
USA	0.81	0.82	0.80	0.71	0.71	2.61			
ZAF	0.67	0.66	0.73	0.69	0.77	0.85	11.14		
AUS	0.65	0.66	0.65	0.66	0.62	0.67	0.73	6.38	
IRL	0.77	0.75	0.78	0.78	0.70	0.78	0.77	0.73	2.33

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JER int  
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	CAN	DFS	GBR	NLD	NZL	USA	ZAF	AUS	IRL
CAN	6.45								
DFS	0.86	15.30							
GBR	0.79	0.84	4.00						
NLD	0.87	0.90	0.82	3.32					
NZL	0.67	0.67	0.68	0.67	3.98				
USA	0.85	0.84	0.81	0.80	0.70	2.61			
ZAF	0.75	0.75	0.77	0.76	0.77	0.86	11.14		
AUS	0.73	0.73	0.73	0.72	0.66	0.73	0.77	6.38	
IRL	0.81	0.75	0.77	0.79	0.67	0.77	0.80	0.77	2.33

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RDC hco  
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	CAN	DEU	DFS	NOR	USA	NLD
CAN	7.61					
DEU	0.90	14.54				
DFS	0.73	0.80	12.25			
NOR	0.86	0.89	0.86	16.41		

USA	0.83	0.83	0.85	0.71	2.75	
NLD	0.81	0.83	0.77	0.66	0.80	5.58

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RDC      crc

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	CAN	DEU	DFS	GBR	NOR	NZL	USA	NLD	IRL
CAN	6.48								
DEU	0.84	10.05							
DFS	0.84	0.89	12.65						
GBR	0.77	0.72	0.71	4.12					
NOR	0.84	0.82	0.85	0.64	13.93				
NZL	0.57	0.59	0.55	0.64	0.59	0.11			
USA	0.78	0.81	0.80	0.76	0.77	0.70	8.30		
NLD	0.87	0.89	0.93	0.77	0.83	0.60	0.81	3.62	
IRL	0.62	0.62	0.64	0.82	0.63	0.57	0.61	0.63	2.84

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RDC      cc1

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	CAN	DEU	DFS	GBR	NOR	NLD	USA
CAN	7.11						
DEU	0.90	13.64					
DFS	0.72	0.80	12.99				
GBR	0.76	0.79	0.68	0.03			
NOR	0.78	0.86	0.92	0.76	13.92		
NLD	0.79	0.80	0.89	0.72	0.73	4.17	
USA	0.83	0.75	0.81	0.67	0.75	0.85	2.71

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RDC      cc2

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	CAN	DEU	DFS	GBR	NOR	NZL	USA	ZAF	NLD	AUS	IRL
CAN	6.77										
DEU	0.92	11.29									
DFS	0.82	0.94	12.81								
GBR	0.74	0.78	0.78	4.12							
NOR	0.81	0.85	0.89	0.76	13.92						
NZL	0.70	0.70	0.70	0.71	0.72	5.70					
USA	0.87	0.89	0.82	0.80	0.76	0.70	2.48				
ZAF	0.72	0.81	0.76	0.71	0.77	0.65	0.83	17.45			
NLD	0.88	0.95	0.88	0.77	0.80	0.71	0.84	0.76	3.59		
AUS	0.67	0.68	0.64	0.67	0.65	0.63	0.69	0.70	0.66	7.63	
IRL	0.78	0.81	0.78	0.81	0.76	0.70	0.80	0.84	0.81	0.80	2.84

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RDC      int

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	CAN	DEU	DFS	GBR	NOR	NZL	USA	ZAF	NLD	AUS	IRL
CAN	6.61										
DEU	0.90	11.10									
DFS	0.88	0.94	13.12								
GBR	0.83	0.85	0.82	4.12							
NOR	0.80	0.79	0.73	0.74	13.93						
NZL	0.68	0.68	0.67	0.69	0.69	5.70					
USA	0.92	0.90	0.81	0.82	0.74	0.67	2.48				
ZAF	0.83	0.85	0.80	0.77	0.84	0.68	0.85	17.45			
NLD	0.90	0.92	0.94	0.86	0.76	0.68	0.83	0.81	3.46		
AUS	0.75	0.74	0.73	0.74	0.74	0.67	0.75	0.77	0.67	7.63	
IRL	0.83	0.83	0.80	0.82	0.74	0.68	0.80	0.86	0.81	0.83	2.84

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^LAPPENDIX II. Number of common bulls

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BSW

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common bulls below diagonal  
common three quarter sib group above diagonal  
CAN DEA FRA USA CHE NLD

CAN	0	94	53	103	97	30
DEA	84	0	192	190	579	132
FRA	45	147	0	71	162	74
USA	94	149	54	0	205	52
CHE	81	487	124	170	0	95
NLD	27	125	60	48	89	0

BSW

common bulls below diagonal									
common three quarter sib group above diagonal									
	CAN	CHE	DEA	NLD	NZL	USA	GBR	FRA	ITA
CAN	0	122	118	40	18	135	48	73	111
CHE	103	0	595	104	27	269	64	163	447
DEA	103	492	0	152	40	234	61	201	587
NLD	35	95	140	0	25	64	38	79	127
NZL	17	21	35	19	0	18	13	21	31
USA	131	234	182	59	15	0	66	91	170
GBR	45	49	46	33	10	64	0	48	70
FRA	62	123	152	63	16	63	40	0	183
ITA	97	380	472	103	25	119	51	139	0

BSW

common bulls below diagonal							
common three quarter sib group above diagonal							
	CAN	CHE	DEA	NLD	USA	GBR	FRA
CAN	0	122	118	40	136	48	77
CHE	103	0	594	103	269	67	170
DEA	103	490	0	152	233	65	213
NLD	35	95	140	0	64	38	84
USA	132	234	181	59	0	69	96
GBR	46	52	49	33	68	0	53
FRA	66	129	163	69	69	46	0

BSW

common bulls below diagonal									
common three quarter sib group above diagonal									
	CAN	CHE	DEA	NLD	NZL	USA	GBR	FRA	ITA
CAN	0	109	104	36	14	130	45	70	99
CHE	90	0	587	104	23	325	64	170	447
DEA	91	486	0	153	33	308	61	212	585
NLD	32	95	140	0	20	87	38	84	127
NZL	13	17	28	14	0	24	10	17	25
USA	122	301	263	76	20	0	76	116	217
GBR	41	49	46	33	7	74	0	51	70
FRA	61	129	162	69	12	83	44	0	195
ITA	87	380	471	103	21	151	51	150	0

BSW

common bulls below diagonal								
common three quarter sib group above diagonal								
	CAN	DEA	NLD	NZL	USA	GBR	ITA	SVN
CAN	0	109	38	14	135	47	106	35
DEA	95	0	152	33	307	61	681	101
NLD	34	140	0	20	87	38	132	48
NZL	13	28	14	0	24	10	25	8
USA	127	263	76	20	0	76	240	42
GBR	43	46	33	7	74	0	72	22
ITA	93	602	109	21	170	53	0	97
SVN	32	96	49	7	36	18	97	0

GUE  
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GUE  
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common bulls below diagonal  
common three quarter sib group above diagonal

	CAN	GBR	NZL	USA	AUS
CAN	0	17	2	40	18
GBR	14	0	14	54	28
NZL	1	12	0	10	25
USA	39	51	7	0	19
AUS	13	22	23	16	0

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GUE  
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common bulls below diagonal  
common three quarter sib group above diagonal

	CAN	GBR	USA
CAN	0	18	40
GBR	14	0	57
USA	39	54	0

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GUE  
-----  
common bulls below diagonal  
common three quarter sib group above diagonal

	CAN	GBR	NZL	USA	AUS
CAN	0	12	0	39	23
GBR	9	0	13	83	33
NZL	0	11	0	24	23
USA	37	85	23	0	65
AUS	19	27	23	63	0

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GUE  
-----  
common bulls below diagonal  
common three quarter sib group above diagonal

	CAN	GBR	NZL	USA	AUS
CAN	0	12	0	39	23
GBR	9	0	13	83	33
NZL	0	11	0	24	23
USA	37	85	23	0	65
AUS	19	27	23	63	0

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HOL  
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common bulls below diagonal  
common three quarter sib group above diagonal

	CAN	CZE	DEU	DFS	FRA	USA	POL	CHE	NLD	ITA	JPN
CAN	0	1080	2248	1345	1279	2928	1322	819	1387	1833	1138
CZE	797	0	1818	1225	1203	1453	1167	486	1474	1307	808
DEU	1815	1387	0	2570	2319	2953	2232	1122	3055	2654	1317
DFS	1262	824	1942	0	1657	1689	1378	726	2185	1647	964
FRA	953	737	1311	968	0	1664	1454	705	1937	1680	1121
USA	3372	1176	2328	1538	1005	0	1879	878	1862	2464	1456
POL	1209	935	1967	1141	990	1964	0	545	1588	1549	816
CHE	740	341	1046	673	648	808	434	0	901	771	460
NLD	1366	1281	2703	1902	1280	1658	1429	894	0	1780	1054
ITA	1611	955	1900	1373	1012	2069	1257	721	1513	0	1161
JPN	644	354	591	507	414	765	442	296	533	550	0

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HOL  
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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
BEL	0	767	606	1215	864	902	866	526	811	1244	515	820	569	964
CAN	770	0	855	2383	1431	1569	1637	573	1875	1541	713	3102	1202	1380
CHE	614	784	0	1158	731	723	752	433	765	946	430	939	501	721
DEU	1241	1879	1092	0	2765	2273	2252	947	2682	3561	1030	3221	1982	2553
DFS	811	1349	685	2045	0	1527	1628	780	1630	2239	866	1843	1249	1677
ESP	977	1363	677	2001	1349	0	1518	721	1703	1746	745	1845	1177	1751
GBR	847	1721	715	1727	1286	1382	0	1029	1653	1904	973	2054	1053	1617
IRL	519	572	445	830	660	740	1070	0	659	946	766	693	407	772
ITA	815	1648	714	1931	1362	1530	1347	595	0	1848	720	2578	1359	1679
NLD	1422	1530	942	3281	2013	1827	1677	896	1605	0	1112	2137	1465	2061
NZL	415	656	359	790	620	617	836	664	562	1005	0	857	452	818
USA	786	3625	876	2456	1636	1609	2009	681	2110	1930	793	0	1690	1871
POL	481	1067	384	1646	999	947	813	311	1039	1275	340	1677	0	1353
FRA	956	1044	654	1443	964	1667	1058	630	1008	1345	502	1110	878	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	859	1058	2375	1438	1386	1689	125	1888	1550	3147	1247	1278
CHE	788	0	447	1154	731	719	765	58	764	946	939	527	487
CZE	824	317	0	1654	1094	1072	951	113	1210	1377	1455	1129	758
DEU	1871	1087	1317	0	2761	2566	2298	165	2657	3533	3181	2140	1508
DFS	1355	685	815	2038	0	1680	1666	149	1631	2238	1848	1346	1026
FRA	1059	658	663	1460	972	0	1642	120	1680	2074	1872	1412	1258
GBR	1779	736	669	1773	1324	1083	0	145	1705	1957	2140	1116	1116
ISR	90	35	89	132	112	68	106	0	140	156	163	107	104
ITA	1663	712	923	1908	1361	1021	1407	104	0	1847	2576	1424	1208
NLD	1545	942	1257	3255	2012	1368	1738	123	1602	0	2137	1586	1124
USA	3689	876	1196	2418	1636	1122	2113	159	2108	1930	0	1755	1652
POL	1124	417	918	1884	1122	940	889	80	1108	1440	1766	0	832
JPN	761	336	383	682	580	482	597	48	623	628	919	470	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	758	606	544	1208	865	902	959	868	528	75	807	1246	497	972	560	332	749	347	524
CAN	760	0	844	1037	2303	1408	1557	1351	1610	561	122	1825	1509	653	3235	1167	443	1311	738	1183
CHE	614	768	0	447	1148	732	722	709	752	433	59	759	946	411	1036	487	264	648	311	454
CZE	437	793	317	0	1648	1094	1051	1065	940	432	113	1207	1377	474	1513	1052	288	720	474	724
DEU	1233	1785	1079	1304	0	2749	2274	2534	2239	940	166	2626	3502	971	3729	1930	557	1732	810	1422
DFS	811	1318	686	815	2020	0	1535	1672	1632	780	151	1624	2242	823	2234	1222	510	1323	651	964
ESP	977	1335	677	847	1992	1356	0	1752	1521	722	136	1700	1751	719	2162	1156	517	1212	665	1115
FRA	946	1010	642	655	1409	950	1655	0	1612	773	123	1661	2049	797	2562	1326	481	1319	605	1195
GBR	847	1685	715	661	1705	1286	1383	1048	0	1030	145	1644	1907	934	2433	1032	503	1469	694	1053
IRL	519	553	445	331	822	660	740	624	1070	0	98	657	949	748	858	396	336	769	385	457
ISR	45	87	35	89	131	112	102	67	104	78	0	139	158	106	188	102	60	112	85	101
ITA	812	1584	709	920	1863	1351	1526	991	1341	594	104	0	1836	679	2740	1325	454	1198	680	1138
NLD	1424	1490	942	1257	3198	2014	1830	1326	1678	897	123	1595	0	1044	2700	1424	504	1523	688	1057
NZL	396	593	340	355	730	580	591	479	803	650	89	530	938	0	1087	417	353	1195	528	555
USA	867	3697	972	1225	2674	1770	1878	1398	2255	783	176	2170	2370	1026	0	1694	634	2011	1155	1950
POL	466	1017	367	807	1564	965	920	846	794	301	69	1001	1219	310	1646	0	229	774	464	758
ZAF	278	407	222	203	427	377	474	336	442	295	39	370	419	281	610	156	0	475	314	408
AUS	648	1341	573	506	1296	974	984	900	1295	665	71	943	1325	1187	2043	568	415	0	674	902
URY	257	693	234	317	566	445	575	353	557	298	47	501	532	427	1417	353	265	523	0	565
JPN	325	632	289	343	574	499	530	414	510	282	39	529	533	268	790	384	257	474	284	0

HOL

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	SVN
BEL	0	760	1206	865	902	868	528	806	1246	497	972	559	332	749	347	959	524	181
CAN	764	0	2308	1416	1564	1619	567	1832	1519	658	3248	1170	447	1319	743	1359	1188	205
DEU	1232	1794	0	2746	2273	2239	940	2625	3500	971	3724	1924	557	1732	809	2534	1422	324
DFS	811	1328	2017	0	1535	1632	780	1624	2241	823	2232	1221	510	1323	650	1672	964	256
ESP	977	1351	1992	1356	0	1521	722	1699	1750	719	2160	1156	517	1211	665	1751	1114	247
GBR	847	1698	1705	1286	1383	0	1030	1644	1907	934	2433	1032	503	1469	693	1612	1053	214
IRL	519	561	822	660	740	1070	0	657	949	748	858	396	336	769	385	773	457	125
ITA	812	1596	1863	1351	1525	1341	594	0	1836	679	2740	1321	454	1198	680	1661	1138	250
NLD	1424	1503	3197	2013	1830	1678	897	1595	0	1044	2700	1421	504	1523	688	2049	1057	271
NZL	396	596	730	580	591	803	650	530	938	0	1087	417	353	1195	528	797	555	126
USA	867	3726	2674	1770	1878	2255	783	2170	2370	1026	0	1692	634	2011	1155	2562	1950	245
POL	466	1023	1561	964	920	794	301	1000	1219	310	1646	0	229	774	464	1326	757	220
ZAF	278	414	427	377	474	442	295	370	419	281	610	156	0	475	314	481	408	91
AUS	648	1346	1296	974	984	1295	665	943	1325	1187	2043	568	415	0	674	1319	902	179
URY	257	699	566	445	575	557	298	501	532	427	1417	353	265	523	0	605	565	95
FRA	946	1018	1409	950	1655	1048	624	991	1326	479	1398	846	336	900	353	0	1195	211
JPN	325	635	574	499	530	510	282	529	533	268	790	384	257	474	284	414	0	165
SVN	147	157	314	201	218	160	97	213	237	86	188	182	64	124	51	150	89	0

JER

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common bulls below diagonal  
common three quarter sib group above diagonal

	CAN	DFS	USA	NLD
CAN	0	93	326	30
DFS	88	0	145	80
USA	315	132	0	67
NLD	23	77	67	0

JER

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common bulls below diagonal  
common three quarter sib group above diagonal

	CAN	DFS	GBR	NLD	NZL	USA	IRL
CAN	0	98	146	40	163	385	13
DFS	91	0	172	142	151	161	53
GBR	147	167	0	95	216	212	75
NLD	34	139	89	0	81	91	33
NZL	163	128	223	73	0	287	137
USA	388	148	229	94	308	0	44
IRL	12	49	77	33	155	46	0

JER

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common bulls below diagonal  
common three quarter sib group above diagonal

	CAN	DFS	GBR	NLD	USA
CAN	0	98	151	40	387
DFS	91	0	172	141	160
GBR	151	167	0	94	217
NLD	34	138	89	0	91
USA	390	148	234	94	0

JER

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common bulls below diagonal  
common three quarter sib group above diagonal

	CAN	DFS	GBR	NLD	NZL	USA	ZAF	AUS	IRL
CAN	0	95	143	40	146	386	131	223	13
DFS	88	0	173	142	148	208	154	163	53
GBR	142	167	0	95	211	239	173	223	75
NLD	33	139	89	0	75	105	78	78	33
NZL	144	124	219	68	0	368	208	432	137

USA	387	183	264	110	440	0	316	511	50
ZAF	129	136	176	74	218	329	0	250	42
AUS	216	133	230	71	477	554	238	0	62
IRL	12	49	77	33	155	52	43	60	0

JER

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common bulls below diagonal  
common three quarter sib group above diagonal

	CAN	DFS	GBR	NLD	NZL	USA	ZAF	AUS	IRL
CAN	0	96	144	40	148	389	133	225	13
DFS	89	0	173	142	148	208	154	163	53
GBR	144	167	0	95	211	239	173	223	75
NLD	34	139	89	0	75	105	78	78	33
NZL	148	124	219	68	0	368	208	432	137
USA	393	183	264	110	440	0	316	511	50
ZAF	132	136	176	74	218	329	0	250	42
AUS	220	133	230	71	477	554	238	0	62
IRL	12	49	77	33	155	52	43	60	0

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RDC

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common bulls below diagonal  
common three quarter sib group above diagonal

	CAN	DEU	DFS	NOR	USA	NLD
CAN	0	10	172	7	101	6
DEU	10	0	59	14	15	10
DFS	179	50	0	123	159	55
NOR	6	13	101	0	70	39
USA	95	14	152	70	0	38
NLD	6	10	52	39	36	0

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RDC

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common bulls below diagonal  
common three quarter sib group above diagonal

	CAN	DEU	DFS	GBR	NOR	NZL	USA	NLD	IRL
CAN	0	13	172	74	7	69	145	6	4
DEU	12	0	64	14	15	18	20	14	5
DFS	179	52	0	108	144	170	188	57	19
GBR	75	13	105	0	57	75	97	37	24
NOR	6	14	116	60	0	46	77	45	59
NZL	69	18	166	74	45	0	102	20	15
USA	139	19	183	94	77	105	0	43	29
NLD	6	14	54	36	45	20	41	0	13
IRL	4	5	14	23	58	15	29	13	0

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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	13	172	77	7	6	146
DEU	12	0	62	15	15	14	20
DFS	179	50	0	114	132	57	188
GBR	77	14	110	0	59	37	98
NOR	6	14	108	62	0	43	77
NLD	6	14	54	36	43	0	43
USA	140	19	183	94	77	41	0

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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
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CAN	0	13	169	70	7	59	168	74	6	72	4
DEU	12	0	60	14	15	15	21	3	14	42	5
DFS	176	49	0	108	132	158	210	59	57	218	19
GBR	71	13	105	0	56	70	111	44	37	80	24
NOR	6	14	108	59	0	37	82	0	43	70	59
NZL	60	15	154	68	36	0	104	37	17	130	13
USA	172	20	209	110	82	106	0	74	46	133	30
ZAF	78	3	56	41	0	35	69	0	3	44	3
NLD	6	14	54	36	43	17	44	3	0	33	13
AUS	73	40	194	79	59	130	133	45	31	0	19
IRL	4	5	14	23	58	13	30	3	13	18	0

RDC

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	169	71	7	59	168	74	6	72	4
DEU	12	0	60	14	15	15	21	3	14	42	5
DFS	176	49	0	108	144	158	210	59	57	218	19
GBR	72	13	105	0	57	70	111	44	37	80	24
NOR	6	14	116	60	0	38	82	0	45	74	59
NZL	60	15	154	68	37	0	104	37	17	130	13
USA	172	20	209	110	82	106	0	74	46	133	30
ZAF	78	3	56	41	0	35	69	0	3	44	3
NLD	6	14	54	36	45	17	44	3	0	33	13
AUS	73	40	194	79	63	130	133	45	31	0	19
IRL	4	5	14	23	58	13	30	3	13	18	0

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