Service PopReport at Institute of Farm Animal Genetics
FRIEDRICH-LOEFFLER-INSTITUT
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Bundesforschungsinstitut für Tiergesundheit

PopReport
A Pedigree Analysis Report

Population: 52
Inputfile: POPREP.TXT
Initiated by: quaglia@anabic.it
Submitted at: 2020-08-26 11:42:58
Started at: 2020-08-26 11:43:01
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Courtesy: Department of Animal Breeding and Genetics
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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'.
  116625 input lines processed.
  116625 animals accepted.
- INFO: (concerning Inbreeding Report)
  This table shows the shortening of the number of male and female animals per year for the AGR computations. The original (orig) number of records is shortened (cut) to keep the product of $male * female$ within acceptable limits. See details later in the Inbreeding Report.

Year	No. of Male		No. of Female	
	orig.	cut	orig.	cut
1973	744	744	7191	5376
1974	884	884	8926	4525
1975	985	985	10505	4061
1976	1038	1038	11928	3854
1977	1087	1087	12938	3680
1978	1108	1108	13962	3610
1979	1077	1077	14125	3714
1980	1129	1129	14734	3543
1981	1128	1128	15068	3546
1982	1112	1112	15166	3597
1983	1137	1137	15398	3518
1984	1196	1196	15627	3344
1985	1234	1234	16087	3241
1986	1300	1300	16495	3077
1987	1371	1371	17047	2918
1988	1392	1392	17396	2874
1989	1392	1392	17523	2874
1990	1370	1370	17421	2920
1991	1310	1310	17192	3053
1992	1267	1267	17048	3157
1993	1225	1225	17085	3265
1994	1177	1177	16974	3398
1995	1115	1115	16616	3587
1996	1067	1067	16038	3749
1997	1045	1045	15682	3828
1998	1014	1014	15691	3945
1999	1034	1034	16077	3868
2000	1005	1005	16641	3980
2001	1034	1034	17211	3868

Year	No. of Male		No. of Female	
	orig.	cut	orig.	cut
2002	1053	1053	18123	3799
2003	1086	1086	19108	3683
2004	1152	1152	20207	3472
2005	1240	1240	21581	3226
2006	1368	1368	23090	2924
2007	1429	1429	24008	2799
2008	1527	1527	24453	2620
2009	1540	1540	24355	2597
2010	1555	1555	23916	2572
2011	1569	1569	23292	2549
2012	1541	1541	22796	2596
2013	1482	1482	22179	2699
2014	1409	1409	21353	2839
2015	1377	1377	20923	2905
2016	1337	1337	20552	2992
2017	1282	1282	19274	3120
2018	1146	1146	16753	3490
2019	977	977	14331	4094

Pedigree Analysis Report for Population: 52

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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 (Sϕrenson *et al.*, 2005). The following formula was used to compute pedigree completeness (MacCluer *et al.*, 1983):

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

and

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

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

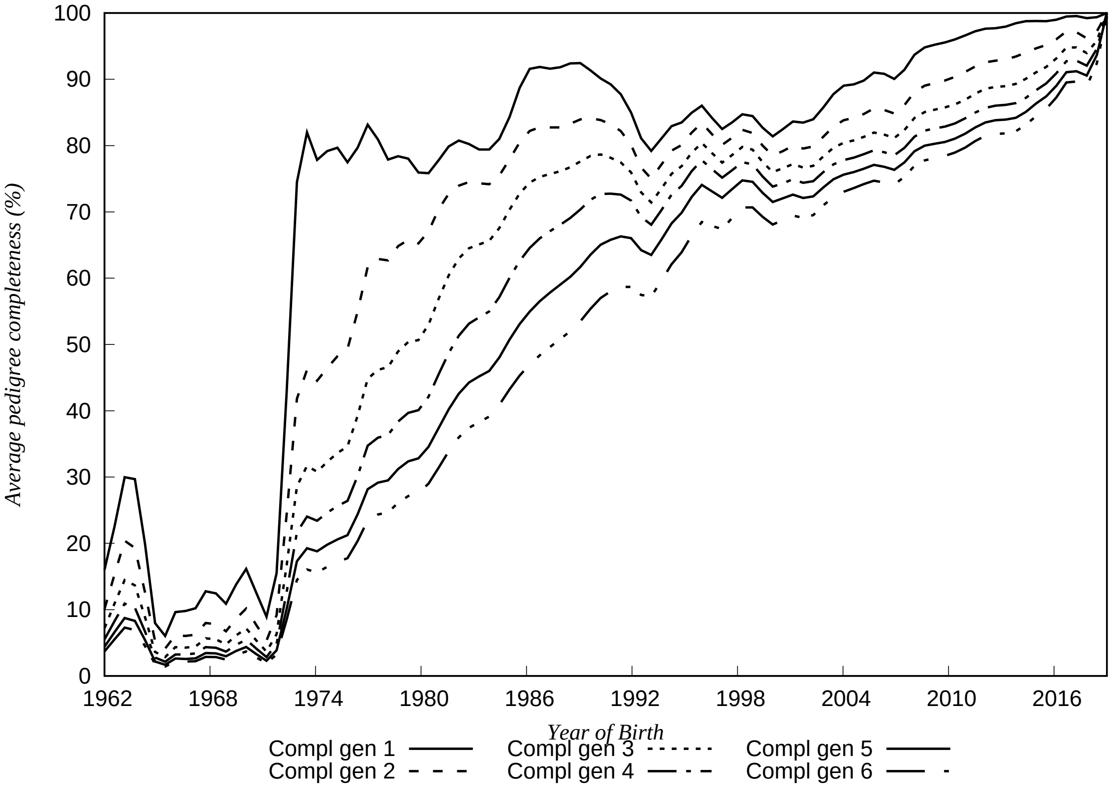
Year	No of Animals	Compl. gen 1	Compl. gen 2	Compl. gen 3	Compl. gen 4	Compl. gen 5	Compl. (%) gen 6(%)
1948	1	0.0	0.0	0.0	0.0	0.0	0.0
1949	4	0.0	0.0	0.0	0.0	0.0	0.0
1950	2	0.0	0.0	0.0	0.0	0.0	0.0
1951	6	16.7	8.3	5.6	4.2	3.3	2.8
1952	7	28.6	14.3	9.5	7.1	5.7	4.8
1953	4	50.0	29.2	19.4	14.6	11.7	9.7
1954	5	60.0	33.3	22.2	16.7	13.3	11.1
1955	6	66.7	44.8	31.8	23.9	19.1	15.9
1956	1	100.0	66.7	47.6	35.7	28.6	23.8
1957	7	28.6	23.8	17.6	13.4	10.7	8.9
1958	6	16.7	16.7	13.9	10.9	8.7	7.3
1959	11	36.4	21.2	14.9	11.4	9.2	7.6
1960	8	37.5	22.9	16.0	12.1	9.8	8.1
1961	16	25.0	15.6	10.6	8.1	6.5	5.4
1962	25	16.0	10.1	7.2	5.5	4.4	3.7
1963	28	28.6	19.6	13.9	10.5	8.4	7.0
1964	61	26.2	16.7	11.8	8.9	7.2	6.0
1965	199	6.5	4.4	3.0	2.3	1.8	1.5
1966	273	9.5	6.1	4.3	3.2	2.6	2.2
1967	329	9.7	5.9	4.2	3.2	2.5	2.1
1968	477	13.2	8.3	5.9	4.5	3.6	3.0
1969	670	11.0	6.8	4.8	3.7	3.0	2.5
1970	914	16.2	10.2	7.2	5.5	4.4	3.7
1971	1851	9.7	5.8	4.0	3.1	2.5	2.1
1972	1576	23.0	13.4	9.2	7.0	5.6	4.7
1973	1845	76.6	43.0	29.4	22.3	17.8	14.9
1974	2148	78.2	44.6	30.8	23.4	18.8	15.6

Continue...

Year	No of Animals	Compl. 1 gen	Compl. 2 gen	Compl. 3 gen	Compl. 4 gen	Compl. 5 gen	Compl. (%) 6 gen (%)
1975	2009	80.1	47.8	33.3	25.4	20.4	17.0
1976	1953	77.5	50.5	35.6	27.2	21.9	18.3
1977	1729	83.2	61.9	45.0	34.9	28.3	23.6
1978	1959	78.2	62.5	46.3	36.1	29.3	24.5
1979	1983	78.6	65.7	50.0	39.3	32.0	26.8
1980	2237	75.6	65.4	51.0	40.4	33.1	27.8
1981	2178	77.8	70.4	56.9	45.5	37.4	31.4
1982	2230	80.7	73.7	62.4	50.7	42.0	35.5
1983	2266	79.8	74.5	64.9	53.7	44.8	37.9
1984	2241	79.6	74.3	65.9	55.3	46.3	39.4
1985	2227	84.1	77.8	70.2	59.9	50.6	43.1
1986	2433	91.0	81.8	74.0	64.0	54.4	46.5
1987	2606	91.7	82.8	75.5	66.5	57.1	48.9
1988	2607	91.9	82.8	76.2	68.2	59.2	51.0
1989	2305	92.5	83.9	77.5	70.2	61.5	53.3
1990	2106	90.5	84.0	78.7	72.5	64.6	56.5
1991	1977	88.8	82.9	77.9	72.7	66.0	58.3
1992	2054	84.6	79.8	75.7	71.5	65.9	58.6
1993	2222	79.2	75.0	71.4	68.0	63.4	57.1
1994	2274	82.4	78.6	75.0	71.8	67.4	61.2
1995	2186	83.8	80.5	77.4	74.5	70.5	64.6
1996	1981	86.0	83.4	80.4	77.8	74.1	68.5
1997	1927	82.6	80.2	77.5	75.2	72.1	67.3
1998	2084	84.3	82.0	79.4	77.1	74.3	70.1
1999	2383	84.1	81.5	79.0	76.8	74.2	70.4
2000	2589	81.4	78.5	76.0	73.8	71.5	68.1
2001	2821	83.5	79.9	77.2	74.9	72.6	69.4
2002	3205	83.5	79.5	76.6	74.3	72.0	69.1
2003	3204	86.2	81.7	78.7	76.3	74.0	71.3
2004	3146	89.0	83.8	80.4	77.8	75.6	73.0
2005	3389	89.5	84.5	81.1	78.5	76.3	74.0
2006	3721	91.2	85.7	82.0	79.3	77.1	74.7
2007	3362	90.1	84.9	81.2	78.6	76.4	74.2
2008	3132	93.5	87.9	84.0	81.2	79.0	76.8
2009	2736	95.1	89.3	85.3	82.5	80.2	78.0
2010	2781	95.7	90.0	85.9	83.0	80.7	78.6
2011	2594	96.7	91.2	87.0	84.2	81.9	79.8
2012	2622	97.6	92.5	88.5	85.6	83.4	81.4
2013	2713	97.8	92.9	88.9	86.1	83.9	81.8
2014	2822	98.6	93.6	89.5	86.6	84.4	82.4
2015	2900	98.8	94.7	91.1	88.4	86.4	84.5
2016	2721	98.9	95.8	92.8	90.5	88.6	86.8
2017	1403	99.6	97.4	95.1	93.1	91.5	90.0
2018	124	99.2	96.2	94.1	92.3	90.9	89.3
2019	3	100.0	100.0	100.0	100.0	100.0	99.5

The average pedigee completeness for animals born within the last 10 years: 1 generations deep = 97.9%. 2 generations deep = 93.3%. 3 generations deep = 89.6%. 4 generations deep = 86.9%. 5 generations deep = 84.8%. 6 generations deep = 82.8%.

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 1962 and 2019 for the 52 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%)

	Classes										
Year	1	2	3	4	5	6	7	8	9	10	11
1948	1	-	-	-	-	-	-	-	-	-	-
1949	4	-	-	-	-	-	-	-	-	-	-
1950	2	-	-	-	-	-	-	-	-	-	-
1951	6	-	-	-	-	-	-	-	-	-	-
1952	7	-	-	-	-	-	-	-	-	-	-
1953	4	-	-	-	-	-	-	-	-	-	-
1954	5	-	-	-	-	-	-	-	-	-	-
1955	6	-	-	-	-	-	-	-	-	-	-
1956	1	-	-	-	-	-	-	-	-	-	-
1957	6	1	-	-	-	-	-	-	-	-	-
1958	5	-	-	-	1	-	-	-	-	-	-
1959	11	-	-	-	-	-	-	-	-	-	-
1960	8	-	-	-	-	-	-	-	-	-	-
1961	16	-	-	-	-	-	-	-	-	-	-
1962	25	-	-	-	-	-	-	-	-	-	-
1963	28	-	-	-	-	-	-	-	-	-	-
1964	61	-	-	-	-	-	-	-	-	-	-
1965	196	-	3	-	-	-	-	-	-	-	-
1966	272	1	-	-	-	-	-	-	-	-	-
1967	329	-	-	-	-	-	-	-	-	-	-
1968	475	-	1	-	1	-	-	-	-	-	-
1969	669	1	-	-	-	-	-	-	-	-	-
1970	909	1	4	-	-	-	-	-	-	-	-
1971	1850	-	1	-	-	-	-	-	-	-	-
1972	1571	1	-	1	3	-	-	-	-	-	-
1973	1842	-	1	-	2	-	-	-	-	-	-
1974	2138	3	2	-	5	-	-	-	-	-	-
1975	1988	1	8	1	10	-	1	-	-	-	-
1976	1921	-	18	-	14	-	-	-	-	-	-
1977	1682	8	20	4	14	-	1	-	-	-	-
1978	1879	21	33	5	21	-	-	-	-	-	-
1979	1905	25	34	6	11	-	2	-	-	-	-
1980	2114	43	56	3	18	-	3	-	-	-	-
1981	2032	53	65	4	22	1	1	-	-	-	-
1982	2103	41	44	8	32	2	-	-	-	-	-
1983	2148	33	44	11	20	9	1	-	-	-	-
1984	2102	45	63	7	19	5	-	-	-	-	-

Continue...

	Classes										
Year	1	2	3	4	5	6	7	8	9	10	11
1985	2099	56	40	10	18	4	-	-	-	-	-
1986	2296	66	36	8	22	3	2	-	-	-	-
1987	2457	72	38	11	18	8	2	-	-	-	-
1988	2428	89	50	17	9	14	-	-	-	-	-
1989	2135	85	36	4	29	11	5	-	-	-	-
1990	1965	55	42	7	22	8	6	1	-	-	-
1991	1849	67	24	15	10	10	2	-	-	-	-
1992	1891	100	26	8	13	15	1	-	-	-	-
1993	2080	77	29	10	15	10	-	1	-	-	-
1994	2121	82	31	14	6	19	1	-	-	-	-
1995	2060	77	22	3	5	19	-	-	-	-	-
1996	1842	65	35	6	3	30	-	-	-	-	-
1997	1798	73	30	9	1	16	-	-	-	-	-
1998	1911	90	34	15	2	29	3	-	-	-	-
1999	2224	87	32	12	-	27	1	-	-	-	-
2000	2420	94	30	12	-	33	-	-	-	-	-
2001	2636	87	25	26	3	44	-	-	-	-	-
2002	2975	112	32	14	1	67	1	3	-	-	-
2003	2982	120	39	11	2	49	-	1	-	-	-
2004	2947	115	29	9	3	41	1	1	-	-	-
2005	3138	126	29	16	1	73	2	4	-	-	-
2006	3479	113	34	13	3	75	3	1	-	-	-
2007	3149	110	34	8	-	57	4	-	-	-	-
2008	2954	95	19	10	-	53	1	-	-	-	-
2009	2575	91	36	5	-	29	-	-	-	-	-
2010	2547	139	23	9	-	60	2	1	-	-	-
2011	2396	105	22	5	2	62	-	2	-	-	-
2012	2406	110	38	7	-	57	2	2	-	-	-
2013	2462	146	36	9	-	58	1	1	-	-	-
2014	2560	126	36	20	-	73	5	2	-	-	-
2015	2586	180	38	10	1	81	2	1	1	-	-
2016	2417	180	48	12	1	60	2	1	-	-	-
2017	1214	119	25	5	1	36	2	1	-	-	-
2018	109	9	-	2	-	4	-	-	-	-	-
2019	2	1	-	-	-	-	-	-	-	-	-

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

	Animals			Sires			Dams		
Year	Tot No	Inbred No	Avg F	Tot No	Inbred No	Avg F	Tot No	Inbred No	Avg F
1948	1	-	-	-	-	-	-	-	-
1949	4	-	-	-	-	-	-	-	-
1950	2	-	-	-	-	-	-	-	-
1951	6	-	-	2	-	-	1	-	-
1952	7	-	-	2	-	-	2	-	-
1953	4	-	-	3	-	-	2	-	-
1954	5	-	-	3	-	-	3	-	-
1955	6	-	-	4	-	-	4	-	-
1956	1	-	-	1	-	-	1	-	-
1957	7	1	0.0089	2	-	-	2	-	-
1958	6	1	0.0417	1	-	-	1	-	-
1959	11	-	-	4	1	0.0156	4	-	-
1960	8	-	-	4	1	0.0625	3	-	-
1961	16	-	-	4	-	-	4	-	-
1962	25	-	-	4	-	-	5	-	-
1963	28	-	-	8	-	-	8	-	-
1964	61	-	-	15	1	0.0042	17	-	-
1965	199	3	0.0019	13	1	0.0048	11	-	-
1966	273	1	0.0002	25	1	0.0025	27	-	-
1967	329	-	-	32	3	0.0098	31	-	-
1968	477	2	0.0008	50	1	0.0013	66	-	-
1969	670	1	0.0001	59	1	0.0011	81	-	-
1970	914	6	0.0006	112	3	0.0040	156	-	-
1971	1851	2	0.0001	108	3	0.0041	185	-	-
1972	1576	5	0.0006	169	6	0.0048	365	1	0.0002
1973	1845	6	0.0004	290	5	0.0024	1380	1	0.0001
1974	2148	15	0.0008	291	5	0.0030	1626	2	0.0002
1975	2009	26	0.0020	302	5	0.0027	1561	4	0.0004
1976	1953	36	0.0030	294	6	0.0036	1503	5	0.0003
1977	1729	56	0.0044	301	9	0.0042	1425	9	0.0006
1978	1959	113	0.0060	286	8	0.0042	1521	5	0.0005
1979	1983	112	0.0055	283	11	0.0058	1556	22	0.0020
1980	2237	186	0.0076	292	19	0.0070	1694	24	0.0016
1981	2178	254	0.0093	274	26	0.0090	1684	32	0.0022
1982	2230	296	0.0093	272	31	0.0106	1838	61	0.0037
1983	2266	378	0.0095	286	47	0.0161	1831	89	0.0048
1984	2241	482	0.0103	293	52	0.0130	1814	134	0.0055
1985	2227	550	0.0096	319	77	0.0141	1873	175	0.0076
1986	2433	686	0.0098	363	97	0.0150	2220	225	0.0067

Continue...

	Animal			Sires			Dams		
Year	Tot No	Inbred No	Avg F	Tot No	Inbred No	Avg F	Tot No	Inbred No	Avg F
1987	2606	842	0.0103	395	115	0.0134	2416	288	0.0071
1988	2607	928	0.0117	406	135	0.0127	2415	369	0.0085
1989	2305	919	0.0137	427	156	0.0155	2146	380	0.0084
1990	2106	1006	0.0141	376	178	0.0179	1931	421	0.0088
1991	1977	1022	0.0130	347	194	0.0196	1824	449	0.0100
1992	2054	1162	0.0147	341	210	0.0172	1872	500	0.0096
1993	2222	1278	0.0137	354	233	0.0153	2000	649	0.0107
1994	2274	1385	0.0139	339	246	0.0184	2014	710	0.0119
1995	2186	1440	0.0128	352	283	0.0212	1904	773	0.0119
1996	1981	1430	0.0161	344	290	0.0216	1710	749	0.0128
1997	1927	1374	0.0156	340	293	0.0201	1598	767	0.0127
1998	2084	1559	0.0190	377	342	0.0204	1768	954	0.0131
1999	2383	1774	0.0164	385	354	0.0201	2031	1180	0.0147
2000	2589	1870	0.0169	395	374	0.0203	2170	1265	0.0143
2001	2821	2039	0.0182	442	426	0.0189	2444	1460	0.0136
2002	3205	2279	0.0196	477	463	0.0191	2817	1725	0.0143
2003	3204	2326	0.0187	480	470	0.0200	2885	1814	0.0141
2004	3146	2311	0.0186	491	482	0.0213	2893	1877	0.0146
2005	3389	2521	0.0216	549	545	0.0233	3131	2075	0.0159
2006	3721	2780	0.0207	609	602	0.0226	3507	2315	0.0155
2007	3362	2494	0.0200	616	612	0.0238	3149	2076	0.0159
2008	3132	2391	0.0200	639	635	0.0241	3006	1990	0.0152
2009	2736	2117	0.0198	674	670	0.0254	2634	1770	0.0163
2010	2781	2175	0.0240	689	685	0.0248	2681	1779	0.0172
2011	2594	2072	0.0243	695	691	0.0241	2523	1671	0.0162
2012	2622	2149	0.0253	709	707	0.0242	2562	1716	0.0178
2013	2713	2239	0.0260	713	710	0.0269	2656	1791	0.0175
2014	2822	2345	0.0281	711	709	0.0248	2793	1861	0.0181
2015	2900	2500	0.0296	737	736	0.0267	2855	1999	0.0184
2016	2721	2432	0.0296	697	695	0.0273	2690	1990	0.0190
2017	1403	1302	0.0336	462	461	0.0274	1392	1108	0.0214
2018	124	112	0.0346	83	82	0.0323	124	103	0.0203
2019	3	3	0.0424	3	3	0.0285	3	3	0.0222

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

		F			
Year	No of Animals	Min	Max	Avg	Std
1948	1	0.0000	0.0000	0.0000	-
1949	4	0.0000	0.0000	0.0000	0.0000
1950	2	0.0000	0.0000	0.0000	0.0000
1951	6	0.0000	0.0000	0.0000	0.0000
1952	7	0.0000	0.0000	0.0000	0.0000
1953	4	0.0000	0.0000	0.0000	0.0000
1954	5	0.0000	0.0000	0.0000	0.0000
1955	6	0.0000	0.0000	0.0000	0.0000
1956	1	0.0000	0.0000	0.0000	-
1957	7	0.0000	0.0625	0.0089	0.0236
1958	6	0.0000	0.2500	0.0417	0.1021
1959	11	0.0000	0.0000	0.0000	0.0000
1960	8	0.0000	0.0000	0.0000	0.0000
1961	16	0.0000	0.0000	0.0000	0.0000
1962	25	0.0000	0.0000	0.0000	0.0000
1963	28	0.0000	0.0000	0.0000	0.0000
1964	61	0.0000	0.0000	0.0000	0.0000
1965	199	0.0000	0.1250	0.0019	0.0153
1966	273	0.0000	0.0625	0.0002	0.0038
1967	329	0.0000	0.0000	0.0000	0.0000
1968	477	0.0000	0.2500	0.0008	0.0130
1969	670	0.0000	0.0938	0.0001	0.0036
1970	914	0.0000	0.1250	0.0006	0.0085
1971	1851	0.0000	0.1250	0.0001	0.0029
1972	1576	0.0000	0.2500	0.0006	0.0120
1973	1845	0.0000	0.2500	0.0004	0.0088
1974	2148	0.0000	0.2500	0.0008	0.0129
1975	2009	0.0000	0.3125	0.0020	0.0208
1976	1953	0.0000	0.2500	0.0030	0.0242
1977	1729	0.0000	0.3125	0.0044	0.0283
1978	1959	0.0000	0.2500	0.0060	0.0318
1979	1983	0.0000	0.3125	0.0055	0.0289
1980	2237	0.0000	0.3442	0.0076	0.0335
1981	2178	0.0000	0.3442	0.0093	0.0358
1982	2230	0.0000	0.2813	0.0093	0.0373
1983	2266	0.0000	0.3125	0.0095	0.0373
1984	2241	0.0000	0.2832	0.0103	0.0355
1985	2227	0.0000	0.2832	0.0096	0.0336
1986	2433	0.0000	0.3125	0.0098	0.0340

Continue...

		F			
Year	No of Animals	Min	Max	Avg	Std
1987	2606	0.0000	0.3125	0.0103	0.0344
1988	2607	0.0000	0.2813	0.0117	0.0351
1989	2305	0.0000	0.3125	0.0137	0.0418
1990	2106	0.0000	0.3750	0.0141	0.0417
1991	1977	0.0000	0.3223	0.0130	0.0357
1992	2054	0.0000	0.3019	0.0147	0.0371
1993	2222	0.0000	0.3750	0.0137	0.0353
1994	2274	0.0000	0.3172	0.0139	0.0355
1995	2186	0.0000	0.2742	0.0128	0.0324
1996	1981	0.0000	0.2916	0.0161	0.0391
1997	1927	0.0000	0.2871	0.0156	0.0333
1998	2084	0.0000	0.3301	0.0190	0.0409
1999	2383	0.0000	0.3133	0.0164	0.0358
2000	2589	0.0000	0.2871	0.0169	0.0359
2001	2821	0.0000	0.2927	0.0182	0.0391
2002	3205	0.0000	0.3830	0.0196	0.0434
2003	3204	0.0000	0.3790	0.0187	0.0380
2004	3146	0.0000	0.3532	0.0186	0.0362
2005	3389	0.0000	0.3813	0.0216	0.0440
2006	3721	0.0000	0.3878	0.0207	0.0417
2007	3362	0.0000	0.3233	0.0200	0.0394
2008	3132	0.0000	0.3009	0.0200	0.0375
2009	2736	0.0000	0.2767	0.0198	0.0326
2010	2781	0.0000	0.3594	0.0240	0.0426
2011	2594	0.0000	0.3795	0.0243	0.0437
2012	2622	0.0000	0.3825	0.0253	0.0432
2013	2713	0.0000	0.3857	0.0260	0.0425
2014	2822	0.0000	0.3884	0.0281	0.0476
2015	2900	0.0000	0.4213	0.0296	0.0473
2016	2721	0.0000	0.3864	0.0296	0.0440
2017	1403	0.0000	0.3829	0.0336	0.0473
2018	124	0.0000	0.2746	0.0346	0.0486
2019	3	0.0367	0.0512	0.0424	0.0077

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 inbred animals.

Max : the highest inbreeding coefficient.

Avg *F* : the mean inbreeding coefficient.

Std : the standard deviation of inbreeding coefficients.

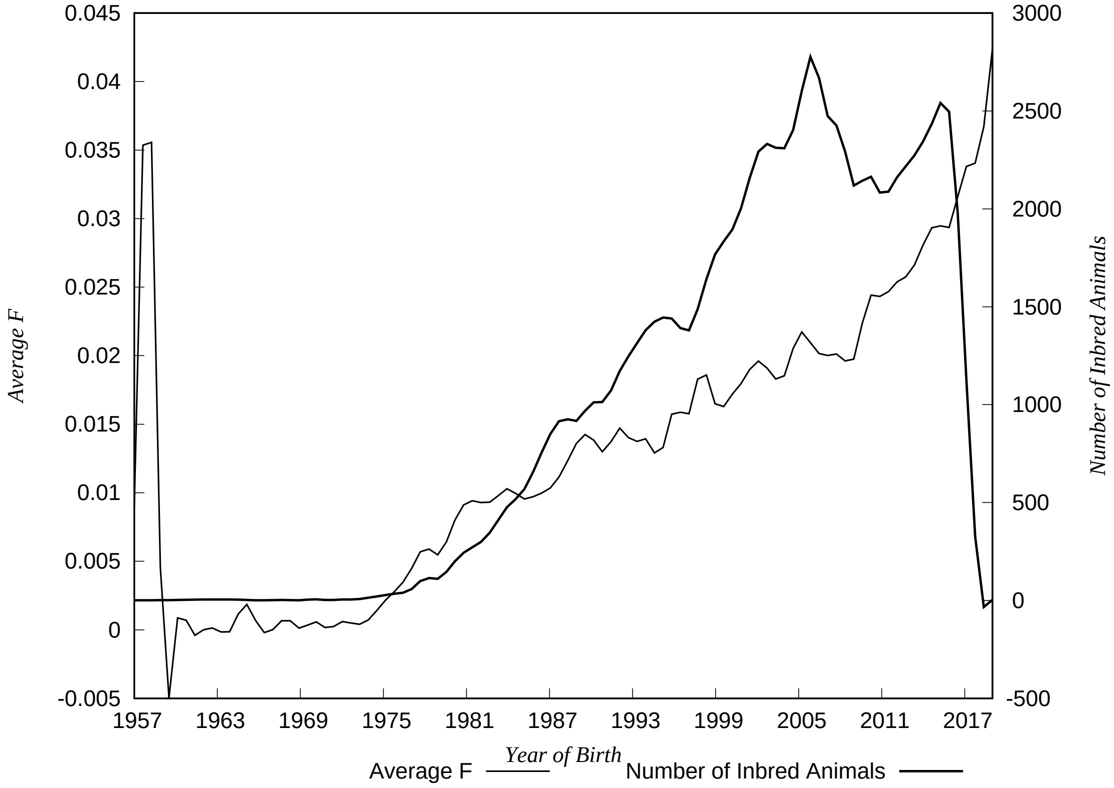
Table 5: Inbreeding coefficients (F) of INBRED animals by year

		F			
Year	No of Animals	Min	Max	Avg	Std
1957	1	0.0625	0.0625	0.0625	-
1958	1	0.2500	0.2500	0.2500	-
1965	3	0.1250	0.1250	0.1250	0.0000
1966	1	0.0625	0.0625	0.0625	-
1968	2	0.1328	0.2500	0.1914	0.0829
1969	1	0.0938	0.0938	0.0938	-
1970	6	0.0059	0.1250	0.0947	0.0502
1971	2	0.0020	0.1250	0.0635	0.0870
1972	5	0.0625	0.2500	0.2000	0.0815
1973	6	0.0029	0.2500	0.1151	0.1128
1974	15	0.0039	0.2500	0.1159	0.1054
1975	26	0.0020	0.3125	0.1572	0.0976
1976	36	0.0010	0.2500	0.1601	0.0817
1977	56	0.0015	0.3125	0.1356	0.0845
1978	113	0.0001	0.2500	0.1047	0.0851
1979	112	0.0007	0.3125	0.0970	0.0770
1980	186	0.0001	0.3442	0.0912	0.0768
1981	254	0.0001	0.3442	0.0798	0.0732
1982	296	0.0001	0.2813	0.0702	0.0789
1983	378	0.0000	0.3125	0.0570	0.0751
1984	482	0.0000	0.2832	0.0479	0.0637
1985	550	0.0000	0.2832	0.0390	0.0585
1986	686	0.0000	0.3125	0.0347	0.0569
1987	842	0.0000	0.3125	0.0319	0.0546
1988	928	0.0000	0.2813	0.0327	0.0526
1989	919	0.0000	0.3125	0.0344	0.0606
1990	1006	0.0000	0.3750	0.0295	0.0564
1991	1022	0.0000	0.3223	0.0251	0.0465
1992	1162	0.0000	0.3019	0.0260	0.0462
1993	1278	0.0000	0.3750	0.0238	0.0438
1994	1385	0.0000	0.3172	0.0229	0.0431
1995	1440	0.0000	0.2742	0.0195	0.0382
1996	1430	0.0000	0.2916	0.0223	0.0445
1997	1374	0.0000	0.2871	0.0218	0.0377
1998	1559	0.0000	0.3301	0.0254	0.0455
1999	1774	0.0000	0.3133	0.0220	0.0399
2000	1870	0.0000	0.2871	0.0233	0.0404
2001	2039	0.0000	0.2927	0.0252	0.0441

Continue...

		F			
Year	No of Animals	Min	Max	Avg	Std
2002	2279	0.0000	0.3830	0.0275	0.0493
2003	2326	0.0002	0.3790	0.0257	0.0425
2004	2311	0.0000	0.3532	0.0253	0.0402
2005	2521	0.0001	0.3813	0.0291	0.0489
2006	2780	0.0001	0.3878	0.0276	0.0462
2007	2494	0.0001	0.3233	0.0270	0.0437
2008	2391	0.0001	0.3009	0.0262	0.0410
2009	2117	0.0001	0.2767	0.0256	0.0350
2010	2175	0.0000	0.3594	0.0307	0.0460
2011	2072	0.0015	0.3795	0.0304	0.0469
2012	2149	0.0006	0.3825	0.0309	0.0459
2013	2239	0.0001	0.3857	0.0315	0.0449
2014	2345	0.0001	0.3884	0.0338	0.0503
2015	2500	0.0001	0.4213	0.0343	0.0493
2016	2432	0.0004	0.3864	0.0331	0.0453
2017	1302	0.0029	0.3829	0.0362	0.0481
2018	112	0.0049	0.2746	0.0383	0.0497
2019	3	0.0367	0.0512	0.0424	0.0077

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 (Ne) 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 Ne is a 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 $Ne = 1/2\Delta F$. 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.

Ne **:** 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

	Avg F					
Year	Animals	Sires	Dams	Parents	ΔF	Ne
1948	-	-	-	-	-	-
1949	-	-	-	-	-	-
1950	-	-	-	-	-	-
1951	0.0000	0.0000	0.0000	0.0000	0.0000	-
1952	0.0000	0.0000	0.0000	0.0000	0.0000	-
1953	0.0000	0.0000	0.0000	0.0000	0.0000	-
1954	0.0000	0.0000	0.0000	0.0000	0.0000	-
1955	0.0000	0.0000	0.0000	0.0000	0.0000	-
1956	0.0000	0.0000	0.0000	0.0000	0.0000	-
1957	0.0016	0.0000	0.0000	0.0000	0.0016	304
1958	0.0074	0.0000	0.0000	0.0000	0.0074	67
1959	0.0066	0.0031	0.0000	0.0016	0.0051	99
1960	0.0065	0.0142	0.0000	0.0074	-0.0009	-534
1961	0.0052	0.0136	0.0000	0.0069	-0.0017	-286
1962	0.0039	0.0130	0.0000	0.0065	-0.0026	-191
1963	0.0031	0.0108	0.0000	0.0055	-0.0024	-206
1964	0.0019	0.0085	0.0000	0.0043	-0.0023	-213
1965	0.0018	0.0086	0.0000	0.0044	-0.0027	-187
1966	0.0007	0.0067	0.0000	0.0034	-0.0027	-184
1967	0.0005	0.0082	0.0000	0.0042	-0.0038	-133
1968	0.0006	0.0042	0.0000	0.0021	-0.0016	-319
1969	0.0004	0.0037	0.0000	0.0019	-0.0014	-354
1970	0.0005	0.0037	0.0000	0.0018	-0.0013	-371
1971	0.0003	0.0041	0.0000	0.0021	-0.0017	-288
1972	0.0004	0.0050	0.0001	0.0026	-0.0022	-229

Continue...

	Avg F					
Year	Animals	Sires	Dams	Parents	ΔF	Ne
1973	0.0004	0.0047	0.0001	0.0024	-0.0021	-242
1974	0.0005	0.0063	0.0002	0.0032	-0.0028	-181
1975	0.0008	0.0072	0.0002	0.0037	-0.0030	-169
1976	0.0011	0.0076	0.0002	0.0039	-0.0029	-175
1977	0.0015	0.0079	0.0003	0.0041	-0.0026	-194
1978	0.0022	0.0078	0.0003	0.0041	-0.0019	-263
1979	0.0029	0.0082	0.0006	0.0044	-0.0015	-328
1980	0.0038	0.0087	0.0007	0.0047	-0.0010	-522
1981	0.0049	0.0102	0.0010	0.0056	-0.0007	-713
1982	0.0060	0.0117	0.0015	0.0066	-0.0005	-931
1983	0.0070	0.0126	0.0021	0.0073	-0.0003	-1494
1984	0.0079	0.0134	0.0028	0.0081	-0.0002	-3047
1985	0.0085	0.0142	0.0037	0.0089	-0.0004	-1186
1986	0.0089	0.0147	0.0045	0.0096	-0.0006	-772
1987	0.0095	0.0147	0.0051	0.0099	-0.0004	-1211
1988	0.0100	0.0147	0.0060	0.0103	-0.0003	-1634
1989	0.0105	0.0145	0.0068	0.0106	0.0000	-12836
1990	0.0111	0.0141	0.0073	0.0107	0.0004	1213
1991	0.0115	0.0140	0.0079	0.0109	0.0006	852
1992	0.0120	0.0138	0.0083	0.0110	0.0010	505
1993	0.0125	0.0135	0.0087	0.0111	0.0014	349
1994	0.0130	0.0140	0.0094	0.0116	0.0014	355
1995	0.0134	0.0150	0.0100	0.0124	0.0010	501
1996	0.0140	0.0165	0.0105	0.0134	0.0006	869
1997	0.0142	0.0178	0.0110	0.0143	-0.0001	-4348
1998	0.0148	0.0190	0.0116	0.0152	-0.0004	-1301
1999	0.0153	0.0203	0.0122	0.0161	-0.0009	-565
2000	0.0156	0.0217	0.0128	0.0172	-0.0016	-307
2001	0.0162	0.0229	0.0131	0.0179	-0.0018	-284
2002	0.0170	0.0234	0.0135	0.0183	-0.0013	-371
2003	0.0177	0.0233	0.0138	0.0185	-0.0008	-664
2004	0.0180	0.0228	0.0140	0.0183	-0.0003	-1541
2005	0.0188	0.0226	0.0144	0.0184	0.0004	1401
2006	0.0190	0.0221	0.0147	0.0183	0.0007	710
2007	0.0194	0.0218	0.0148	0.0183	0.0012	427
2008	0.0197	0.0216	0.0149	0.0182	0.0016	319
2009	0.0199	0.0217	0.0152	0.0184	0.0015	324
2010	0.0204	0.0220	0.0155	0.0187	0.0017	294
2011	0.0210	0.0225	0.0158	0.0191	0.0020	254
2012	0.0218	0.0230	0.0162	0.0195	0.0023	216
2013	0.0223	0.0233	0.0163	0.0198	0.0026	193
2014	0.0233	0.0237	0.0167	0.0202	0.0032	157
2015	0.0246	0.0244	0.0170	0.0207	0.0040	125
2016	0.0259	0.0249	0.0175	0.0212	0.0048	105
2017	0.0272	0.0252	0.0180	0.0215	0.0058	86
2018	0.0278	0.0253	0.0181	0.0217	0.0062	81
2019	0.0284	0.0254	0.0184	0.0219	0.0066	76

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 Ne (Falconer & Mackay, 1996):

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

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 Ne 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

	Number of				
Year	Animals	Sires	Dams	Parents	*Ne*
1948	1	1	1	2	1
1949	5	1	1	2	1
1950	7	1	1	2	1
1951	13	3	2	5	3
1952	20	4	4	8	6
1953	24	7	6	13	9
1954	29	10	9	19	13
1955	35	13	13	26	18
1956	35	14	14	28	20
1957	38	16	16	32	22
1958	42	16	17	33	23
1959	47	19	20	39	27
1960	48	19	21	40	28
1961	60	20	23	43	30
1962	80	23	25	48	34
1963	102	26	29	55	38
1964	162	38	45	83	58
1965	354	45	54	99	69
1966	621	65	80	145	100
1967	939	83	107	190	131
1968	1408	114	169	283	191
1969	2062	156	244	400	266

Continue...

	Number of				
Year	Animals	Sires	Dams	Parents	*Ne*
1970	2951	227	392	619	403
1971	4774	282	559	841	525
1972	6289	363	875	1238	718
1973	7935	516	2136	2652	1164
1974	9810	613	3396	4009	1454
1975	11490	703	4410	5113	1698
1976	12966	787	5327	6114	1920
1977	14025	899	6191	7090	2198
1978	15070	975	7101	8076	2400
1979	15202	1060	7984	9044	2620
1980	15863	1103	8815	9918	2745
1981	16196	1096	9090	10186	2739
1982	16278	1091	9218	10309	2732
1983	16535	1101	9375	10476	2759
1984	16823	1076	9416	10492	2704
1985	17321	1077	9656	10733	2713
1986	17795	1107	10145	11252	2795
1987	18418	1153	10739	11892	2915
1988	18788	1183	11181	12364	2995
1989	18915	1254	11479	12733	3165
1990	18791	1269	11584	12853	3202
1991	18502	1284	11603	12887	3237
1992	18315	1310	11776	13086	3301
1993	18310	1322	11949	13271	3333
1994	18151	1319	11840	13159	3323
1995	17731	1293	11461	12754	3253
1996	17105	1266	10945	12211	3177
1997	16727	1208	10536	11744	3034
1998	16705	1184	10374	11558	2976
1999	17111	1169	10485	11654	2945
2000	17646	1171	10771	11942	2957
2001	18245	1159	11071	12230	2938
2002	19176	1169	11616	12785	2974
2003	20194	1174	12241	13415	3000
2004	21359	1198	12916	14114	3070
2005	22821	1254	13899	15153	3221
2006	24458	1315	14986	16301	3385
2007	25437	1391	15751	17142	3579
2008	25980	1508	16313	17821	3865
2009	25895	1589	16612	18201	4061
2010	25471	1669	16685	18354	4248
2011	24861	1742	16651	18393	4416
2012	24337	1805	16577	18382	4558
2013	23661	1850	16408	18258	4655
2014	22762	1867	15961	17828	4680
2015	22300	1905	15743	17648	4758
2016	21889	1920	15463	17383	4782
2017	20556	1847	14697	16544	4594

Continue...

	Number of				
Year	Animals	Sires	Dams	Parents	*Ne*
2018	17899	1713	13201	14914	4245
2019	15308	1572	11638	13210	3878

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 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:

$2000 male * 2000 female = 4000000 computations$

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)

		AGR		F		Generation Interval
Year	No Animals	Avg	Δf	Avg	ΔF	() = True GI
1948	1	0.00000	-	0.00000	-	-
1949	5	0.00000	-	0.00000	-	-
1950	7	0.00000	-	0.00000	-	-
1951	13	0.00595	-	0.00000	-	-
1952	20	0.00750	-	0.00000	-	3 (2.8)
1953	24	0.01259	-	0.00000	-	2 (2.0)
1954	29	0.01295	-	0.00000	-	2 (2.0)
1955	35	0.01420	-	0.00000	-	3 (3.0)
1956	35	0.01575	0.01575	0.00000	0.00000	8 (-)
1957	38	0.01383	0.01383	0.00890	0.00890	2 (2.0)

Continue...

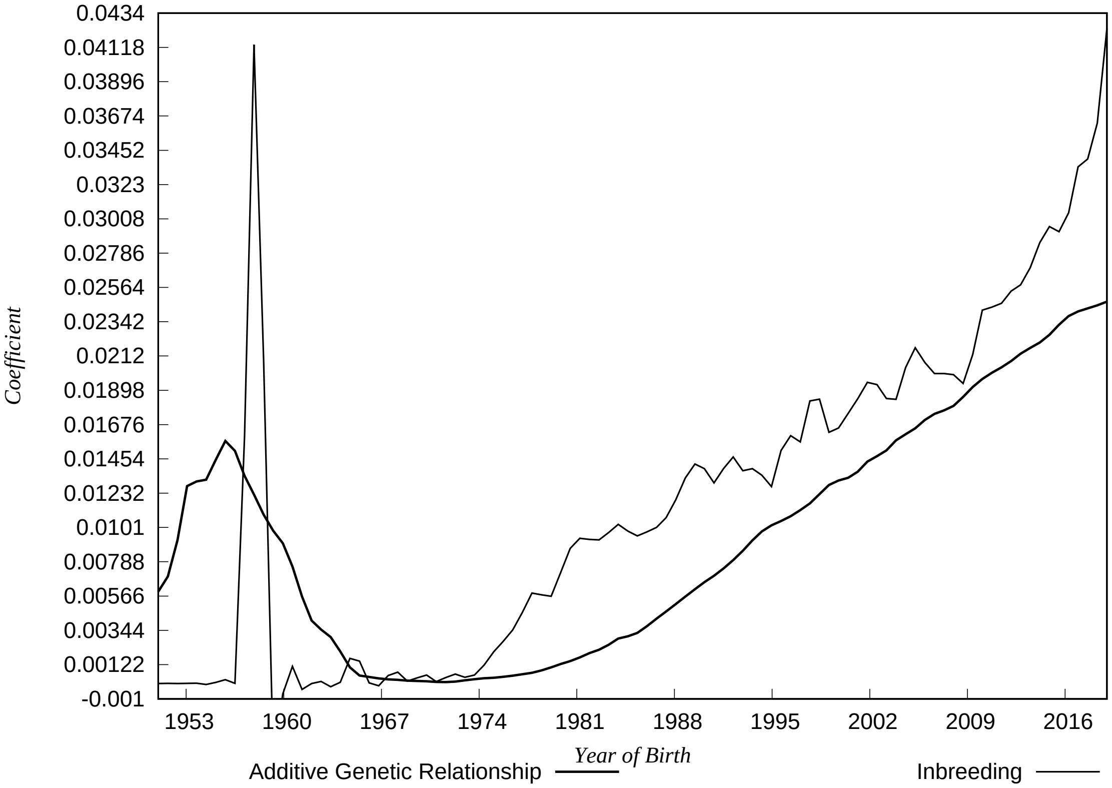
		AGR		F		Generation Interval
Year	No Animals	Avg	Δf	Avg	ΔF	() = True GI
1958	42	0.01200	0.01200	0.04170	0.04170	8 (-)
1959	47	0.01018	0.00426	0.00000	0.00000	3 (2.7)
1960	48	0.00896	0.00147	0.00000	0.00000	4 (4.2)
1961	60	0.00649	-0.00617	0.00000	0.00000	2 (2.0)
1962	80	0.00405	-0.00902	0.00000	0.00000	3 (3.0)
1963	102	0.00332	-0.01103	0.00000	0.00000	3 (3.4)
1964	162	0.00215	-0.01382	0.00000	0.00000	4 (3.6)
1965	354	0.00076	-0.01325	0.00190	-0.00706	3 (3.3)
1966	621	0.00043	-0.01170	0.00020	-0.04331	3 (2.6)
1967	939	0.00030	-0.00998	0.00000	0.00000	3 (3.2)
1968	1408	0.00024	-0.00881	0.00080	0.00080	3 (3.0)
1969	2062	0.00017	-0.00636	0.00010	0.00010	3 (3.4)
1970	2951	0.00015	-0.00392	0.00060	0.00060	4 (3.6)
1971	4774	0.00010	-0.00323	0.00010	0.00010	4 (4.1)
1972	6289	0.00010	-0.00205	0.00060	0.00060	4 (4.1)
1973	6120	0.00020	-0.00056	0.00040	-0.00150	5 (4.8)
1974	5409	0.00031	-0.00013	0.00080	0.00060	5 (5.4)
1975	5046	0.00037	0.00007	0.00200	0.00200	6 (5.6)
1976	4892	0.00046	0.00022	0.00300	0.00220	6 (5.7)
1977	4767	0.00058	0.00041	0.00440	0.00430	6 (5.7)
1978	4718	0.00073	0.00058	0.00600	0.00540	6 (6.0)
1979	4791	0.00099	0.00089	0.00550	0.00540	6 (6.0)
1980	4672	0.00130	0.00120	0.00760	0.00700	6 (6.0)
1981	4674	0.00160	0.00140	0.00930	0.00890	6 (6.3)
1982	4709	0.00200	0.00170	0.00930	0.00851	6 (6.1)
1983	4655	0.00234	0.00197	0.00950	0.00752	6 (6.2)
1984	4540	0.00292	0.00246	0.01030	0.00732	6 (6.4)
1985	4475	0.00312	0.00255	0.00960	0.00522	6 (6.1)
1986	4377	0.00369	0.00296	0.00980	0.00382	6 (6.3)
1987	4289	0.00439	0.00340	0.01030	0.00483	6 (6.2)
1988	4266	0.00507	0.00378	0.01170	0.00413	6 (6.4)
1989	4266	0.00578	0.00418	0.01370	0.00444	7 (6.5)
1990	4290	0.00646	0.00446	0.01410	0.00485	7 (6.5)
1991	4363	0.00708	0.00475	0.01300	0.00353	6 (5.8)
1992	4424	0.00781	0.00491	0.01470	0.00445	6 (5.5)
1993	4490	0.00869	0.00558	0.01370	0.00414	6 (5.7)
1994	4575	0.00964	0.00597	0.01390	0.00414	6 (5.6)
1995	4702	0.01026	0.00590	0.01280	0.00253	6 (5.8)
1996	4816	0.01066	0.00562	0.01610	0.00445	6 (6.0)
1997	4873	0.01121	0.00546	0.01560	0.00193	6 (5.7)
1998	4959	0.01189	0.00547	0.01900	0.00497	6 (6.0)
1999	4902	0.01279	0.00575	0.01640	0.00344	6 (6.0)
2000	4985	0.01320	0.00543	0.01690	0.00223	6 (6.2)
2001	4902	0.01359	0.00494	0.01820	0.00456	6 (6.4)
2002	4852	0.01449	0.00490	0.01960	0.00578	7 (6.5)
2003	4769	0.01493	0.00472	0.01870	0.00598	6 (6.4)
2004	4624	0.01583	0.00522	0.01860	0.00254	6 (6.4)
2005	4466	0.01634	0.00519	0.02160	0.00610	7 (6.5)

Continue...

		AGR		F		Generation Interval
Year	No Animals	Avg	Δf	Avg	ΔF	() = True GI
2006	4292	0.01710	0.00527	0.02070	0.00173	7 (6.6)
2007	4228	0.01759	0.00486	0.02000	0.00366	7 (6.8)
2008	4147	0.01796	0.00483	0.02000	0.00315	7 (6.6)
2009	4137	0.01885	0.00534	0.01980	0.00163	7 (6.8)
2010	4127	0.01967	0.00525	0.02400	0.00449	7 (6.7)
2011	4118	0.02024	0.00539	0.02430	0.00571	7 (6.7)
2012	4137	0.02079	0.00504	0.02530	0.00683	7 (6.9)
2013	4181	0.02146	0.00521	0.02600	0.00450	7 (7.4)
2014	4248	0.02197	0.00495	0.02810	0.00756	8 (7.6)
2015	4282	0.02268	0.00518	0.02960	0.00980	8 (7.9)
2016	4329	0.02361	0.00575	0.02960	0.00980	6 (6.4)
2017	4402	0.02411	0.00535	0.03360	0.01408	8 (-)
2018	4636	0.02439	0.00481	0.03460	0.01086	8 (-)
2019	5071	0.02472	0.00456	0.04240	0.01855	8 (-)

Fixed Time interval used to calculate Delta AGR: 8

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



The average rate of change of the additive genetic relationships between 1951 and 2019 for the 52 breed was 0.00026 per year based on the slope of the regression fitted. This result in a Δf per generation of 0.00209. The rate of change of the average inbreeding coefficients based on the slope of the regression between 1951 and 2019 was 0.00046, which represents a ΔF per generation of 0.00376. The effective population sizes for the 52 breed, based on Δf and ΔF were 239 and 133, respectively.

Figure 4: Average Log(1-F) by year of birth for animals born between 1948 and 2019.

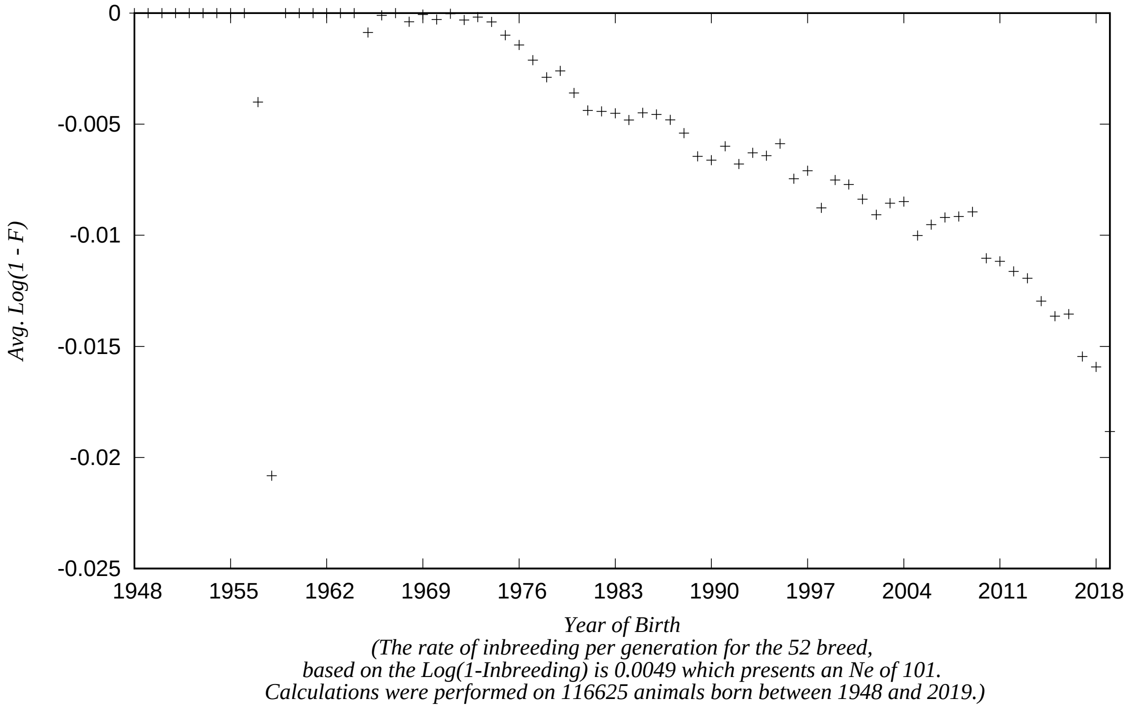


Figure 5: The Rate of Inbreeding and Increase in the Additive Genetic Relationships by year of birth

PopReport
A Population Monitoring Report

Population: 52
Inputfile: POPREP.TXT
Initiated by: quaglia@anabic.it
Submitted at: 2020-08-26 11:42:58
Started at: 2020-08-26 11:43:01
Finished at: 2020-08-26 12:23:04

Courtesy: Department of Animal Breeding and Genetics
Institute of Farm Animal Genetics (FLI)
Eildert.Groeneveld@gmx.de
Höltystrasse 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'.
  116625 input lines processed.
  116625 animals accepted.
- INFO: (concerning Inbreeding Report)
  This table shows the shortening of the number of male and female animals per year for the AGR computations. The original (orig) number of records is shortened (cut) to keep the product of $male * female$ within acceptable limits. See details later in the Inbreeding Report.

Year	No. of Male		No. of Female	
	orig.	cut	orig.	cut
1973	744	744	7191	5376
1974	884	884	8926	4525
1975	985	985	10505	4061
1976	1038	1038	11928	3854
1977	1087	1087	12938	3680
1978	1108	1108	13962	3610
1979	1077	1077	14125	3714
1980	1129	1129	14734	3543
1981	1128	1128	15068	3546
1982	1112	1112	15166	3597
1983	1137	1137	15398	3518
1984	1196	1196	15627	3344
1985	1234	1234	16087	3241
1986	1300	1300	16495	3077
1987	1371	1371	17047	2918
1988	1392	1392	17396	2874
1989	1392	1392	17523	2874
1990	1370	1370	17421	2920
1991	1310	1310	17192	3053
1992	1267	1267	17048	3157
1993	1225	1225	17085	3265
1994	1177	1177	16974	3398
1995	1115	1115	16616	3587
1996	1067	1067	16038	3749
1997	1045	1045	15682	3828
1998	1014	1014	15691	3945
1999	1034	1034	16077	3868
2000	1005	1005	16641	3980
2001	1034	1034	17211	3868

Year	No. of Male		No. of Female	
	orig.	cut	orig.	cut
2002	1053	1053	18123	3799
2003	1086	1086	19108	3683
2004	1152	1152	20207	3472
2005	1240	1240	21581	3226
2006	1368	1368	23090	2924
2007	1429	1429	24008	2799
2008	1527	1527	24453	2620
2009	1540	1540	24355	2597
2010	1555	1555	23916	2572
2011	1569	1569	23292	2549
2012	1541	1541	22796	2596
2013	1482	1482	22179	2699
2014	1409	1409	21353	2839
2015	1377	1377	20923	2905
2016	1337	1337	20552	2992
2017	1282	1282	19274	3120
2018	1146	1146	16753	3490
2019	977	977	14331	4094

Monitoring the Population 52

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Helmut Lichtenberg – Integration and WEB service
Eildert Groeneveld – Project Leader

August 26, 2020

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-ΔFp	Falconer & Mackay (1996)	$\Delta F_p = \frac{F_t - F_{t-1}}{1 - F_{t-1}}$	$F_t = \oslash$ inbreeding coefficient of offspring, $F_{t-1} = \oslash$ inbreeding coefficient of direct parents
N_e-ΔFg	Falconer & Mackay (1996)	$\Delta F_g = \frac{F_t - F_{t-1}}{1 - F_{t-1}}$	$F_{t-1} = \oslash$ inbreeding coefficient of the $\oslash$ parents generation
N_e-Coan	Falconer & Mackay (1996)	$\Delta f_g = \frac{f_t - f_{t-1}}{1 - f_{t-1}}$	$f_t = \oslash$ additiv genetic relationship (AGR) of offspring, $f_{t-1} = \oslash$ 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)	$\Delta F_i = 1 - \sqrt[ecg_i - 1]{1 - F_i}$	ecg = sum of all known ancestors with $\left(\frac{1}{2}\right)^n$, 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 $\mathrm{N_e}$ estimate is based for each of the six $\mathrm{N_e}$-methods

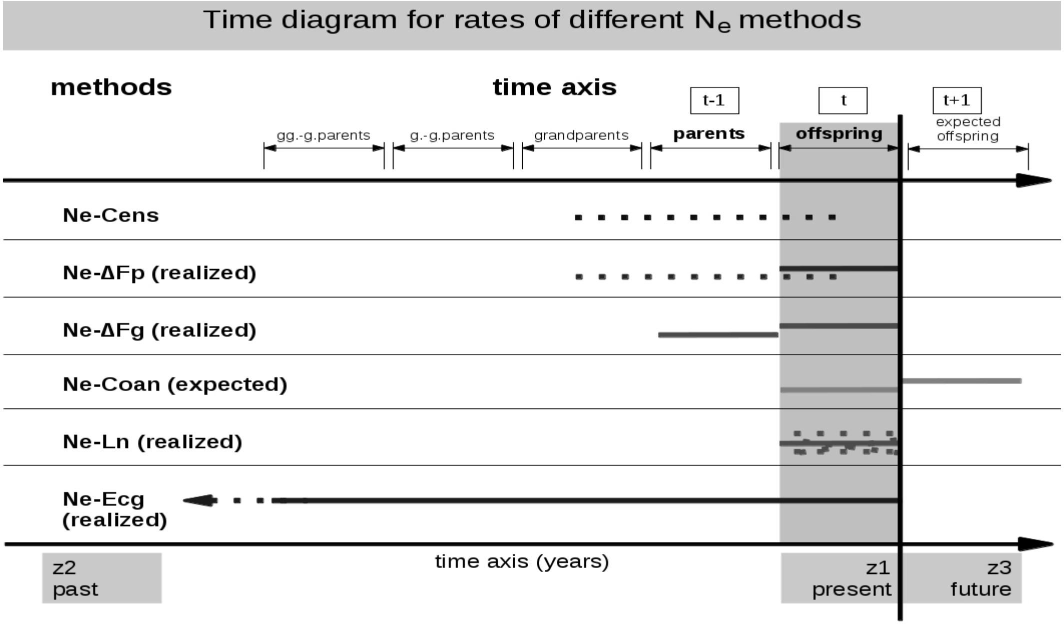

Table 2: Order of methods in cascade

Method	Based on data from
N_e-Ln	animals born in generation t
N_e-ΔFp	animals and their parents born in generation t
N_e-ΔFg	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-ΔFp 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 chosing 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 possibly 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 $\mathrm{N_e}$ 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 $\mathbf{N_e}$** 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, excuting 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 methods is disguarded. 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 read. 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.

References

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Breed: 52 • 116625 pedigree records • generation interval: 8 • August 26, 2020

Figure 2: Number of breeding animals

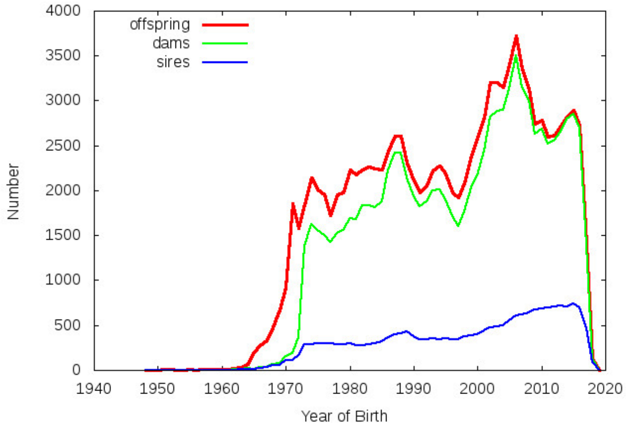

Figure 3: Average pedigree completeness for 1 to 6 generations

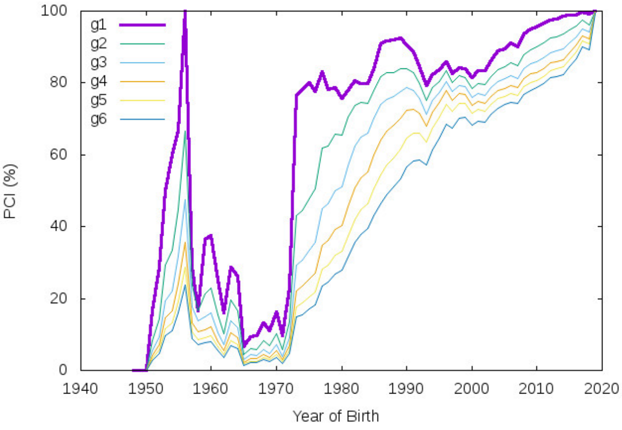

Figure 4: Average Additiv Genetic Relationship (Coan) and Inbreeding (F)

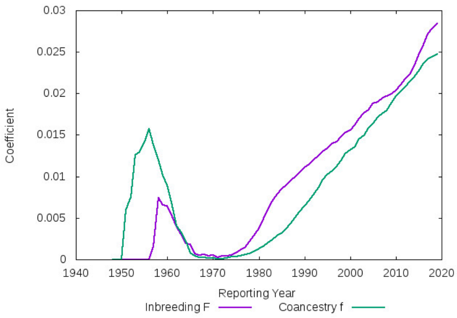

Figure 5: Average ln(1-F) by year of birth

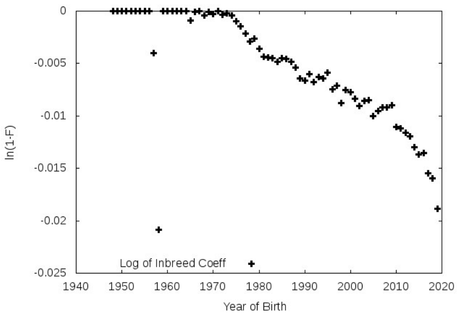

Figure 6: Ne with different calculation methods by reporting year

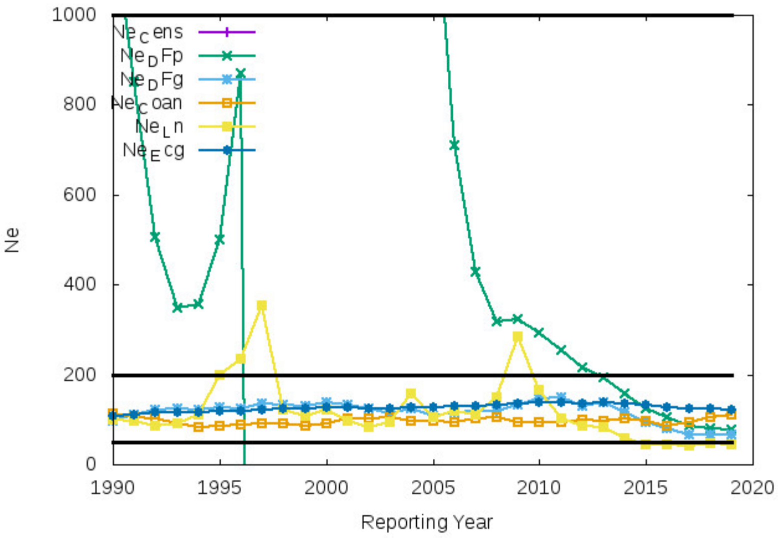

Table 3: Effective Population Size N_e

N_e-Method	2019	2018	2017	2016	2015	2014	data history
N_e-Cens	3878	4245	4594	4782	4758	4680	2011 – 2004
N_e-ΔF_p	76	81	86	105	125	157	2019 – 2004
N_e-ΔF_g	67	66	67	80	94	115	2019 – 2004
N_e-Coan	110	104	93	87	97	101	2027 – 2012
N_e-Ln	43	48	42	44	45	57	2019 – 2012
N_e-Ecg	121	123	124	128	132	136	2019 – 1948

Proposed N_e: N_e-Coan (substructure) = 110
Note: The last year is assumed to have complete data!

Table 4: Decision tree for $\mathbf{N_e}$ calculation

Year	N_e-Cens	N_e-ΔF_p	N_e-ΔF_g	N_e-Coan	N_e-Ln	N_e-Ecg
2019	3878	76	67	110	43	121
2018	4245	81	66	104	48	123
2017	4594	86	67	93	42	124
2016	4782	105	80	87	44	128
2015	4758	125	94	97	45	132
2014	4680	157	115	101	57	136
2013	4655	193	138	96	83	138
2012	4558	216	130	99	87	136
σ	247.8	14.6	10.3	7.1	10.9	1.9

Table 5: Decision cascade – side conditions

Method	Completeness [Years]	Stability [σ]	Diff	OK
N_e-Coan[a]	16/16	7.1|10.3/20	3.75	yes
N_e-Ln	8/8	10.9/20	-	yes
N_e-ΔF_p	8/8	14.6/20	-	yes
N_e-ΔF_g	8/8	10.3/20	-	yes
N_e-Coan	8/8	7.1/20	-	yes
N_e-Ecg	8/8	1.9/20	-	yes
N_e-Cens	8/8	247.8/20	-	no

---

[a] Avg N_e-Coan – Avg N_e-ΔF_g: 98.38 - 94.62 = 3.75

Service PopReport at Institute of Farm Animal Genetics
FRIEDRICH-LOEFFLER-INSTITUT
FLI
Bundesforschungsinstitut für Tiergesundheit

PopReport
A Population Structure Report

Population: 52
Inputfile: POPREP.TXT
Initiated by: quaglia@anabic.it
Submitted at: 2020-08-26 11:42:58
Started at: 2020-08-26 11:43:01
Finished at: 2020-08-26 12:23:04

Courtesy: Department of Animal Breeding and Genetics
Institute of Farm Animal Genetics (FLI)
Eildert.Groeneveld@gmx.de
Höltystrasse 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'.
  116625 input lines processed.
  116625 animals accepted.
- INFO: (concerning Inbreeding Report)
  This table shows the shortening of the number of male and female animals per year for the AGR computations. The original (orig) number of records is shortened (cut) to keep the product of $male * female$ within acceptable limits. See details later in the Inbreeding Report.

Year	No. of Male		No. of Female	
	orig.	cut	orig.	cut
1973	744	744	7191	5376
1974	884	884	8926	4525
1975	985	985	10505	4061
1976	1038	1038	11928	3854
1977	1087	1087	12938	3680
1978	1108	1108	13962	3610
1979	1077	1077	14125	3714
1980	1129	1129	14734	3543
1981	1128	1128	15068	3546
1982	1112	1112	15166	3597
1983	1137	1137	15398	3518
1984	1196	1196	15627	3344
1985	1234	1234	16087	3241
1986	1300	1300	16495	3077
1987	1371	1371	17047	2918
1988	1392	1392	17396	2874
1989	1392	1392	17523	2874
1990	1370	1370	17421	2920
1991	1310	1310	17192	3053
1992	1267	1267	17048	3157
1993	1225	1225	17085	3265
1994	1177	1177	16974	3398
1995	1115	1115	16616	3587
1996	1067	1067	16038	3749
1997	1045	1045	15682	3828
1998	1014	1014	15691	3945
1999	1034	1034	16077	3868
2000	1005	1005	16641	3980
2001	1034	1034	17211	3868

Year	No. of Male		No. of Female	
	orig.	cut	orig.	cut
2002	1053	1053	18123	3799
2003	1086	1086	19108	3683
2004	1152	1152	20207	3472
2005	1240	1240	21581	3226
2006	1368	1368	23090	2924
2007	1429	1429	24008	2799
2008	1527	1527	24453	2620
2009	1540	1540	24355	2597
2010	1555	1555	23916	2572
2011	1569	1569	23292	2549
2012	1541	1541	22796	2596
2013	1482	1482	22179	2699
2014	1409	1409	21353	2839
2015	1377	1377	20923	2905
2016	1337	1337	20552	2992
2017	1282	1282	19274	3120
2018	1146	1146	16753	3490
2019	977	977	14331	4094

Population Structure Report
for Population: 52

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Contents

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List of Figures

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 constrast 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 occuring 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 52 breed in 1964, 15 sires and 17 dams produced the 61 offspring during this year. In the batch of future parents (select) born in this year 1964 15 sires and 17 dams were represented.

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

Year	sires			dams			Number of animals
	services	births	select	services	births	select	born
1951	-	2	2	-	1	1	6
1952	-	2	2	-	2	2	7
1953	-	3	3	-	2	2	4
1954	-	3	3	-	3	3	5
1955	-	4	4	-	4	4	6
1956	-	1	1	-	1	1	1
1957	-	2	2	-	2	2	7
1958	-	1	1	-	1	1	6
1959	-	4	4	-	4	4	11
1960	-	4	4	-	3	3	8
1961	-	4	4	-	4	4	16
1962	-	4	4	-	5	5	25
1963	-	8	8	-	8	8	28

Continue...

Year	sires			dams			Number of animals
	services	births	select	services	births	select	born
1964	-	15	15	-	17	17	61
1965	-	13	12	-	11	10	199
1966	-	25	25	-	27	26	273
1967	-	32	32	-	31	31	329
1968	-	50	49	-	66	65	477
1969	-	59	54	-	81	71	670
1970	-	112	105	-	156	141	914
1971	-	108	95	-	185	146	1851
1972	-	169	149	-	365	295	1576
1973	-	290	217	-	1380	730	1845
1974	-	291	216	-	1626	843	2148
1975	-	302	239	-	1561	849	2009
1976	-	294	226	-	1503	875	1953
1977	-	301	233	-	1425	789	1729
1978	-	286	229	-	1521	857	1959
1979	-	283	225	-	1556	845	1983
1980	-	292	229	-	1694	936	2237
1981	-	274	222	-	1684	968	2178
1982	-	272	220	-	1838	1068	2230
1983	-	286	232	-	1831	1053	2266
1984	-	293	239	-	1814	1017	2241
1985	-	319	254	-	1873	1044	2227
1986	-	363	289	-	2220	1109	2433
1987	-	395	293	-	2416	1203	2606
1988	-	406	300	-	2415	1249	2607
1989	-	427	318	-	2146	1153	2305
1990	-	376	306	-	1931	1154	2106
1991	-	347	287	-	1824	1100	1977
1992	-	341	275	-	1872	1112	2054
1993	-	354	285	-	2000	1189	2222
1994	-	339	290	-	2014	1216	2274
1995	-	352	308	-	1904	1226	2186
1996	-	344	301	-	1710	1132	1981
1997	-	340	308	-	1598	1061	1927
1998	-	377	315	-	1768	1143	2084
1999	-	385	329	-	2031	1349	2383
2000	-	395	325	-	2170	1321	2589
2001	-	442	377	-	2444	1484	2821
2002	-	477	397	-	2817	1673	3205
2003	-	480	403	-	2885	1687	3204
2004	-	491	393	-	2893	1554	3146
2005	-	549	427	-	3131	1658	3389
2006	-	609	465	-	3507	1725	3721
2007	-	616	458	-	3149	1529	3362
2008	-	639	455	-	3006	1373	3132
2009	-	674	445	-	2634	1186	2736
2010	-	689	459	-	2681	1121	2781
2011	-	695	404	-	2523	919	2594

Continue...

Year	sires			dams			Number of animals
	services	births	select	services	births	select	born
2012	-	709	364	-	2562	762	2622
2013	-	713	279	-	2656	558	2713
2014	-	711	203	-	2793	345	2822
2015	-	737	65	-	2855	78	2900
2016	-	697	5	-	2690	5	2721
2017	-	462	-	-	1392	-	1403
2018	-	83	-	-	124	-	124
2019	-	3	-	-	3	-	3
Total	-	6173	4789	-	58557	32822	116625

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 52 breed in 1966, 3 two year-old males were used in reproduction while 3 three year-old males were used. The average age of males that produced offspring during 1966 was 2.4 year.

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

Year	age of males in year																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	≥ 16	Avg
1951	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0
1952	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	3.0
1953	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0
1954	2	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.3
1955	3	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1.8
1956	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0
1957	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0
1958	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	3.0
1959	3	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	2.8
1960	2	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	3.8
1961	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0
1962	3	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	3.5
1963	5	1	–	1	–	–	–	1	–	–	–	–	–	–	–	–	2.4
1964	8	1	–	1	–	2	–	–	1	1	–	1	–	–	–	–	3.8
1965	8	2	1	–	–	–	1	–	–	–	1	–	–	–	–	–	2.5
1966	16	3	3	–	–	1	–	1	–	–	–	–	–	–	1	–	2.4
1967	20	1	2	3	1	–	2	–	1	–	–	1	1	–	–	–	2.9
1968	27	3	6	4	5	–	1	2	–	1	–	–	–	–	–	1	2.8
1969	35	4	3	3	2	6	1	1	1	–	1	–	–	2	–	–	2.9
1970	49	17	17	7	5	3	5	4	1	–	–	1	–	–	1	2	3.1
1971	35	18	10	12	8	4	6	6	1	–	3	1	1	–	–	3	3.9

Continue...

Year	age of males in year															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	≥ 16	Avg
1972	48	25	29	13	17	9	9	3	9	1	2	–	1	1	–	2	3.8
1973	27	75	48	42	21	27	16	11	7	9	2	1	–	1	1	2	4.2
1974	17	58	75	28	34	16	23	10	12	5	6	1	1	2	1	2	4.5
1975	11	48	63	54	22	28	16	20	11	11	6	6	1	1	1	3	5.0
1976	13	71	38	45	36	12	21	14	12	9	10	5	3	2	–	3	4.9
1977	17	73	72	24	32	21	7	15	11	8	6	8	1	1	1	4	4.6
1978	14	65	67	45	11	22	6	7	14	9	10	5	6	1	–	4	4.8
1979	13	71	65	49	27	6	10	6	5	7	6	6	4	4	1	3	4.5
1980	15	70	66	44	28	19	4	7	4	7	6	3	6	4	4	5	4.7
1981	17	73	54	43	24	18	11	5	3	2	3	5	4	4	1	7	4.5
1982	9	59	66	45	27	14	12	9	2	4	2	5	8	3	1	6	4.8
1983	15	85	57	40	25	18	13	6	8	–	1	4	2	4	3	5	4.3
1984	14	70	77	41	21	16	16	7	5	5	1	2	2	3	3	10	4.6
1985	18	81	66	63	32	14	7	12	3	4	3	1	2	3	3	7	4.3
1986	17	103	89	37	42	20	13	5	9	6	2	2	1	2	3	12	4.4
1987	23	111	82	79	30	32	12	2	6	1	4	1	1	1	1	9	4.0
1988	19	87	103	71	53	24	15	9	1	4	–	2	1	2	1	14	4.4
1989	26	98	82	91	43	33	18	11	7	1	2	–	1	2	1	11	4.3
1990	9	92	81	67	48	26	15	14	3	6	1	1	–	1	1	11	4.5
1991	7	83	92	59	40	21	18	9	3	4	1	1	1	–	2	6	4.3
1992	13	84	77	75	35	22	18	9	4	–	1	–	–	1	–	2	3.9
1993	11	89	92	61	45	24	14	5	7	3	2	–	–	–	–	1	3.8
1994	12	82	86	62	39	35	12	3	4	2	2	–	–	–	–	–	3.8
1995	10	84	81	68	43	23	28	7	2	5	–	1	–	–	–	–	3.9
1996	11	91	69	55	47	33	9	15	8	1	4	–	1	–	–	–	4.0
1997	7	77	90	53	41	27	17	11	9	1	1	5	–	–	–	1	4.1
1998	5	86	78	86	41	24	20	15	8	7	3	1	3	–	–	–	4.2
1999	5	84	72	75	63	35	19	12	10	2	4	1	–	3	–	–	4.3
2000	6	86	61	72	72	48	15	14	5	7	3	2	1	1	2	–	4.4
2001	7	91	69	74	69	45	44	13	9	9	7	2	2	–	–	1	4.6
2002	6	81	93	61	55	55	55	33	13	10	4	3	4	2	–	2	4.9
2003	10	94	90	64	45	49	43	28	28	10	6	3	2	3	3	2	4.9
2004	6	89	86	86	58	34	33	31	30	18	3	2	3	5	2	5	5.1

Continue...

Year	age of males in year															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	≥ 16	Avg
2005	8	95	95	90	77	52	24	31	26	21	14	1	1	4	3	7	5.1
2006	9	116	100	94	78	62	41	24	20	24	14	10	–	–	6	11	5.1
2007	17	108	110	89	79	56	48	34	19	17	8	13	4	–	1	13	5.1
2008	11	141	117	101	61	58	43	34	19	14	7	8	8	3	–	14	4.9
2009	5	120	136	103	87	59	46	33	22	18	11	4	7	5	3	15	5.2
2010	14	103	117	123	95	67	43	35	21	27	14	3	1	5	3	18	5.3
2011	9	97	118	110	110	75	55	37	20	16	13	6	2	2	5	20	5.4
2012	10	78	111	100	100	107	59	46	30	12	6	16	6	3	–	25	5.8
2013	9	92	86	97	102	94	79	59	28	17	8	5	9	3	3	22	5.9
2014	5	102	86	85	95	70	80	66	42	26	12	4	4	6	3	25	6.1
2015	14	92	101	98	74	82	70	67	38	35	18	8	4	2	6	28	6.2
2016	7	101	85	79	86	69	71	46	46	35	19	13	5	3	1	31	6.3
2017	–	51	72	59	57	48	35	42	22	16	18	11	5	2	2	22	6.6
2018	–	12	15	14	7	9	4	5	2	1	1	4	1	–	1	7	7.1
2019	–	–	1	–	–	–	1	1	–	–	–	–	–	–	–	–	6.0
Total	804	3975	3811	3146	2395	1775	1305	954	632	459	283	189	121	97	75	404	6.4

For example: For the 52 breed in 1968, 2 two year-old females were used in reproduction while 4 three year-old females were used. The avarage age of females that produced offspring during 1968 was 1.3 year.

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

Year	age of females in year																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	≥ 16	Avg
1951	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0
1952	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0
1953	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0
1954	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0
1955	3	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	2.8
1956	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0
1957	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0
1958	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0
1959	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0
1960	2	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	2.3
1961	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0
1962	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0
1963	6	1	–	–	–	–	–	–	–	1	–	–	–	–	–	–	2.3
1964	16	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1.5
1965	9	1	–	–	–	–	1	–	–	–	–	–	–	–	–	–	1.6
1966	26	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	1.2
1967	29	1	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1.2
1968	57	2	4	1	1	1	–	–	–	–	–	–	–	–	–	–	1.3
1969	70	3	5	1	1	–	–	1	–	–	–	–	–	–	–	–	1.3
1970	121	15	6	10	2	1	1	–	–	–	–	–	–	–	–	–	1.5
1971	114	12	25	11	9	9	1	1	1	1	–	1	–	–	–	–	2.2
1972	232	25	44	21	19	11	8	2	–	2	–	–	–	–	–	1	2.1
1973	617	133	170	145	118	71	59	54	5	3	1	2	–	–	1	1	2.9
1974	436	189	369	183	162	91	68	62	55	2	3	2	–	–	1	3	3.5
1975	197	153	370	278	154	146	87	65	52	43	5	5	1	2	–	3	4.2
1976	190	160	236	291	217	114	95	77	46	33	32	7	3	–	–	2	4.4
1977	161	215	219	172	197	163	83	88	42	29	32	20	2	–	–	2	4.6
1978	150	230	252	206	170	165	131	69	51	34	29	14	15	2	1	2	4.6
1979	90	183	269	235	204	148	159	102	62	54	23	6	11	5	1	4	5.0

Continue...

Year	age of females in year															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	≥ 16	Avg
1980	117	175	268	228	210	188	130	124	98	62	38	16	17	13	6	4	5.3
1981	75	200	222	218	240	191	158	109	91	79	41	25	16	6	6	7	5.5
1982	100	256	255	212	220	230	175	128	84	79	47	28	14	3	4	3	5.3
1983	57	265	247	240	213	198	188	154	100	59	47	37	14	4	5	3	5.4
1984	20	246	271	231	232	184	174	154	124	73	35	35	17	11	2	5	5.6
1985	44	197	302	303	217	211	158	135	121	89	46	19	15	7	5	4	5.5
1986	56	248	342	295	302	281	162	169	123	101	81	29	13	9	4	5	5.5
1987	46	291	304	314	309	298	256	179	161	90	84	47	19	9	3	6	5.7
1988	22	287	346	307	292	276	240	218	158	105	71	51	24	12	4	2	5.7
1989	18	245	275	262	266	253	222	185	143	100	79	40	28	13	5	12	5.9
1990	15	223	264	245	226	214	171	154	137	99	75	48	27	22	10	1	6.0
1991	11	215	236	220	201	197	165	129	136	125	71	46	39	19	8	6	6.1
1992	8	224	248	257	231	174	168	144	134	91	81	50	28	18	6	10	6.0
1993	6	220	250	269	264	207	180	152	129	119	96	38	35	15	13	7	6.1
1994	10	225	220	260	256	242	189	153	144	100	79	51	38	21	6	20	6.2
1995	4	232	221	230	220	223	202	138	126	108	74	47	37	21	11	10	6.2
1996	6	187	204	184	165	218	200	158	118	85	72	49	36	12	9	7	6.3
1997	5	181	190	185	173	157	157	141	115	103	66	43	36	26	12	8	6.4
1998	6	193	210	207	192	165	161	164	129	109	85	52	50	18	11	16	6.4
1999	5	212	207	245	246	233	187	162	138	130	106	73	36	32	10	9	6.4
2000	7	204	243	228	235	261	207	159	161	147	120	88	60	25	14	11	6.6
2001	7	255	247	222	281	270	264	223	157	139	126	104	71	42	16	20	6.7
2002	10	315	328	266	281	273	276	252	213	159	138	119	78	54	33	22	6.7
2003	8	326	357	327	264	244	254	252	212	186	134	118	80	53	36	34	6.6
2004	8	331	353	351	296	234	253	230	219	159	147	101	87	58	31	35	6.6
2005	11	378	388	371	362	329	233	224	202	167	143	117	71	57	36	42	6.4
2006	13	421	448	425	387	374	286	229	216	170	164	133	100	52	36	53	6.4
2007	8	359	391	403	380	300	281	229	170	153	144	114	82	61	35	39	6.4
2008	11	337	343	373	357	341	266	251	187	131	111	107	73	45	35	38	6.4
2009	5	293	330	302	297	261	246	223	187	130	97	76	75	51	23	38	6.5
2010	6	242	331	340	335	281	262	211	173	165	109	83	59	31	24	29	6.4
2011	6	235	265	330	316	255	275	205	186	127	107	81	52	44	21	18	6.5
2012	6	201	253	282	301	291	266	230	199	176	119	99	58	35	21	25	6.7

Continue...

Year	age of females in year															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	≥ 16	Avg
2013	3	201	260	283	311	317	297	236	190	184	131	97	54	37	23	32	6.8
2014	4	222	245	306	290	325	293	253	209	173	170	105	86	57	25	30	7.0
2015	7	239	233	307	304	295	301	274	250	180	146	132	80	51	26	30	7.0
2016	2	240	259	275	276	275	265	258	251	188	118	106	83	43	24	27	6.9
2017	2	128	142	155	159	141	116	128	128	87	71	52	36	18	11	18	6.7
2018	–	12	7	16	15	13	10	15	11	7	8	3	4	2	1	–	6.8
2019	–	–	–	–	–	1	–	1	1	–	–	–	–	–	–	–	7.7
Total	3306	10784	12474	12028	11377	10342	8988	7655	6345	4937	3802	2716	1860	1116	615	704	7.3

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 52 in 1969, 4 females were in their second parity while in 1972, 4 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
1951	1	–	–	–	–	–	–	–	–	–
1952	2	–	–	–	–	–	–	–	–	–
1953	2	–	–	–	–	–	–	–	–	–
1954	3	–	–	–	–	–	–	–	–	–
1955	4	–	–	–	–	–	–	–	–	–
1956	1	–	–	–	–	–	–	–	–	–
1957	2	–	–	–	–	–	–	–	–	–
1958	1	–	–	–	–	–	–	–	–	–
1959	4	–	–	–	–	–	–	–	–	–
1960	3	–	–	–	–	–	–	–	–	–
1961	4	–	–	–	–	–	–	–	–	–
1962	5	–	–	–	–	–	–	–	–	–
1963	8	–	–	–	–	–	–	–	–	–
1964	17	–	–	–	–	–	–	–	–	–
1965	11	1	–	–	–	–	–	–	–	–
1966	27	–	–	–	–	–	–	–	–	–
1967	31	1	–	–	–	–	–	–	–	–
1968	65	1	–	–	–	–	–	–	–	–
1969	79	4	–	–	–	–	–	–	–	–
1970	153	6	–	–	–	–	–	–	–	–
1971	171	14	–	–	–	–	–	–	–	–
1972	331	36	4	–	–	–	–	–	–	–
1973	1266	138	10	1	–	–	–	–	–	–
1974	1272	349	46	9	2	–	–	–	–	–
1975	1031	424	124	21	3	1	–	–	–	–
1976	959	380	135	39	5	1	1	–	–	–
1977	911	335	129	46	17	2	–	1	–	–
1978	988	349	125	39	21	6	1	–	1	–
1979	972	407	119	47	14	4	–	–	–	–
1980	1035	410	172	59	14	10	1	–	–	–
1981	979	451	179	67	15	3	1	1	–	–
1982	1086	458	218	59	18	3	–	–	–	–
1983	1077	448	192	103	16	5	–	–	–	–
1984	1022	480	200	81	31	9	2	–	–	–
1985	1088	480	192	86	28	7	–	–	–	–

Continue...

Year	parity number									
	1	2	3	4	5	6	7	8	9	10
1986	1384	489	230	84	31	8	2	–	–	–
1987	1483	546	236	106	43	9	2	–	–	–
1988	1455	595	226	91	39	12	5	–	–	–
1989	1223	560	231	88	38	15	1	–	–	–
1990	1095	495	219	75	32	13	5	–	–	–
1991	1031	446	218	90	32	6	4	1	–	–
1992	1116	440	202	81	30	4	1	1	–	–
1993	1154	518	208	75	31	12	4	–	1	–
1994	1140	527	214	93	29	13	3	1	–	–
1995	1056	528	180	90	34	16	1	2	–	1
1996	935	476	197	67	36	7	2	–	–	–
1997	893	416	185	66	24	16	3	1	–	–
1998	975	463	206	87	29	8	3	1	–	–
1999	1192	526	203	82	26	5	4	–	–	–
2000	1279	540	223	89	33	6	5	2	–	–
2001	1430	589	274	112	37	13	1	2	–	–
2002	1643	724	292	119	32	11	4	1	1	–
2003	1643	756	301	131	46	9	7	–	–	–
2004	1574	795	333	130	44	18	5	1	–	–
2005	1783	805	335	140	54	15	6	1	–	–
2006	1990	912	372	143	69	23	3	1	–	–
2007	1787	790	349	149	59	18	7	–	–	–
2008	1670	779	360	128	48	20	4	1	–	–
2009	1511	643	292	119	41	21	9	1	1	–
2010	1502	703	282	140	47	14	5	1	1	–
2011	1448	658	260	104	39	15	4	3	–	–
2012	1460	637	283	109	53	17	5	3	1	–
2013	1540	678	278	104	37	15	5	5	–	–
2014	1616	749	264	108	31	17	7	4	2	–
2015	1618	788	294	96	39	15	8	2	2	1
2016	1506	743	290	99	30	14	7	2	–	–
2017	759	364	176	64	19	5	4	2	–	1
2018	55	41	20	6	2	–	–	–	–	–
2019	–	1	1	1	–	–	–	–	–	–
Total	58557	24892	10079	3923	1398	461	142	41	10	3

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 52 breed the Generation interval (average age of parents when their selected offspring were born) for the selection path between sire to son (ss) was 4.7 year in 1964. This values was calculated based on the avarage ages of 10 selected sons, born during 1964. 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, 1.9 and 3.4 year, respectively. During 1964, the generation interval for the males was 4.9 year and 2.4 year for the female born during this year. The generation interval in 1964 for all four selection paths together, or for the population in total (pop), was 3.6 year, based on the average age of parents of 17 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 daugthers 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
1952	3.8	1	3.2	1	2.0	1	2.0	1	3.5	2	2.0	2	2.8	2
1953	2.0	1	2.0	2	2.0	1	2.0	1	2.0	3	2.0	2	2.0	3
1954	2.0	2	2.0	1	2.0	2	2.0	1	2.0	3	2.0	3	2.0	3
1955	2.0	3	4.0	1	2.0	3	8.0	1	2.5	4	3.5	4	3.0	4
1957	2.0	1	2.0	1	2.0	1	2.0	1	2.0	2	2.0	2	2.0	2
1959	4.0	3	2.0	1	2.0	3	2.0	1	3.5	4	2.0	4	2.7	4
1960	5.3	3	2.0	1	3.6	2	2.0	1	4.5	4	3.1	3	4.2	4
1961	2.0	1	2.0	3	2.0	1	2.0	3	2.0	4	2.0	4	2.0	4
1962	6.9	2	2.0	2	2.0	3	2.0	2	4.5	4	2.0	5	3.0	5
1963	2.2	4	3.7	5	2.0	4	4.2	4	3.1	9	3.1	8	3.4	9
1964	4.7	10	5.2	6	1.9	11	3.4	6	4.9	16	2.4	17	3.6	17
1965	3.5	8	3.5	7	2.0	6	2.9	6	3.5	15	2.4	12	3.3	15

Continue...

Year	Generation interval and number of animal													
	ss	Nss	sd	Nsd	ms	Nms	md	Nmd	male	Nmale	female	Nfemale	pop	Npop
1966	3.1	14	3.1	12	1.9	14	2.4	12	3.1	26	2.2	26	2.6	27
1967	3.3	11	3.7	23	2.3	11	2.0	21	3.6	34	2.1	32	3.2	34
1968	4.2	23	3.5	42	2.4	23	2.2	42	3.7	65	2.2	65	3.0	68
1969	4.3	17	4.4	55	2.6	18	2.1	55	4.4	72	2.2	73	3.4	79
1970	4.8	22	4.5	123	2.4	21	2.3	122	4.6	145	2.3	143	3.6	155
1971	6.4	19	4.8	137	2.7	18	2.9	130	5.0	156	2.9	148	4.1	160
1972	6.3	17	5.2	294	3.5	14	2.9	289	5.2	311	2.9	303	4.1	320
1973	6.2	81	5.9	667	4.3	81	3.6	662	6.0	748	3.7	743	4.8	750
1974	8.1	95	6.3	769	5.0	95	4.2	765	6.5	864	4.3	860	5.4	865
1975	7.5	111	6.3	759	5.5	111	4.8	754	6.4	870	4.9	865	5.6	873
1976	7.3	85	6.2	788	5.3	85	5.0	795	6.3	873	5.0	880	5.7	882
1977	6.0	99	6.3	696	6.0	99	5.1	696	6.2	795	5.2	795	5.7	799
1978	7.0	100	6.8	764	6.5	100	5.1	766	6.8	864	5.3	866	6.0	867
1979	6.4	89	6.4	756	5.9	89	5.5	762	6.4	845	5.5	851	6.0	853
1980	5.3	110	6.2	829	5.8	110	6.0	832	6.1	939	6.0	942	6.0	946
1981	6.0	121	6.5	849	6.3	121	6.2	853	6.5	970	6.2	974	6.3	974
1982	6.5	111	6.3	954	6.5	111	5.9	961	6.4	1065	5.9	1072	6.1	1073
1983	5.7	126	6.5	921	5.8	127	6.1	935	6.4	1047	6.0	1062	6.2	1062
1984	6.6	137	6.6	871	6.7	140	6.1	883	6.6	1008	6.2	1023	6.4	1031
1985	5.4	129	6.3	923	6.1	128	6.0	921	6.2	1052	6.0	1049	6.1	1058
1986	5.6	143	6.5	971	6.2	144	6.2	975	6.4	1114	6.2	1119	6.3	1126
1987	6.1	133	6.3	1063	6.1	133	6.3	1075	6.3	1196	6.2	1208	6.2	1215
1988	5.5	118	6.5	1126	6.4	118	6.4	1136	6.4	1244	6.4	1254	6.4	1258
1989	6.6	113	6.5	1039	6.1	113	6.5	1054	6.5	1152	6.5	1167	6.5	1171
1990	6.9	121	6.3	1028	6.2	121	6.6	1038	6.4	1149	6.6	1159	6.5	1162
1991	4.8	97	4.8	967	6.1	97	6.8	1007	4.8	1064	6.7	1104	5.8	1105
1992	3.8	123	4.4	928	6.6	123	6.5	993	4.3	1051	6.5	1116	5.5	1118
1993	4.0	112	4.4	964	6.4	112	6.7	1084	4.4	1076	6.6	1196	5.7	1198
1994	4.1	132	4.4	1002	6.3	132	6.7	1089	4.4	1134	6.7	1221	5.6	1221
1995	4.4	113	4.8	1068	6.8	113	6.7	1119	4.7	1181	6.7	1232	5.8	1233
1996	4.7	112	5.1	1020	6.9	112	6.8	1030	5.1	1132	6.8	1142	6.0	1142
1997	3.8	120	4.7	940	6.4	120	6.9	952	4.6	1060	6.9	1072	5.7	1074
1998	4.6	106	4.9	1034	6.3	106	7.1	1046	4.9	1140	7.0	1152	6.0	1155
1999	4.6	130	5.1	1203	6.3	130	7.0	1226	5.1	1333	6.9	1356	6.0	1360
2000	4.8	104	5.3	1180	7.1	104	7.1	1225	5.2	1284	7.1	1329	6.2	1334
2001	5.3	138	5.6	1286	6.8	138	7.2	1357	5.6	1424	7.2	1495	6.4	1499
2002	5.4	152	5.8	1455	6.8	152	7.2	1533	5.8	1607	7.2	1685	6.5	1696
2003	5.5	144	5.6	1475	6.4	144	7.2	1553	5.6	1619	7.1	1697	6.4	1704
2004	5.1	162	5.7	1345	6.9	162	7.2	1403	5.6	1507	7.2	1565	6.4	1570
2005	6.2	191	6.0	1411	6.7	191	6.8	1477	6.1	1602	6.8	1668	6.5	1672
2006	6.4	212	6.2	1460	6.4	212	7.0	1520	6.3	1672	6.9	1732	6.6	1740
2007	6.1	171	6.7	1308	6.5	171	6.9	1367	6.6	1479	6.9	1538	6.8	1544
2008	6.7	180	6.4	1166	6.5	180	6.9	1199	6.4	1346	6.8	1379	6.6	1381
2009	6.8	141	6.8	1034	6.6	141	6.8	1053	6.8	1175	6.8	1194	6.8	1197
2010	6.9	147	6.6	960	6.2	147	6.9	985	6.6	1107	6.8	1132	6.7	1132
2011	6.0	149	6.6	770	6.4	149	7.1	774	6.5	919	7.0	923	6.7	925
2012	6.7	137	6.9	625	6.7	137	7.1	629	6.9	762	7.0	766	6.9	768
2013	8.0	115	7.6	444	6.8	115	7.1	446	7.7	559	7.1	561	7.4	561

Continue...

Year	Generation interval and number of animal													
	ss	Nss	sd	Nsd	ms	Nms	md	Nmd	male	Nmale	female	Nfemale	pop	Npop
2014	7.2	94	8.1	251	6.8	94	7.3	251	7.9	345	7.2	345	7.6	346
2015	8.4	29	8.9	49	6.9	29	7.4	49	8.7	78	7.2	78	7.9	78
2016	6.6	3	6.4	2	7.5	3	4.5	2	6.5	5	6.3	5	6.4	5
Total	5.8	-	5.9	-	6.2	-	6.4	-	5.9	-	6.4	-	6.2	-

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 populaiton are also identified (Figures 1 to 8). The information is presented separetly for sires and dams considering *all* and *selected offspring.*

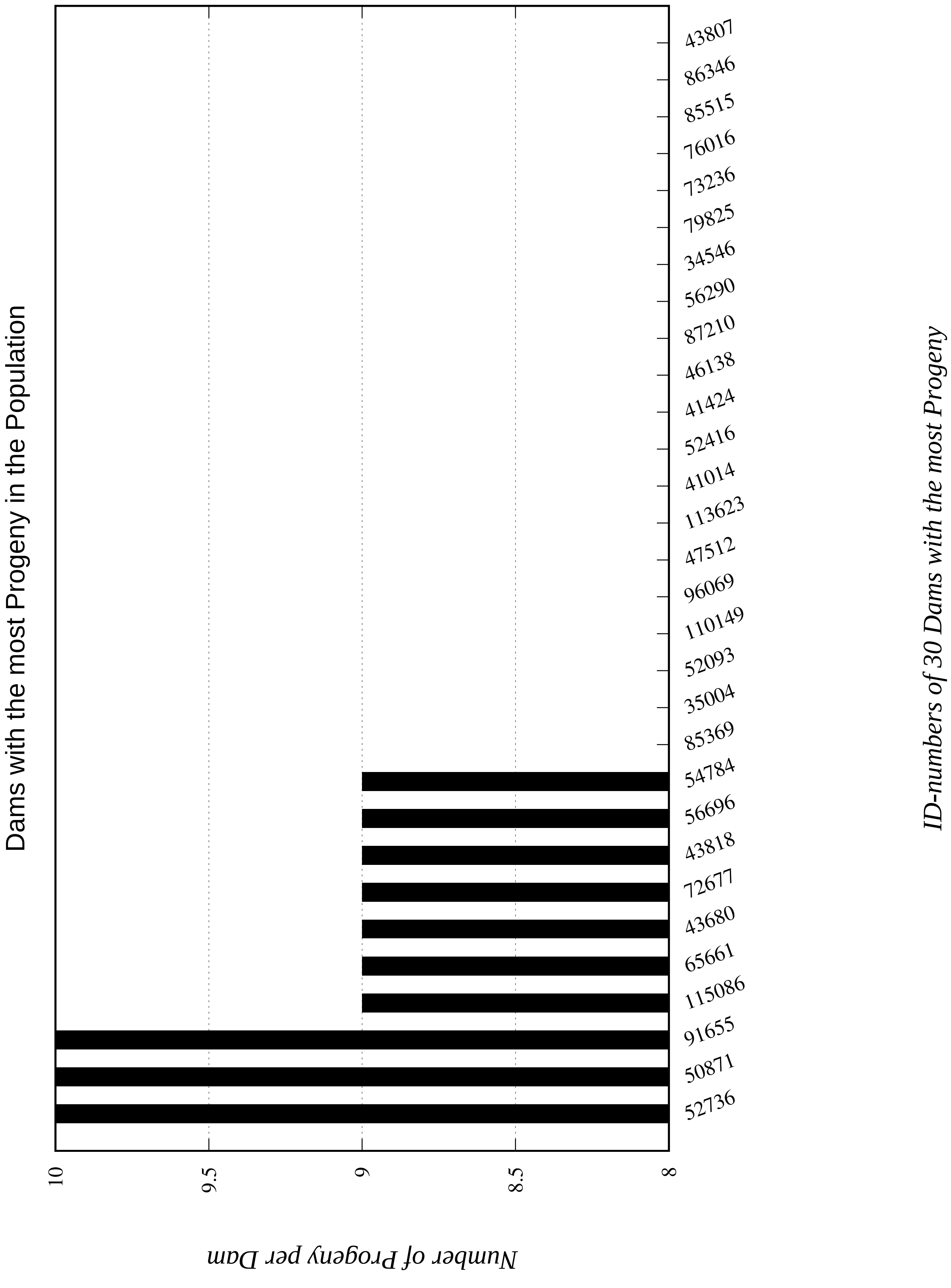
Table 6: The maximum and average number of family sizes

	All offspring				Selected offspring				Selected sons				Selected daughters			
	sires		dams		sires		dams		sires		dams		sires		dams	
Year	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg
1949	2	1.7	1	1.0	2	1.7	1	1.0	2	2.0	-	-	2	1.5	1	1.0
1951	44	12.8	5	3.0	24	7.8	5	3.0	3	1.7	3	3.0	23	8.7	2	1.5
1952	3	2.0	1	1.0	3	2.0	1	1.0	2	1.5	1	1.0	2	1.5	1	1.0
1953	1	1.0	4	2.5	1	1.0	4	2.5	1	1.0	1	1.0	-	-	3	3.0
1954	7	5.5	3	1.7	7	5.5	2	1.3	3	2.0	1	1.0	4	3.5	1	1.0
1955	46	16.3	4	2.0	33	12.0	2	1.3	9	3.7	1	1.0	24	12.5	2	2.0
1957	85	29.0	4	2.3	61	21.0	4	2.0	23	12.0	2	1.3	38	19.5	2	1.5
1958	150	50.7	2	1.3	84	28.7	1	1.0	15	8.0	1	1.0	69	35.0	1	1.0
1959	223	46.4	2	1.2	108	23.2	2	1.2	9	3.0	1	1.0	99	26.0	2	1.2
1960	7	3.5	3	2.0	6	2.5	3	2.0	3	2.0	2	1.5	3	2.0	3	2.5
1961	49	16.3	7	1.8	38	11.0	7	1.8	7	2.8	5	2.0	31	11.0	2	1.2
1962	81	22.3	5	1.9	39	12.5	3	1.5	10	4.1	2	1.2	29	9.2	3	1.3
1963	70	15.9	6	2.4	56	11.7	5	2.2	16	5.0	3	1.3	40	8.5	5	1.9
1964	229	31.1	6	2.0	127	18.8	5	1.6	25	4.4	2	1.2	121	18.0	3	1.5
1965	109	23.1	7	1.8	64	13.3	4	1.5	9	2.8	2	1.0	55	12.2	3	1.4
1966	106	22.0	6	1.7	83	14.6	6	1.4	13	4.2	2	1.1	77	12.4	5	1.4
1967	107	14.1	7	1.7	54	9.0	6	1.5	9	2.8	3	1.1	50	8.6	5	1.4
1968	569	25.3	6	1.8	301	14.2	6	1.5	32	4.1	2	1.1	269	12.8	6	1.5
1969	432	20.8	9	1.9	240	13.1	6	1.6	24	4.2	3	1.2	216	12.0	5	1.5
1970	259	11.8	8	1.7	136	8.2	8	1.5	22	3.5	3	1.1	114	7.8	5	1.5
1971	92	9.7	7	1.6	63	6.7	6	1.4	9	1.9	2	1.1	58	6.4	6	1.4
1972	960	20.8	8	1.6	484	15.9	6	1.4	45	3.9	2	1.1	439	14.8	5	1.4
1973	130	12.5	6	1.6	46	7.7	5	1.4	6	2.2	3	1.2	46	7.1	4	1.3
1974	116	8.2	7	1.7	74	6.1	5	1.5	24	2.5	4	1.2	50	5.7	5	1.4
1975	173	13.2	7	1.7	85	9.4	5	1.5	18	2.5	4	1.2	76	8.6	5	1.4

Continue...

	All offspring				Selected offspring				Selected sons				Selected daughters			
	sires		dams		sires		dams		sires		dams		sires		dams	
Year	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg
1976	195	14.9	7	1.8	98	10.0	6	1.5	11	2.3	3	1.2	87	9.6	6	1.4
1977	222	16.9	7	1.8	105	11.8	7	1.5	19	2.8	3	1.2	86	11.0	7	1.5
1978	80	11.2	7	1.8	51	7.5	6	1.5	9	2.0	4	1.2	48	7.3	5	1.4
1979	96	13.6	7	1.7	56	9.1	6	1.5	21	3.0	3	1.2	42	8.1	6	1.4
1980	312	16.7	8	1.8	180	11.1	6	1.5	33	2.8	3	1.2	147	10.1	6	1.4
1981	537	16.2	7	1.8	270	10.9	7	1.5	29	3.1	4	1.2	241	9.9	5	1.4
1982	448	17.5	10	1.7	234	11.0	7	1.5	18	3.8	2	1.1	220	10.2	6	1.4
1983	133	15.3	7	1.7	74	9.6	6	1.5	26	3.4	4	1.2	72	8.6	5	1.4
1984	356	15.1	8	1.7	197	10.3	8	1.5	17	3.7	4	1.3	182	9.3	6	1.4
1985	74	9.6	8	1.7	47	6.5	7	1.6	15	2.2	3	1.2	38	6.1	7	1.5
1986	70	8.1	8	1.7	34	5.5	6	1.5	8	2.3	3	1.2	33	5.1	5	1.5
1987	61	11.6	8	1.8	47	9.0	8	1.6	7	2.5	4	1.3	46	8.2	7	1.5
1988	1179	24.6	8	1.8	670	15.1	6	1.6	62	6.3	3	1.2	608	14.1	6	1.5
1989	545	25.9	8	1.8	296	15.8	7	1.6	38	5.2	5	1.2	258	14.2	5	1.5
1990	378	19.3	9	1.8	216	12.6	7	1.6	22	3.9	4	1.1	198	11.5	7	1.5
1991	523	22.9	7	1.8	297	14.9	7	1.5	33	4.4	5	1.2	264	13.9	6	1.5
1992	126	12.0	7	1.9	56	8.2	7	1.6	10	2.2	5	1.3	56	7.8	6	1.5
1993	111	12.1	9	1.9	68	8.4	8	1.6	8	2.4	5	1.3	60	7.8	6	1.5
1994	1341	38.2	7	1.8	807	24.6	6	1.5	101	6.4	3	1.3	706	22.6	6	1.4
1995	194	21.3	7	1.9	94	13.5	6	1.6	14	3.2	5	1.3	90	12.6	5	1.5
1996	219	18.5	8	1.8	118	10.9	7	1.5	18	3.0	4	1.3	100	10.1	7	1.4
1997	435	20.1	9	1.9	216	12.5	8	1.5	24	3.4	5	1.2	192	11.2	4	1.4
1998	382	19.0	9	1.9	159	10.7	8	1.5	18	2.6	5	1.2	141	9.8	5	1.4
1999	889	32.7	10	1.9	457	18.1	6	1.5	95	6.2	3	1.3	362	16.4	5	1.4
2000	981	28.7	10	1.8	492	15.4	8	1.4	69	5.9	3	1.3	423	13.7	5	1.3
2001	522	22.1	8	1.8	217	11.2	7	1.4	41	3.7	4	1.2	176	10.3	6	1.3
2002	80	14.9	9	1.7	58	7.8	8	1.4	12	2.4	5	1.3	46	7.1	6	1.3
2003	429	17.6	8	1.7	160	8.0	7	1.3	39	4.1	4	1.2	121	7.1	4	1.2
2004	54	12.8	8	1.7	32	5.2	5	1.3	9	1.9	4	1.2	27	4.8	5	1.2
2005	468	17.7	8	1.7	111	6.6	6	1.3	19	3.2	3	1.1	92	5.8	6	1.2
2006	290	13.3	8	1.6	72	5.1	4	1.2	22	2.7	3	1.2	68	4.5	4	1.1
2007	172	12.7	6	1.5	63	4.2	5	1.2	17	2.1	4	1.2	46	3.7	3	1.1
2008	334	12.9	7	1.5	71	4.2	5	1.1	19	2.5	5	1.2	52	3.5	3	1.0
2009	63	12.1	6	1.5	14	3.2	3	1.1	7	1.7	2	1.2	12	2.8	3	1.1
2010	37	10.5	5	1.3	10	2.1	3	1.1	5	1.6	2	1.1	7	2.0	2	1.0
2011	85	8.4	4	1.3	8	1.9	1	1.0	4	1.5	1	1.0	5	1.7	1	1.0
2012	104	8.1	4	1.2	6	1.9	1	1.0	3	1.3	1	1.0	4	1.6	1	1.0
2013	47	5.7	4	1.1	2	1.3	1	1.0	1	1.0	1	1.0	1	1.0	1	1.0
2014	23	4.2	2	1.0	-	-	-	-	-	-	-	-	-	-	-	-
2015	6	1.9	2	1.0	-	-	-	-	-	-	-	-	-	-	-	-
2016	3	1.7	1	1.0	-	-	-	-	-	-	-	-	-	-	-	-
Total	1341	15.8	10	1.7	807	9.9	8	1.5	101	3.3	5	1.2	706	9.1	7	1.4

Figure 1: Dams with the most Progeny in the Population



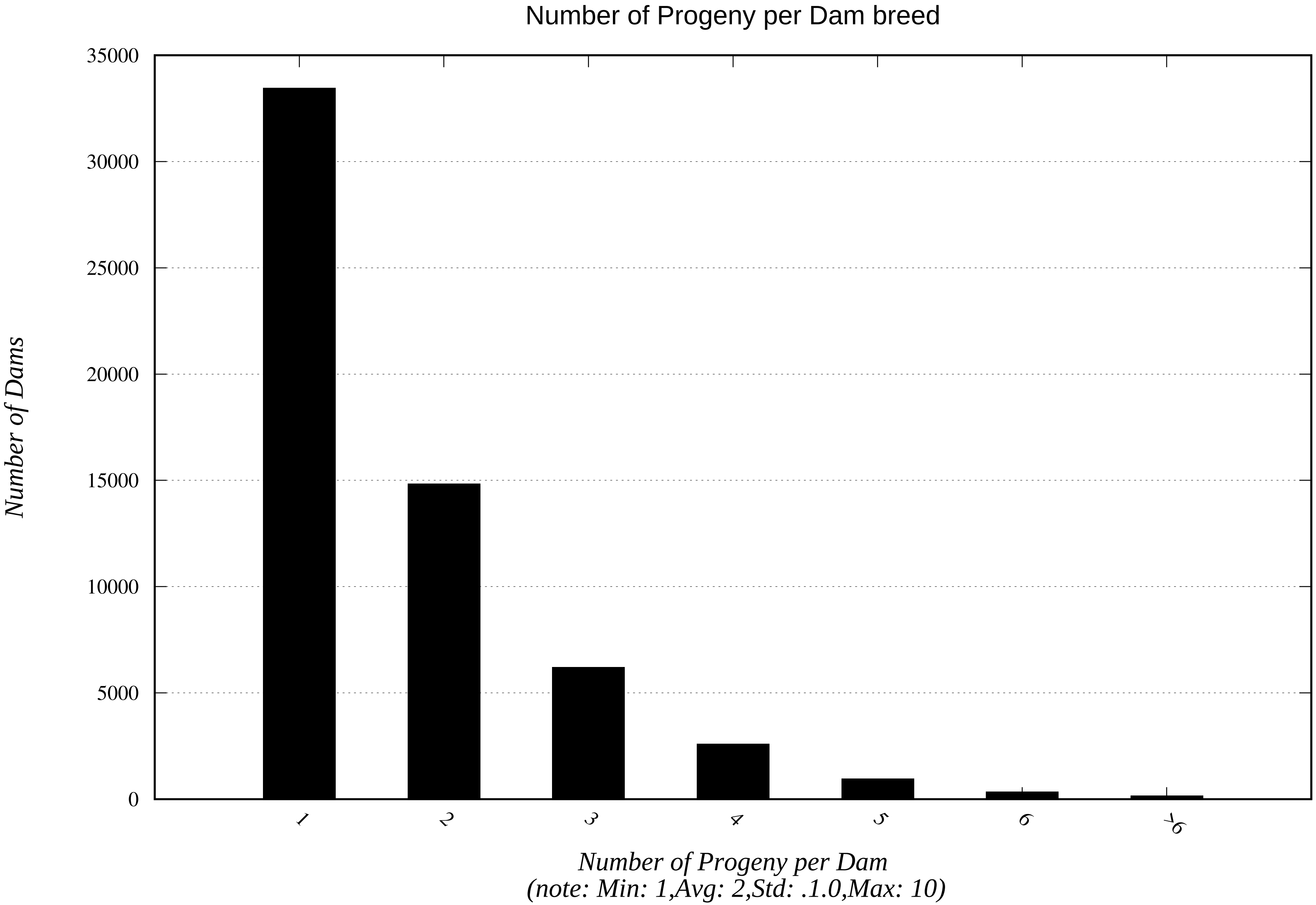
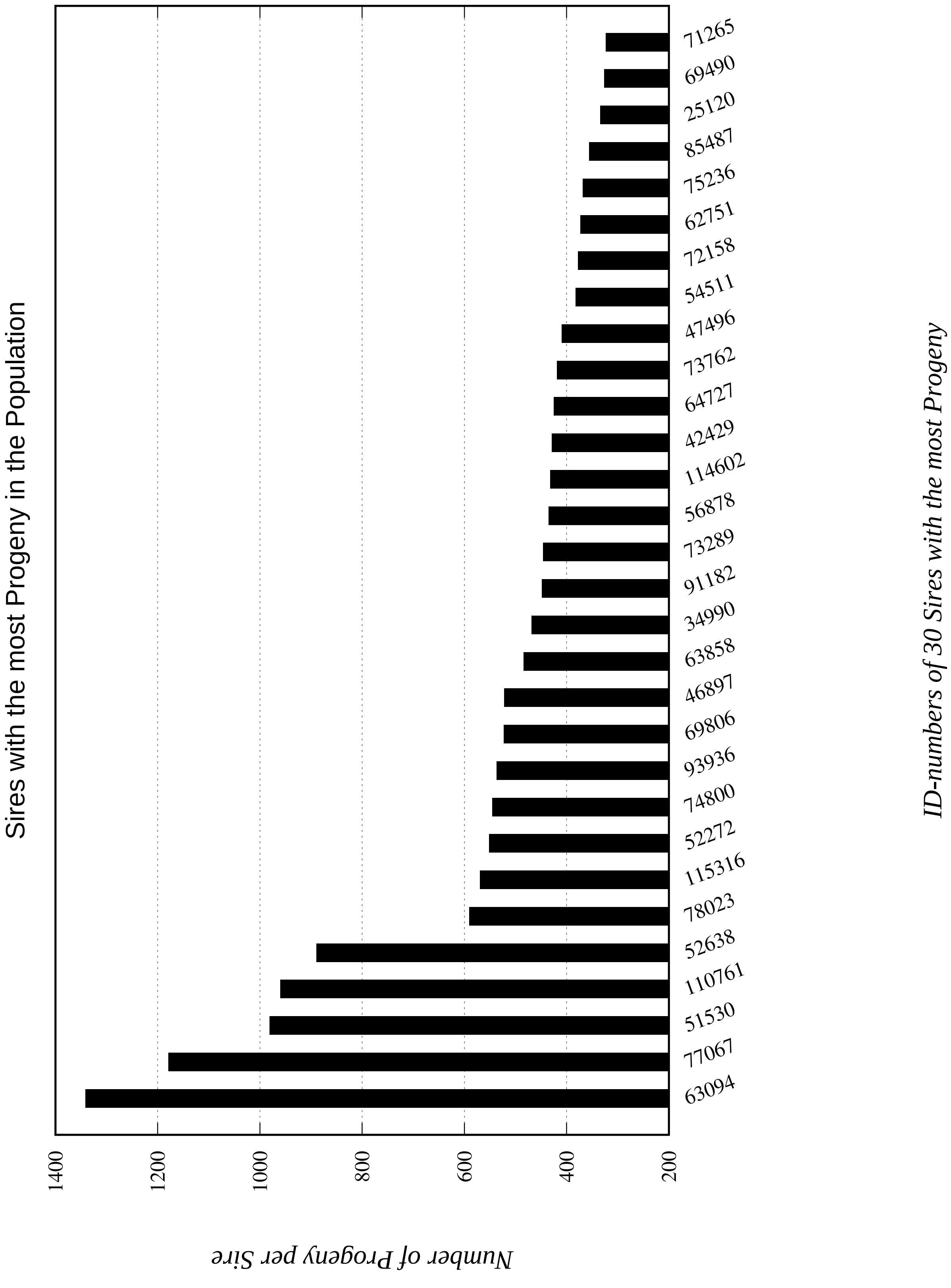


Figure 2: Number of Progeny per Dam

Figure 3: Sires with the most Progeny in the Population



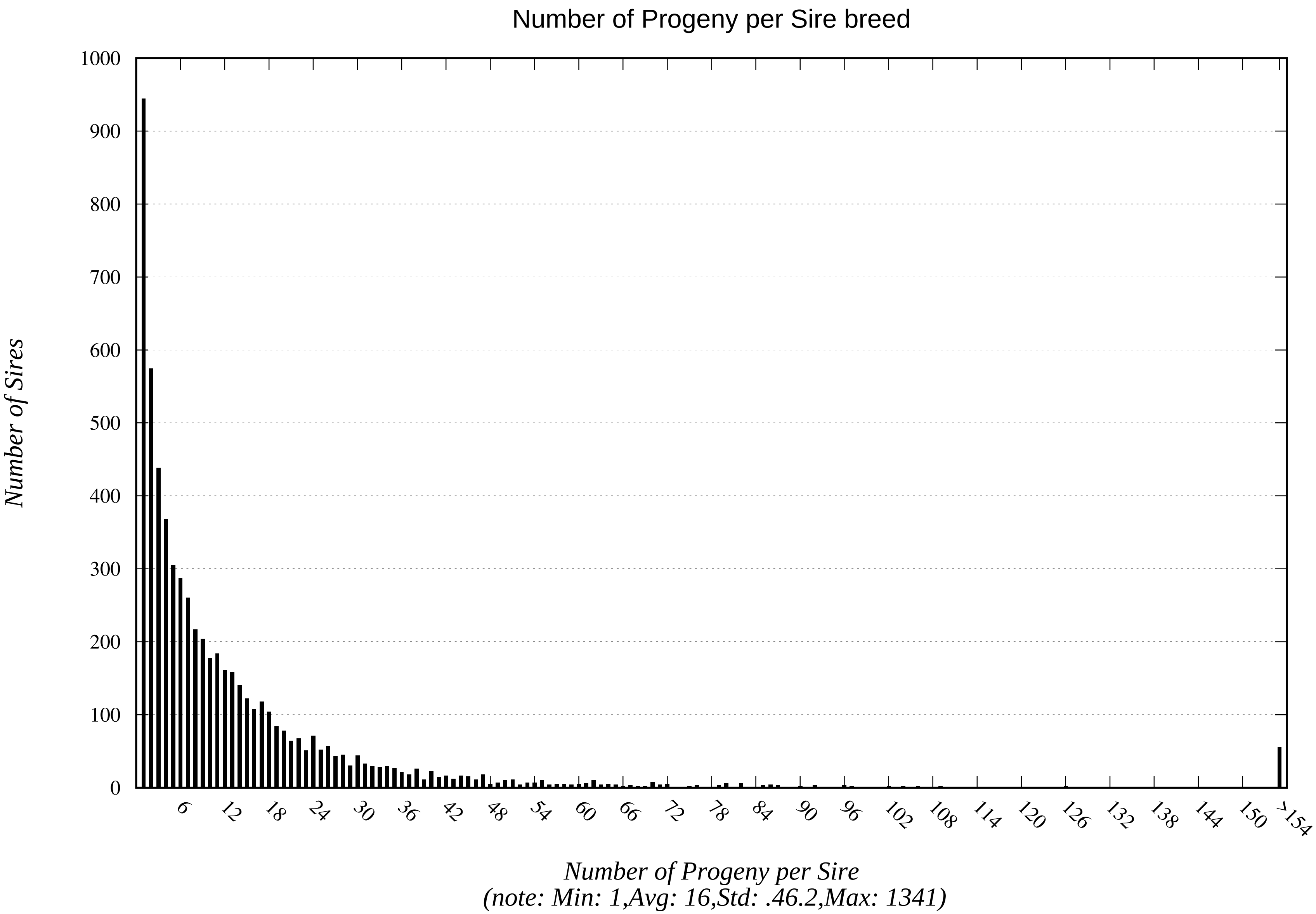


Figure 4: Number of Progeny per Sire

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

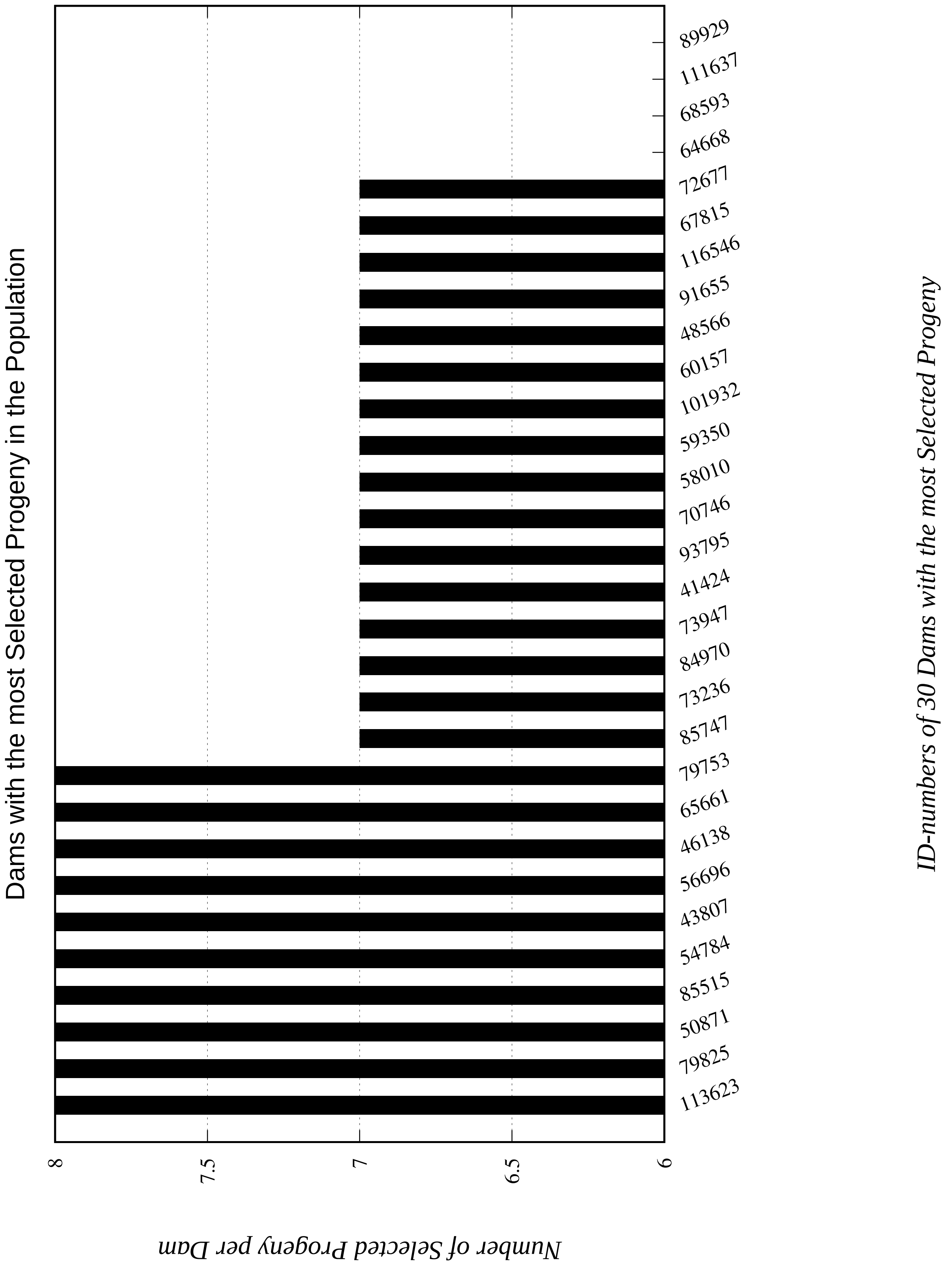


Figure 6: Number of Selected Progeny per Dam

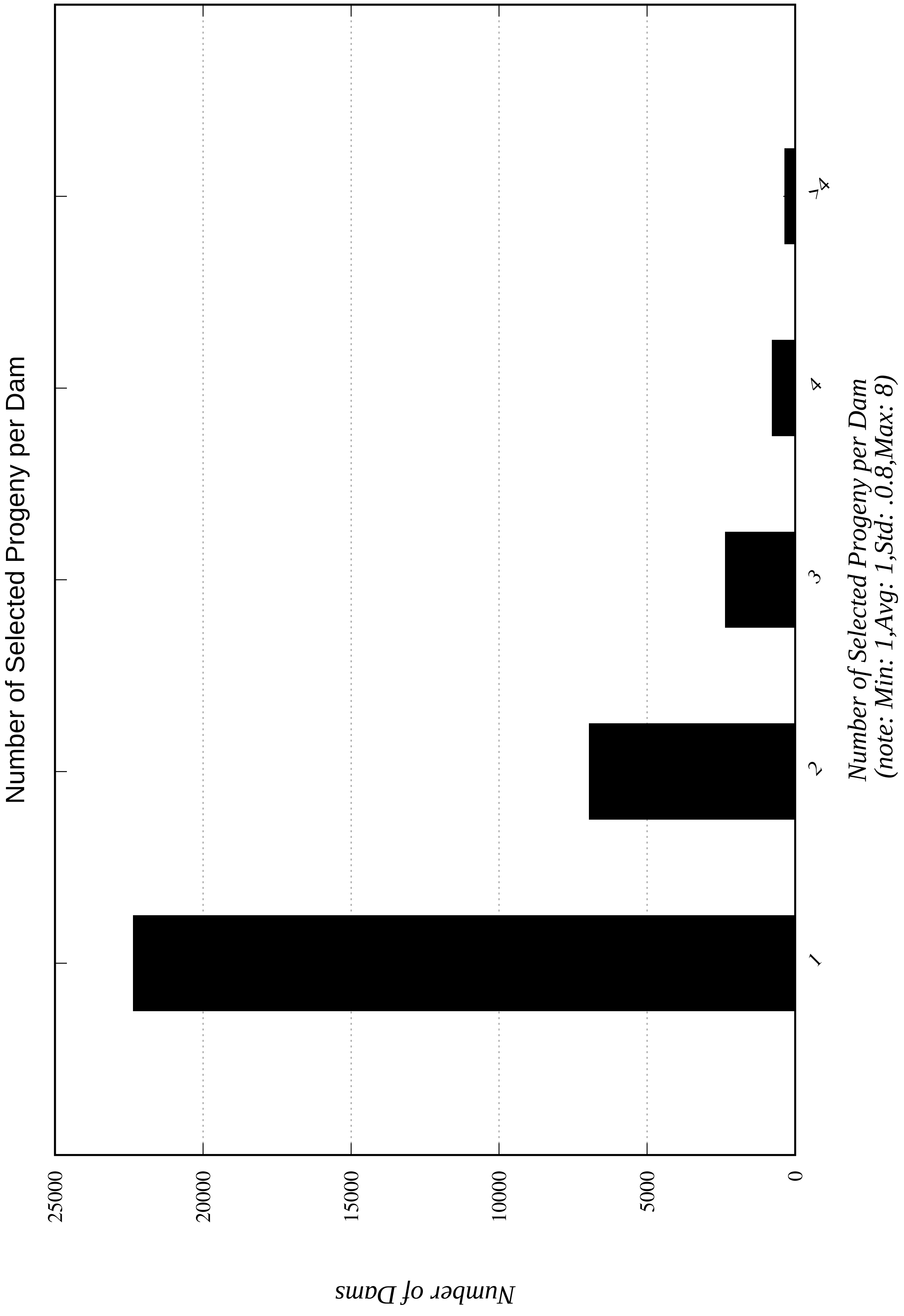
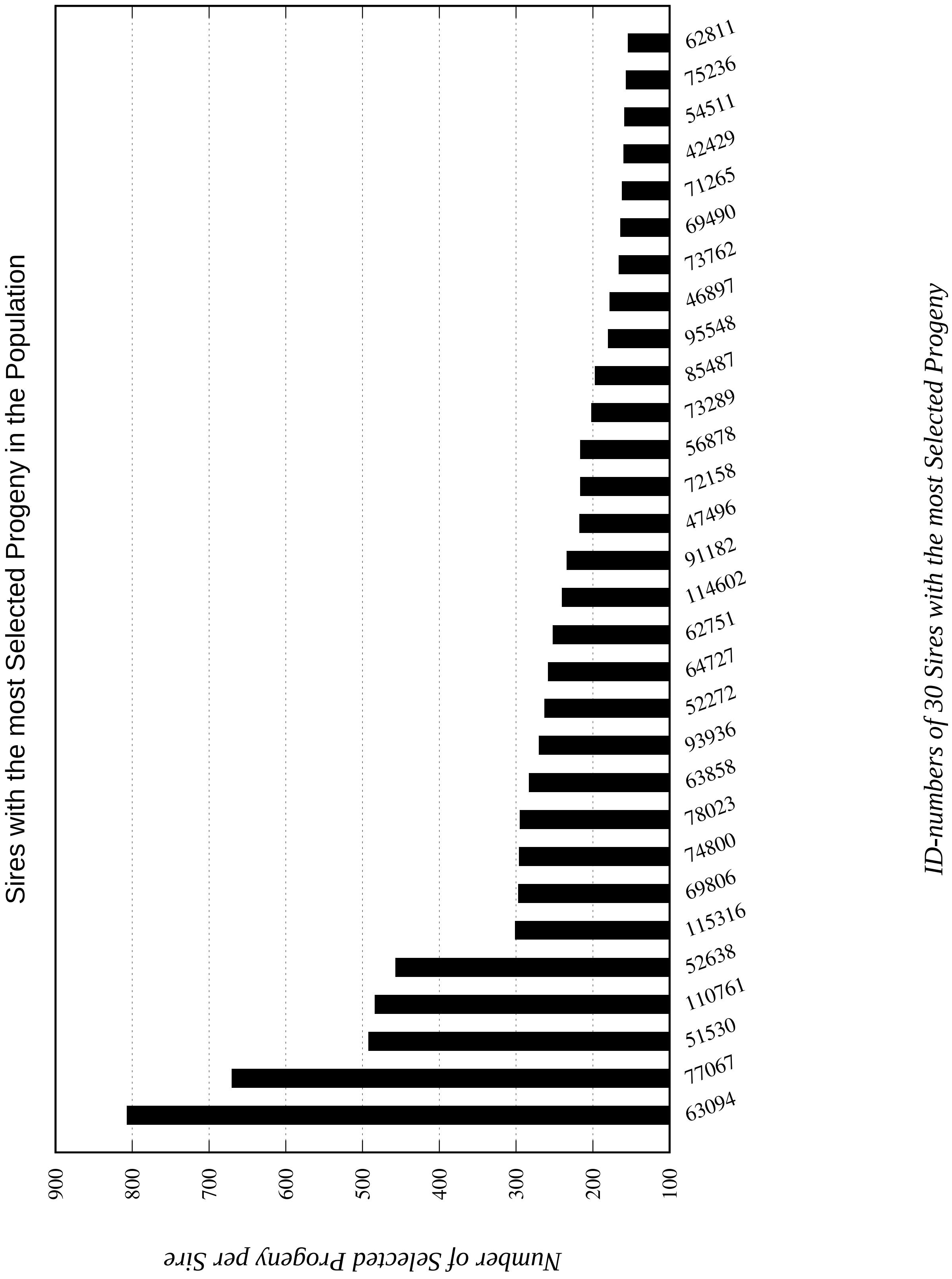


Figure 7: Sires with the most Selected Progeny in the Population



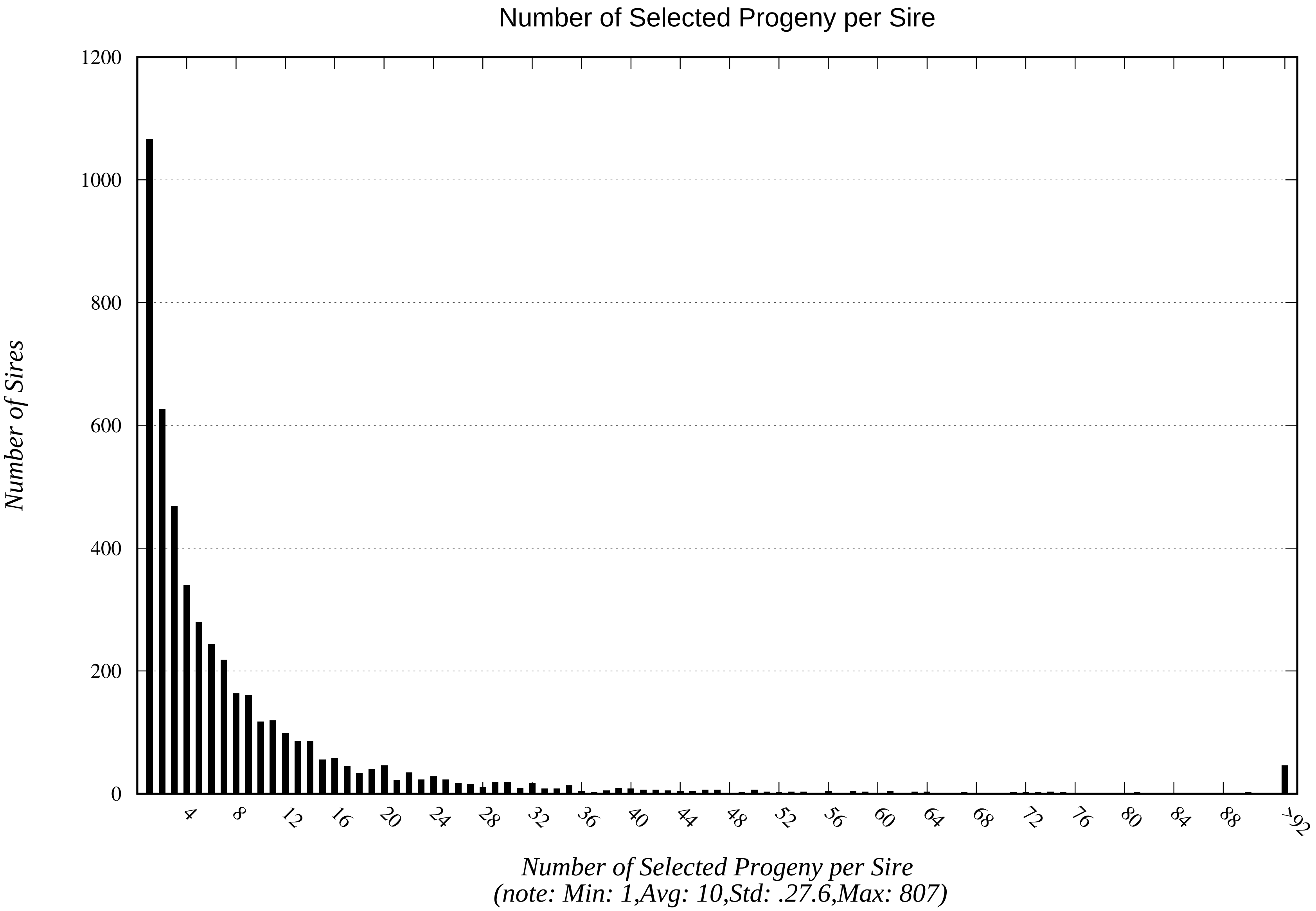


Figure 8: Number of Selected Progeny per Sire