

PopReport

A Pedigree Analysis Report

Population: UNKNOWN
Inputfile: POPREP.TXT
Initiated by: quaglia@anabic.it
Submitted at: 2019-08-26 08:50:27
Started at: 2019-08-26 08:51:01
Finished at: 2019-08-26 09:08:12

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Some Notes About Your PopReport Job:

- INFO: This job ran on machine rie-ex-web160 with 12 CPUs and MemTotal: 32950668 kB
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24773 input lines processed.
24773 animals accepted.
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No shortening of infiles for the AGR computations done.

Pedigree Analysis Report for Population: UNKNOWN

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Contents

1 Pedigree completeness per year	1
2 Inbreeding	4
2.1 Distribution of animals by year and inbreeding level	4
2.2 Number of <i>all</i> and <i>inbred</i> animals, sires and dams by year	6
2.3 Descriptive statistics of inbreeding coefficients of <i>all</i> animals by year	8
2.4 Descriptive statistics of inbreeding coefficient of <i>inbred</i> animals by year	10
3 Effective Population Size	12
3.1 Effective Population Size based on the rate of inbreeding	12
3.2 Effective population size based on the number of parents	14
4 The Average and Rate of Additive Genetic Relationships by year	16

List of Tables

1 The average pedigree completeness (%) for 1 to 6 generations deep by year	1
2 Distribution of animals by year and inbreeding levels	4
3 Numbers and average inbreeding of animals and parents by year	6
4 Inbreeding coefficients (F) of ALL animals by year	8
5 Inbreeding coefficients (F) of INBRED animals by year	10
6 Effective population size by year via rate of inbreeding	12
7 Effective population size by year via number of parents	14
8 Average Additive Genetic Relationships (AGR)	16

List of Figures

1 Average pedigree completeness for 1 to 6 generations	3
2 Comparison between the average inbreeding coefficients (F) and the number of inbred animals by year	11
3 Average Additive Genetic Relationships and Inbreeding Coefficients by year of birth	19
4 Average $\text{Log}(1-F)$ by year of birth for animals born between 1951 and 2017.	20
5 The Rate of Inbreeding and Increase in the Additive Genetic Relationships by year of birth	21

1 Pedigree completeness per year

An estimate of an individual's inbreeding coefficient depends on the extent to which its ancestry is known to some defined generation in the past. The more complete the knowledge of an individual's ancestry, the more reliable is its estimate of inbreeding coefficient relative to some defined base population. MacCluer *et al.* (1983) proposed an index to measure pedigree completeness. This index summarizes the proportion of known ancestors in each ascending generation. It quantifies the chance of detecting inbreeding in the pedigree (Sørensen *et al.*, 2005). The following formula was used to compute pedigree completeness (MacCluer *et al.*, 1983):

$$I_d = \frac{4I_{d_{pat}}I_{d_{mat}}}{I_{d_{pat}} + I_{d_{mat}}}$$

and

$$I_{d_k} = \frac{1}{d} \sum_{i=1}^d a_i \quad k = pat, mat$$

where k represents the paternal (*pat*) or maternal line (*mat*) of an individual, a_i is the proportion of known ancestors in generation i . The d is the number of generations considered in the calculation of the pedigree completeness. For example, if $d = 5$ then five ancestral generations will be taken into account in the computations. The values for pedigree completeness range from 0 to 1. If all ancestors of an individual to some specified generation (d) are known, then $I_d = 1$ or if one of the parent (*i.e.* sire or dam) is unknown, $I_d = 0$. The pedigree completeness values averaged per year are presented on the Table.

Table 1: The average pedigree completeness (%) for 1 to 6 generations deep by year

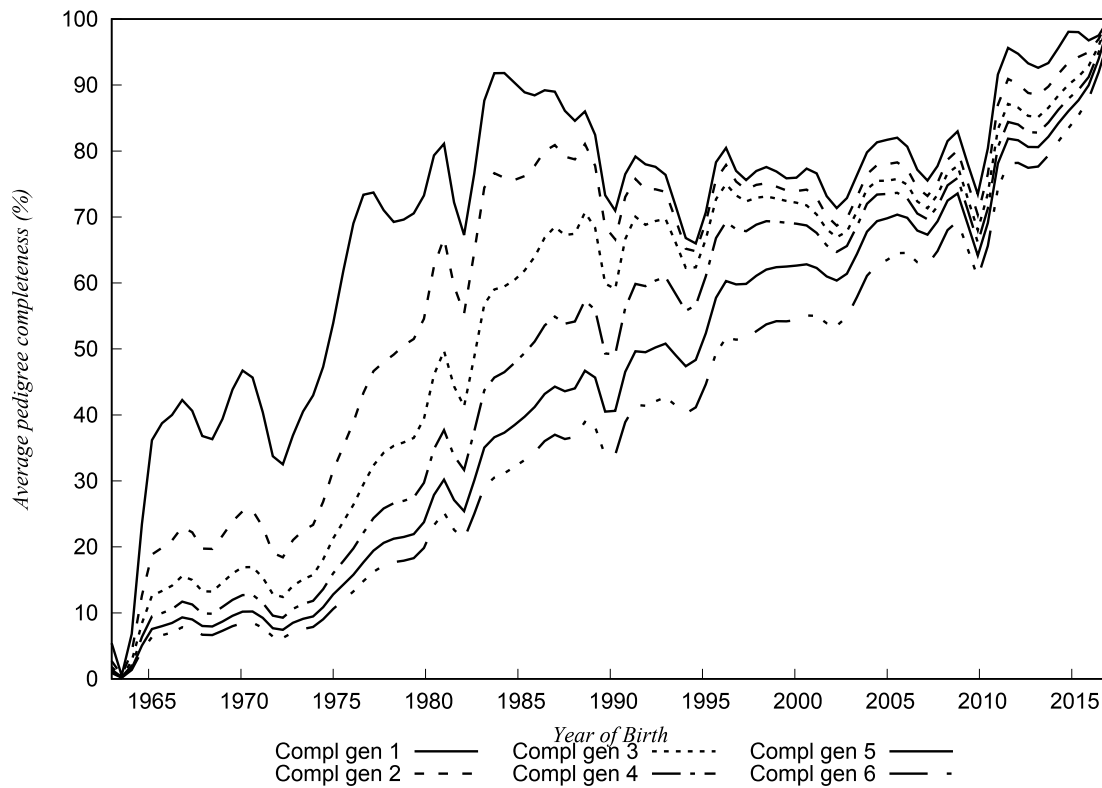
Year	No of Animals	Compl. gen 1	Compl. gen 2	Compl. gen 3	Compl. gen 4	Compl. gen 5	Compl. (%) gen 6(%)
1951	1	0.0	0.0	0.0	0.0	0.0	0.0
1952	1	0.0	0.0	0.0	0.0	0.0	0.0
1954	1	0.0	0.0	0.0	0.0	0.0	0.0
1959	1	0.0	0.0	0.0	0.0	0.0	0.0
1960	4	25.0	12.5	8.3	6.2	5.0	4.2
1961	7	0.0	0.0	0.0	0.0	0.0	0.0
1962	6	16.7	8.3	5.6	4.2	3.3	2.8
1963	55	5.4	2.7	1.8	1.4	1.1	0.9
1964	62	4.8	3.0	2.0	1.5	1.2	1.0
1965	99	33.3	17.5	11.7	8.8	7.0	5.9
1966	123	39.0	20.1	13.5	10.1	8.1	6.7
1967	130	42.3	23.2	15.7	11.8	9.4	7.9
1968	151	36.4	19.5	13.1	9.8	7.9	6.6
1969	170	39.4	21.7	14.6	10.9	8.7	7.3
1970	172	46.5	25.2	16.8	12.6	10.1	8.4
1971	230	42.6	24.2	16.1	12.1	9.7	8.1
1972	361	32.1	18.1	12.2	9.1	7.3	6.1
1973	391	38.4	21.8	14.6	11.0	8.8	7.3
1974	490	43.5	23.7	16.0	12.0	9.6	8.0
1975	449	53.9	31.6	21.3	16.0	12.8	10.6
1976	460	68.0	38.2	25.9	19.4	15.5	13.0
1977	429	74.1	45.8	31.5	23.7	18.9	15.8
1978	477	69.8	48.5	34.9	26.3	21.0	17.5
1979	375	69.9	50.9	36.0	27.1	21.6	18.0
1980	437	74.1	55.6	40.3	30.4	24.3	20.3
1981	534	81.1	66.8	49.7	37.7	30.2	25.2
1982	461	67.0	55.0	41.0	31.4	25.2	21.0

Continue...

Year	No of Animals	Compl. 1 gen	Compl. 2 gen	Compl. 3 gen	Compl. 4 gen	Compl. 5 gen	Compl. (%) 6 gen (%)
1983	469	84.7	72.1	54.8	42.2	33.8	28.1
1984	404	92.1	76.3	59.2	46.0	36.9	30.8
1985	411	89.8	75.7	60.9	48.4	38.9	32.5
1986	349	88.5	78.1	64.4	51.5	41.5	34.6
1987	417	89.0	80.9	68.5	54.9	44.3	37.0
1988	368	84.5	78.5	67.1	53.8	43.7	36.4
1989	418	84.7	80.0	70.3	57.4	46.8	39.1
1990	415	70.6	65.9	57.8	47.8	39.4	32.9
1991	456	78.1	74.8	68.7	58.2	48.2	40.3
1992	437	77.8	74.0	68.7	59.5	49.5	41.4
1993	450	76.4	73.8	69.7	60.9	50.8	42.7
1994	371	67.4	65.7	62.7	56.0	47.5	40.3
1995	512	68.5	67.2	64.8	59.2	50.7	43.2
1996	524	80.5	77.7	74.6	68.7	59.6	51.0
1997	405	76.0	74.6	72.7	67.8	59.6	51.3
1998	464	77.2	75.0	73.0	69.0	61.3	52.9
1999	564	76.9	74.6	72.8	69.3	62.4	54.2
2000	590	75.8	73.9	72.2	69.0	62.6	54.3
2001	551	77.3	73.6	71.0	68.1	62.6	55.2
2002	861	71.8	69.1	67.3	65.0	60.5	53.5
2003	767	73.9	70.7	68.6	66.4	62.2	55.7
2004	752	80.2	76.9	74.6	72.4	68.2	61.5
2005	858	81.7	78.0	75.5	73.5	69.8	63.5
2006	748	81.1	77.6	75.2	73.1	70.1	64.7
2007	828	75.6	73.2	71.3	69.6	67.2	62.6
2008	737	79.6	76.9	75.0	73.2	70.9	66.4
2009	694	82.1	79.2	76.8	75.0	72.7	68.6
2010	658	73.7	70.5	68.1	66.2	64.2	60.9
2011	820	91.6	87.0	83.3	80.6	78.1	74.3
2012	605	95.0	90.4	86.8	84.2	81.8	78.3
2013	607	92.7	88.4	85.0	82.6	80.4	77.4
2014	630	94.3	90.7	87.5	85.3	83.2	80.4
2015	430	98.4	93.8	90.5	88.4	86.6	84.1
2016	122	96.7	95.2	93.3	91.7	90.5	88.5
2017	4	100.0	100.0	100.0	100.0	99.1	97.0

The average pedigree completeness for animals born within the last 10 years: 1 generations deep = 88%. 2 generations deep = 84.3%. 3 generations deep = 81.3%. 4 generations deep = 79.1%. 5 generations deep = 76.9%. 6 generations deep = 73.5%.

Figure 1: Average pedigree completeness for 1 to 6 generations



The figure above presents the average percentage of pedigree completeness for a pedigree depth of 1 to 6 generations by year of birth, between 1963 and 2017 for the UNKNOWN breed.

2 Inbreeding

2.1 Distribution of animals by year and inbreeding level

This section presents a distribution of animals by inbreeding levels and year of birth. Eleven inbreeding classes of size 5% were defined. The last inbreeding class included all animals with inbreeding coefficient $>50\%$. The number of animals by inbreeding class and year are given in the table.

Table 2: Distribution of animals by year and inbreeding levels

(Classes 1=0-5%, 2=6-10%, 3=11-15%, 4=16-20%, 5=21-25%, 6=26-30%, 7=31-35%, 8=36-40%, 9=41-45%, 10=46-50% and 11= $>50\%$)

Year	Classes										
	1	2	3	4	5	6	7	8	9	10	11
1951	1	-	-	-	-	-	-	-	-	-	-
1952	1	-	-	-	-	-	-	-	-	-	-
1954	1	-	-	-	-	-	-	-	-	-	-
1959	1	-	-	-	-	-	-	-	-	-	-
1960	4	-	-	-	-	-	-	-	-	-	-
1961	7	-	-	-	-	-	-	-	-	-	-
1962	6	-	-	-	-	-	-	-	-	-	-
1963	55	-	-	-	-	-	-	-	-	-	-
1964	62	-	-	-	-	-	-	-	-	-	-
1965	98	-	-	-	1	-	-	-	-	-	-
1966	123	-	-	-	-	-	-	-	-	-	-
1967	130	-	-	-	-	-	-	-	-	-	-
1968	151	-	-	-	-	-	-	-	-	-	-
1969	170	-	-	-	-	-	-	-	-	-	-
1970	172	-	-	-	-	-	-	-	-	-	-
1971	230	-	-	-	-	-	-	-	-	-	-
1972	360	-	-	-	1	-	-	-	-	-	-
1973	387	-	1	-	3	-	-	-	-	-	-
1974	489	-	-	-	1	-	-	-	-	-	-
1975	441	2	6	-	-	-	-	-	-	-	-
1976	455	2	3	-	-	-	-	-	-	-	-
1977	424	3	-	-	2	-	-	-	-	-	-
1978	463	12	1	-	1	-	-	-	-	-	-
1979	366	1	3	-	5	-	-	-	-	-	-
1980	425	2	6	-	4	-	-	-	-	-	-
1981	512	1	15	4	2	-	-	-	-	-	-
1982	432	1	19	-	9	-	-	-	-	-	-
1983	460	3	4	1	1	-	-	-	-	-	-
1984	387	9	1	1	6	-	-	-	-	-	-
1985	392	2	8	6	3	-	-	-	-	-	-
1986	329	11	5	-	4	-	-	-	-	-	-
1987	382	15	11	5	2	1	1	-	-	-	-
1988	342	5	7	4	10	-	-	-	-	-	-
1989	377	15	14	5	7	-	-	-	-	-	-
1990	380	17	10	-	8	-	-	-	-	-	-
1991	426	14	12	-	4	-	-	-	-	-	-
1992	393	23	10	4	4	2	1	-	-	-	-

Continue...

Year	Classes										
	1	2	3	4	5	6	7	8	9	10	11
1993	419	12	14	1	3	1	-	-	-	-	-
1994	336	18	9	1	5	2	-	-	-	-	-
1995	452	27	11	10	8	3	1	-	-	-	-
1996	471	28	10	4	8	3	-	-	-	-	-
1997	357	23	8	5	6	5	1	-	-	-	-
1998	396	36	7	8	11	5	-	1	-	-	-
1999	468	47	19	23	4	3	-	-	-	-	-
2000	459	56	40	26	9	-	-	-	-	-	-
2001	455	48	28	13	5	2	-	-	-	-	-
2002	711	67	39	28	7	8	-	1	-	-	-
2003	625	60	33	13	14	20	1	1	-	-	-
2004	602	82	17	16	7	26	2	-	-	-	-
2005	733	64	24	15	2	19	1	-	-	-	-
2006	667	39	13	11	1	13	-	4	-	-	-
2007	772	30	9	6	3	8	-	-	-	-	-
2008	670	31	19	5	1	9	1	1	-	-	-
2009	602	44	16	9	6	17	-	-	-	-	-
2010	581	40	10	7	4	15	-	1	-	-	-
2011	704	52	17	18	1	28	-	-	-	-	-
2012	525	42	18	8	-	11	1	-	-	-	-
2013	506	57	23	5	-	14	-	1	1	-	-
2014	546	56	14	5	1	7	1	-	-	-	-
2015	378	30	9	1	2	9	1	-	-	-	-
2016	100	16	4	-	-	-	2	-	-	-	-
2017	4	-	-	-	-	-	-	-	-	-	-

2.2 Number of *all* and *inbred* animals, sires and dams by year

This section presents the number of *all* and *inbred* animals, sires and dams by year. The following information is given in the table for all animals, sires and dams:

Tot No. : the number of animals / sires / dams in a given year.

Inbred No. : the number of inbred animals / sires / dams in a given year.

Avg F : the average inbreeding coefficient.

Table 3: Numbers and average inbreeding of animals and parents by year

Year	Animals			Sires			Dams		
	Tot No	Inbred No	Avg F	Tot No	Inbred No	Avg F	Tot No	Inbred No	Avg F
1951	1	-	-	-	-	-	-	-	-
1952	1	-	-	-	-	-	-	-	-
1954	1	-	-	-	-	-	-	-	-
1959	1	-	-	-	-	-	-	-	-
1960	4	-	-	1	-	-	1	-	-
1961	7	-	-	-	-	-	-	-	-
1962	6	-	-	2	-	-	1	-	-
1963	55	-	-	5	-	-	3	-	-
1964	62	-	-	3	-	-	3	-	-
1965	99	1	0.0025	22	-	-	36	-	-
1966	123	-	-	19	-	-	50	-	-
1967	130	-	-	30	-	-	56	1	0.0045
1968	151	-	-	31	-	-	56	-	-
1969	170	-	-	33	-	-	65	-	-
1970	172	-	-	38	-	-	88	-	-
1971	230	-	-	36	-	-	106	-	-
1972	361	1	0.0007	42	-	-	122	-	-
1973	391	4	0.0022	42	-	-	159	-	-
1974	490	1	0.0005	66	-	-	219	-	-
1975	449	8	0.0019	71	-	-	253	1	0.0010
1976	460	5	0.0011	69	-	-	317	-	-
1977	429	5	0.0016	58	-	-	317	-	-
1978	477	18	0.0025	62	-	-	328	-	-
1979	375	13	0.0048	51	-	-	265	1	0.0005
1980	437	20	0.0046	57	-	-	318	1	0.0004
1981	534	45	0.0069	66	2	0.0019	423	7	0.0025
1982	461	41	0.0109	58	1	0.0011	314	8	0.0037
1983	469	20	0.0030	61	1	0.0010	396	7	0.0023
1984	404	37	0.0069	58	-	-	370	16	0.0038
1985	411	46	0.0085	67	3	0.0008	366	20	0.0053
1986	349	36	0.0078	52	2	0.0033	313	17	0.0040
1987	417	68	0.0123	57	3	0.0037	371	15	0.0028
1988	368	51	0.0130	62	4	0.0081	320	17	0.0029
1989	418	83	0.0147	68	6	0.0056	373	19	0.0040
1990	415	80	0.0129	60	8	0.0070	320	23	0.0054
1991	456	97	0.0109	60	7	0.0085	390	28	0.0047
1992	437	109	0.0159	48	10	0.0153	367	39	0.0072
1993	450	109	0.0117	54	11	0.0160	379	40	0.0060
1994	371	107	0.0148	47	8	0.0141	289	44	0.0096

Continue...

Year	Animal			Sires			Dams		
	Tot No	Inbred No	Avg F	Tot No	Inbred No	Avg F	Tot No	Inbred No	Avg F
1995	512	173	0.0201	50	12	0.0141	392	72	0.0125
1996	524	222	0.0181	57	14	0.0185	430	78	0.0089
1997	405	186	0.0220	58	16	0.0093	315	74	0.0122
1998	464	228	0.0263	55	23	0.0077	370	90	0.0119
1999	564	329	0.0268	63	28	0.0084	458	140	0.0153
2000	590	357	0.0335	68	30	0.0096	485	150	0.0143
2001	551	303	0.0250	79	42	0.0140	462	153	0.0148
2002	861	476	0.0262	95	58	0.0179	799	247	0.0148
2003	767	429	0.0308	96	68	0.0224	715	255	0.0172
2004	752	465	0.0318	100	77	0.0230	720	303	0.0208
2005	858	563	0.0246	103	81	0.0232	819	362	0.0188
2006	748	490	0.0227	107	87	0.0254	723	345	0.0240
2007	828	523	0.0158	116	98	0.0277	793	401	0.0237
2008	737	496	0.0186	113	97	0.0249	723	383	0.0258
2009	694	490	0.0250	116	102	0.0260	679	363	0.0257
2010	658	400	0.0229	106	92	0.0292	649	365	0.0243
2011	820	589	0.0290	145	133	0.0226	804	501	0.0260
2012	605	461	0.0251	118	109	0.0221	594	376	0.0236
2013	607	471	0.0309	123	116	0.0253	597	385	0.0313
2014	630	506	0.0246	124	120	0.0222	622	413	0.0250
2015	430	362	0.0261	102	99	0.0243	428	307	0.0236
2016	122	111	0.0311	49	48	0.0285	121	91	0.0268
2017	4	4	0.0202	4	4	0.0160	4	4	0.0121

2.3 Descriptive statistics of inbreeding coefficients of *all* animals by year

This section presents the summary statistics of inbreeding coefficients of *all* animals born in a given year. The columns in the table are:

No. of animals : all animals born in a given year.

Min : the lowest inbreeding coefficient.

Max : the highest inbreeding coefficient.

Avg F : the mean inbreeding coefficient.

Std : the standard deviation of inbreeding coefficients.

Table 4: Inbreeding coefficients (F) of ALL animals by year

Year	No of Animals	F			
		Min	Max	Avg	Std
1951	1	0.0000	0.0000	0.0000	-
1952	1	0.0000	0.0000	0.0000	-
1954	1	0.0000	0.0000	0.0000	-
1959	1	0.0000	0.0000	0.0000	-
1960	4	0.0000	0.0000	0.0000	0.0000
1961	7	0.0000	0.0000	0.0000	0.0000
1962	6	0.0000	0.0000	0.0000	0.0000
1963	55	0.0000	0.0000	0.0000	0.0000
1964	62	0.0000	0.0000	0.0000	0.0000
1965	99	0.0000	0.2500	0.0025	0.0251
1966	123	0.0000	0.0000	0.0000	0.0000
1967	130	0.0000	0.0000	0.0000	0.0000
1968	151	0.0000	0.0000	0.0000	0.0000
1969	170	0.0000	0.0000	0.0000	0.0000
1970	172	0.0000	0.0000	0.0000	0.0000
1971	230	0.0000	0.0000	0.0000	0.0000
1972	361	0.0000	0.2500	0.0007	0.0132
1973	391	0.0000	0.2500	0.0022	0.0227
1974	490	0.0000	0.2500	0.0005	0.0113
1975	449	0.0000	0.1250	0.0019	0.0149
1976	460	0.0000	0.1250	0.0011	0.0109
1977	429	0.0000	0.2500	0.0016	0.0178
1978	477	0.0000	0.2500	0.0025	0.0162
1979	375	0.0000	0.2500	0.0048	0.0310
1980	437	0.0000	0.2500	0.0046	0.0281
1981	534	0.0000	0.2500	0.0069	0.0293
1982	461	0.0000	0.2500	0.0109	0.0425
1983	469	0.0000	0.2500	0.0030	0.0191
1984	404	0.0000	0.2500	0.0069	0.0333
1985	411	0.0000	0.2500	0.0085	0.0334
1986	349	0.0000	0.2500	0.0078	0.0327
1987	417	0.0000	0.3125	0.0123	0.0388
1988	368	0.0000	0.2500	0.0130	0.0455
1989	418	0.0000	0.2500	0.0147	0.0434
1990	415	0.0000	0.2500	0.0129	0.0409
1991	456	0.0000	0.2500	0.0109	0.0333
1992	437	0.0000	0.3125	0.0159	0.0433
1993	450	0.0000	0.2524	0.0117	0.0352
1994	371	0.0000	0.2813	0.0148	0.0426

Continue...

Year	No of Animals	<i>F</i>			
		Min	Max	Avg	Std
1995	512	0.0000	0.3125	0.0201	0.0504
1996	524	0.0000	0.2656	0.0181	0.0443
1997	405	0.0000	0.3125	0.0220	0.0516
1998	464	0.0000	0.3750	0.0263	0.0561
1999	564	0.0000	0.2656	0.0268	0.0488
2000	590	0.0000	0.2500	0.0335	0.0535
2001	551	0.0000	0.2578	0.0250	0.0476
2002	861	0.0000	0.3750	0.0262	0.0527
2003	767	0.0000	0.3750	0.0308	0.0620
2004	752	0.0000	0.3296	0.0318	0.0609
2005	858	0.0000	0.3301	0.0246	0.0506
2006	748	0.0000	0.3809	0.0227	0.0514
2007	828	0.0000	0.2896	0.0158	0.0368
2008	737	0.0000	0.3751	0.0186	0.0426
2009	694	0.0000	0.2806	0.0250	0.0516
2010	658	0.0000	0.3857	0.0229	0.0518
2011	820	0.0000	0.2998	0.0290	0.0567
2012	605	0.0000	0.3254	0.0251	0.0476
2013	607	0.0000	0.4035	0.0309	0.0535
2014	630	0.0000	0.3312	0.0246	0.0414
2015	430	0.0000	0.3269	0.0261	0.0466
2016	122	0.0000	0.3474	0.0311	0.0472
2017	4	0.0123	0.0279	0.0202	0.0069

2.4 Descriptive statistics of inbreeding coefficient of *inbred* animals by year

This section presents the summary statistics of inbreeding coefficients of *inbred* animals by year of birth. The columns in the table are:

No. of animals : all *inbred* animals born in a given year.

Min : the lowest inbreeding coefficient among in-

bred animals.

Max : the highest inbreeding coefficient.

Avg F : the mean inbreeding coefficient.

Std : the standard deviation of inbreeding coefficients.

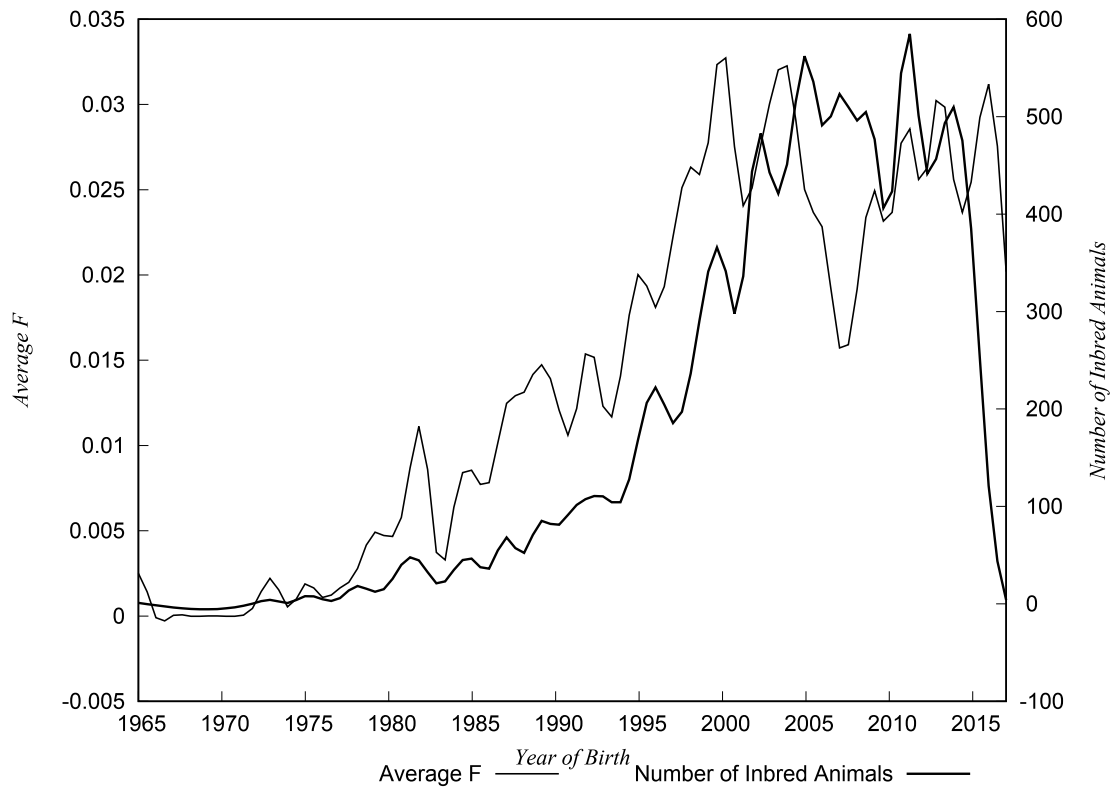
Table 5: Inbreeding coefficients (F) of INBRED animals by year

Year	No of Animals	F			
		Min	Max	Avg	Std
1965	1	0.2500	0.2500	0.2500	-
1972	1	0.2500	0.2500	0.2500	-
1973	4	0.1250	0.2500	0.2188	0.0625
1974	1	0.2500	0.2500	0.2500	-
1975	8	0.0625	0.1250	0.1094	0.0289
1976	5	0.0625	0.1250	0.1000	0.0342
1977	5	0.0625	0.2500	0.1375	0.1027
1978	18	0.0078	0.2500	0.0673	0.0519
1979	13	0.0313	0.2500	0.1394	0.0977
1980	20	0.0078	0.2500	0.1012	0.0889
1981	45	0.0078	0.2500	0.0823	0.0634
1982	41	0.0078	0.2500	0.1223	0.0827
1983	20	0.0078	0.2500	0.0715	0.0616
1984	37	0.0078	0.2500	0.0753	0.0844
1985	46	0.0039	0.2500	0.0761	0.0700
1986	36	0.0027	0.2500	0.0755	0.0731
1987	68	0.0078	0.3125	0.0757	0.0669
1988	51	0.0039	0.2500	0.0941	0.0862
1989	83	0.0029	0.2500	0.0740	0.0716
1990	80	0.0005	0.2500	0.0671	0.0714
1991	97	0.0012	0.2500	0.0512	0.0562
1992	109	0.0029	0.3125	0.0636	0.0672
1993	109	0.0010	0.2524	0.0484	0.0579
1994	107	0.0020	0.2813	0.0513	0.0666
1995	173	0.0001	0.3125	0.0595	0.0721
1996	222	0.0010	0.2656	0.0428	0.0599
1997	186	0.0005	0.3125	0.0479	0.0676
1998	228	0.0002	0.3750	0.0536	0.0704
1999	329	0.0002	0.2656	0.0459	0.0567
2000	357	0.0002	0.2500	0.0553	0.0593
2001	303	0.0001	0.2578	0.0455	0.0564
2002	476	0.0002	0.3750	0.0474	0.0634
2003	429	0.0001	0.3750	0.0551	0.0744
2004	465	0.0000	0.3296	0.0514	0.0706
2005	563	0.0000	0.3301	0.0375	0.0584
2006	490	0.0000	0.3809	0.0346	0.0602
2007	523	0.0000	0.2896	0.0250	0.0438
2008	496	0.0000	0.3751	0.0277	0.0495

Continue...

Year	No of Animals	F			
		Min	Max	Avg	Std
2009	490	0.0000	0.2806	0.0354	0.0583
2010	400	0.0000	0.3857	0.0378	0.0621
2011	589	0.0002	0.2998	0.0404	0.0633
2012	461	0.0001	0.3254	0.0330	0.0521
2013	471	0.0001	0.4035	0.0398	0.0578
2014	506	0.0002	0.3312	0.0306	0.0442
2015	362	0.0004	0.3269	0.0310	0.0493
2016	111	0.0011	0.3474	0.0342	0.0484
2017	4	0.0123	0.0279	0.0202	0.0069

Figure 2: Comparison between the average inbreeding coefficients (F) and the number of inbred animals by year



3 Effective Population Size

3.1 Effective Population Size based on the rate of inbreeding

Effective population size (N_e) is the number of individuals that would give rise to the observed or calculated rate of inbreeding (ΔF), if they bred in the manner of the idealized population (Falconer & Mackay, 1996). The N_e is a measure of genetic diversity within a population. It is therefore an important parameter in breeding of domestic animals and planning strategies for conservation of endangered animal and plant species (Nomura, 2002). This section presents effective population size calculated using $N_e = 1/2\Delta F$. The rate of inbreeding per generation (ΔF) was calculated using

$$\Delta F = \frac{F_t - F_{t-1}}{1 - F_{t-1}}$$

where F_t and F_{t-1} are the average inbreeding of offspring and their parents, respectively (Falconer & Mackay, 1996). The columns in the table are:

Avg F Animals : average inbreeding coefficient for animals born in a given year.

Avg F Sires : average inbreeding coefficient for sires of animals born in a given year.

Avg F Dams : average inbreeding coefficient for dams of animals born in a given year.

Avg F Parents : average inbreeding coefficient for sires and dams of animals born in a given year.

ΔF : the rate of inbreeding per generation.

N_e : the effective population size.

Note: The effective population size was not computed for $\Delta F = 0$ since it is undefined.

Table 6: Effective population size by year via rate of inbreeding

Year	Avg F				ΔF	N_e
	Animals	Sires	Dams	Parents		
1951	-	-	-	-	-	-
1952	-	-	-	-	-	-
1954	-	-	-	-	-	-
1959	-	-	-	-	-	-
1960	0.0000	0.0000	0.0000	0.0000	0.0000	-
1961	0.0000	0.0000	0.0000	0.0000	0.0000	-
1962	0.0000	0.0000	0.0000	0.0000	0.0000	-
1963	0.0000	0.0000	0.0000	0.0000	0.0000	-
1964	0.0000	0.0000	0.0000	0.0000	0.0000	-
1965	0.0011	0.0000	0.0000	0.0000	0.0011	466
1966	0.0007	0.0000	0.0000	0.0000	0.0007	704
1967	0.0005	0.0000	0.0017	0.0008	-0.0003	-1800
1968	0.0004	0.0000	0.0012	0.0006	-0.0002	-2622
1969	0.0003	0.0000	0.0009	0.0005	-0.0001	-4497
1970	0.0003	0.0000	0.0007	0.0003	0.0000	-10012
1971	0.0000	0.0000	0.0006	0.0003	-0.0003	-1722
1972	0.0002	0.0000	0.0005	0.0002	0.0000	-11672
1973	0.0008	0.0000	0.0000	0.0000	0.0008	656
1974	0.0008	0.0000	0.0000	0.0000	0.0008	660
1975	0.0011	0.0000	0.0003	0.0001	0.0009	530
1976	0.0012	0.0000	0.0002	0.0001	0.0010	476
1977	0.0013	0.0000	0.0002	0.0001	0.0012	402
1978	0.0016	0.0000	0.0002	0.0001	0.0016	322
1979	0.0020	0.0000	0.0002	0.0001	0.0019	266
1980	0.0027	0.0000	0.0003	0.0001	0.0026	194

Continue...

Year	Avg F				ΔF	N_e
	Animals	Sires	Dams	Parents		
1981	0.0037	0.0005	0.0007	0.0006	0.0031	161
1982	0.0053	0.0005	0.0012	0.0008	0.0045	112
1983	0.0055	0.0007	0.0016	0.0012	0.0044	115
1984	0.0063	0.0007	0.0023	0.0015	0.0048	104
1985	0.0068	0.0008	0.0030	0.0019	0.0050	101
1986	0.0073	0.0010	0.0035	0.0022	0.0051	98
1987	0.0082	0.0008	0.0036	0.0022	0.0060	83
1988	0.0084	0.0020	0.0035	0.0027	0.0057	87
1989	0.0106	0.0028	0.0038	0.0033	0.0074	68
1990	0.0116	0.0046	0.0040	0.0043	0.0073	68
1991	0.0120	0.0060	0.0039	0.0050	0.0071	70
1992	0.0133	0.0083	0.0045	0.0063	0.0070	72
1993	0.0132	0.0095	0.0051	0.0073	0.0059	84
1994	0.0134	0.0120	0.0061	0.0089	0.0045	111
1995	0.0145	0.0143	0.0076	0.0108	0.0038	133
1996	0.0154	0.0142	0.0083	0.0111	0.0044	115
1997	0.0172	0.0151	0.0095	0.0122	0.0051	99
1998	0.0190	0.0135	0.0103	0.0118	0.0072	69
1999	0.0217	0.0126	0.0120	0.0123	0.0095	53
2000	0.0248	0.0104	0.0127	0.0116	0.0134	37
2001	0.0256	0.0102	0.0131	0.0117	0.0140	36
2002	0.0269	0.0112	0.0141	0.0128	0.0143	35
2003	0.0282	0.0129	0.0150	0.0140	0.0144	35
2004	0.0291	0.0153	0.0165	0.0160	0.0133	38
2005	0.0285	0.0182	0.0171	0.0176	0.0111	45
2006	0.0269	0.0207	0.0186	0.0196	0.0075	67
2007	0.0252	0.0227	0.0199	0.0211	0.0041	121
2008	0.0240	0.0243	0.0217	0.0229	0.0011	441
2009	0.0230	0.0256	0.0230	0.0242	-0.0013	-396
2010	0.0215	0.0272	0.0236	0.0252	-0.0038	-132
2011	0.0223	0.0269	0.0250	0.0258	-0.0036	-137
2012	0.0226	0.0257	0.0249	0.0253	-0.0027	-184
2013	0.0252	0.0246	0.0261	0.0254	-0.0002	-2419
2014	0.0263	0.0244	0.0260	0.0252	0.0011	448
2015	0.0266	0.0230	0.0258	0.0245	0.0022	232
2016	0.0275	0.0219	0.0261	0.0241	0.0035	144
2017	0.0269	0.0221	0.0261	0.0241	0.0029	175

3.2 Effective population size based on the number of parents

This section presents the effective population size calculated based on the number of parents. The following formula was used to calculate N_e (Falconer & Mackay, 1996):

$$N_e = \frac{4N_m N_f}{N_m + N_f} * .7$$

where N_m and N_f are the number of male and female parents, respectively.

Accounting for mass selection as proposed by Caballero (1994) yields the added factor of .7 assuming that selection is on a trait with a heritability of .4 .

The above formula refers to the number of breeding males and females in a population with discrete generations. Here, we identify a generation of animals as those animals born in the time span of one generation interval (GI window) which ends in the reporting year. The parents of animals born in this GI window are then entered in the above equation to compute the N_e for each reporting year as listed in the table.

Thus, a sliding window will run over the years

counting all animals born in that window and their sires and dams. To obtain the number of years involved in that GI window go to the population report and find the total generation interval which is the last figure at the bottom of table 5.

This setup implies that the number of parents in consecutive reporting years will include, in part, to the same animals.

The columns in the table are:

Number of animals : born in GI window ending in the reporting year

Number of sires : of animals born in the GI window

Number of dams : of animals born in the GI window

Number of parents : number of sires plus dams of animals born in the GI window

Ne : effective population size in the reporting year

Table 7: Effective population size by year via number of parents

Year	Number of				N_e
	Animals	Sires	Dams	Parents	
1951	1	1	1	2	1
1952	2	1	1	2	1
1954	3	1	1	2	1
1959	2	1	1	2	1
1960	5	2	2	4	3
1961	12	2	2	4	3
1962	18	4	3	7	5
1963	73	8	6	14	10
1964	135	11	9	20	14
1965	233	32	45	77	52
1966	352	43	93	136	82
1967	475	58	146	204	116
1968	620	73	197	270	149
1969	735	88	254	342	183
1970	845	104	333	437	222
1971	976	120	398	518	258
1972	1214	128	457	585	280
1973	1475	129	545	674	292
1974	1814	153	689	842	351
1975	2093	161	834	995	378
1976	2381	166	1015	1181	399
1977	2580	175	1164	1339	426

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Year	Number of				<i>N_e</i>
	Animals	Sires	Dams	Parents	
1978	2696	184	1315	1499	452
1979	2680	189	1363	1552	465
1980	2627	184	1437	1621	457
1981	2712	182	1562	1744	456
1982	2713	183	1580	1763	459
1983	2753	177	1610	1787	447
1984	2680	177	1656	1833	448
1985	2716	185	1729	1914	468
1986	2628	189	1714	1903	477
1987	2511	181	1670	1851	457
1988	2418	187	1680	1867	471
1989	2367	181	1628	1809	456
1990	2378	182	1552	1734	456
1991	2423	163	1557	1720	413
1992	2511	160	1579	1739	407
1993	2544	157	1555	1712	399
1994	2547	152	1533	1685	387
1995	2641	145	1581	1726	372
1996	2750	145	1637	1782	373
1997	2699	143	1580	1723	367
1998	2726	146	1613	1759	375
1999	2840	154	1652	1806	394
2000	3059	159	1782	1941	409
2001	3098	176	1830	2006	450
2002	3435	185	2114	2299	476
2003	3797	187	2395	2582	486
2004	4085	189	2631	2820	494
2005	4379	206	2889	3095	538
2006	4537	217	3079	3296	568
2007	4814	242	3337	3579	632
2008	4690	247	3334	3581	644
2009	4617	254	3314	3568	661
2010	4523	257	3310	3567	668
2011	4485	284	3307	3591	732
2012	4342	283	3229	3512	729
2013	4121	291	3055	3346	744
2014	4014	299	2991	3290	761
2015	3750	289	2845	3134	735
2016	3214	274	2477	2751	691
2017	2398	230	1947	2177	576

4 The Average and Rate of Additive Genetic Relationships by year

The coefficient of inbreeding (F) of an individual is equal to the additive genetic relationship (AGR) between its parents or the coefficient of co-ancestry *i.e.* $F_i = f_{sd}$ where i is the individual and s and d are its sire and dam respectively (Falconer & Mackay, 1996). Under random mating, the rate of inbreeding (ΔF) is equal to the rate of additive genetic relationships (Δf). Thus, the effective size (Ne) can be obtained from either $\frac{1}{2\Delta F}$ or $\frac{1}{2\Delta f}$. Therefore, the discrepancy between the two effective sizes indicates a deviation from a random mating system.

In this report, the additive genetic relationships were computed using the PEDIG Fortran Package of Boichard (2002) and specifically the *par3.f* program (see the PEDIG manual for details). Briefly, the average additive genetic relationship among individuals within a group (*e.g.* animals born in a given year) is computed as the average inbreeding of the progeny of all possible matings among the individuals. Two steps were followed to calculate the rate of AGR (Δf) per generation or for animals born in a given year and a generation earlier. Firstly, the generation interval for animals born in a given year was calculated as the average age of their parents they were born. Secondly, the generation interval was subtracted from the year of birth of the current cohort to obtain the year of birth of the cohort born a generation earlier. Thus, the rate of additive genetic relationship is:

$$\Delta f = \frac{f_t - f_{t-1}}{1 - f_{t-1}}$$

where f_t and f_{t-1} are the average additive genetic relationship of the cohort born in generation t (or

the current year) and the cohort born a generation earlier.

The number of animals born in the cohort beginning with the reporting year as well their average AGR and inbreeding and their rate is presented in the Table. Notice that the AGR value reported is the average of all possible matings between males and females in the cohort. Thus, with 1000 males and 2000 females in the cohort this average is based on $1000 * 2000 = 2000000$ additive genetic relationships. The generation interval between this cohort and their parents is also presented. The average and rate of inbreeding and AGR are also presented in the Figures below. The effective population size based on the rate of AGR (computed as a regression of AGR on year) over the entire period is also presented.

Note: Due to computer hardware constraints, datasets with huge numbers of animals will be shortened preventing weeks of computation. The currently implemented algorithm is based on the number of acceptable computations in terms of CPU time:

$$2000male * 2000female = 4000000computations$$

This should give a sufficiently precise estimate of the average AGR.

Operationally, from cohorts larger than 2000 males and 2000 females 2000 males and 2000 females as picked through a random number generator, thereby cutting the files to be processed down to a size which can computationally be handled.

The affected years will be documented in the coverpages of this report. Please refer to this information.

Table 8: Average Additive Genetic Relationships (AGR)

Year	No Animals	AGR		F		Generation Interval
		Avg	Δf	Avg	ΔF	() = True GI
1951	1	0.00000	-	0.00000	-	-
1952	2	0.00000	-	0.00000	-	-
1953	-	-	-	-	-	-
1954	3	0.00000	-	0.00000	-	-
1955	-	-	-	-	-	-
1956	-	-	-	-	-	-
1957	-	-	-	-	-	-
1958	-	-	-	-	-	-
1959	2	0.00000	-	0.00000	-	-
1960	5	0.00000	0.00000	0.00000	0.00000	6 (-)

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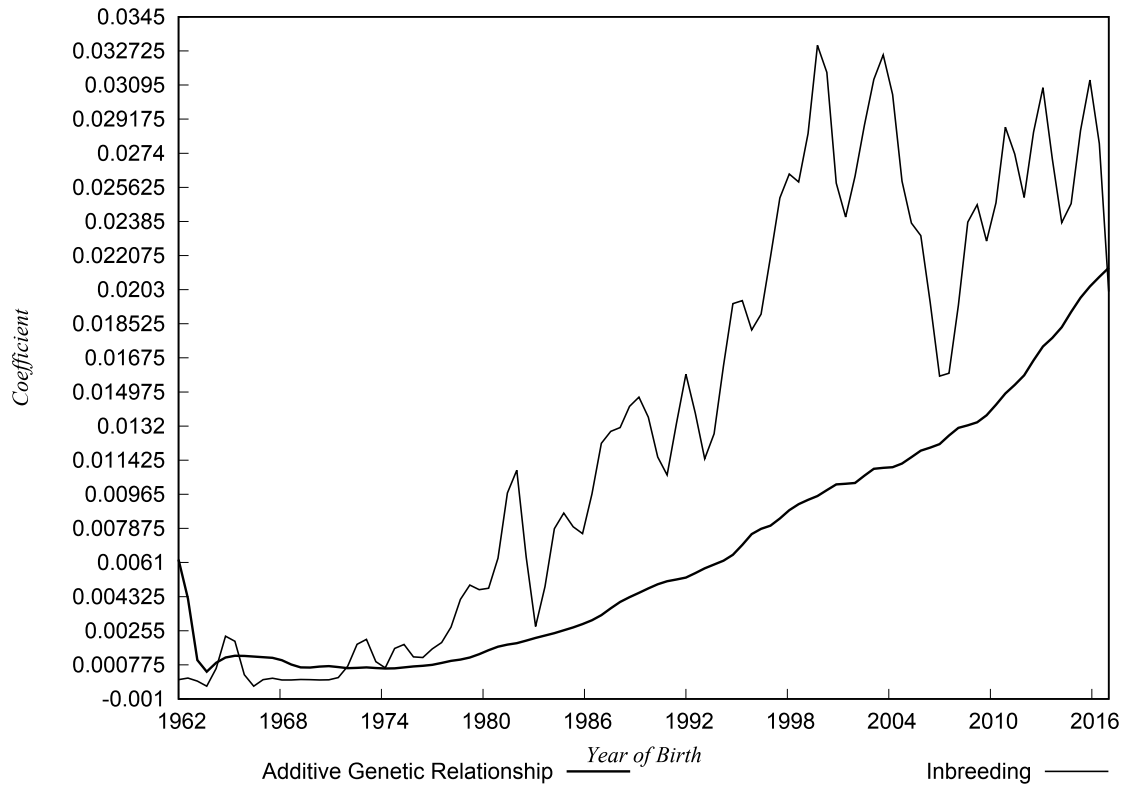
Year	No Animals	AGR		F		Generation Interval
		Avg	Δf	Avg	ΔF	() = True GI
1961	12	0.00000	-	0.00000	-	-
1962	18	0.00625	-	0.00000	-	-
1963	73	0.00147	-	0.00000	-	2 (2.1)
1964	135	0.00070	-	0.00000	-	2 (2.0)
1965	233	0.00121	0.00121	0.00250	0.00250	2 (2.3)
1966	352	0.00123	0.00123	0.00000	0.00000	6 (-)
1967	475	0.00117	0.00117	0.00000	0.00000	6 (-)
1968	620	0.00105	-0.00523	0.00000	0.00000	3 (2.6)
1969	735	0.00068	-0.00079	0.00000	0.00000	3 (3.3)
1970	845	0.00065	-0.00005	0.00000	0.00000	4 (3.6)
1971	976	0.00070	-0.00051	0.00000	-0.00251	4 (3.5)
1972	1214	0.00060	-0.00064	0.00070	0.00070	4 (4.2)
1973	1475	0.00064	-0.00053	0.00220	0.00220	4 (4.0)
1974	1814	0.00059	-0.00046	0.00050	0.00050	4 (3.9)
1975	2093	0.00061	-0.00008	0.00190	0.00190	5 (4.6)
1976	2381	0.00070	0.00005	0.00110	0.00110	5 (4.8)
1977	2580	0.00077	0.00006	0.00160	0.00160	5 (5.2)
1978	2696	0.00096	0.00037	0.00250	0.00180	6 (5.8)
1979	2680	0.00110	0.00045	0.00480	0.00261	6 (5.9)
1980	2627	0.00141	0.00082	0.00460	0.00410	5 (5.4)
1981	2712	0.00175	0.00115	0.00690	0.00501	6 (5.7)
1982	2713	0.00190	0.00120	0.01090	0.00981	6 (5.5)
1983	2753	0.00215	0.00138	0.00300	0.00140	6 (6.1)
1984	2680	0.00237	0.00141	0.00690	0.00441	6 (6.0)
1985	2716	0.00263	0.00153	0.00850	0.00372	6 (6.2)
1986	2628	0.00293	0.00153	0.00780	0.00321	7 (6.5)
1987	2511	0.00336	0.00161	0.01230	0.00544	7 (6.6)
1988	2418	0.00399	0.00209	0.01300	0.00212	7 (6.7)
1989	2367	0.00443	0.00229	0.01470	0.01174	7 (6.7)
1990	2378	0.00484	0.00247	0.01290	0.00604	7 (6.8)
1991	2423	0.00515	0.00253	0.01090	0.00242	7 (6.9)
1992	2511	0.00532	0.00240	0.01590	0.00816	7 (7.0)
1993	2544	0.00575	0.00240	0.01170	-0.00061	7 (7.1)
1994	2547	0.00611	0.00213	0.01480	0.00182	7 (6.9)
1995	2641	0.00668	0.00226	0.02010	0.00548	7 (6.7)
1996	2750	0.00766	0.00283	0.01810	0.00527	7 (6.9)
1997	2699	0.00802	0.00288	0.02200	0.01122	7 (7.0)
1998	2726	0.00874	0.00343	0.02630	0.01057	7 (6.6)
1999	2840	0.00928	0.00355	0.02680	0.01528	6 (6.3)
2000	3059	0.00967	0.00358	0.03350	0.01898	7 (6.7)
2001	3098	0.01019	0.00353	0.02500	0.00500	6 (6.2)
2002	3435	0.01024	0.00261	0.02620	0.00825	7 (7.1)
2003	3797	0.01093	0.00294	0.03080	0.00900	7 (6.8)
2004	4085	0.01103	0.00231	0.03180	0.00565	7 (6.8)
2005	4379	0.01137	0.00211	0.02460	-0.00226	7 (6.8)
2006	4537	0.01197	0.00232	0.02270	-0.01117	7 (6.7)
2007	4814	0.01226	0.00209	0.01580	-0.00944	7 (7.0)
2008	4690	0.01305	0.00284	0.01860	-0.00780	7 (6.6)

Continue...

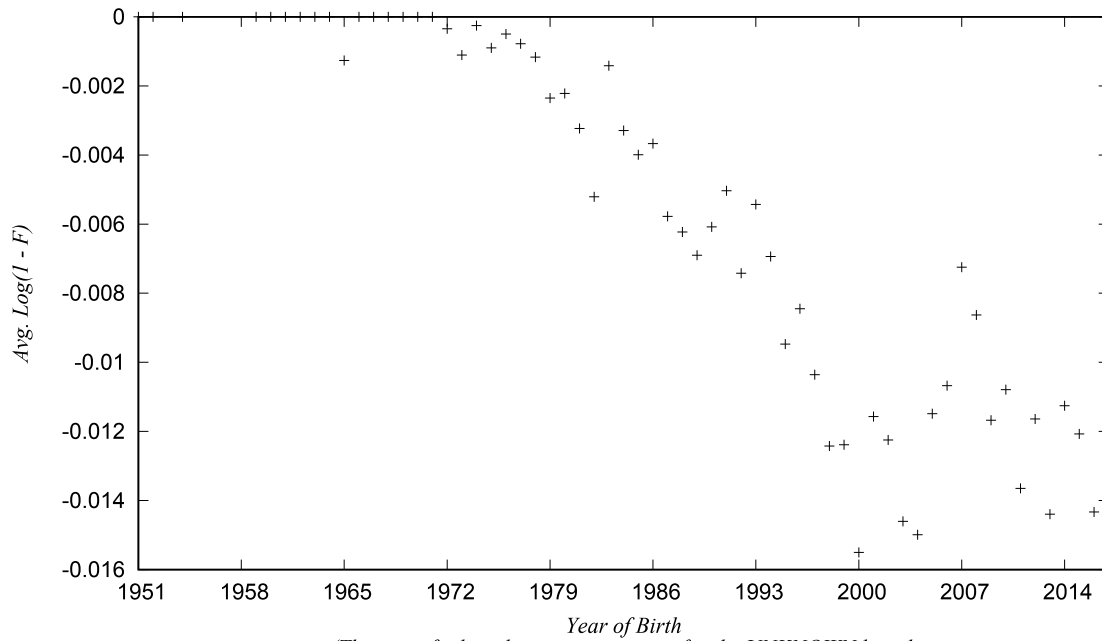
Year	No Animals	AGR		<i>F</i>		Generation Interval
		Avg	Δf	Avg	ΔF	() = True GI
2009	4617	0.01331	0.00240	0.02500	-0.00598	7 (6.9)
2010	4523	0.01396	0.00296	0.02290	-0.00919	7 (6.8)
2011	4485	0.01500	0.00367	0.02900	0.00451	7 (6.9)
2012	4342	0.01584	0.00392	0.02510	0.00246	6 (6.0)
2013	4121	0.01723	0.00503	0.03090	0.01534	7 (7.3)
2014	4014	0.01808	0.00510	0.02460	0.00611	8 (8.4)
2015	3750	0.01946	0.00624	0.02610	0.00113	6 (-)
2016	3214	0.02057	0.00670	0.03110	0.00839	6 (-)
2017	2398	0.02144	0.00654	0.02020	-0.00906	6 (-)

Fixed Time interval used to calculate Delta AGR: 6

Figure 3: Average Additive Genetic Relationships and Inbreeding Coefficients by year of birth

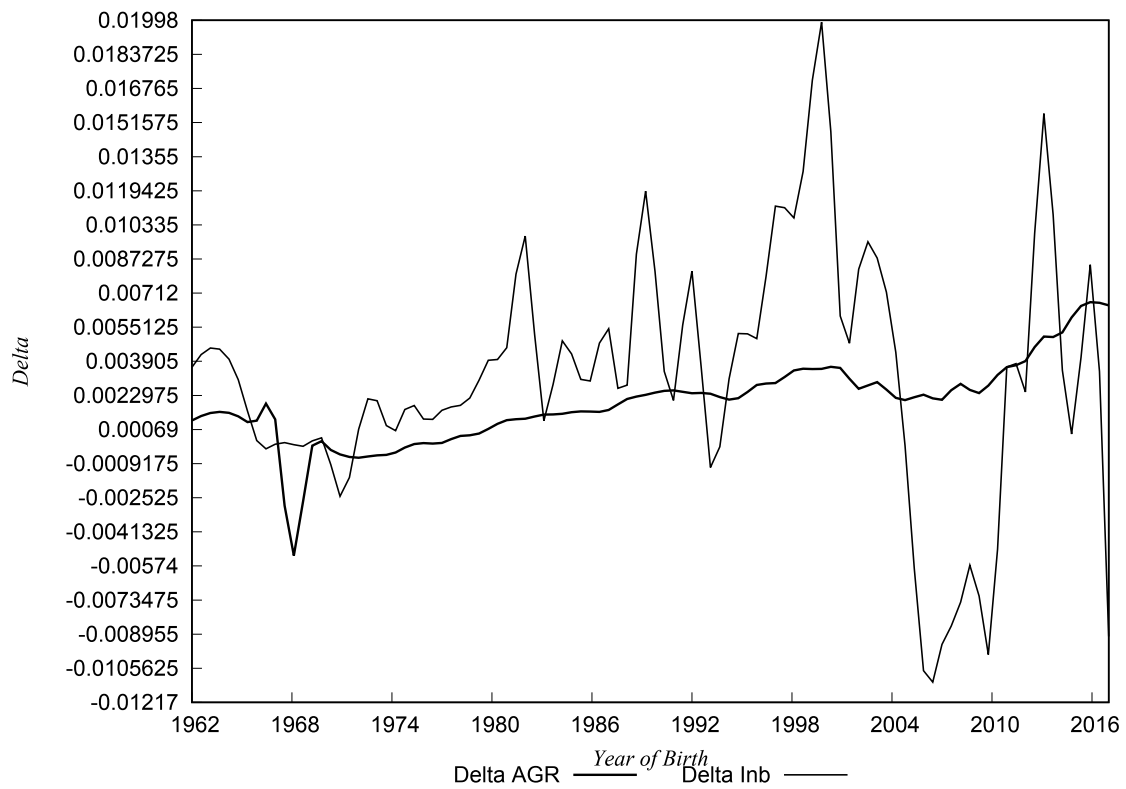


The average rate of change of the additive genetic relationships between 1962 and 2017 for the UNKNOWN breed was 0.00034 per year based on the slope of the regression fitted. This result in a Δf per generation of 0.00208. The rate of change of the average inbreeding coefficients based on the slope of the regression between 1962 and 2017 was 0.00063, which represents a ΔF per generation of 0.00386. The effective population sizes for the UNKNOWN breed, based on Δf and ΔF were 240 and 130, respectively.

Figure 4: Average $\text{Log}(1-F)$ by year of birth for animals born between 1951 and 2017.

(The rate of inbreeding per generation for the UNKNOWN breed, based on the Log(1-Inbreeding) is 0.0044 which presents an N_e of 114. Calculations were performed on 24773 animals born between 1951 and 2017.)

Figure 5: The Rate of Inbreeding and Increase in the Additive Genetic Relationships by year of birth



PopReport

A Population Monitoring Report

Population: UNKNOWN
Inputfile: POPREP.TXT
Initiated by: quaglia@anabic.it
Submitted at: 2019-08-26 08:50:27
Started at: 2019-08-26 08:51:01
Finished at: 2019-08-26 09:08:12

Courtesy: Department of Animal Breeding and Genetics
Institute of Farm Animal Genetics (FLI)
Eildert.Groeneveld@gmx.de
Höltystasse 10
D-31535 Mariensee, Germany
<http://popreport.fli.de>

Some Notes About Your PopReport Job:

- INFO: This job ran on machine rie-ex-web160 with 12 CPUs and MemTotal: 32950668 kB
- INFO: Your entered dateformat was 'YYYYMMDD', your dateseparator 'undef'.
24773 input lines processed.
24773 animals accepted.
- INFO: (concerning Inbreeding Report)
No shortening of infiles for the AGR computations done.

Monitoring the Population UNKNOWN

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August 26, 2019

Methods in monitoring breeding populations

A number of methods are available to estimate the effective population size on the basis of pedigrees. When it comes to monitoring animal genetic resources not all methods are equally well suited. Further, depending on the conditions in the population under consideration, different methods may have to be chosen. Issues requiring possibly different methods to be chosen are e.g. sub population

stratification, pedigree completeness, and sampling. Guidelines on the appropriate choice are given below.

Table 1 presents six methods for census and pedigree based N_e estimates. For details see Groeneveld et al. (2009) and Gutiérrez et al. (2009). Based on the rates computed, the N_e is estimated as $N_e = \frac{1}{2 \times \Delta F^*}$ for the pedigree based methods.

Table 1: Methods for estimating the effective population size N_e

Method	Source	Formula	Description
N_e -Cens	Wright (1923)	$N_e = 4 * \frac{S_n * D_n}{S_n + D_n} * 0.7$	S_n = number of sires per generation, D_n = number of dams per generation
N_e - ΔF_p	Falconer & Mackay (1996)	$\Delta F_p = \frac{F_t - F_{t-1}}{1 - F_{t-1}}$	$F_t = \circlearrowleft$ inbreeding coefficient of offspring, $F_{t-1} = \circlearrowleft$ inbreeding coefficient of direct parents
N_e - ΔF_g	Falconer & Mackay (1996)	$\Delta F_g = \frac{F_t - F_{t-1}}{1 - F_{t-1}}$	$F_{t-1} = \circlearrowleft$ inbreeding coefficient of the \circlearrowleft parents generation
N_e -Coan	Falconer & Mackay (1996)	$\Delta f_g = \frac{f_t - f_{t-1}}{1 - f_{t-1}}$	$f_t = \circlearrowleft$ additive genetic relationship (AGR) of offspring, $f_{t-1} = \circlearrowleft$ AGR of parents
N_e -Ln	Pérez-Enciso (1995)	$\Delta F_{ln} = (-1)bL$	b = slope from the logarithmic regression of $\ln(1 - F)$ on year of birth, L = generation interval
N_e -Ecg	Gutiérrez et al. (2009)	$\Delta F_i = 1 - \text{ecg}_i^{-1} \sqrt{1 - F_i}$	ecg = sum of all known ancestors with $(\frac{1}{2})^n$, F_i = individual inbreeding coefficient

Choosing the best method

Given the number of methods available, a decision has to be taken on the choice of the most appropriate method for the population under consideration.

Populations are often monitored for effective population size with the objective to start an action once the size falls below some threshold. This may be the start of a management program or the establishment of a gene bank.

In this situation it is important to obtain an estimate from a method which can respond quickly to changes in population size. Different methods use time windows of different length. Thus, the method with the shortest window is best suited for our monitoring purposes.

There is, however, one other aspect which requires attention before considering the time window: we have two different classes of pedigree based methods: the first is based on inbreeding while the second computes the coancestry of an hypothetical contemporary breeding population. With random mating both are expected to produce the same results. If

however there is a population stratification, i.e. selection within herds with little exchange of breeding stocks, then the average inbreeding will be high but the coancestry across the whole population will be much smaller. In this case the latter method better reflects the loss of genetic diversity in the complete breeding population.

For this reason the decision tree for picking the best method consists of these two major steps:

1. test for population stratification such as selection within herds
2. among the remaining methods chose the one requiring the shortest data history

The choice among the remaining methods is based on the window length required for the N_e computation. As can be seen from the Figure A the methods require data windows with different lengths and will, thus, respond to rapid changes in population size with different sensitivity. Ordering them according to the window length and putting the least appropriate N_e -Cens last, gives Table 2.

Figure 1: Data history on which the respective N_e estimate is based for each of the six N_e -methods

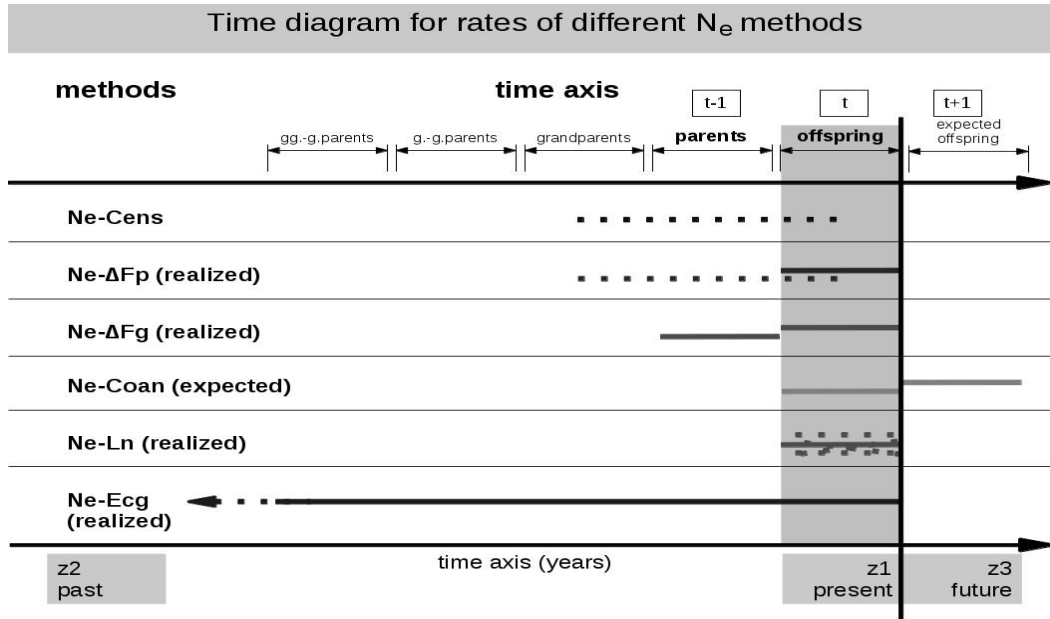


Table 2: Order of methods in cascade

Method	Based on data from
N_e -Ln	animals born in generation t
N_e - ΔF_p	animals and their parents born in generation t
N_e - ΔF_g	animals born in generation t and $t - 1$
N_e -Coan	animals born in generation $t + 1$ and t
N_e -Ecg	animals with their complete ancestors born in generation t
N_e -Cens	parents of animals born in generation t

Thus, N_e -Ln will be chosen by default. However, if the side conditions are not met, then the second shortest N_e - ΔF_p will be considered, again looking at the side condition, and so on.

The required side conditions are the completeness of N_e and a relatively stable development of the N_e

from one year to the next. Due to random processes the rate of inbreeding can be negative, resulting in a negative N_e , which is clearly meaningless and leads to the rejection of the method.

Further, if the N_e changes drastically from one year to the next, this is also considered dubious.

Defining the side condition

We are assuming a yearly assessment of the effective population size N_e . Thus, we are using reporting years, where the most recent year is the relevant one to assess the population size. However, populations can have very different generation intervals. As indicated in Figure 6 the minimum time an N_e estimate is based on is one generation interval. Above, we have given the reasoning for choosing a method. However, a few more conditions need to be determined. When looking at the N_e estimates across reporting years, it is clear that they vary pos-

sibly considerably from one year to the next due to sampling. This variation will even lead to negative N_e estimates which do not make sense. While presenting these in Table 3 and 4 as actual negative numbers we define a side condition that for one generation interval we must not have an undefined or missing estimate. Table 4 shows the actual estimates for one generation interval, one line for each reporting year. Thus, we define **side condition 1** as: "**neither missing nor negative N_e in any reporting year for the length of one generation interval**". As an example, with a generation interval of 7 years, none of the last 7 years must

have a negative N_e .

Negative estimates are actually a special case of the more general side condition 2, which addresses variability of the N_e estimates: if one method has a much smaller variation in N_e estimates, we would be much more comfortable using this than others that are worse in stability. Thus, side condition 2 determines a threshold as far as variability of the estimates go for a method to be discarded. Here, we have chosen the square root of the residual after fitting a linear regression to the yearly N_e estimates. The cut off point for rejecting a method is set to $20 N_e$. This means that the **side condition 2 sets the standard error of the estimate to $20 N_e$** which is actually quite large.

For populations with very short generation intervals, like one year, we would not have a means of assessing the variability of the estimates, because on the basis of side condition 1 we would have only one data point. Thus, a minimum of 4 years, i.e. datapoints are required.

Five of the six methods are based on the rate of inbreeding while N_e -Coan is based on the additive genetic relationship. A test on population stratification can be made based on the consistent difference in population size between methods N_e -Coan and N_e - ΔFg . These two means are computed on the respective N_e across all years as defined above.

Summing up we have introduced:

side condition 1: neither missing no negative N_e estimates over the last number of years of the generation interval length but a minimum of 4 years

side condition 2: standard error of the estimate of a linear fit over the reporting years included in side condition 1 must not get larger than $20 N_e$.

It must be noted that the side conditions are pure heuristics and that different users may want to use different values.

We even consider it advisable to critically evaluate the selection procedure for an N_e each time a statement about the population size is made.

The decision tree in detail

Data for executing the decision tree are given in Table 4. It gives the input data for the decision tree

with as many years as constitute one generation interval. The last line gives the standard error of the estimate from a linear regression of N_e on years.

Table 5 provides the data used in the side conditions.

The first line in the body of Table 5 gives the difference between N_e -Coan and N_e - ΔFg which is used to assess population stratification. This is followed by the 6 methods with the completeness and stability column. The last column shows an 'OK', if the side conditions as described above are met. If a user decides that a certain cut off point should be modified, for instance changing the stability value from $20 N_e$ to 10, this can be done in this table and will likely change the last column. Numbers in red indicate that the current thresholds are not met, while all others are printed in green.

The cascade

The decision tree can be easily followed on the basis of Table 5. Actually, its entries have already been sorted: the most appropriate methods coming first with the census method being last if all others fail due to not meeting the side conditions.

Thus, executing the decision tree is simple: starting at the top of Table 5 the method which has the first 'yes' in the 'OK' column is the method of choice.

Population stratification

A comparison of N_e from inbreeding (N_e - ΔFg) and coancestry based (N_e -Coan) will give insight into whether something close to random mating is performed: both estimates should be rather similar. If however N_e -Coan is substantially larger, selection within herds can be assumed and this parameter be chosen. The investigator will probably be able to either substantiate or discard this claim. Figure 4 will give a quick overview about the situation: in such a case the slope of the N_e -Coan will be flatter.

Table 5 shows the decision going from top to bottom. The first line is an evaluation of the N_e - ΔFg . The entry in column 'OK' is set only to 'yes' if the N_e for the coancestry method N_e -Coan is numerically larger than for the inbreeding based N_e - ΔFg no matter how big the difference is and if the side conditions completeness and stability are met. This is equally arbitrary than the cut off points chosen for the side conditions 1 and 2. Other values (like a difference of 2) may be equally appropriate.

Deciding on the final method

Table 5 shows the decision going from top to bottom. The first line with a 'yes' in the 'OK' column represents the method of choice following the rational outlined above. As we go from one line to next, we move from the best choice to the next best. Where we encounter a 'no' under the 'OK' column, a side condition has not been met, and, thus, the method is disregarded. As outlined above, we have the two side conditions 'Completeness' and 'Stability' which are reflected in the two columns with the respective headings in Table 5. The entries to the 'Completeness' column are the pairs 'actually complete' vs 'total number' of years. Thus, '4/8' means that out of the required 8 years 4 estimates were positive.

The 'Stability' column gives the actual σ estimate along with the threshold much like the completeness column. Violations of the constraints are printed in red. A method is only 'OK' if both - and for N_e -Coan in line 1 all three - constraints are met.

Please note, that the most current year has to be complete as far as data goes. If you can provide data for some months only you should remove this year completely. Otherwise the computation of N_e might be incorrect.

It also has to be noted that the procedure chosen is heuristic in particular the threshold for the variability of the N_e . Thus, in the face of additional information on the breed considered a user may find a different choice more appropriate.

In any case, mostly it is important to be sure about the order of the population size and not so much about the value behind the decimal point.

A word of warning

Figure 2 provides counts per reporting year. The user should study them and relate them to the N_e estimates. Drastic changes should be reflected in the estimates. Also, in those cases N_e -Ecg will likely not

be a good procedure as it basically takes an average over the complete pedigree length.

Surprisingly, pedigrees are often quite incomplete which directly impacts on the utility of the methods. To assess the quality of the pedigree Figure 3 should be studied. Incomplete pedigrees will likely overestimate the population size. This will also be reflected by Figure 5 which will look more like a cluster of dots than something that looks like a regression line. Also, Figure 6 gives a visual impression how stable estimates are.

To some degree, the effect of incomplete pedigrees will be accounted for by the side conditions. But it is the obligation of the user to decide at which point an estimate still makes sense in the face of bad pedigrees.

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- [Wright, 1923] Wright, S. (1923). Mendelian analysis of the pure breeds of livestock. *J. Hered.*, (14):339–348.

Breed: UNKNOWN • 24773 pedigree records • generation interval: 6 • August 26, 2019

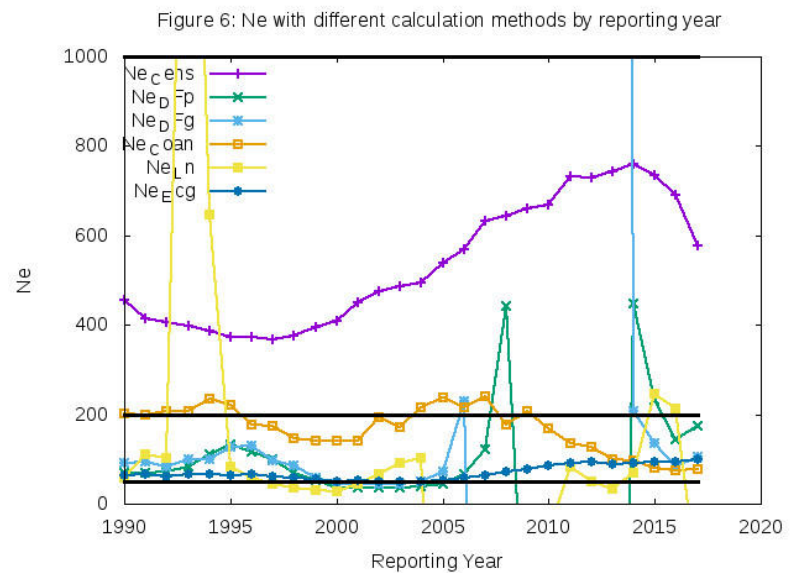
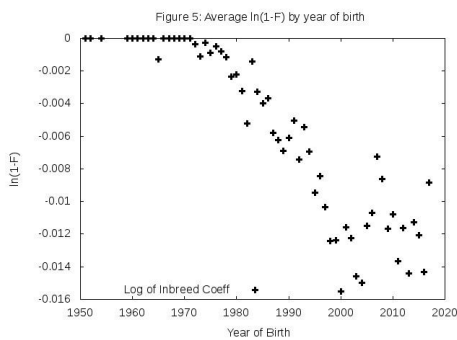
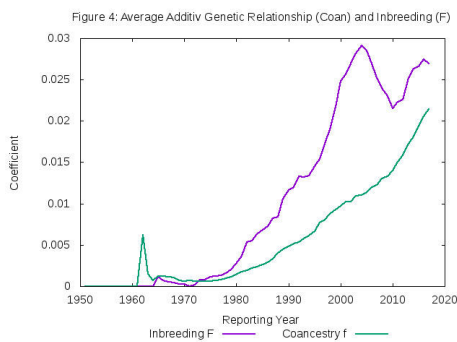
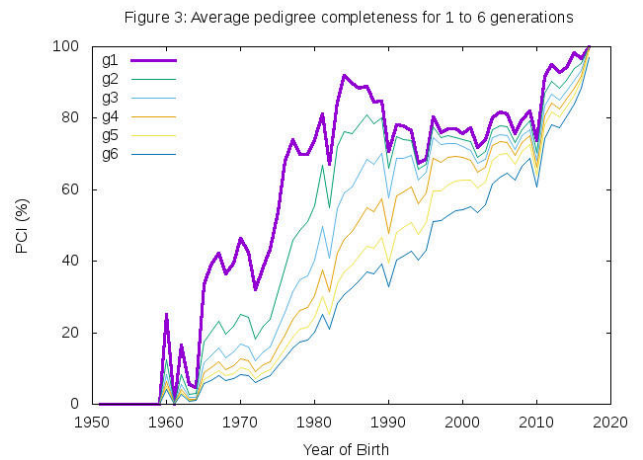
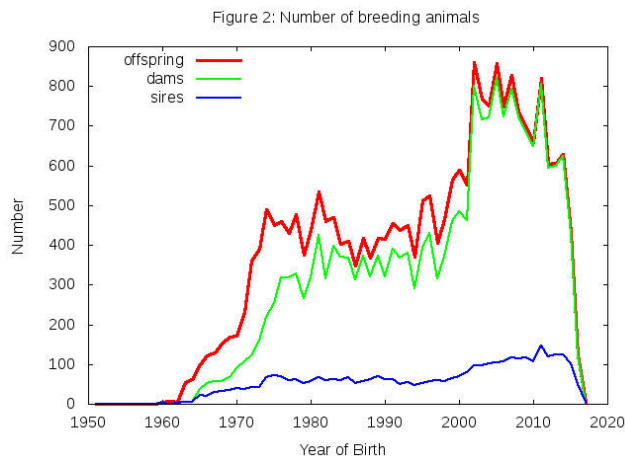


Table 3: Effective Population Size N_e

N_e -Method	2017	2016	2015	2014	2013	2012	data history
N_e -Cens	576	691	735	761	744	729	2011 – 2006
N_e - ΔF_p	175	144	232	448	-2419	-184	2017 – 2006
N_e - ΔF_g	106	82	136	206	16683	-114	2017 – 2006
N_e -Coan	76	75	80	98	99	128	2023 – 2012
N_e -Ln	-165	214	247	68	32	50	2017 – 2012
N_e -Ecg	99	95	94	90	89	94	2017 – 1951

Proposed N_e : N_e -Coan = 76

Note: The last year is assumed to have complete data!

Table 4: Decision tree for N_e calculation

Year	N_e -Cens	N_e - ΔF_p	N_e - ΔF_g	N_e -Coan	N_e -Ln	N_e -Ecg
2017	576	175	106	76	-165	99
2016	691	144	82	75	214	95
2015	735	232	136	80	247	94
2014	761	448	206	98	68	90
2013	744	-2419	16683	99	32	89
2012	729	-184	-114	128	50	94
σ	50.2	1064.8	6994.7	8.9	163.8	2.9

Table 5: Decision cascade – side conditions

Method	Completeness [Years]	Stability [σ]	Diff	OK
N_e -Coan ^a	11/12	8.9 6994.7/20	-2757.17	no
N_e -Ln	5/6	163.8/20	-	no
N_e - ΔF_p	4/6	1064.8/20	-	no
N_e - ΔF_g	5/6	6994.7/20	-	no
N_e -Coan	6/6	8.9/20	-	yes
N_e -Ecg	6/6	2.9/20	-	yes
N_e -Cens	6/6	50.2/20	-	no

^aAvg N_e -Coan – Avg N_e - ΔF_g : 92.67 - 2849.83 = -2757.17

PopReport

A Population Structure Report

Population: UNKNOWN
Inputfile: POPREP.TXT
Initiated by: quaglia@anabic.it
Submitted at: 2019-08-26 08:50:27
Started at: 2019-08-26 08:51:01
Finished at: 2019-08-26 09:08:12

Courtesy: Department of Animal Breeding and Genetics
Institute of Farm Animal Genetics (FLI)
Eildert.Groeneveld@gmx.de
Höltystasse 10
D-31535 Mariensee, Germany
<http://popreport.fli.de>

Some Notes About Your PopReport Job:

- INFO: This job ran on machine rie-ex-web160 with 12 CPUs and MemTotal: 32950668 kB
- INFO: Your entered dateformat was 'YYYYMMDD', your dateseparator 'undef'.
24773 input lines processed.
24773 animals accepted.
- INFO: (concerning Inbreeding Report)
No shortening of infiles for the AGR computations done.

Population Structure Report for Population: UNKNOWN

Department of Animal Breeding and Genetics
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August 26, 2019

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Contents

1	Number of breeding males and females by year	1
2	Age structure of parents by birth year of offspring	3
3	Distribution of parity of dams at birth of offspring	8
4	Generation interval	10
5	Family size	12

List of Tables

1	Number of sires and dams in reproduction by year of birth of offspring	1
2	Age distribution of males in reproduction by year of birth of their offspring	3
3	Age distribution of females in reproduction by year of birth of their offspring	6
4	Distribution of females by parity number	8
5	Generation interval and number of animals by year of birth for different selection paths .	10
6	The maximum and average number of family sizes	12

List of Figures

1	Dams with the most Progeny in the Population	14
2	Number of Progeny per Dam	15
3	Sires with the most Progeny in the Population	16
4	Number of Progeny per Sire	17
5	Dams with the most Selected Progeny in the Population	18
6	Number of Selected Progeny per Dam	19
7	Sires with the most Selected Progeny in the Population	20
8	Number of Selected Progeny per Sire	21

1 Number of breeding males and females by year

The number of breeding animals at a given time determines the genetic structure of the population in subsequent generations. Under simplified conditions (*e.g.* ratio of males to females is 1:1, random selection, distribution of family size is Poisson, *etc.*), the number of breeding males and females can be used to calculate the effective population size (to be defined later). In the context of this report, an animal only becomes a 'breeding' animal by either having a service record (if available) or show up as a parent in a birth record of an offspring. This may contrast to a situation, where animals get 'selected' with the intent to use them as parents but effectively are never put into service.

The number of breeding males and females used in the population in a given year is presented in this table. The table is broken down by birth year with the last column (Number of animals born) giving the total number of animals born for the current breed for that particular year.

It is the objective of this table to provide an overview about the genetic composition of each birth year's batch of new animals: giving the number of sires and dams that produced the current year's crop of offspring. Thus, for 'services' and 'birth' we find under column 'sires' the number of sires involved in the services and births. The same applies to the column 'dams'. Thus, the ratio of 'number of animals born' and the counts in 'birth'

gives the average number of offspring per sire/dam in that year.

The column 'select' goes one step further: firstly, based on the set of animals born in the particular year, it is determined how many of those offspring became parents in later years. Then, for this subset the number of sires and dams are determined and printed under column 'select'. Clearly, this figure has to be less or equal to the corresponding figure under 'births'. Keeping this figure high will help avoid inbreeding.

The description for each column is:

Services: The number of sires/dams that participated in services in a given year.

Births: The number of sires/dams with offspring in a given year.

Select: Those animals born in the given year which became parents later on determine the subset. "Select" gives the number of sires and dams represented in this subset.

The total number of sires and dams is not the sum of the sire and dam columns but rather the total number of sires and dams occurring in all years. This figure will tend to be smaller than the sum from the years, as the same sire or dam may show up in multiple years.

For example:For the UNKNOWN breed in 1965, 22 sires and 36 dams produced the 99 offspring during this year. In the batch of future parents (select) born in this year 1965 19 sires and 24 dams were represented.

Table 1: Number of sires and dams in reproduction by year of birth of offspring

Year	sires			dams			Number of animals born
	services	births	select	services	births	select	
1960	-	1	1	-	1	1	4
1962	-	2	2	-	1	1	6
1963	-	5	5	-	3	3	55
1964	-	3	3	-	3	3	62
1965	-	22	19	-	36	24	99
1966	-	19	18	-	50	40	123
1967	-	30	26	-	56	39	130
1968	-	31	27	-	56	45	151
1969	-	33	27	-	65	46	170
1970	-	38	31	-	88	64	172
1971	-	36	34	-	106	55	230
1972	-	42	38	-	122	79	361

Continue...

Year	sires			dams			Number of animals
	services	births	select	services	births	select	born
1973	-	42	37	-	159	100	391
1974	-	66	50	-	219	142	490
1975	-	71	62	-	253	149	449
1976	-	69	55	-	317	202	460
1977	-	58	49	-	317	193	429
1978	-	62	56	-	328	188	477
1979	-	51	44	-	265	153	375
1980	-	57	42	-	318	165	437
1981	-	66	53	-	423	190	534
1982	-	58	50	-	314	140	461
1983	-	61	50	-	396	192	469
1984	-	58	49	-	370	180	404
1985	-	67	55	-	366	189	411
1986	-	52	48	-	313	192	349
1987	-	57	48	-	371	228	417
1988	-	62	53	-	320	188	368
1989	-	68	63	-	373	231	418
1990	-	60	49	-	320	174	415
1991	-	60	56	-	390	254	456
1992	-	48	42	-	367	253	437
1993	-	54	45	-	379	265	450
1994	-	47	43	-	289	188	371
1995	-	50	50	-	392	245	512
1996	-	57	52	-	430	294	524
1997	-	58	51	-	315	223	405
1998	-	55	52	-	370	275	464
1999	-	63	59	-	458	296	564
2000	-	68	64	-	485	317	590
2001	-	79	70	-	462	313	551
2002	-	95	84	-	799	460	861
2003	-	96	82	-	715	357	767
2004	-	100	89	-	720	372	752
2005	-	103	85	-	819	365	858
2006	-	107	79	-	723	306	748
2007	-	116	81	-	793	270	828
2008	-	113	77	-	723	222	737
2009	-	116	79	-	679	204	694
2010	-	106	66	-	649	155	658
2011	-	145	63	-	804	148	820
2012	-	118	34	-	594	58	605
2013	-	123	13	-	597	17	607
2014	-	124	5	-	622	6	630
2015	-	102	-	-	428	-	430
2016	-	49	-	-	121	-	122
2017	-	4	-	-	4	-	4
Total	-	1157	899	-	12287	6597	24773

2 Age structure of parents by birth year of offspring

This section gives a quick overview of the age structure of breeding males and females by birth year of offspring as summarized in the Tables. The animals of interest or cohort is *the total number of animals born in a given year*. The second row in the header of tables lists the different age groups (in *years*) for male and female parents. It should be noted that parents greater or equal to 16 years of age were grouped together i.e.

age group ≥ 16 years. The values in the body of table are the number of male/female parents in a given age-year subgroup. A dash (“-”) in the table indicates that there were no animals of a particular age group in a given year. The last column presents the average age of all male/female parents.

For example: For the UNKNOWN breed in 1966, 4 two year-old males were used in reproduction while 2 three year-old males were used. The average age of males that produced offspring during 1966 was 1.6 year.

Table 2: Age distribution of males in reproduction by year of birth of their offspring

Year	age of males in year																Avg
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	≥ 16	
1960	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	8.0
1962	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1963	4	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1.4
1964	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1965	16	4	1	-	-	1	-	-	-	-	-	-	-	-	-	-	1.5
1966	12	4	2	-	1	-	-	-	-	-	-	-	-	-	-	-	1.6
1967	11	6	5	5	1	1	-	-	-	-	-	-	-	-	1	-	2.8
1968	12	5	5	6	1	-	2	-	-	-	-	-	-	-	-	-	2.6
1969	10	5	7	4	5	-	1	1	-	-	-	-	-	-	-	-	2.9
1970	9	6	4	3	5	4	4	1	2	-	-	-	-	-	-	-	3.9
1971	13	6	3	5	2	3	2	1	1	-	-	-	-	-	-	-	3.1
1972	10	5	4	6	3	4	3	2	3	-	2	-	-	-	-	-	4.3
1973	7	6	9	6	4	3	4	-	1	1	1	-	-	-	-	-	4.0
1974	8	23	10	4	4	3	3	1	2	3	4	1	-	-	-	-	4.1
1975	4	11	16	6	5	6	5	1	4	2	5	5	1	-	-	-	5.4
1976	6	4	12	11	4	2	5	3	3	2	3	6	7	1	-	-	6.4
1977	2	3	10	10	7	5	1	2	2	2	2	3	5	3	1	-	6.6
1978	3	13	11	5	5	4	4	2	-	2	2	5	1	2	2	1	5.9
1979	-	10	7	11	3	5	1	4	2	-	-	2	3	1	-	2	5.8
1980	4	5	10	15	11	1	3	-	2	1	-	1	1	1	1	1	5.0
1981	2	6	14	10	14	14	1	1	-	-	2	-	1	-	1	-	4.8

Continue...

Year	age of males in year																Avg
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	≥ 16	
1982	2	10	11	7	13	6	6	2	-	-	-	-	-	-	-	1	4.4
1983	1	9	14	9	4	13	4	4	-	-	-	-	-	-	-	2	4.9
1984	-	9	13	15	8	2	3	2	-	-	-	-	-	-	-	1	4.6
1985	2	3	10	20	12	7	5	5	2	2	-	-	1	-	-	2	5.2
1986	1	6	5	10	8	9	2	5	-	-	-	-	-	-	-	-	5.1
1987	1	7	5	9	13	7	6	2	5	1	-	-	-	-	-	-	5.2
1988	1	6	9	13	8	9	5	1	1	1	3	-	-	-	-	-	5.2
1989	1	6	12	11	11	7	6	4	2	2	-	1	-	1	-	-	5.3
1990	1	3	14	11	8	5	6	4	4	4	1	-	-	-	-	-	5.3
1991	1	3	9	12	8	9	7	4	1	1	4	1	-	-	-	-	5.6
1992	1	2	9	6	10	8	2	-	2	2	3	1	-	-	-	-	5.5
1993	-	3	8	11	7	7	5	2	1	1	2	1	2	-	-	-	5.8
1994	-	3	10	8	12	1	3	2	1	1	-	1	-	-	-	-	5.1
1995	-	4	9	10	8	8	1	2	1	1	-	-	1	-	-	-	5.1
1996	-	6	6	9	12	9	4	2	1	1	1	-	-	-	-	-	5.3
1997	-	6	12	7	6	11	3	4	2	2	-	-	-	-	-	-	5.2
1998	1	3	20	7	6	2	7	5	2	2	1	1	-	-	-	-	4.9
1999	1	6	18	16	7	7	2	1	-	-	-	-	-	-	-	-	4.3
2000	2	8	10	17	15	5	1	5	-	-	-	-	-	-	-	-	4.5
2001	2	16	12	12	18	6	4	1	2	2	-	-	-	-	-	-	4.4
2002	-	11	23	10	14	13	8	3	-	-	3	-	-	-	-	-	5.0
2003	1	4	22	24	13	10	5	5	3	3	-	1	-	-	-	-	5.0
2004	-	2	18	23	20	12	6	2	2	2	4	-	-	-	-	-	5.3
2005	1	2	21	13	24	18	5	4	2	2	4	2	-	-	-	-	5.4
2006	1	11	18	19	10	21	6	4	2	2	2	2	-	-	-	-	5.2
2007	1	10	21	21	20	8	10	3	-	-	1	1	1	-	-	-	5.1
2008	-	11	18	23	19	13	9	7	-	-	2	1	1	1	-	-	5.2
2009	-	6	21	18	23	14	4	10	4	4	2	1	1	-	-	-	5.5
2010	-	3	17	22	20	18	6	4	5	5	2	1	1	1	-	-	5.6
2011	3	7	23	24	30	19	8	4	4	4	3	-	1	-	1	1	5.4
2012	-	9	17	22	15	15	10	5	3	3	1	2	1	1	-	1	5.6
2013	2	10	14	20	26	15	8	5	5	5	2	-	3	-	1	1	5.6
2014	1	11	24	20	18	22	5	4	2	2	4	2	-	1	-	1	5.3

Continue...

Year	age of males in year																Avg
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	≥ 16	
2015	-	4	14	29	12	10	11	8	4	1	4	1	2	-	1	1	5.8
2016	-	5	3	11	14	5	3	5	1	-	-	2	-	-	-	-	5.2
2017	-	-	-	-	1	1	-	2	-	-	-	-	-	-	-	-	6.8
Total	166	347	621	626	548	408	306	194	129	73	70	45	33	13	9	15	6.1

For example: For the UNKNOWN breed in 1971, 3 two year-old females were used in reproduction while 8 three year-old females were used. The average age of females that produced offspring during 1971 was 2.0 year.

Table 3: Age distribution of females in reproduction by year of birth of their offspring

Year	age of females in year																Avg
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	≥16	
1960	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	9.0
1962	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1963	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1964	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1965	35	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1.3
1966	49	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1967	53	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.1
1968	52	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	1.2
1969	54	1	8	-	1	-	-	1	-	-	-	-	-	-	-	-	1.4
1970	74	-	5	4	1	-	1	-	-	-	-	-	-	-	-	-	1.5
1971	76	3	8	6	6	3	1	-	-	-	-	-	-	-	-	-	2.0
1972	73	8	16	9	5	7	3	1	-	-	-	-	-	-	-	-	2.2
1973	90	8	13	18	11	10	5	1	-	-	-	-	-	-	-	-	2.5
1974	152	9	15	7	4	5	8	6	1	-	1	-	-	-	-	-	2.3
1975	133	22	27	17	14	10	10	7	2	-	-	-	-	-	-	-	2.8
1976	166	13	39	29	15	18	8	9	7	1	1	1	-	-	-	-	2.9
1977	123	29	63	28	22	16	4	4	5	7	3	1	1	-	-	-	3.2
1978	89	19	68	48	34	22	7	8	8	8	4	2	1	1	-	-	3.9
1979	59	5	38	38	33	25	16	14	3	9	4	4	1	2	-	-	4.8
1980	81	10	34	45	37	32	28	14	5	4	7	2	5	1	2	2	4.7
1981	57	18	49	56	49	40	47	32	27	14	10	5	4	2	2	2	5.6
1982	45	8	22	36	34	45	43	25	18	10	10	6	4	3	3	3	5.8
1983	45	5	26	38	50	42	49	45	42	15	15	5	4	5	4	4	6.4
1984	37	6	29	25	40	47	53	33	28	24	20	13	4	8	3	3	6.6
1985	21	5	48	51	31	35	42	31	20	30	15	19	7	2	4	5	6.7
1986	9	10	20	46	48	21	39	36	23	17	12	8	12	3	5	4	6.9
1987	4	15	40	45	47	46	28	34	28	26	13	24	6	6	7	2	6.9
1988	3	21	33	33	42	40	41	15	21	19	14	13	8	2	6	9	6.9
1989	3	16	52	31	31	48	41	35	27	18	29	19	13	4	1	5	7.0

Continue...

Year	age of females in year																Avg
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	≥16	
1990	1	13	31	41	41	24	34	30	29	17	24	16	9	6	1	3	7.1
1991	2	12	34	45	40	37	39	47	32	29	23	19	16	8	1	6	7.4
1992	1	8	22	46	47	39	42	23	36	22	31	21	9	11	2	7	7.6
1993	1	9	47	38	29	55	35	37	28	27	23	24	15	8	2	1	7.2
1994	4	13	18	25	30	35	34	32	34	23	16	12	6	6	1	-	7.2
1995	-	22	53	44	46	45	40	38	32	15	15	20	13	8	1	-	6.6
1996	2	24	41	47	43	36	49	46	36	26	22	27	10	13	5	3	7.2
1997	-	5	22	43	29	39	29	32	27	32	16	12	7	13	4	5	7.6
1998	-	17	39	50	50	33	43	28	23	17	25	13	8	13	4	7	7.0
1999	-	16	60	50	49	50	32	45	39	31	20	29	18	7	4	8	7.2
2000	-	8	43	69	48	49	41	52	41	37	25	23	26	12	4	7	7.5
2001	2	13	44	54	53	45	48	46	39	37	26	20	14	14	3	4	7.3
2002	3	20	80	77	74	94	69	76	81	56	43	46	29	22	19	10	7.6
2003	2	18	76	79	61	61	69	55	60	66	48	49	30	16	15	10	7.7
2004	1	18	66	89	81	71	56	70	53	46	40	45	29	18	19	18	7.7
2005	-	28	71	79	93	79	72	73	60	56	49	50	42	28	17	22	7.8
2006	-	19	64	94	88	69	66	54	53	56	51	26	35	22	10	16	7.5
2007	1	30	69	85	105	97	83	60	54	37	45	42	24	27	10	24	7.4
2008	2	17	87	85	79	83	59	66	58	39	37	48	19	12	9	23	7.3
2009	2	19	54	83	76	72	77	63	65	52	31	23	15	14	10	23	7.5
2010	-	20	55	70	74	66	80	62	48	35	35	30	14	22	16	22	7.6
2011	5	28	65	104	72	101	70	79	70	59	37	38	16	25	17	18	7.4
2012	3	16	57	67	65	60	69	53	53	51	35	29	13	7	5	11	7.3
2013	-	22	57	63	55	65	68	62	48	51	48	25	14	5	4	10	7.3
2014	2	20	56	65	71	51	65	61	44	47	43	37	24	14	10	12	7.7
2015	1	17	30	56	33	27	45	41	31	29	31	17	24	13	9	24	8.2
2016	-	6	9	17	14	10	9	13	14	14	6	3	3	1	1	1	7.1
2017	-	-	-	2	-	1	-	-	-	-	-	1	-	-	-	-	6.5
Total	1625	693	2004	2280	2101	2009	1906	1705	1489	1211	1014	876	552	416	241	334	7.0

3 Distribution of parity of dams at birth of offspring

The rate of genetic progress in the population depends among other things on the turnover of breeding stock. In general, under artificial breeding, animals that stay in the population longer tend to leave more offspring. Thus, the distribution of parity of dams over time may be informative about the rate of turnover in the population. The distribution of

breeding females in different parity groups in a given year is presented in the Table. Dams with parity ≥ 16 are often few in the population and they are conveniently placed together in one group i.e. ≥ 16 group. In this instance, the *cohort is defined as the total number of animals born in a given year.*

For example: For breed UNKNOWN in 1967, 3 females were in their second parity while in 1973, 2 were in their third parity.

Table 4: Distribution of females by parity number

Year	parity number									
	1	2	3	4	5	6	7	8	9	10
1960	1	–	–	–	–	–	–	–	–	–
1962	1	–	–	–	–	–	–	–	–	–
1963	3	–	–	–	–	–	–	–	–	–
1964	3	–	–	–	–	–	–	–	–	–
1965	36	–	–	–	–	–	–	–	–	–
1966	49	1	–	–	–	–	–	–	–	–
1967	53	3	–	–	–	–	–	–	–	–
1968	52	4	1	–	–	–	–	–	–	–
1969	60	5	1	–	–	–	–	–	–	–
1970	81	6	–	1	–	–	–	–	–	–
1971	97	8	–	1	–	–	–	–	–	–
1972	99	22	1	–	1	–	–	–	–	–
1973	136	22	2	–	–	–	–	–	–	–
1974	181	36	3	–	–	–	–	–	–	–
1975	192	52	10	–	–	–	–	–	–	–
1976	251	55	12	2	–	–	–	–	–	–
1977	222	86	12	4	–	–	–	–	–	–
1978	232	77	18	3	2	1	–	–	–	–
1979	163	61	32	11	–	–	–	–	–	–
1980	219	69	27	8	1	–	–	–	–	–
1981	284	104	31	6	4	1	–	–	–	–
1982	204	65	31	11	2	–	1	–	–	–
1983	234	111	34	13	3	–	1	1	–	–
1984	241	74	35	15	4	1	–	–	1	–
1985	233	82	33	11	8	–	–	–	–	–
1986	189	84	29	10	1	–	–	–	–	–
1987	230	92	36	7	4	2	1	–	–	–
1988	203	68	32	10	4	3	1	–	–	–
1989	210	117	34	10	–	2	–	–	–	–
1990	186	87	30	16	3	–	–	–	–	–
1991	217	109	43	15	4	1	1	–	–	–
1992	197	107	39	12	6	3	1	2	–	–
1993	189	118	55	13	2	2	–	–	–	–
1994	149	81	33	21	4	2	1	–	–	–
1995	244	84	41	21	1	1	–	–	–	–

Continue...

Year	parity number									
	1	2	3	4	5	6	7	8	9	10
1996	235	104	58	21	11	1	-	-	-	-
1997	166	82	37	18	7	4	1	-	-	-
1998	221	84	42	8	10	4	-	1	-	-
1999	263	117	49	13	10	4	2	-	-	-
2000	268	136	54	19	6	-	1	1	-	-
2001	273	120	50	16	2	1	-	-	-	-
2002	510	163	86	33	6	2	-	-	-	-
2003	427	169	68	33	15	3	-	-	-	-
2004	388	212	77	27	13	4	-	-	-	-
2005	458	216	83	42	12	6	2	-	-	-
2006	409	179	80	40	12	2	3	1	-	-
2007	459	194	78	33	21	5	1	2	-	-
2008	417	177	80	33	12	3	1	-	1	-
2009	363	191	74	34	12	4	-	-	-	1
2010	368	172	67	25	12	4	1	-	-	-
2011	445	211	99	34	12	1	2	-	-	-
2012	311	175	66	25	10	7	-	-	-	-
2013	324	159	72	27	14	-	1	-	-	-
2014	362	154	67	29	7	3	-	-	-	-
2015	221	113	65	20	8	-	1	-	-	-
2016	56	38	13	11	1	2	-	-	-	-
2017	2	1	-	-	1	-	-	-	-	-
Total	12287	5057	2020	762	268	79	23	8	2	1

4 Generation interval

Generation interval is one of the key factors affecting the rate of genetic progress and therefore the genetic structure of the population. As a general rule, the shorter the generation interval the rapid is the genetic change in the population holding other factors constant. Generation interval can be defined as the average age of the parents at the *birth of their selected offspring* (Falconer & Mackay, 1996). In the calculation of generation interval, an offspring is considered selected if it has produced at least one progeny. Computation of the generation interval for a given year was carried out as follows:

1. All animals born in a given year were considered (subset 1)
2. Animals in subset 1 that become parents in the later years were identified (subset 2)

3. The parents of animals in subset 2 were identified (subset 3)
4. The generation interval was calculated as the average age of the animals in subset 3 at birth of their offspring in subset 2.

In livestock, transfer of genes from parents to offspring occurs through four selection paths i.e. sires to sons, sires to daughters, dams to sons and dams to daughters. Thus, the generation interval were computed for the four selection paths and is expressed in *years*. Furthermore, generation interval was calculated separately for the males and females. The values in the body of the table are the average generation intervals for a given selection path followed by the number of animals within that path. The overall generation interval for the entire population is also provided in the table.

For example: For the UNKNOWN breed the Generation interval (average age of parents when their selected offspring were born) for the selection path between sire to son (ss) was 3.5 year in 1972. This values was calculated based on the avarage ages of 9 selected sons, born during 1972. During the same year the generation intervals for the sire to daughter (sd), dam to son (ds) and dam to daughter (dd) selection paths were 5.2, 2.0 and 3.1 year, respectively. During 1972, the generation interval for the males was 5.0 year and 3.0 year for the female born during this year. The generation interval in 1972 for all four selection paths together, or for the population in total (pop), was 4.2 year, based on the average age of parents of 86 selected offspring.

Table 5: Generation interval and number of animals by year of birth for different selection paths

(*ss=sire to son,Nss=number of selected males for ss,sd=sire to daughter,Nsd=number of females for sd,ms=dams to sons,Nms=number of males for ms,md=dams to daughters and Nmd=number of females for md,male=avg age of sires,Nmale=number of sires where age is known,female=avg age of dams,Nmale=number of dams where age is known,pop=interval for the population,Npop=number of selected offspring*)

Year	Generation interval and number of animal													
	ss	Nss	sd	Nsd	ms	Nms	md	Nmd	male	Nmale	female	Nfemale	pop	Npop
1963	3.1	1	2.0	4	2.0	1	2.0	2	2.2	5	2.0	3	2.1	5
1964	2.0	1	2.0	2	2.0	1	2.0	2	2.0	3	2.0	3	2.0	3
1965	2.8	4	2.1	19	4.3	4	2.0	20	2.2	23	2.4	24	2.3	26
1968	3.5	2	3.1	44	2.0	2	2.0	44	3.2	46	2.0	46	2.6	47
1969	4.0	2	4.1	48	5.5	2	2.2	45	4.1	50	2.4	47	3.3	50
1970	7.2	4	4.4	60	2.0	3	2.5	61	4.6	64	2.5	64	3.6	70
1971	2.0	4	4.3	51	2.4	6	2.7	49	4.2	55	2.7	55	3.5	60
1972	3.5	9	5.2	71	2.0	8	3.1	72	5.0	80	3.0	80	4.2	86
1973	3.6	7	4.6	89	3.2	8	3.5	92	4.5	96	3.4	100	4.0	104
1974	4.9	6	4.5	134	2.1	6	3.3	136	4.6	140	3.2	142	3.9	147
1975	6.5	19	5.6	123	3.5	19	3.6	130	5.7	142	3.6	149	4.6	150
1976	6.5	17	5.9	183	3.8	16	3.6	189	6.0	200	3.7	205	4.8	208

Continue...

Year	Generation interval and number of animal													
	ss	Nss	sd	Nsd	ms	Nms	md	Nmd	male	Nmale	female	Nfemale	pop	Npop
1977	5.2	18	6.6	174	4.8	18	3.9	178	6.5	192	3.9	196	5.2	196
1978	7.1	17	6.7	172	4.8	17	4.8	176	6.7	189	4.8	193	5.8	195
1979	7.8	20	6.2	131	5.6	20	5.4	133	6.4	151	5.5	153	5.9	155
1980	6.1	25	5.3	142	6.6	25	5.0	144	5.4	167	5.2	169	5.4	171
1981	7.2	14	5.0	177	6.4	14	6.3	178	5.2	191	6.3	192	5.7	192
1982	5.7	19	4.8	125	8.0	18	6.0	123	4.9	144	6.2	141	5.5	147
1983	4.8	16	5.3	179	6.7	16	7.1	176	5.2	195	7.1	192	6.1	195
1984	5.0	20	5.1	164	7.1	20	6.9	162	5.0	184	6.9	182	6.0	184
1985	5.3	17	5.3	174	7.4	17	7.2	174	5.3	191	7.2	191	6.2	191
1986	6.3	15	5.7	178	6.7	15	7.3	177	5.8	193	7.2	192	6.5	195
1987	6.0	21	5.9	209	7.6	21	7.3	208	5.9	230	7.3	229	6.6	231
1988	5.7	15	5.9	169	8.0	15	7.5	173	5.9	184	7.6	188	6.7	191
1989	6.4	22	5.9	200	6.6	23	7.6	208	6.0	222	7.5	231	6.7	231
1990	5.5	11	6.2	161	7.3	11	7.4	165	6.1	172	7.4	176	6.8	184
1991	6.6	17	5.5	221	8.8	18	8.1	237	5.6	238	8.1	255	6.9	261
1992	5.6	12	5.8	221	8.4	12	8.2	241	5.8	233	8.2	253	7.0	254
1993	4.9	12	6.5	242	7.5	12	7.8	256	6.5	254	7.8	268	7.1	271
1994	6.4	22	5.6	142	8.1	22	7.8	168	5.7	164	7.8	190	6.9	191
1995	5.4	23	6.0	208	7.9	23	7.4	226	6.0	231	7.4	249	6.7	250
1996	6.2	26	5.8	261	7.8	26	7.9	270	5.9	287	7.9	296	6.9	296
1997	6.0	19	5.8	198	8.5	19	8.0	205	5.8	217	8.1	224	7.0	224
1998	4.3	25	5.8	246	7.3	25	7.4	253	5.6	271	7.4	278	6.6	279
1999	4.7	30	4.7	256	7.3	30	7.6	268	4.7	286	7.5	298	6.3	300
2000	5.2	29	5.0	274	8.0	29	8.1	289	5.0	303	8.1	318	6.7	320
2001	4.6	20	4.7	272	7.2	20	7.6	294	4.7	292	7.6	314	6.2	314
2002	5.1	29	5.7	346	8.2	29	8.1	432	5.6	375	8.1	461	7.1	464
2003	5.0	29	5.3	273	7.7	29	7.9	329	5.3	302	7.9	358	6.8	360
2004	5.8	32	5.3	302	8.5	32	7.9	340	5.4	334	8.0	372	6.8	374
2005	5.4	35	5.5	293	7.7	35	7.9	333	5.5	328	7.9	368	6.8	371
2006	5.1	36	5.2	236	7.9	36	7.9	270	5.2	272	7.9	306	6.7	307
2007	5.6	29	5.6	207	8.9	29	7.9	242	5.6	236	8.0	271	7.0	272
2008	4.7	31	5.1	160	6.9	31	7.8	192	5.1	191	7.6	223	6.6	224
2009	5.4	31	5.8	157	7.6	31	7.6	175	5.7	188	7.6	206	6.9	206
2010	5.5	23	5.8	119	7.9	23	7.7	132	5.7	142	7.7	155	6.8	155
2011	6.1	33	5.8	109	7.3	33	8.0	115	5.8	142	7.8	148	6.9	148
2012	5.5	17	4.6	40	7.2	17	7.1	41	4.9	57	7.1	58	6.0	58
2013	5.5	6	7.0	11	7.1	6	8.7	11	6.4	17	8.1	17	7.3	17
2014	5.3	3	10.5	3	6.9	3	10.7	3	7.9	6	8.8	6	8.4	6
Total	5.5	-	5.5	-	7.1	-	7.0	-	5.5	-	7.0	-	6.3	-

5 Family size

Family size refers to the number of offspring of an individual that become breeding individuals in the next generation (Falconer & Mackay, 1996). Under *ideal conditions* as specified by Falconer & Mackay (1996), parents have an equal chance of contributing offspring to the next generation. In practice, particularly in production animals, genetic contribution of the parents is not the same. Unequal contribution leads to differences or variation in family size.

The consequence of increased variation in family size is an increase in the rate of inbreeding and the reduction in the effective population size ($Ne = 1/2\Delta F$ where Ne is the effective population size and ΔF is the rate of inbreeding per generation).

The variance of family size can be minimized, i.e. regressed to zero as the number of offspring become equal for all parents. The Table presents the summary statistics for family size (i.e. the maximum

and average) for the male and female parents. Offspring have been categorized into four groups as follows:

All offspring: all offspring born in the population.

Selected offspring: offspring that have a service record.

Selected sons: male offspring that have a service record.

Selected daughters: female offspring that have a service record.

In addition, the distribution of family size is also presented. The most influential individuals in the population are also identified (Figures 1 to 8). The information is presented separately for sires and dams considering *all* and *selected offspring*.

Table 6: The maximum and average number of family sizes

Year	All offspring				Selected offspring				Selected sons				Selected daughters			
	sires		dams		sires		dams		sires		dams		sires		dams	
	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg
1952	2	2.0	-	-	2	2.0	-	-	1	1.0	-	-	1	1.0	-	-
1959	1	1.0	-	-	1	1.0	-	-	1	1.0	-	-	-	-	-	-
1960	17	10.0	1	1.0	14	8.5	1	1.0	1	1.0	1	1.0	13	7.5	-	-
1961	10	5.8	2	1.3	9	5.0	2	1.3	-	-	1	1.0	9	5.0	1	1.0
1962	11	10.0	3	1.7	11	8.0	3	1.7	2	2.0	2	2.0	9	6.7	1	1.0
1963	39	15.0	3	1.4	21	10.5	3	1.3	4	1.6	1	1.0	21	9.8	3	1.3
1964	37	11.1	9	1.8	26	7.8	8	1.5	6	2.2	1	1.0	24	7.0	7	1.5
1965	55	8.6	5	1.4	43	6.9	4	1.3	11	3.5	1	1.0	32	6.4	4	1.3
1966	33	10.1	4	1.5	14	6.5	3	1.3	2	1.5	1	1.0	14	6.8	3	1.3
1967	36	7.8	4	1.5	26	6.2	3	1.3	5	3.5	2	1.3	21	5.6	3	1.3
1968	37	12.6	8	1.5	16	6.0	4	1.2	2	1.5	1	1.0	16	6.0	4	1.2
1969	33	10.4	5	1.5	17	5.8	3	1.2	4	1.6	1	1.0	13	5.9	3	1.2
1970	25	5.6	6	1.7	10	3.5	4	1.4	2	1.5	2	1.1	10	3.5	3	1.3
1971	33	10.1	6	1.6	26	8.7	6	1.5	3	1.8	2	1.1	26	8.6	4	1.4
1972	24	8.0	6	1.5	22	6.3	5	1.3	6	1.9	2	1.1	21	5.8	5	1.3
1973	41	14.3	7	1.6	24	8.1	6	1.4	2	1.4	2	1.0	22	8.9	5	1.4
1974	46	10.7	6	1.6	22	7.3	4	1.4	4	4.0	2	1.0	18	6.6	4	1.4
1975	46	18.3	6	1.5	28	9.8	4	1.3	6	2.0	2	1.1	24	9.9	4	1.3
1976	56	18.0	7	1.6	34	10.1	7	1.5	5	2.0	4	1.4	34	9.2	7	1.4
1977	105	18.5	8	1.5	46	10.2	7	1.4	10	2.8	3	1.2	43	9.6	4	1.3
1978	53	13.9	4	1.5	22	7.2	4	1.2	6	2.4	1	1.0	22	6.3	4	1.2
1979	55	20.1	5	1.5	26	11.2	3	1.4	5	2.1	1	1.0	22	10.0	3	1.4
1980	64	16.8	8	1.7	33	10.3	5	1.5	5	1.7	2	1.2	33	9.8	5	1.4
1981	53	12.9	7	1.8	26	8.3	5	1.5	4	2.0	2	1.1	26	7.5	5	1.5
1982	89	17.4	6	1.7	53	11.0	5	1.5	6	1.9	2	1.1	52	10.3	5	1.4

Continue...

Year	All offspring				Selected offspring				Selected sons				Selected daughters			
	sires		dams		sires		dams		sires		dams		sires		dams	
	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg
1983	81	15.3	6	1.9	50	10.8	5	1.6	3	1.8	2	1.1	48	10.3	5	1.5
1984	39	11.5	6	1.8	34	10.1	5	1.5	6	2.4	2	1.2	28	9.6	4	1.4
1985	64	21.4	5	1.9	38	13.9	4	1.7	10	2.4	1	1.0	30	12.1	4	1.6
1986	74	14.7	7	1.9	59	10.9	5	1.6	3	1.6	2	1.1	59	11.1	5	1.5
1987	75	19.0	7	1.9	55	14.9	5	1.5	5	2.7	2	1.1	54	14.1	4	1.5
1988	77	20.5	8	1.9	60	14.1	6	1.7	3	1.6	2	1.1	58	13.4	5	1.6
1989	63	16.7	6	1.8	49	12.5	4	1.5	9	2.7	1	1.0	40	11.6	4	1.4
1990	71	18.8	6	1.7	47	14.0	5	1.4	5	2.8	2	1.2	42	12.7	5	1.3
1991	106	23.3	6	1.9	51	16.0	6	1.6	3	1.6	2	1.0	50	14.9	5	1.5
1992	54	16.1	8	1.9	38	10.6	6	1.6	12	3.3	4	1.3	26	10.8	5	1.5
1993	71	20.7	8	2.0	30	12.8	7	1.7	6	4.0	4	1.3	30	11.8	7	1.6
1994	105	29.9	7	1.9	54	16.7	6	1.5	4	2.0	3	1.3	51	15.8	5	1.4
1995	59	21.4	10	1.8	29	14.5	9	1.5	5	2.8	4	1.3	28	12.5	6	1.4
1996	71	24.2	6	2.0	51	16.1	5	1.6	12	3.4	4	1.2	51	14.9	5	1.6
1997	62	20.1	6	1.9	26	11.7	5	1.5	4	2.0	3	1.2	26	11.6	5	1.4
1998	81	23.9	7	1.9	54	14.5	5	1.4	11	3.9	2	1.1	43	12.5	4	1.3
1999	68	25.3	6	1.8	40	14.2	5	1.4	10	3.0	3	1.1	39	13.2	3	1.3
2000	101	26.5	7	1.8	41	13.1	5	1.4	8	3.1	3	1.2	39	11.4	4	1.3
2001	76	16.9	7	1.7	17	7.1	7	1.4	5	2.5	2	1.2	12	6.2	5	1.3
2002	66	23.2	6	1.6	41	11.0	5	1.2	15	3.0	2	1.1	30	9.5	3	1.2
2003	76	22.9	6	1.7	26	9.4	4	1.3	5	2.7	2	1.2	26	8.3	4	1.2
2004	82	22.2	5	1.6	34	7.8	3	1.1	12	3.2	2	1.1	22	6.3	2	1.1
2005	48	14.9	7	1.5	18	5.2	3	1.1	9	3.1	3	1.3	13	4.0	2	1.1
2006	55	15.1	6	1.6	11	5.0	2	1.1	3	1.6	1	1.0	10	4.4	2	1.1
2007	55	15.3	4	1.4	10	3.5	2	1.1	4	2.0	1	1.0	10	3.6	2	1.1
2008	50	19.0	4	1.4	18	4.3	2	1.1	9	2.7	1	1.0	9	3.3	1	1.0
2009	35	12.0	3	1.2	3	1.4	1	1.0	1	1.0	1	1.0	3	1.4	1	1.0
2010	25	11.1	3	1.2	2	1.4	-	-	1	1.0	-	-	2	1.7	-	-
2011	28	7.2	3	1.1	1	1.0	-	-	-	-	-	-	1	1.0	-	-
2012	30	6.6	2	1.0	-	-	-	-	-	-	-	-	-	-	-	-
2013	5	2.3	1	1.0	-	-	-	-	-	-	-	-	-	-	-	-
2014	1	1.0	1	1.0	-	-	-	-	-	-	-	-	-	-	-	-
Total	106	16.4	10	1.7	60	10.0	9	1.4	15	2.4	4	1.1	59	9.3	7	1.4

Figure 1: Dams with the most Progeny in the Population

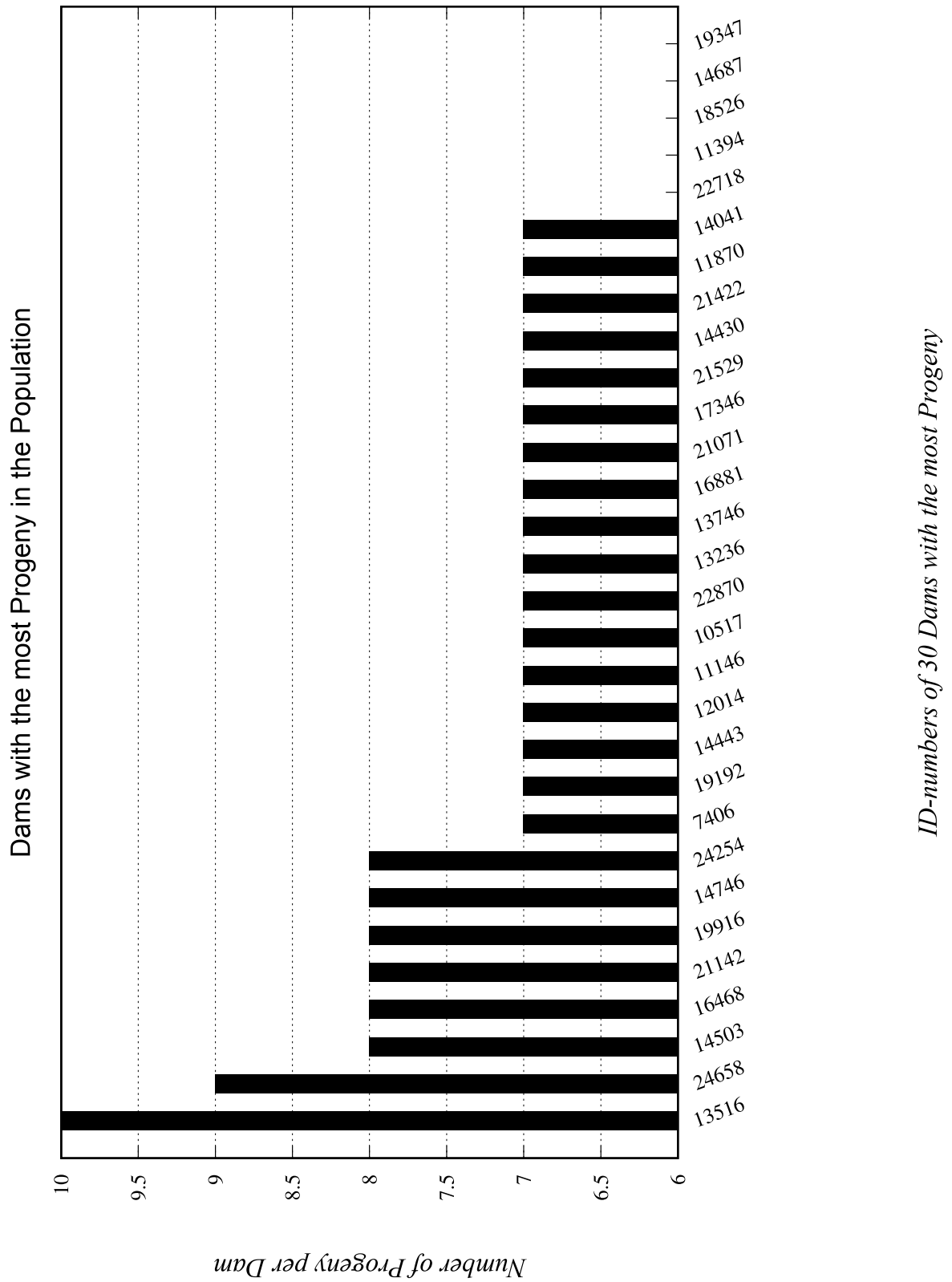


Figure 2: Number of Progeny per Dam

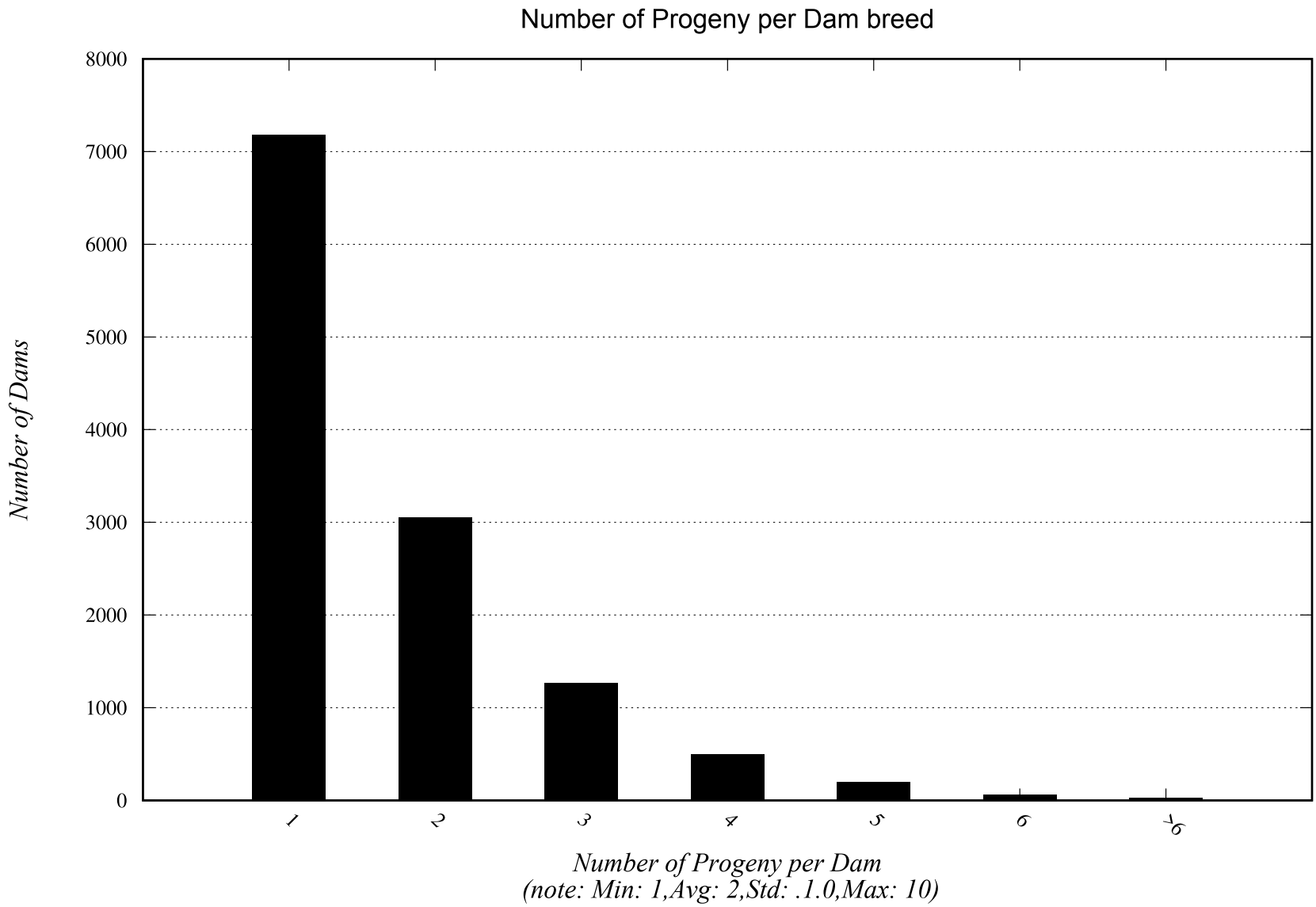


Figure 3: Sires with the most Progeny in the Population

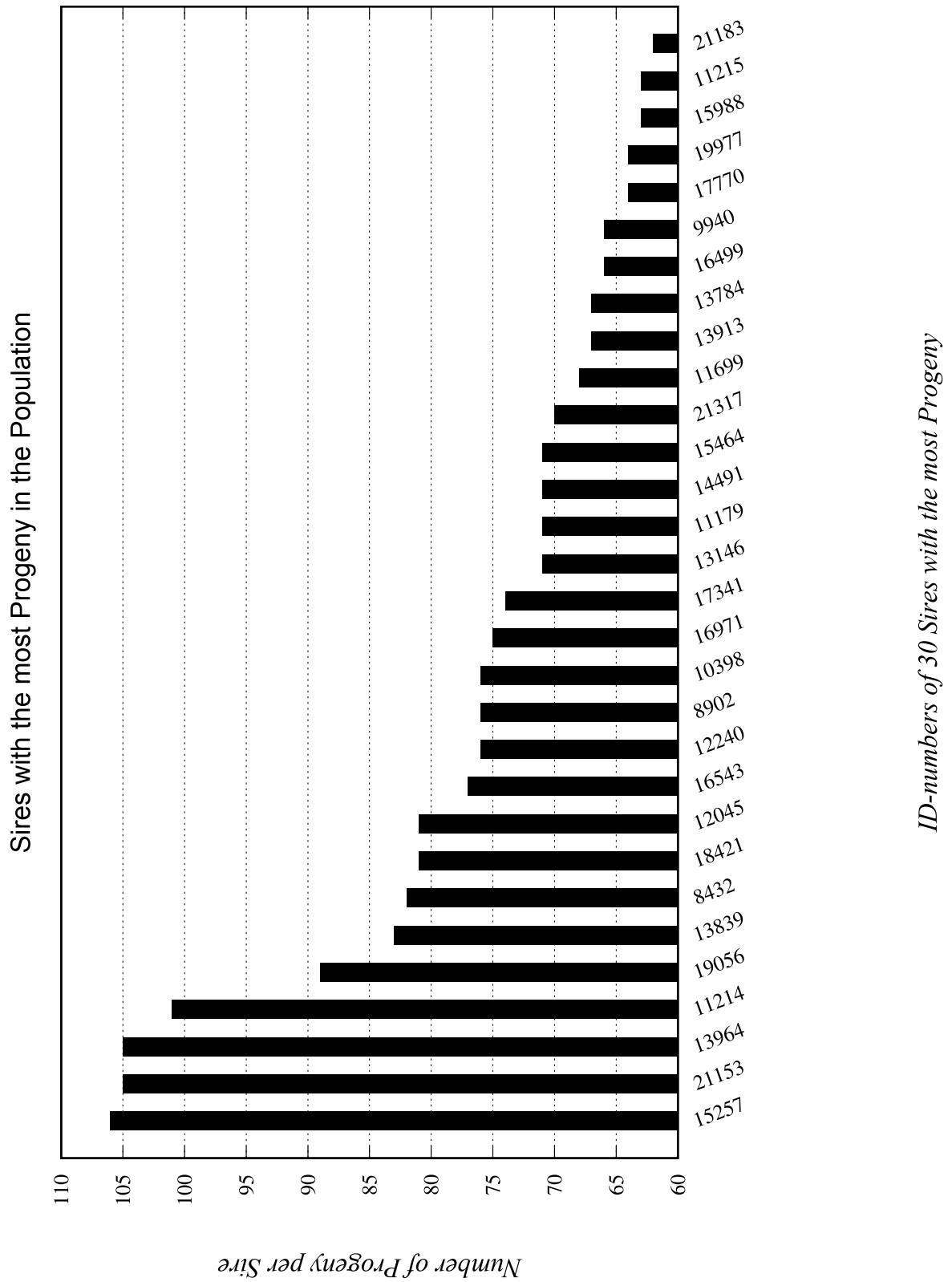


Figure 4: Number of Progeny per Sire

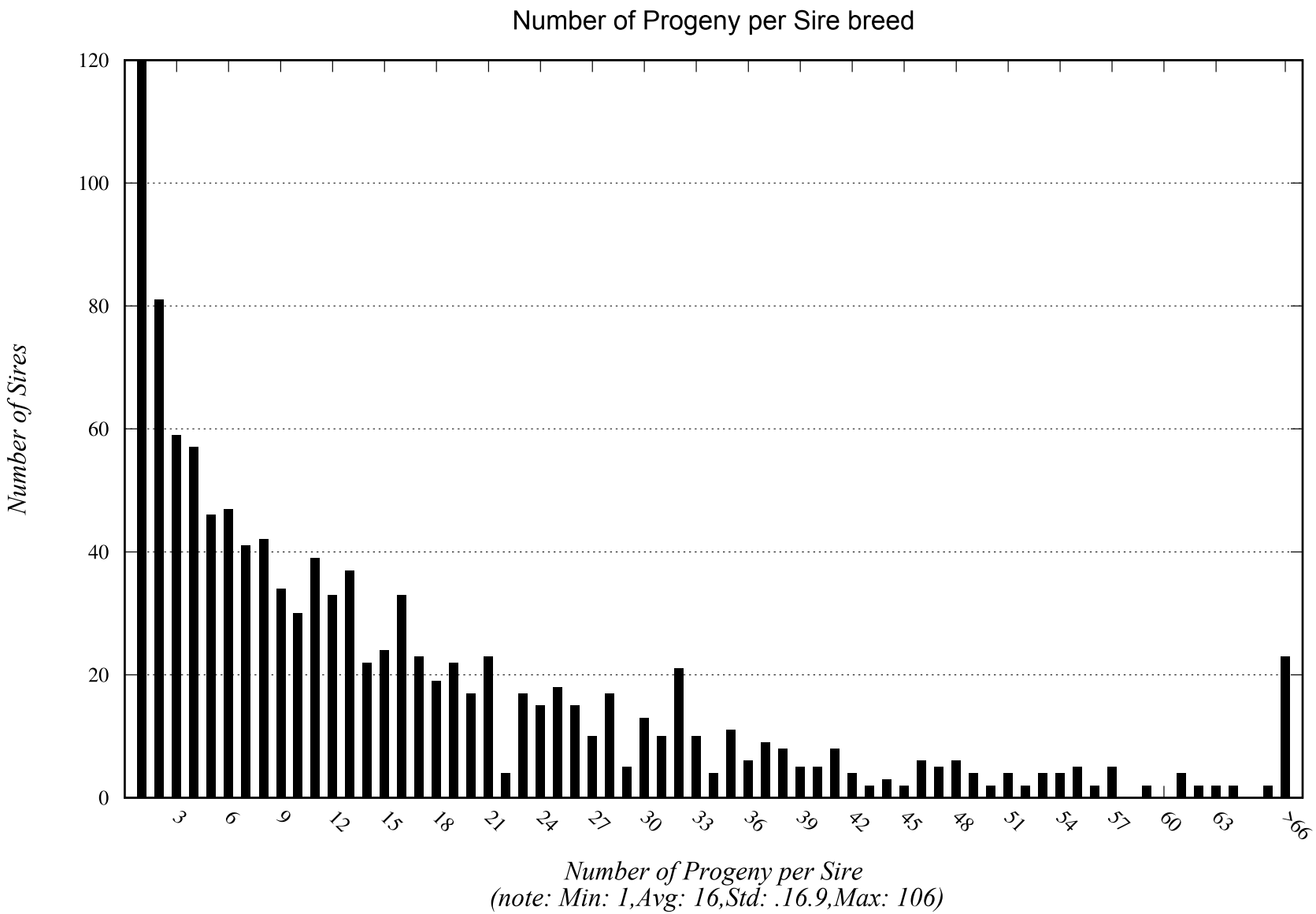


Figure 5: Dams with the most Selected Progeny in the Population

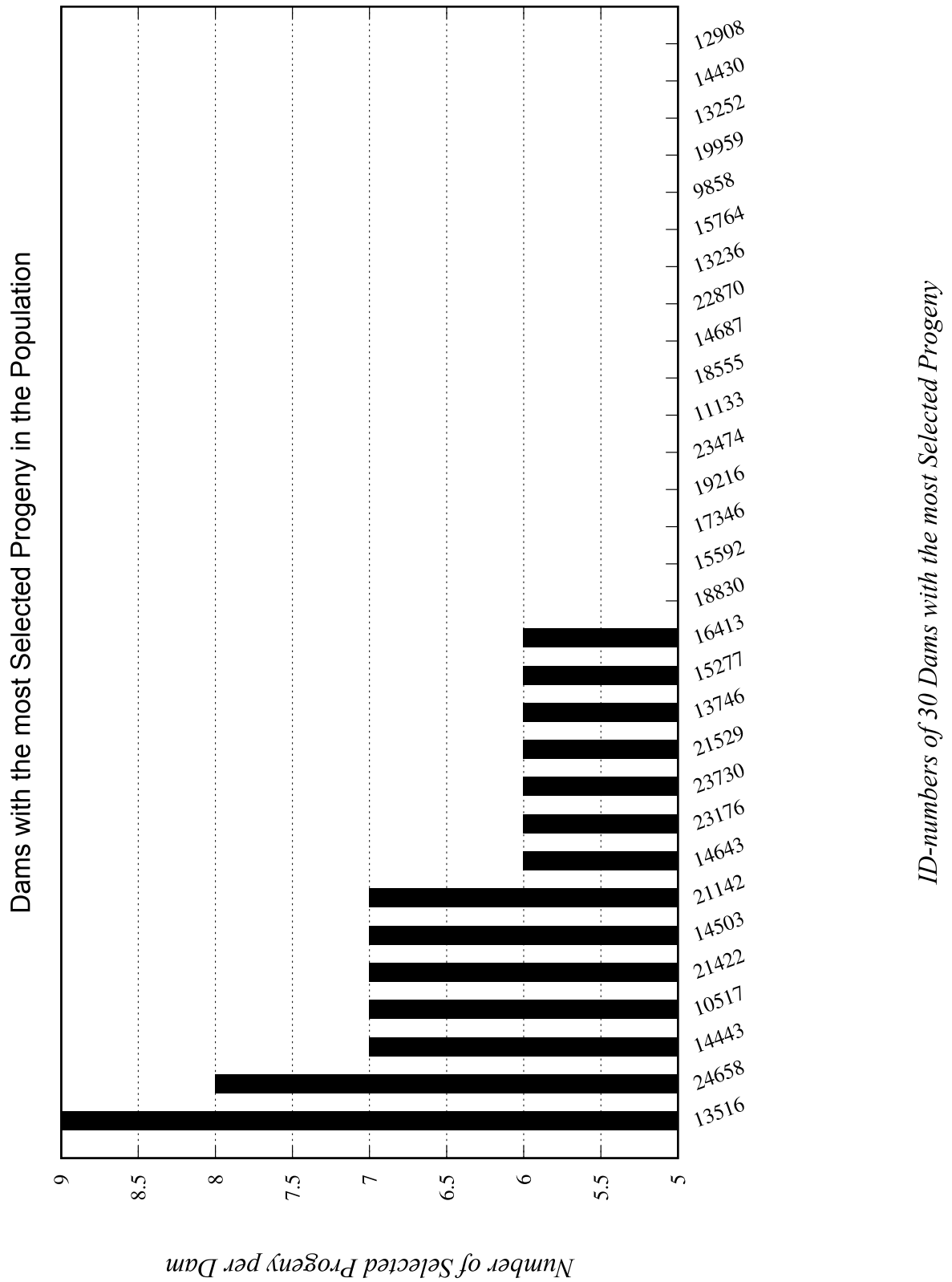


Figure 6: Number of Selected Progeny per Dam

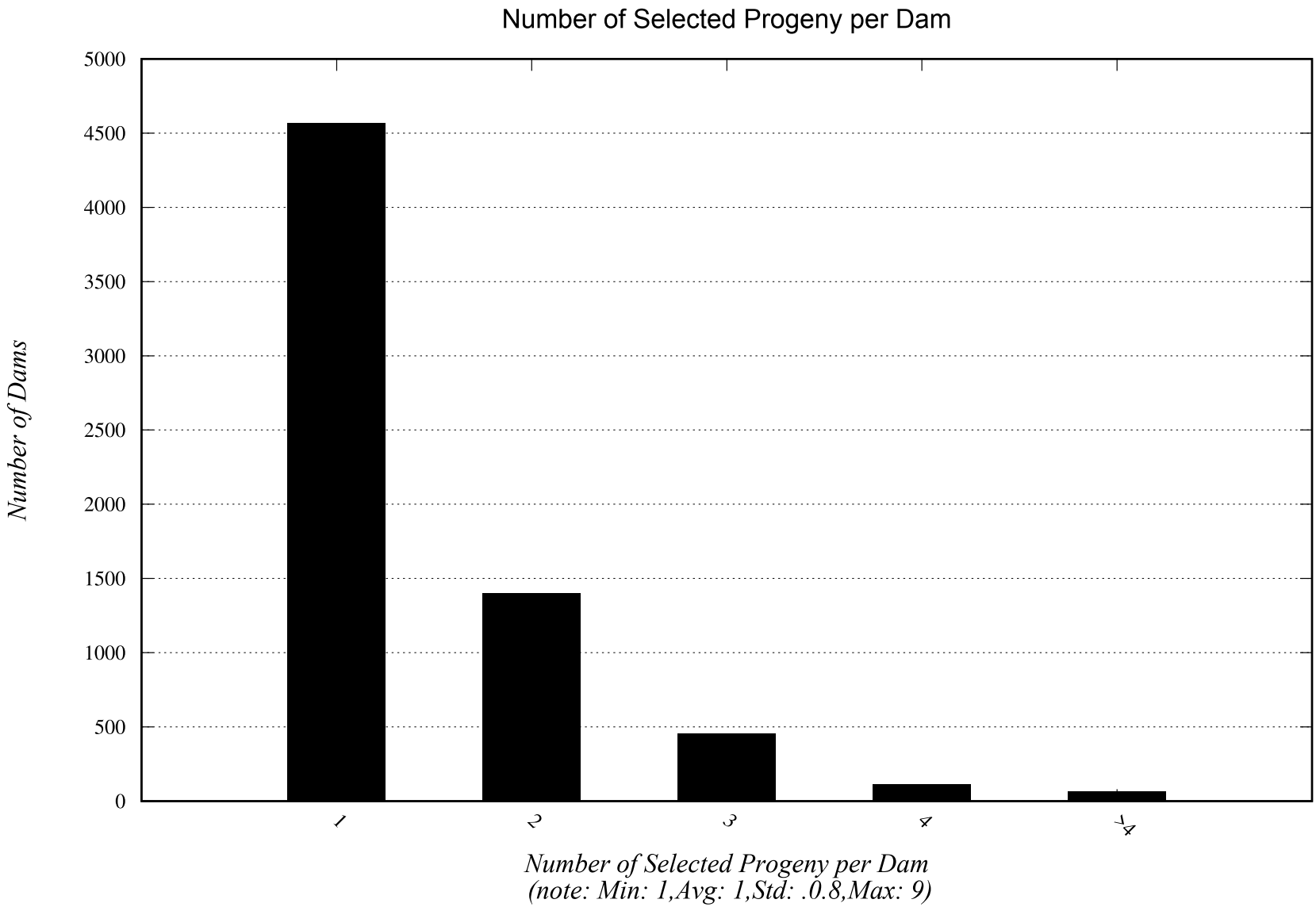


Figure 7: Sires with the most Selected Progeny in the Population

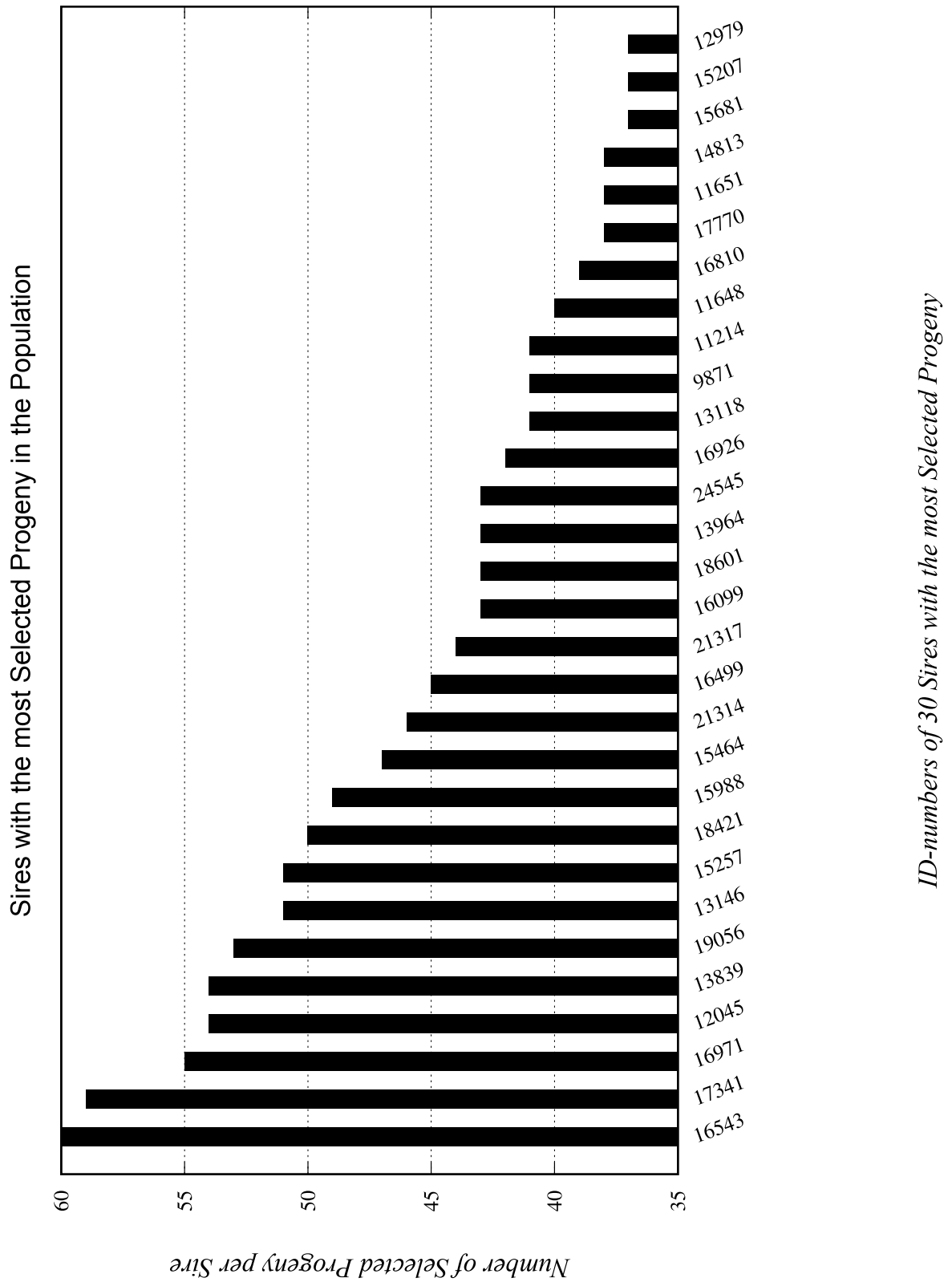


Figure 8: Number of Selected Progeny per Sire

