

PopReport

A Pedigree Analysis Report

Population: 54
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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
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58848 input lines processed.
58848 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
1977	555	555	8628	7207
1978	538	538	9981	7435
1979	556	556	11041	7194
1980	535	535	11652	7477
1981	510	510	12065	7843
1982	509	509	12777	7859
1983	511	511	12269	7828
1984	505	505	11991	7921
1985	524	524	11103	7634
1986	573	573	10681	6981
1987	626	626	10580	6390
1988	647	647	10584	6182
1989	671	671	10245	5961
1990	672	672	9996	5952
1991	696	696	9560	5747
1992	671	671	9168	5961
1993	657	657	8732	6088
1994	619	619	8283	6462
1995	623	623	7921	6421
1996	584	584	7677	6849
1997	601	601	7529	6656
1998	592	592	7541	6757
1999	601	601	7595	6656
2000	587	587	7648	6814
2001	590	590	7713	6780
2002	570	570	7917	7018
2003	562	562	7971	7117
2004	531	531	8031	7533
2005	540	540	8179	7407

Year	No. of Male		No. of Female	
	orig.	cut	orig.	cut
2006	543	543	8131	7366
2007	525	525	7808	7619

Pedigree Analysis Report for Population: 54

Department of Animal Breeding and Genetics
Institute of Farm Animal Genetics (FLI)
Höltyst. 10
D-31535 Neustadt, Germany
Eildert.Groeneveld@fli.de

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Developers

Frits Voordewind: PERL/SQL/GNU-Plot/Report, SA Studbook, Bloenfontein, South Africa

Bobbie van der Westhuizen: PERL/SQL/GNU-Plot/Report, SA Studbook, Centurion, South Africa

Norman Maiwashe: Report/Descriptions, ARC, Irene, South Africa

Ralf Fischer: Computation of Inbreeding, LfULG , Köllitsch, Germany

Didier Boichard: PEDIG software, INRA, France

Lina Yordanova: SQL, University of Stara Zagora, Bulgaria

Helmut Lichtenberg: Integration and WEB service, FLI, Germany

Eildert Groeneveld: Project Leader, FLI, Germany

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

$$I_d = \frac{4I_{dpat}I_{dmat}}{I_{dpat} + I_{dmat}}$$

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

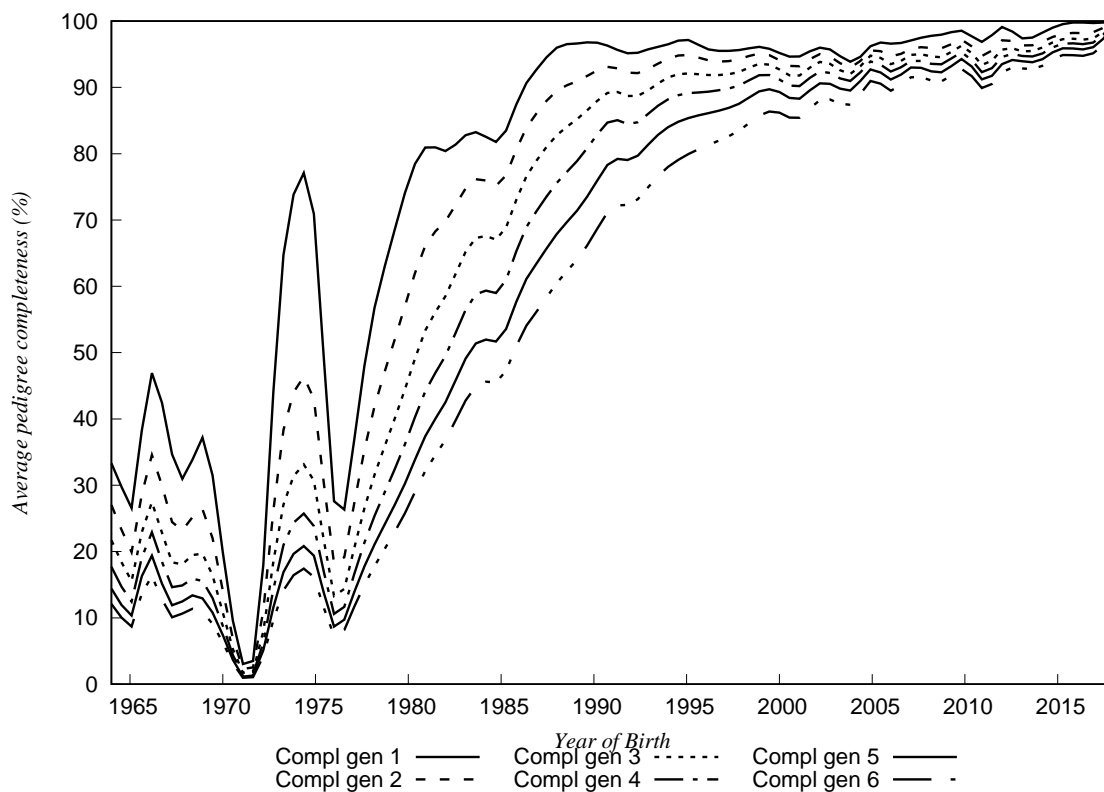
Year	No of Animals	Compl. gen 1	Compl. gen 2	Compl. gen 3	Compl. gen 4	Compl. gen 5	Compl. (%) gen 6(%)
1947	8	0.0	0.0	0.0	0.0	0.0	0.0
1949	14	21.4	10.7	7.1	5.4	4.3	3.6
1951	10	60.0	38.6	25.7	19.3	15.4	12.9
1952	1	0.0	0.0	0.0	0.0	0.0	0.0
1953	6	83.3	68.7	48.5	36.4	29.1	24.2
1954	1	100.0	50.0	33.3	25.0	20.0	16.7
1955	6	66.7	64.3	58.7	45.9	36.7	30.6
1956	1	0.0	0.0	0.0	0.0	0.0	0.0
1957	7	28.6	23.8	20.8	17.6	14.3	11.9
1958	3	100.0	64.4	47.3	37.7	31.2	26.1
1959	6	16.7	11.1	7.4	5.6	4.4	3.7
1960	9	22.2	18.5	14.4	11.9	10.4	9.1
1961	7	42.9	21.4	14.3	10.7	8.6	7.1
1962	9	55.6	34.4	25.7	20.0	16.5	14.1
1963	13	15.4	11.5	8.7	7.0	5.7	4.8
1964	21	33.3	27.0	21.7	17.7	14.4	12.1
1965	27	25.9	19.5	15.2	12.1	10.0	8.4
1966	35	45.7	34.0	27.2	22.8	19.4	16.3
1967	47	38.3	26.7	20.0	15.9	12.9	10.9
1968	64	31.2	23.6	18.5	15.3	12.9	11.0
1969	73	37.0	26.1	19.4	15.3	12.7	10.7
1970	171	19.9	14.1	10.8	8.8	7.4	6.3
1971	1129	3.8	2.8	2.1	1.7	1.4	1.2
1972	992	11.2	7.1	5.2	4.1	3.4	2.8
1973	1196	56.1	33.2	23.4	18.1	14.6	12.2
1974	1181	75.4	45.1	32.2	25.0	20.2	16.9
1975	1006	68.3	41.5	29.6	23.0	18.7	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 (%)
1976	1880	27.6	18.2	13.3	10.6	8.7	7.3
1977	1799	35.0	25.9	19.5	15.8	13.2	11.1
1978	2465	54.2	39.9	30.0	24.1	20.0	16.9
1979	2070	65.8	49.6	38.0	30.7	25.6	21.7
1980	1786	75.7	58.7	46.0	37.5	31.4	26.8
1981	1569	81.1	66.6	53.9	44.7	37.9	32.6
1982	1717	80.4	69.8	58.5	49.5	42.5	36.8
1983	1374	82.6	74.4	64.7	55.9	48.6	42.3
1984	1515	82.9	76.2	67.7	59.4	52.0	45.6
1985	1596	82.2	75.5	67.5	59.5	52.2	46.0
1986	1697	88.7	81.9	74.4	66.7	59.0	52.2
1987	1738	93.0	86.4	79.3	71.7	63.8	56.5
1988	1594	96.0	89.5	82.8	75.6	67.9	60.5
1989	1402	96.6	90.8	85.0	78.6	71.1	63.7
1990	1126	96.8	92.3	87.5	82.2	75.1	67.8
1991	1103	96.0	93.1	89.4	85.1	79.0	71.9
1992	1179	95.1	92.1	88.6	84.4	79.1	72.4
1993	1247	95.8	92.9	89.7	86.2	81.6	75.2
1994	1251	96.5	94.3	91.5	88.2	84.0	78.0
1995	1236	97.2	94.9	92.1	89.1	85.3	79.8
1996	1119	95.9	94.2	91.9	89.3	86.0	81.1
1997	995	95.5	93.9	91.9	89.7	86.7	82.3
1998	1106	95.7	94.4	92.5	90.5	87.8	83.8
1999	1242	96.1	95.1	93.6	91.9	89.5	85.9
2000	1286	95.2	94.1	92.7	91.2	89.3	86.2
2001	1319	94.6	93.1	91.7	90.1	88.2	85.3
2002	1420	95.9	94.9	93.7	92.2	90.4	87.8
2003	1165	95.3	94.2	93.1	91.8	90.2	87.9
2004	1024	93.9	93.1	92.2	91.2	89.8	87.7
2005	1263	96.4	95.7	94.9	94.0	92.8	91.1
2006	1197	96.6	94.7	93.5	92.4	91.2	89.5
2007	945	97.0	95.7	94.8	93.9	92.9	91.4
2008	880	97.7	96.0	94.8	93.7	92.6	91.2
2009	859	98.1	96.1	94.8	93.8	92.6	91.2
2010	822	98.4	97.1	96.2	95.2	94.2	92.7
2011	736	96.9	94.7	93.3	92.2	91.1	89.8
2012	810	99.1	97.1	95.7	94.6	93.5	92.3
2013	830	97.5	96.4	95.5	94.8	94.0	92.9
2014	791	98.0	96.7	95.8	94.9	94.0	93.0
2015	731	99.3	97.9	97.1	96.4	95.7	94.7
2016	594	99.8	98.2	97.3	96.6	95.8	94.8
2017	302	99.7	98.4	97.5	96.9	96.2	95.3
2018	25	100.0	100.0	100.0	99.8	99.3	98.2

The average pedigree completeness for animals born within the last 10 years: 1 generations deep = 98.4%. 2 generations deep = 96.8%. 3 generations deep = 95.7%. 4 generations deep = 94.9%. 5 generations deep = 93.9%. 6 generations deep = 92.7%.

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 1964 and 2018 for the 54 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
1947	8	-	-	-	-	-	-	-	-	-	-
1949	14	-	-	-	-	-	-	-	-	-	-
1951	10	-	-	-	-	-	-	-	-	-	-
1952	1	-	-	-	-	-	-	-	-	-	-
1953	6	-	-	-	-	-	-	-	-	-	-
1954	1	-	-	-	-	-	-	-	-	-	-
1955	4	-	1	-	1	-	-	-	-	-	-
1956	1	-	-	-	-	-	-	-	-	-	-
1957	7	-	-	-	-	-	-	-	-	-	-
1958	3	-	-	-	-	-	-	-	-	-	-
1959	6	-	-	-	-	-	-	-	-	-	-
1960	9	-	-	-	-	-	-	-	-	-	-
1961	7	-	-	-	-	-	-	-	-	-	-
1962	8	1	-	-	-	-	-	-	-	-	-
1963	13	-	-	-	-	-	-	-	-	-	-
1964	20	-	-	-	1	-	-	-	-	-	-
1965	26	-	1	-	-	-	-	-	-	-	-
1966	34	-	1	-	-	-	-	-	-	-	-
1967	46	-	-	-	1	-	-	-	-	-	-
1968	63	-	1	-	-	-	-	-	-	-	-
1969	73	-	-	-	-	-	-	-	-	-	-
1970	170	1	-	-	-	-	-	-	-	-	-
1971	1127	1	-	1	-	-	-	-	-	-	-
1972	990	-	1	1	-	-	-	-	-	-	-
1973	1195	-	1	-	-	-	-	-	-	-	-
1974	1177	-	1	-	3	-	-	-	-	-	-
1975	998	3	1	-	4	-	-	-	-	-	-
1976	1862	10	-	-	8	-	-	-	-	-	-
1977	1764	12	9	-	14	-	-	-	-	-	-
1978	2408	26	14	-	17	-	-	-	-	-	-
1979	2021	20	24	-	5	-	-	-	-	-	-
1980	1738	15	13	-	19	1	-	-	-	-	-
1981	1512	20	17	-	20	-	-	-	-	-	-
1982	1632	33	19	1	31	1	-	-	-	-	-
1983	1295	36	15	2	19	5	1	1	-	-	-
1984	1404	66	19	3	15	8	-	-	-	-	-
1985	1478	64	23	2	22	7	-	-	-	-	-

Continue...

Year	Classes										
	1	2	3	4	5	6	7	8	9	10	11
1986	1576	86	22	3	6	3	1	-	-	-	-
1987	1587	74	38	4	17	16	-	2	-	-	-
1988	1456	76	28	7	13	13	-	1	-	-	-
1989	1294	70	24	3	1	10	-	-	-	-	-
1990	1031	58	20	3	7	7	-	-	-	-	-
1991	1010	68	16	1	2	5	1	-	-	-	-
1992	1084	66	11	4	4	10	-	-	-	-	-
1993	1124	92	11	4	3	9	3	1	-	-	-
1994	1128	92	13	2	2	14	-	-	-	-	-
1995	1120	81	10	8	4	13	-	-	-	-	-
1996	1003	84	13	7	2	10	-	-	-	-	-
1997	861	86	27	8	-	13	-	-	-	-	-
1998	957	109	11	10	3	16	-	-	-	-	-
1999	1088	112	23	10	1	7	1	-	-	-	-
2000	1111	123	24	11	2	15	-	-	-	-	-
2001	1154	121	18	5	-	20	1	-	-	-	-
2002	1210	140	22	12	5	31	-	-	-	-	-
2003	998	113	24	9	3	17	1	-	-	-	-
2004	884	98	16	9	2	13	2	-	-	-	-
2005	1032	183	26	4	-	17	1	-	-	-	-
2006	983	170	21	4	1	18	-	-	-	-	-
2007	776	142	10	5	-	12	-	-	-	-	-
2008	714	130	9	7	-	20	-	-	-	-	-
2009	697	125	12	7	-	18	-	-	-	-	-
2010	631	158	11	7	1	13	1	-	-	-	-
2011	547	161	11	9	-	6	1	1	-	-	-
2012	581	193	16	5	-	14	1	-	-	-	-
2013	567	226	7	10	1	17	2	-	-	-	-
2014	545	219	10	2	4	11	-	-	-	-	-
2015	459	237	17	13	-	5	-	-	-	-	-
2016	366	193	12	11	4	8	-	-	-	-	-
2017	179	113	2	2	1	5	-	-	-	-	-
2018	11	13	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:

a given year.

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

Tot No. : the number of 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
1947	8	-	-	-	-	-	-	-	-
1949	14	-	-	4	-	-	3	-	-
1951	10	-	-	8	-	-	6	-	-
1952	1	-	-	-	-	-	-	-	-
1953	6	-	-	5	-	-	5	-	-
1954	1	-	-	1	-	-	1	-	-
1955	6	2	0.0625	3	-	-	4	-	-
1956	1	-	-	-	-	-	-	-	-
1957	7	-	-	3	1	0.0417	2	1	0.1250
1958	3	-	-	3	-	-	3	-	-
1959	6	-	-	1	-	-	1	-	-
1960	9	1	0.0013	2	-	-	2	-	-
1961	7	-	-	3	-	-	3	-	-
1962	9	1	0.0069	5	1	0.0023	5	-	-
1963	13	-	-	6	-	-	2	-	-
1964	21	2	0.0140	5	-	-	7	1	0.0089
1965	27	1	0.0046	6	-	-	8	-	-
1966	35	2	0.0038	12	1	0.0104	16	1	0.0027
1967	47	1	0.0053	17	2	0.0147	19	-	-
1968	64	3	0.0028	22	1	0.0114	20	1	0.0004
1969	73	1	0.0004	28	2	0.0089	27	-	-
1970	171	4	0.0010	33	4	0.0063	35	1	0.0031
1971	1129	7	0.0003	40	2	0.0063	43	1	0.0007
1972	992	5	0.0004	67	4	0.0073	111	2	0.0006
1973	1196	3	0.0002	137	5	0.0048	666	4	0.0005
1974	1181	6	0.0007	143	5	0.0032	887	1	0.0001
1975	1006	11	0.0014	143	4	0.0044	680	-	-
1976	1880	25	0.0015	139	2	0.0018	510	3	0.0010
1977	1799	67	0.0033	158	4	0.0022	627	-	-
1978	2465	109	0.0036	198	7	0.0030	1670	4	0.0002
1979	2070	125	0.0035	191	11	0.0027	1591	10	0.0008
1980	1786	146	0.0054	216	18	0.0030	1455	19	0.0011
1981	1569	226	0.0076	190	28	0.0071	1414	39	0.0020
1982	1717	382	0.0109	195	36	0.0087	1544	64	0.0026
1983	1374	429	0.0130	179	47	0.0106	1197	75	0.0035
1984	1515	531	0.0139	204	64	0.0109	1356	137	0.0067
1985	1596	604	0.0144	217	75	0.0124	1481	160	0.0053
1986	1697	762	0.0135	211	95	0.0175	1622	284	0.0078
1987	1738	907	0.0189	244	125	0.0199	1692	333	0.0078

Continue...

Year	Animal			Sires			Dams		
	Tot No	Inbred No	Avg <i>F</i>	Tot No	Inbred No	Avg <i>F</i>	Tot No	Inbred No	Avg <i>F</i>
1988	1594	963	0.0194	262	163	0.0201	1541	378	0.0085
1989	1402	905	0.0172	262	180	0.0194	1354	429	0.0111
1990	1126	833	0.0195	235	173	0.0211	1095	401	0.0124
1991	1103	886	0.0203	218	181	0.0236	1067	465	0.0152
1992	1179	955	0.0206	212	176	0.0209	1132	547	0.0164
1993	1247	1054	0.0230	211	186	0.0209	1219	682	0.0166
1994	1251	1084	0.0233	232	208	0.0228	1215	685	0.0168
1995	1236	1082	0.0248	238	221	0.0247	1203	735	0.0165
1996	1119	999	0.0263	242	227	0.0257	1080	703	0.0183
1997	995	888	0.0295	240	233	0.0266	964	677	0.0186
1998	1106	1001	0.0301	249	241	0.0289	1063	778	0.0212
1999	1242	1143	0.0293	252	246	0.0304	1198	934	0.0216
2000	1286	1177	0.0315	282	275	0.0305	1237	1008	0.0236
2001	1319	1190	0.0309	303	297	0.0320	1283	1047	0.0238
2002	1420	1317	0.0349	315	309	0.0333	1392	1156	0.0241
2003	1165	1072	0.0344	318	313	0.0335	1141	982	0.0258
2004	1024	934	0.0345	286	282	0.0368	973	862	0.0274
2005	1263	1188	0.0368	298	297	0.0383	1221	1101	0.0285
2006	1197	1092	0.0362	302	300	0.0395	1157	1025	0.0284
2007	945	881	0.0376	274	272	0.0409	933	852	0.0304
2008	880	814	0.0401	263	260	0.0420	856	770	0.0304
2009	859	792	0.0406	260	255	0.0412	844	764	0.0315
2010	822	779	0.0425	273	265	0.0417	807	741	0.0344
2011	736	665	0.0415	244	241	0.0423	715	637	0.0316
2012	810	753	0.0446	265	262	0.0447	799	714	0.0318
2013	830	783	0.0487	260	257	0.0483	816	749	0.0333
2014	791	746	0.0458	242	240	0.0472	782	709	0.0372
2015	731	696	0.0489	261	257	0.0469	725	682	0.0380
2016	594	567	0.0512	233	230	0.0506	590	549	0.0383
2017	302	289	0.0500	161	159	0.0512	301	283	0.0381
2018	25	25	0.0550	22	22	0.0553	25	25	0.0429

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
1947	8	0.0000	0.0000	0.0000	0.0000
1949	14	0.0000	0.0000	0.0000	0.0000
1951	10	0.0000	0.0000	0.0000	0.0000
1952	1	0.0000	0.0000	0.0000	-
1953	6	0.0000	0.0000	0.0000	0.0000
1954	1	0.0000	0.0000	0.0000	-
1955	6	0.0000	0.2500	0.0625	0.1046
1956	1	0.0000	0.0000	0.0000	-
1957	7	0.0000	0.0000	0.0000	0.0000
1958	3	0.0000	0.0000	0.0000	0.0000
1959	6	0.0000	0.0000	0.0000	0.0000
1960	9	0.0000	0.0117	0.0013	0.0039
1961	7	0.0000	0.0000	0.0000	0.0000
1962	9	0.0000	0.0625	0.0069	0.0208
1963	13	0.0000	0.0000	0.0000	0.0000
1964	21	0.0000	0.2500	0.0140	0.0549
1965	27	0.0000	0.1250	0.0046	0.0241
1966	35	0.0000	0.1250	0.0038	0.0211
1967	47	0.0000	0.2500	0.0053	0.0365
1968	64	0.0000	0.1069	0.0028	0.0146
1969	73	0.0000	0.0313	0.0004	0.0037
1970	171	0.0000	0.0677	0.0010	0.0072
1971	1129	0.0000	0.1563	0.0003	0.0054
1972	992	0.0000	0.1563	0.0004	0.0065
1973	1196	0.0000	0.1250	0.0002	0.0040
1974	1181	0.0000	0.2500	0.0007	0.0131
1975	1006	0.0000	0.2500	0.0014	0.0166
1976	1880	0.0000	0.2500	0.0015	0.0170
1977	1799	0.0000	0.2500	0.0033	0.0244
1978	2465	0.0000	0.2500	0.0036	0.0239
1979	2070	0.0000	0.2500	0.0035	0.0196
1980	1786	0.0000	0.2504	0.0054	0.0294
1981	1569	0.0000	0.2500	0.0076	0.0321
1982	1717	0.0000	0.2504	0.0109	0.0378
1983	1374	0.0000	0.3750	0.0130	0.0398
1984	1515	0.0000	0.2676	0.0139	0.0375
1985	1596	0.0000	0.2798	0.0144	0.0394
1986	1697	0.0000	0.3125	0.0135	0.0297
1987	1738	0.0000	0.3750	0.0189	0.0433

Continue...

Year	No of Animals	<i>F</i>			
		Min	Max	Avg	Std
1988	1594	0.0000	0.3750	0.0194	0.0406
1989	1402	0.0000	0.2813	0.0172	0.0325
1990	1126	0.0000	0.2664	0.0195	0.0356
1991	1103	0.0000	0.3281	0.0203	0.0315
1992	1179	0.0000	0.2834	0.0206	0.0344
1993	1247	0.0000	0.3512	0.0230	0.0371
1994	1251	0.0000	0.2776	0.0233	0.0350
1995	1236	0.0000	0.2877	0.0248	0.0361
1996	1119	0.0000	0.2931	0.0263	0.0349
1997	995	0.0000	0.2850	0.0295	0.0393
1998	1106	0.0000	0.2848	0.0301	0.0399
1999	1242	0.0000	0.3059	0.0293	0.0327
2000	1286	0.0000	0.2815	0.0315	0.0377
2001	1319	0.0000	0.3422	0.0309	0.0380
2002	1420	0.0000	0.2882	0.0349	0.0442
2003	1165	0.0000	0.3240	0.0344	0.0403
2004	1024	0.0000	0.3192	0.0345	0.0400
2005	1263	0.0000	0.3192	0.0368	0.0364
2006	1197	0.0000	0.2793	0.0362	0.0375
2007	945	0.0000	0.2901	0.0376	0.0352
2008	880	0.0000	0.2896	0.0401	0.0421
2009	859	0.0000	0.2845	0.0406	0.0408
2010	822	0.0000	0.3213	0.0425	0.0386
2011	736	0.0000	0.3846	0.0415	0.0374
2012	810	0.0000	0.3326	0.0446	0.0401
2013	830	0.0000	0.3287	0.0487	0.0440
2014	791	0.0000	0.2913	0.0458	0.0383
2015	731	0.0000	0.2928	0.0489	0.0335
2016	594	0.0000	0.2896	0.0512	0.0412
2017	302	0.0000	0.2860	0.0500	0.0383
2018	25	0.0204	0.1270	0.0550	0.0217

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.

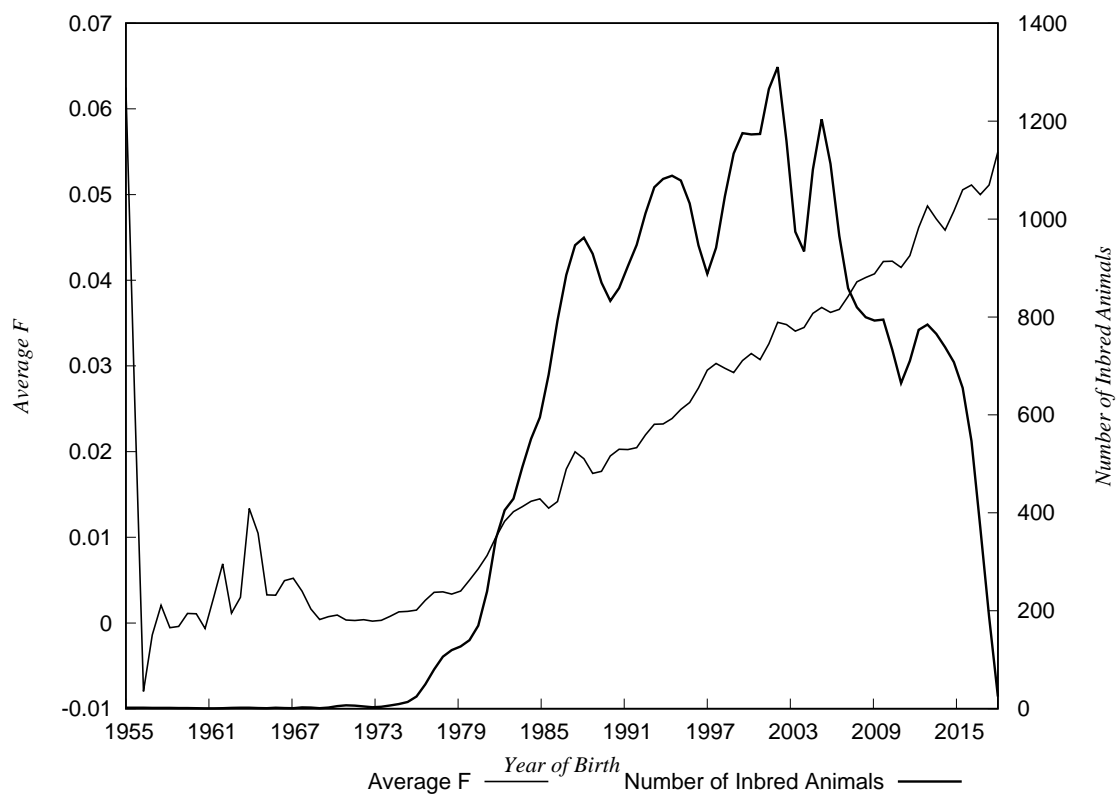
Table 5: Inbreeding coefficients (F) of INBRED animals by year

Year	No of Animals	F			
		Min	Max	Avg	Std
1955	2	0.1250	0.2500	0.1875	0.0884
1960	1	0.0117	0.0117	0.0117	-
1962	1	0.0625	0.0625	0.0625	-
1964	2	0.0430	0.2500	0.1465	0.1464
1965	1	0.1250	0.1250	0.1250	-
1966	2	0.0078	0.1250	0.0664	0.0829
1967	1	0.2500	0.2500	0.2500	-
1968	3	0.0313	0.1069	0.0591	0.0416
1969	1	0.0313	0.0313	0.0313	-
1970	4	0.0313	0.0677	0.0448	0.0174
1971	7	0.0039	0.1563	0.0508	0.0496
1972	5	0.0156	0.1563	0.0699	0.0657
1973	3	0.0313	0.1250	0.0677	0.0502
1974	6	0.0015	0.2500	0.1474	0.1207
1975	11	0.0015	0.2500	0.1251	0.1035
1976	25	0.0156	0.2500	0.1144	0.0965
1977	67	0.0007	0.2500	0.0895	0.0913
1978	109	0.0007	0.2500	0.0814	0.0816
1979	125	0.0004	0.2500	0.0575	0.0572
1980	146	0.0002	0.2504	0.0665	0.0809
1981	226	0.0004	0.2500	0.0530	0.0689
1982	382	0.0002	0.2504	0.0491	0.0674
1983	429	0.0001	0.3750	0.0416	0.0623
1984	531	0.0000	0.2676	0.0397	0.0547
1985	604	0.0001	0.2798	0.0381	0.0566
1986	762	0.0001	0.3125	0.0301	0.0384
1987	907	0.0000	0.3750	0.0361	0.0545
1988	963	0.0001	0.3750	0.0320	0.0482
1989	905	0.0000	0.2813	0.0267	0.0372
1990	833	0.0002	0.2664	0.0264	0.0391
1991	886	0.0001	0.3281	0.0253	0.0333
1992	955	0.0002	0.2834	0.0255	0.0365
1993	1054	0.0000	0.3512	0.0272	0.0389
1994	1084	0.0000	0.2776	0.0268	0.0363
1995	1082	0.0005	0.2877	0.0283	0.0373
1996	999	0.0006	0.2931	0.0294	0.0357
1997	888	0.0003	0.2850	0.0330	0.0401
1998	1001	0.0003	0.2848	0.0333	0.0407

Continue...

Year	No of Animals	<i>F</i>			
		Min	Max	Avg	Std
1999	1143	0.0005	0.3059	0.0318	0.0329
2000	1177	0.0024	0.2815	0.0344	0.0381
2001	1190	0.0009	0.3422	0.0342	0.0385
2002	1317	0.0005	0.2882	0.0377	0.0448
2003	1072	0.0001	0.3240	0.0374	0.0407
2004	934	0.0022	0.3192	0.0378	0.0404
2005	1188	0.0006	0.3192	0.0391	0.0363
2006	1092	0.0030	0.2793	0.0397	0.0375
2007	881	0.0021	0.2901	0.0403	0.0349
2008	814	0.0011	0.2896	0.0433	0.0422
2009	792	0.0051	0.2845	0.0440	0.0407
2010	779	0.0051	0.3213	0.0448	0.0383
2011	665	0.0057	0.3846	0.0460	0.0367
2012	753	0.0038	0.3326	0.0480	0.0395
2013	783	0.0037	0.3287	0.0516	0.0436
2014	746	0.0071	0.2913	0.0486	0.0377
2015	696	0.0082	0.2928	0.0513	0.0324
2016	567	0.0078	0.2896	0.0536	0.0406
2017	289	0.0112	0.2860	0.0523	0.0377
2018	25	0.0204	0.1270	0.0550	0.0217

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 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		
1947	-	-	-	-	-	-
1949	0.0000	0.0000	0.0000	0.0000	0.0000	-
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	0.0099	0.0000	0.0000	0.0000	0.0099	51
1956	0.0150	0.0000	0.0000	0.0000	0.0150	33
1957	0.0117	0.0057	0.0139	0.0094	0.0024	211
1958	0.0150	0.0074	0.0167	0.0117	0.0033	151
1959	0.0125	0.0069	0.0156	0.0110	0.0015	336
1960	0.0117	0.0089	0.0192	0.0139	-0.0022	-227
1961	0.0099	0.0078	0.0167	0.0121	-0.0022	-226
1962	0.0018	0.0080	0.0156	0.0117	-0.0101	-50
1963	0.0014	0.0055	0.0139	0.0090	-0.0077	-65
1964	0.0054	0.0004	0.0027	0.0014	0.0040	124
1965	0.0053	0.0003	0.0022	0.0012	0.0042	119
1966	0.0052	0.0026	0.0025	0.0025	0.0026	191
1967	0.0054	0.0054	0.0018	0.0037	0.0017	293
1968	0.0048	0.0068	0.0015	0.0044	0.0004	1154
1969	0.0036	0.0073	0.0011	0.0045	-0.0009	-548
1970	0.0027	0.0072	0.0017	0.0046	-0.0019	-264
1971	0.0008	0.0070	0.0011	0.0042	-0.0035	-145
1972	0.0006	0.0061	0.0009	0.0036	-0.0031	-163
1973	0.0004	0.0048	0.0006	0.0027	-0.0023	-216

Continue...

Year	Avg F		Dams	Parents	ΔF	N_e
	Animals	Sires				
1974	0.0005	0.0051	0.0004	0.0028	-0.0023	-217
1975	0.0006	0.0049	0.0003	0.0026	-0.0020	-249
1976	0.0008	0.0047	0.0004	0.0026	-0.0017	-286
1977	0.0013	0.0044	0.0003	0.0024	-0.0011	-476
1978	0.0020	0.0039	0.0003	0.0020	-0.0001	-9111
1979	0.0024	0.0034	0.0004	0.0019	0.0005	976
1980	0.0030	0.0032	0.0005	0.0018	0.0012	407
1981	0.0038	0.0033	0.0008	0.0020	0.0018	274
1982	0.0049	0.0039	0.0012	0.0025	0.0025	203
1983	0.0063	0.0046	0.0015	0.0030	0.0033	150
1984	0.0076	0.0059	0.0023	0.0040	0.0037	136
1985	0.0094	0.0077	0.0031	0.0053	0.0042	119
1986	0.0111	0.0103	0.0042	0.0071	0.0041	123
1987	0.0132	0.0127	0.0052	0.0088	0.0045	112
1988	0.0149	0.0145	0.0061	0.0101	0.0048	104
1989	0.0158	0.0160	0.0073	0.0115	0.0043	115
1990	0.0166	0.0172	0.0083	0.0126	0.0040	126
1991	0.0174	0.0179	0.0093	0.0135	0.0039	127
1992	0.0182	0.0181	0.0107	0.0144	0.0039	128
1993	0.0197	0.0182	0.0121	0.0151	0.0047	107
1994	0.0204	0.0185	0.0136	0.0160	0.0044	113
1995	0.0212	0.0193	0.0149	0.0171	0.0042	119
1996	0.0226	0.0205	0.0160	0.0182	0.0044	113
1997	0.0238	0.0212	0.0169	0.0190	0.0049	102
1998	0.0252	0.0226	0.0176	0.0201	0.0052	97
1999	0.0265	0.0246	0.0184	0.0215	0.0051	99
2000	0.0278	0.0266	0.0195	0.0231	0.0048	104
2001	0.0289	0.0287	0.0207	0.0247	0.0044	114
2002	0.0306	0.0307	0.0219	0.0263	0.0044	113
2003	0.0316	0.0320	0.0229	0.0274	0.0044	114
2004	0.0322	0.0337	0.0239	0.0287	0.0036	138
2005	0.0332	0.0354	0.0249	0.0301	0.0031	159
2006	0.0341	0.0367	0.0259	0.0313	0.0030	169
2007	0.0349	0.0380	0.0267	0.0323	0.0027	185
2008	0.0362	0.0392	0.0276	0.0334	0.0029	172
2009	0.0369	0.0404	0.0288	0.0345	0.0025	200
2010	0.0380	0.0412	0.0299	0.0356	0.0025	197
2011	0.0389	0.0415	0.0305	0.0360	0.0031	162
2012	0.0401	0.0421	0.0310	0.0365	0.0037	134
2013	0.0421	0.0433	0.0319	0.0376	0.0047	107
2014	0.0434	0.0446	0.0329	0.0387	0.0048	103
2015	0.0446	0.0452	0.0339	0.0396	0.0052	95
2016	0.0460	0.0462	0.0348	0.0405	0.0057	88
2017	0.0468	0.0473	0.0351	0.0412	0.0059	85
2018	0.0478	0.0484	0.0358	0.0421	0.0060	83

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	
1947	8	1	1	2	1
1949	22	5	4	9	6
1951	32	13	10	23	16
1952	33	13	10	23	16
1953	39	18	15	33	23
1954	32	18	16	34	24
1955	38	20	20	40	28
1956	25	17	17	34	24
1957	32	20	19	39	27
1958	25	15	16	31	22
1959	30	16	17	33	23
1960	33	13	14	27	19
1961	39	15	16	31	22
1962	42	17	17	34	24
1963	54	22	19	41	29
1964	68	23	24	47	33
1965	92	25	29	54	38
1966	121	32	44	76	52
1967	159	40	61	101	68
1968	216	52	77	129	87
1969	280	66	96	162	110
1970	438	85	129	214	143

Continue...

Year	Number of				N_e
	Animals	Sires	Dams	Parents	
1971	1546	104	164	268	178
1972	2511	149	265	414	267
1973	3672	225	898	1123	504
1974	4806	278	1681	1959	668
1975	5748	322	2201	2523	787
1976	7555	370	2554	2924	905
1977	9183	426	2985	3411	1044
1978	10519	503	4412	4915	1264
1979	11597	556	5620	6176	1417
1980	12187	587	6232	6819	1502
1981	12575	590	6571	7161	1516
1982	13286	592	7186	7778	1531
1983	12780	591	7669	8260	1536
1984	12496	609	8168	8777	1587
1985	11627	620	7971	8591	1611
1986	11254	621	7775	8396	1610
1987	11206	627	7822	8449	1625
1988	11231	672	7714	8386	1731
1989	10916	696	7445	8141	1782
1990	10668	702	7293	7995	1793
1991	10256	724	7082	7806	1839
1992	9839	733	6879	7612	1855
1993	9389	754	6645	7399	1896
1994	8902	756	6286	7042	1890
1995	8544	752	5981	6733	1870
1996	8261	742	5728	6470	1839
1997	8130	725	5591	6316	1797
1998	8133	703	5548	6251	1747
1999	8196	685	5582	6267	1708
2000	8235	704	5663	6367	1753
2001	8303	722	5689	6411	1794
2002	8487	729	5783	6512	1813
2003	8533	739	5801	6540	1835
2004	8562	726	5806	6532	1807
2005	8719	727	5939	6666	1814
2006	8674	737	5976	6713	1837
2007	8333	724	5857	6581	1804
2008	7894	738	5595	6333	1826
2009	7333	737	5244	5981	1809
2010	6990	724	5025	5749	1772
2011	6702	719	4844	5563	1753
2012	6249	720	4616	5336	1744
2013	5882	707	4373	5080	1704
2014	5728	698	4224	4922	1677
2015	5579	692	4110	4802	1658
2016	5314	680	3924	4604	1623
2017	4794	626	3587	4213	1492

Continue...

	Number of				
Year	Animals	Sires	Dams	Parents	<i>Ne</i>
2018	4083	577	3161	3738	1366

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:

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

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
1947	8	0.00000	-	0.00000	-	-
1948		--	-	-	-	-
1949	22	0.00833	-	0.00000	-	2 (2.0)
1950		--	-	-	-	-
1951	32	0.01127	-	0.00000	-	2 (2.0)
1952	33	0.01057	-	0.00000	-	-
1953	39	0.01497	-	0.00000	-	2 (2.0)
1954	32	0.01758	0.01758	0.00000	0.00000	7 (-)
1955	38	0.01974	-	0.06250	-	3 (2.5)
1956	25	0.02484	0.01665	0.00000	0.00000	7 (-)

Continue...

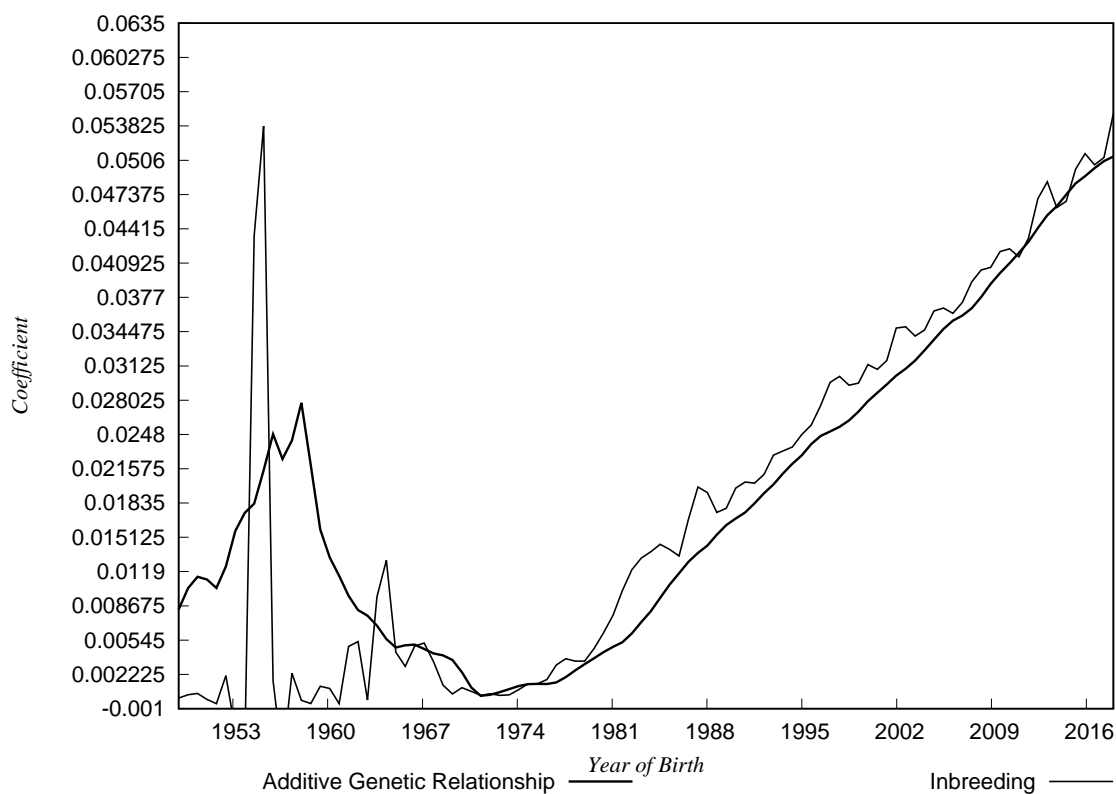
Year	No Animals	AGR		F		Generation Interval
		Avg	Δf	Avg	ΔF	() = True GI
1957	32	0.02215	-	0.00000	-	2 (2.0)
1958	25	0.02785	0.01677	0.00000	0.00000	2 (2.0)
1959	30	0.01925	0.00878	0.00000	0.00000	7 (-)
1960	33	0.01366	-0.00133	0.00130	0.00130	3 (2.5)
1961	39	0.01111	-0.00658	0.00000	0.00000	3 (3.2)
1962	42	0.00861	-0.01135	0.00690	-0.05931	3 (3.1)
1963	54	0.00769	-0.01759	0.00000	0.00000	4 (4.0)
1964	68	0.00616	-0.01635	0.01400	0.01400	6 (6.1)
1965	92	0.00476	-0.02375	0.00460	0.00460	4 (3.8)
1966	121	0.00507	-0.01446	0.00380	0.00380	5 (4.5)
1967	159	0.00470	-0.00908	0.00530	0.00401	4 (4.4)
1968	216	0.00413	-0.00706	0.00280	0.00280	4 (4.2)
1969	280	0.00379	-0.00487	0.00040	-0.00655	4 (4.3)
1970	438	0.00224	-0.00550	0.00100	0.00100	4 (3.5)
1971	1546	0.00040	-0.00579	0.00030	-0.01389	4 (4.1)
1972	2511	0.00031	-0.00448	0.00040	-0.00422	3 (3.3)
1973	3672	0.00067	-0.00443	0.00020	-0.00361	4 (4.3)
1974	4806	0.00109	-0.00362	0.00070	-0.00462	5 (5.1)
1975	5748	0.00133	-0.00281	0.00140	-0.00140	5 (5.3)
1976	7555	0.00131	-0.00249	0.00150	0.00110	6 (5.7)
1977	7762	0.00153	-0.00071	0.00330	0.00230	5 (5.3)
1978	7973	0.00236	0.00196	0.00360	0.00330	5 (4.5)
1979	7750	0.00321	0.00290	0.00350	0.00310	5 (4.8)
1980	8012	0.00402	0.00335	0.00540	0.00520	5 (5.2)
1981	8353	0.00478	0.00369	0.00760	0.00690	6 (5.5)
1982	8368	0.00548	0.00416	0.01090	0.00951	6 (5.5)
1983	8339	0.00692	0.00562	0.01300	0.01152	6 (5.5)
1984	8426	0.00841	0.00690	0.01390	0.01064	6 (5.5)
1985	8158	0.01027	0.00793	0.01440	0.01084	6 (5.6)
1986	7554	0.01184	0.00865	0.01350	0.01004	6 (5.7)
1987	7016	0.01331	0.00933	0.01890	0.01357	6 (5.8)
1988	6829	0.01431	0.00958	0.01940	0.01189	6 (5.7)
1989	6632	0.01577	0.01035	0.01720	0.00637	6 (5.5)
1990	6624	0.01680	0.00995	0.01950	0.00659	6 (5.5)
1991	6443	0.01765	0.00932	0.02030	0.00649	5 (5.3)
1992	6632	0.01900	0.00882	0.02060	0.00629	5 (5.4)
1993	6745	0.02022	0.00848	0.02300	0.00963	5 (5.4)
1994	7081	0.02168	0.00848	0.02330	0.00448	6 (5.6)
1995	7044	0.02284	0.00866	0.02480	0.00551	6 (5.7)
1996	7433	0.02430	0.00867	0.02630	0.00926	6 (5.7)
1997	7257	0.02503	0.00837	0.02950	0.01020	6 (5.8)
1998	7349	0.02568	0.00817	0.03010	0.01000	6 (6.0)
1999	7257	0.02671	0.00786	0.02930	0.00888	6 (6.1)
2000	7401	0.02808	0.00803	0.03150	0.00870	6 (6.0)
2001	7370	0.02919	0.00768	0.03090	0.00778	6 (6.4)
2002	7588	0.03037	0.00771	0.03490	0.01036	7 (6.6)
2003	7679	0.03132	0.00720	0.03440	0.00832	6 (6.4)
2004	8064	0.03263	0.00780	0.03450	0.00515	7 (6.5)

Continue...

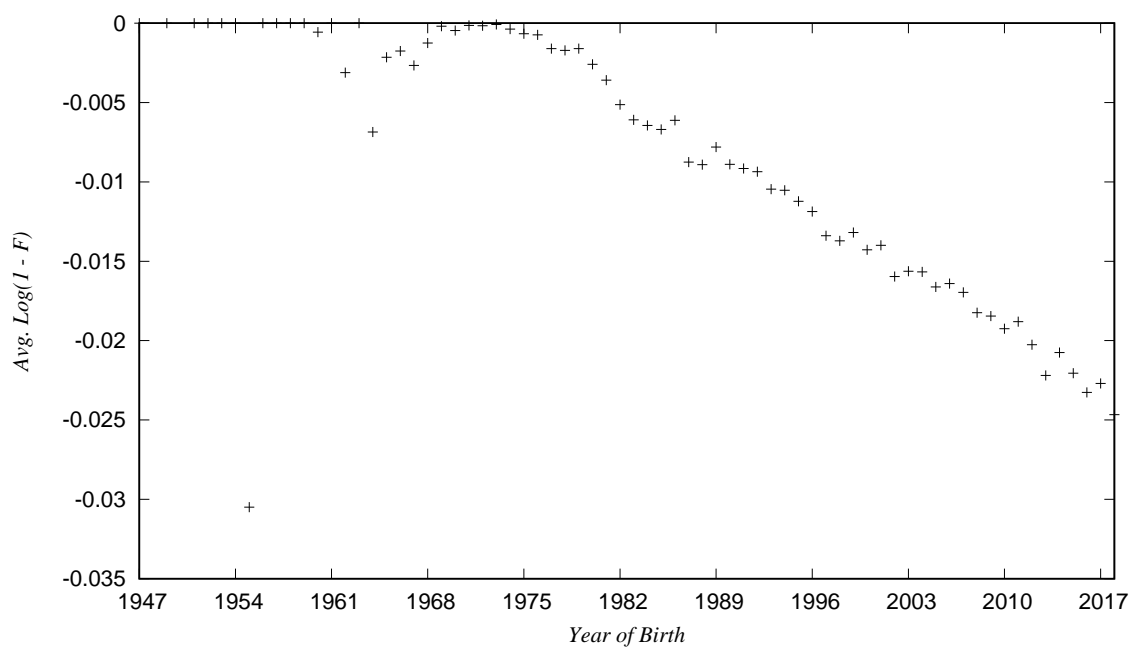
Year	No Animals	AGR		<i>F</i>		Generation Interval
		Avg	Δf	Avg	ΔF	() = True GI
2005	7947	0.03408	0.00862	0.03680	0.00691	6 (6.3)
2006	7909	0.03537	0.00890	0.03620	0.00711	6 (6.3)
2007	8144	0.03611	0.00825	0.03760	0.00630	7 (6.6)
2008	7894	0.03733	0.00838	0.04010	0.00949	7 (6.5)
2009	7333	0.03907	0.00897	0.04060	0.00591	7 (6.8)
2010	6990	0.04047	0.00945	0.04250	0.00839	8 (7.5)
2011	6702	0.04184	0.00952	0.04150	0.00725	7 (6.8)
2012	6249	0.04341	0.00965	0.04460	0.00810	7 (7.0)
2013	5882	0.04526	0.01025	0.04870	0.01297	7 (7.2)
2014	5728	0.04651	0.01079	0.04580	0.00852	8 (8.0)
2015	5579	0.04816	0.01125	0.04890	0.00917	8 (7.8)
2016	5314	0.04919	0.01054	0.05120	0.01105	7 (-)
2017	4794	0.05027	0.01021	0.05000	0.00783	7 (-)
2018	4083	0.05096	0.00952	0.05500	0.01408	7 (-)

Fixed Time interval used to calculate Delta AGR: 7

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

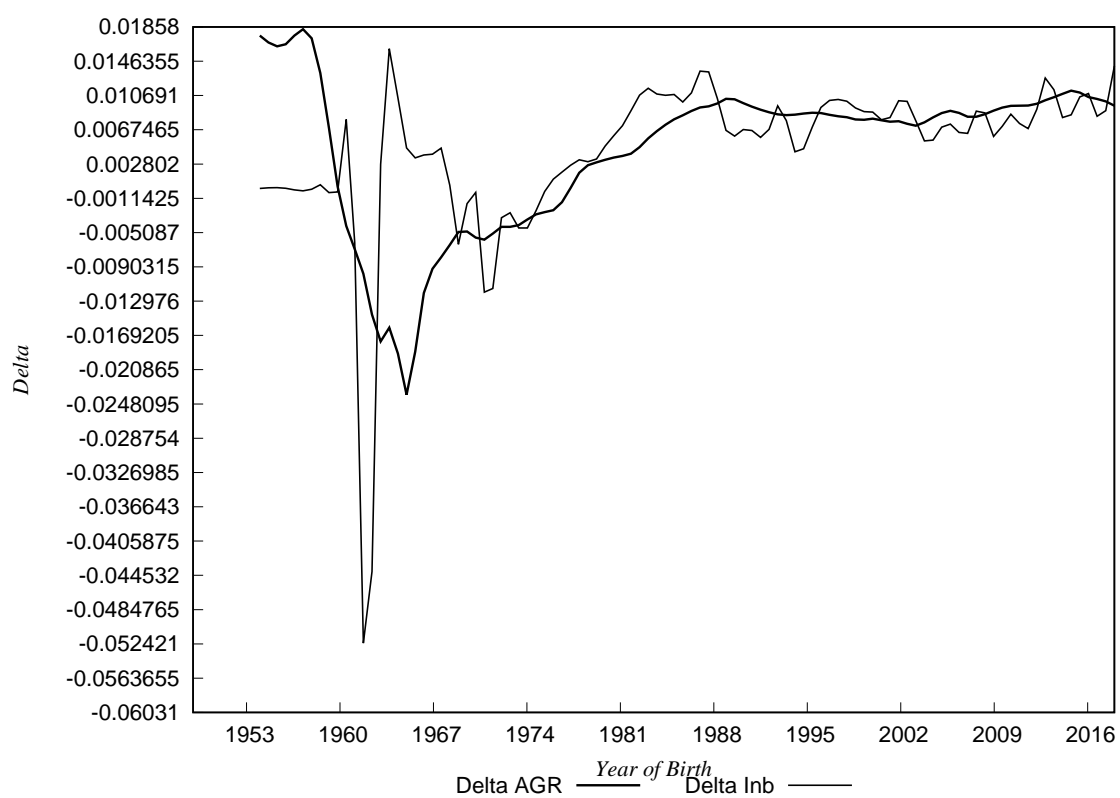


The average rate of change of the additive genetic relationships between 1949 and 2018 for the 54 breed was 0.00056 per year based on the slope of the regression fitted. This result in a Δf per generation of 0.00408. The rate of change of the average inbreeding coefficients based on the slope of the regression between 1949 and 2018 was 0.00075, which represents a ΔF per generation of 0.00546. The effective population sizes for the 54 breed, based on Δf and ΔF were 122 and 92, respectively.

Figure 4: Average $\text{Log}(1-F)$ by year of birth for animals born between 1947 and 2018.

*(The rate of inbreeding per generation for the 54 breed,
based on the Log(1-Inbreeding) is 0.0083 which presents an N_e of 60.
Calculations were performed on 58848 animals born between 1947 and 2018.)*

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



PopReport

A Population Monitoring Report

Population: 54
Inputfile: POPREP.TXT
Initiated by: quaglia@anabic.it
Submitted at: 2020-08-26 12:11:36
Started at: 2020-08-26 12:12:01
Finished at: 2020-08-26 12:38:57

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'.
58848 input lines processed.
58848 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
1977	555	555	8628	7207
1978	538	538	9981	7435
1979	556	556	11041	7194
1980	535	535	11652	7477
1981	510	510	12065	7843
1982	509	509	12777	7859
1983	511	511	12269	7828
1984	505	505	11991	7921
1985	524	524	11103	7634
1986	573	573	10681	6981
1987	626	626	10580	6390
1988	647	647	10584	6182
1989	671	671	10245	5961
1990	672	672	9996	5952
1991	696	696	9560	5747
1992	671	671	9168	5961
1993	657	657	8732	6088
1994	619	619	8283	6462
1995	623	623	7921	6421
1996	584	584	7677	6849
1997	601	601	7529	6656
1998	592	592	7541	6757
1999	601	601	7595	6656
2000	587	587	7648	6814
2001	590	590	7713	6780
2002	570	570	7917	7018
2003	562	562	7971	7117
2004	531	531	8031	7533
2005	540	540	8179	7407

Year	No. of Male		No. of Female	
	orig.	cut	orig.	cut
2006	543	543	8131	7366
2007	525	525	7808	7619

Monitoring the Population 54

Department of Animal Breeding and Genetics
Institute of Farm Animal Genetics
(Friedrich-Loeffler-Institute – FLI)
Höltyst. 10
D–31535 Neustadt, Germany
Eildert.Groeneveld@fli.bund.de

Developers at FLI:

Carina Apelt – Implementation of Monitoring Module
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 - ΔF_p	Falconer & Mackay (1996)	$\Delta F_p = \frac{F_t - F_{t-1}}{1 - F_{t-1}}$	$F_t = \odot$ inbreeding coefficient of offspring, $F_{t-1} = \odot$ inbreeding coefficient of direct parents
N_e - ΔF_g	Falconer & Mackay (1996)	$\Delta F_g = \frac{F_t - F_{t-1}}{1 - F_{t-1}}$	$F_{t-1} = \odot$ inbreeding coefficient of the \odot parents generation
N_e -Coan	Falconer & Mackay (1996)	$\Delta f_g = \frac{f_t - f_{t-1}}{1 - f_{t-1}}$	$f_t = \odot$ additive genetic relationship (AGR) of offspring, $f_{t-1} = \odot$ 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

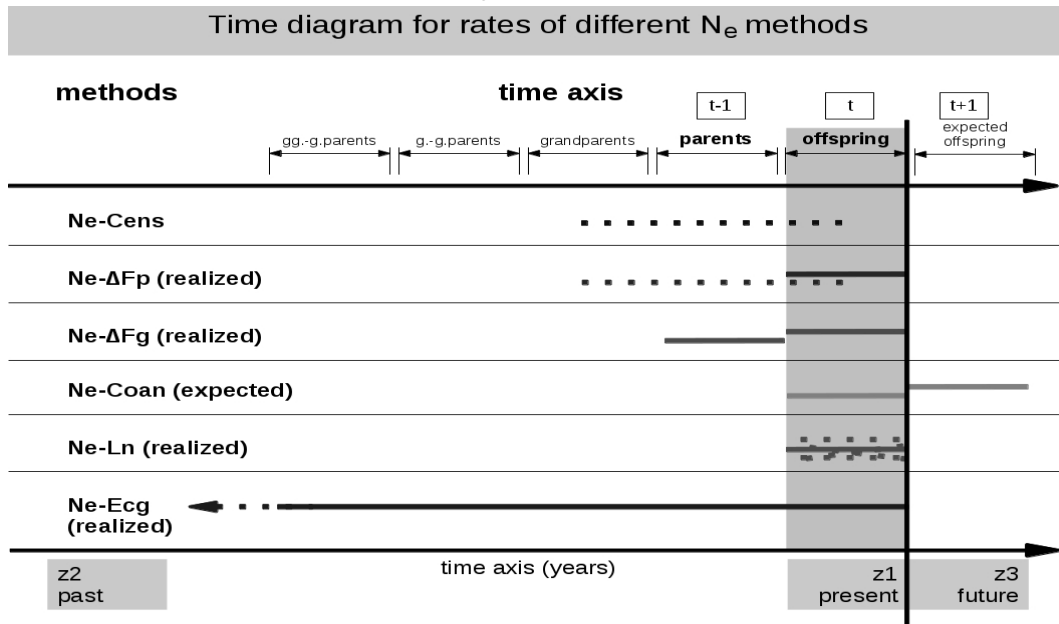


Table 2: Order of methods in cascade

Method	Based on data from
N_e -Ln	animals born in generation t
N_e - 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 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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Breed: 54 • 58848 pedigree records • generation interval: 7 • August 26, 2020

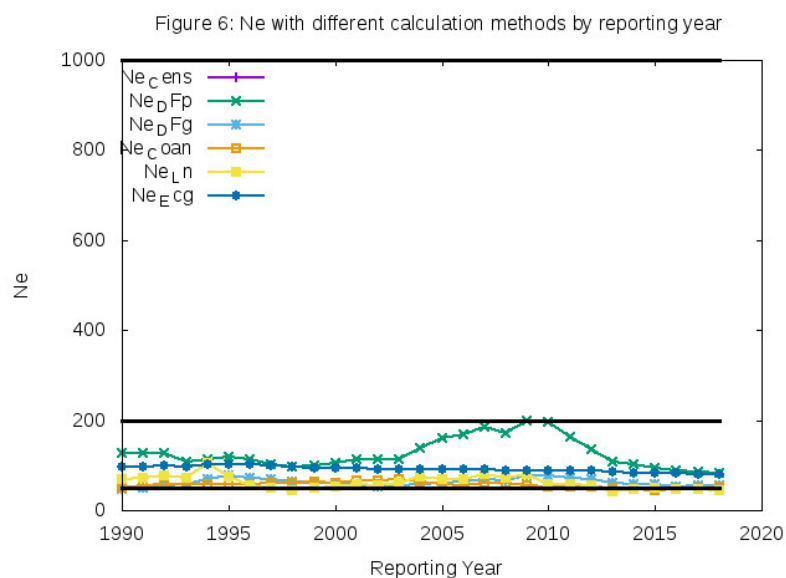
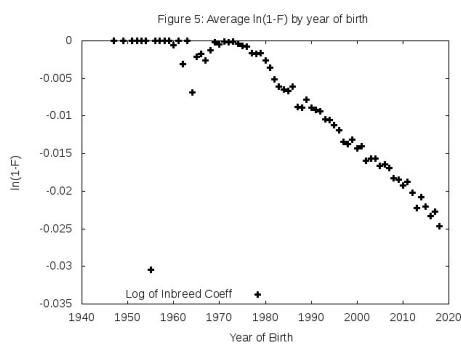
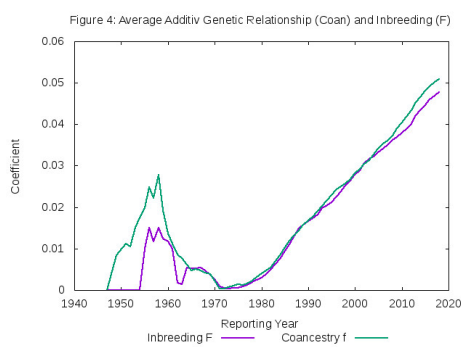
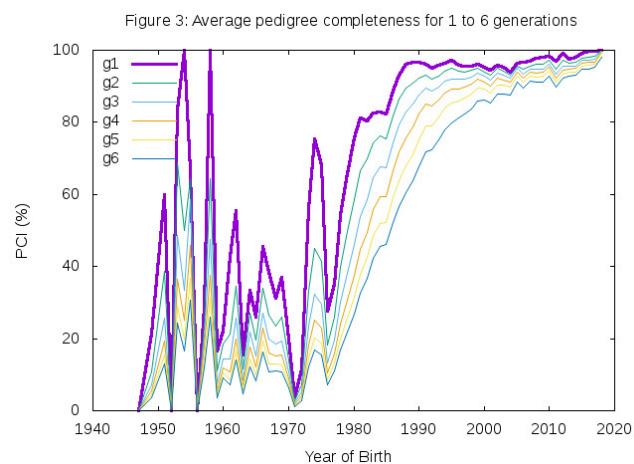
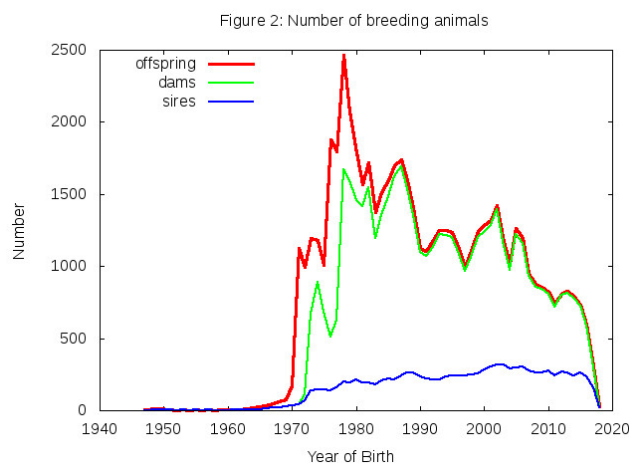


Table 3: Effective Population Size N_e

N_e -Method	2018	2017	2016	2015	2014	2013	data history
N_e -Cens	1366	1492	1623	1658	1677	1704	2011 – 2005
N_e - ΔF_p	83	85	88	95	103	107	2018 – 2005
N_e - ΔF_g	54	54	53	57	57	61	2018 – 2005
N_e -Coan	53	49	47	44	46	49	2025 – 2012
N_e -Ln	43	48	46	50	47	41	2018 – 2012
N_e -Ecg	80	81	82	83	84	85	2018 – 1947

Proposed N_e : N_e -Ln = 43

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
2018	1366	83	54	53	43	80
2017	1492	85	54	49	48	81
2016	1623	88	53	47	46	82
2015	1658	95	57	44	50	83
2014	1677	103	57	46	47	84
2013	1704	107	61	49	41	85
2012	1744	134	69	52	55	88
σ	53.7	7.6	3.1	3.5	4.6	0.7

Table 5: Decision cascade – side conditions

Method	Completeness [Years]	Stability [σ]	Diff	OK
N_e -Coan ^a	14/14	3.5 3.1/20	-9.29	no
N_e -Ln	7/7	4.6/20	-	yes
N_e - ΔF_p	7/7	7.6/20	-	yes
N_e - ΔF_g	7/7	3.1/20	-	yes
N_e -Coan	7/7	3.5/20	-	yes
N_e -Ecg	7/7	0.7/20	-	yes
N_e -Cens	7/7	53.7/20	-	no

^aAvg N_e -Coan – Avg N_e - ΔF_g : 48.57 - 57.86 = -9.29

PopReport

A Population Structure Report

Population: 54
Inputfile: POPREP.TXT
Initiated by: quaglia@anabic.it
Submitted at: 2020-08-26 12:11:36
Started at: 2020-08-26 12:12:01
Finished at: 2020-08-26 12:38:57

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'.
58848 input lines processed.
58848 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
1977	555	555	8628	7207
1978	538	538	9981	7435
1979	556	556	11041	7194
1980	535	535	11652	7477
1981	510	510	12065	7843
1982	509	509	12777	7859
1983	511	511	12269	7828
1984	505	505	11991	7921
1985	524	524	11103	7634
1986	573	573	10681	6981
1987	626	626	10580	6390
1988	647	647	10584	6182
1989	671	671	10245	5961
1990	672	672	9996	5952
1991	696	696	9560	5747
1992	671	671	9168	5961
1993	657	657	8732	6088
1994	619	619	8283	6462
1995	623	623	7921	6421
1996	584	584	7677	6849
1997	601	601	7529	6656
1998	592	592	7541	6757
1999	601	601	7595	6656
2000	587	587	7648	6814
2001	590	590	7713	6780
2002	570	570	7917	7018
2003	562	562	7971	7117
2004	531	531	8031	7533
2005	540	540	8179	7407

Year	No. of Male		No. of Female	
	orig.	cut	orig.	cut
2006	543	543	8131	7366
2007	525	525	7808	7619

Population Structure Report for Population: 54

Department of Animal Breeding and Genetics
Institute of Farm Animal Genetics (FLI)
Höltyst. 10
D-31535 Neustadt, Germany
Eildert.Groeneveld@fli.de

August 26, 2020

Developers

Frits Voordewind: PERL/SQL/Report, SA Studbook, Bloemfontein, South Africa

Bobbie van der Westhuizen: PERL/SQL/Report, SA Studbook, Centurion, South Africa

Azwihangwisi Maiwashe: Report, ARC, Irene, South Africa

Helmut Lichtenberg: Integration and WEB service, FLI, Germany

Eildert Groeneveld: Project Leader, FLI, Germany

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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 54 breed in 1966, 12 sires and 16 dams produced the 35 offspring during this year. In the batch of future parents (select) born in this year 1966 12 sires and 16 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	
1949	-	4	4	-	3	3	14
1951	-	8	8	-	6	6	10
1953	-	5	5	-	5	5	6
1954	-	1	1	-	1	1	1
1955	-	3	3	-	4	4	6
1957	-	3	3	-	2	2	7
1958	-	3	3	-	3	3	3
1959	-	1	1	-	1	1	6
1960	-	2	2	-	2	2	9
1961	-	3	3	-	3	3	7
1962	-	5	4	-	5	4	9
1963	-	6	6	-	2	2	13
1964	-	5	5	-	7	7	21

Continue...

Year	sires			dams			Number of animals
	services	births	select	services	births	select	born
1965	-	6	6	-	8	8	27
1966	-	12	12	-	16	16	35
1967	-	17	17	-	19	19	47
1968	-	22	21	-	20	19	64
1969	-	28	28	-	27	27	73
1970	-	33	31	-	35	33	171
1971	-	40	37	-	43	39	1129
1972	-	67	59	-	111	89	992
1973	-	137	106	-	666	346	1196
1974	-	143	114	-	887	477	1181
1975	-	143	105	-	680	357	1006
1976	-	139	99	-	510	273	1880
1977	-	158	127	-	627	367	1799
1978	-	198	162	-	1670	930	2465
1979	-	191	158	-	1591	930	2070
1980	-	216	170	-	1455	856	1786
1981	-	190	156	-	1414	835	1569
1982	-	195	167	-	1544	922	1717
1983	-	179	153	-	1197	677	1374
1984	-	204	171	-	1356	758	1515
1985	-	217	179	-	1481	789	1596
1986	-	211	160	-	1622	781	1697
1987	-	244	201	-	1692	885	1738
1988	-	262	208	-	1541	793	1594
1989	-	262	215	-	1354	754	1402
1990	-	235	198	-	1095	680	1126
1991	-	218	183	-	1067	668	1103
1992	-	212	173	-	1132	672	1179
1993	-	211	179	-	1219	722	1247
1994	-	232	196	-	1215	724	1251
1995	-	238	195	-	1203	705	1236
1996	-	242	209	-	1080	687	1119
1997	-	240	208	-	964	598	995
1998	-	249	202	-	1063	646	1106
1999	-	252	219	-	1198	690	1242
2000	-	282	211	-	1237	669	1286
2001	-	303	241	-	1283	668	1319
2002	-	315	249	-	1392	685	1420
2003	-	318	225	-	1141	552	1165
2004	-	286	201	-	973	473	1024
2005	-	298	222	-	1221	578	1263
2006	-	302	220	-	1157	548	1197
2007	-	274	184	-	933	408	945
2008	-	263	167	-	856	370	880
2009	-	260	158	-	844	337	859
2010	-	273	161	-	807	309	822
2011	-	244	132	-	715	234	736
2012	-	265	117	-	799	201	810

Continue...

Year	sires			dams			Number of animals
	services	births	select	services	births	select	born
2013	-	260	88	-	816	143	830
2014	-	242	52	-	782	73	791
2015	-	261	15	-	725	17	731
2016	-	233	-	-	590	-	594
2017	-	161	-	-	301	-	302
2018	-	22	-	-	25	-	25
Total	-	3243	2630	-	30863	17733	58848

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 54 breed in 1971, 2 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 1971 was 3.2 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	
1949	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1951	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1953	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1954	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	7.0
1955	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1.7
1957	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1958	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1959	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	4.0
1960	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0
1961	2	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2.3
1962	4	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	3.0
1963	5	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	2.2
1964	1	-	-	-	-	-	-	-	3	-	-	-	1	-	-	-	8.2
1965	3	1	-	-	-	-	-	-	-	1	-	-	-	1	-	-	4.8
1966	4	2	1	2	-	-	-	-	-	-	2	-	-	-	1	-	4.7
1967	8	1	2	-	-	1	-	1	-	-	-	3	-	-	-	1	4.8
1968	12	1	1	2	1	-	-	-	1	-	-	-	1	-	1	2	4.6
1969	16	1	3	1	2	-	-	-	-	-	-	-	1	2	-	2	4.3
1970	19	3	1	1	2	2	-	-	1	1	-	-	-	-	2	1	3.7
1971	21	2	2	5	6	1	1	-	-	-	-	-	-	-	-	2	3.2
1972	32	14	4	8	3	-	1	1	1	-	-	-	-	-	-	3	3.0

Continue...

Year	age of males in year																Avg
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	≥ 16	
1973	24	63	17	7	6	5	1	3	2	1	-	-	-	1	-	7	3.6
1974	12	46	48	9	5	6	5	2	2	1	1	-	-	-	1	5	3.8
1975	16	35	34	23	7	4	6	5	1	3	2	1	-	-	1	5	4.2
1976	11	43	26	22	10	4	4	2	5	2	1	1	1	-	-	7	4.4
1977	13	45	32	22	16	5	6	2	3	5	1	1	2	1	-	4	4.3
1978	15	53	43	35	12	9	7	6	2	3	7	1	1	1	1	2	4.2
1979	16	44	36	30	18	9	6	6	5	4	5	5	1	2	2	2	4.6
1980	13	61	40	33	27	11	5	5	3	5	5	2	1	1	1	3	4.3
1981	9	42	48	29	18	15	4	3	2	1	5	5	1	2	1	5	4.7
1982	8	44	37	34	23	14	9	4	3	1	-	3	5	2	1	7	4.9
1983	7	40	38	22	26	13	9	5	6	2	-	-	3	2	-	6	4.9
1984	15	55	38	32	16	14	7	9	2	5	1	-	-	2	2	6	4.5
1985	14	66	49	29	12	12	10	4	7	2	3	1	-	-	1	7	4.3
1986	15	40	62	30	16	7	9	8	5	5	2	4	-	-	1	7	4.7
1987	18	72	42	45	20	11	5	7	4	4	3	-	3	-	1	9	4.5
1988	22	82	56	30	22	14	8	6	4	4	4	1	1	2	-	6	4.1
1989	14	84	59	40	17	13	7	6	4	2	4	3	1	1	2	5	4.2
1990	7	57	59	44	23	9	8	7	3	3	2	2	4	2	-	5	4.5
1991	9	61	49	42	18	12	6	5	2	3	2	1	2	2	-	4	4.2
1992	1	63	50	36	33	8	8	4	3	-	-	2	1	-	2	1	3.9
1993	8	62	44	40	23	21	2	5	3	1	-	-	1	-	-	1	3.7
1994	4	64	55	38	31	13	15	3	4	2	-	-	1	-	1	1	3.9
1995	11	64	59	41	22	20	8	8	-	4	1	-	-	-	-	-	3.7
1996	11	65	53	46	25	13	17	4	4	1	3	-	-	-	-	-	3.8
1997	4	58	59	46	37	7	9	9	4	2	1	2	-	-	-	2	4.1
1998	8	43	60	51	38	22	7	6	6	3	2	-	2	-	-	1	4.2
1999	5	44	54	50	37	24	15	5	3	8	3	-	-	3	-	1	4.5
2000	4	63	47	46	45	35	13	11	3	1	6	2	1	1	2	2	4.7
2001	9	67	58	34	40	32	28	11	8	3	1	3	1	2	-	6	4.9
2002	3	63	72	51	25	29	25	15	11	5	3	1	2	1	2	7	5.2
2003	9	52	62	51	49	26	17	19	11	5	7	2	3	-	-	5	4.9
2004	1	45	48	47	42	42	13	9	12	9	7	4	1	1	1	4	5.2
2005	2	43	53	48	41	29	28	14	8	10	8	5	3	-	2	4	5.5

Continue...

Year	age of males in year																Avg
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	≥ 16	
2006	6	42	38	52	44	32	29	24	10	6	6	1	2	3	–	7	5.5
2007	4	44	36	38	37	29	25	20	18	3	6	2	3	1	2	6	5.7
2008	1	57	40	26	30	26	20	19	12	14	1	3	2	2	3	7	5.7
2009	2	35	55	28	27	30	25	17	11	9	5	–	2	–	–	14	6.1
2010	2	32	46	59	30	24	23	18	7	5	4	5	–	1	–	17	6.5
2011	4	32	39	42	36	17	18	19	10	6	4	–	3	–	2	12	6.2
2012	2	37	49	35	32	35	16	16	13	5	6	1	5	2	1	10	6.0
2013	1	35	35	34	30	39	32	15	10	8	4	3	2	3	1	8	6.2
2014	3	34	38	27	30	23	29	20	13	7	3	3	1	–	1	10	6.1
2015	3	41	38	37	26	31	17	14	18	8	6	2	3	–	2	15	6.7
2016	1	28	37	31	31	17	19	13	13	14	7	6	3	3	–	10	6.8
2017	2	12	21	26	18	25	10	8	4	8	4	4	3	4	2	10	7.4
2018	–	3	3	4	–	4	1	–	1	1	–	1	–	–	2	2	7.6
Total	522	2286	2078	1642	1186	844	594	424	291	206	149	86	74	51	45	276	7.3

For example: For the 54 breed in 1973, 15 two year-old females were used in reproduction while 5 three year-old females were used. The average age of females that produced offspring during 1973 was 1.2 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
1949	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1951	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1953	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1954	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1955	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1957	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1958	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1959	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1960	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1961	2	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2.3
1962	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1963	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	8.0
1964	6	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1.4
1965	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
1966	15	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1.5
1967	18	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1.1
1968	19	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1.1
1969	25	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1.2
1970	34	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1.1
1971	41	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	1.2
1972	106	2	1	-	-	1	-	1	-	-	-	-	-	-	-	-	1.1
1973	630	15	5	2	2	5	1	4	-	-	-	-	-	-	-	2	1.2
1974	627	87	156	5	3	1	2	1	4	1	-	-	-	-	-	-	1.6
1975	331	73	173	88	6	-	2	3	-	1	-	1	-	-	1	1	2.2
1976	180	61	103	97	50	5	1	2	4	1	3	1	1	-	-	1	2.8
1977	176	103	107	103	76	51	3	1	2	1	1	1	1	1	-	-	3.0
1978	1031	110	149	130	126	75	37	3	2	3	-	1	1	-	-	2	2.2
1979	811	177	203	110	108	83	63	24	6	1	-	1	2	1	-	1	2.5
1980	505	224	246	154	93	91	74	40	15	2	5	2	1	1	-	2	3.1

Continue...

Year	age of females in year																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	≥ 16	Avg
1981	305	250	280	186	103	94	76	49	43	17	3	4	1	–	–	3	3.6
1982	201	260	337	256	137	98	88	75	39	24	16	6	–	2	2	3	4.0
1983	53	209	233	218	174	92	75	50	35	30	13	8	3	3	1	–	4.5
1984	34	216	258	224	213	161	84	59	38	38	13	9	2	3	2	2	4.7
1985	15	239	258	232	206	178	123	82	62	32	24	18	8	1	2	1	5.0
1986	32	233	277	234	214	200	161	95	68	34	32	21	10	8	2	1	5.1
1987	15	260	271	242	221	167	167	131	92	53	34	12	12	8	4	3	5.3
1988	10	269	236	198	185	155	154	112	87	55	35	23	9	7	2	4	5.3
1989	13	208	201	196	140	156	128	96	78	54	38	21	16	8	1	–	5.4
1990	2	180	172	156	140	102	96	83	59	51	29	12	7	3	2	1	5.3
1991	5	179	167	144	134	92	87	75	74	36	29	22	16	6	1	–	5.4
1992	1	157	181	172	138	118	103	63	60	53	32	27	12	9	4	2	5.6
1993	3	164	181	191	161	135	102	83	54	43	52	23	14	10	1	2	5.5
1994	9	143	158	157	158	151	129	87	79	29	47	34	17	6	6	5	5.8
1995	6	176	151	134	143	137	96	96	85	60	41	28	24	12	7	7	6.0
1996	6	132	102	140	123	117	116	104	74	50	35	25	25	17	12	2	6.2
1997	4	100	121	107	115	86	101	91	68	61	46	35	12	11	4	2	6.3
1998	2	87	127	118	140	110	99	89	91	64	60	36	15	11	7	7	6.5
1999	3	112	137	162	147	113	116	105	78	70	50	50	26	9	13	7	6.4
2000	6	138	153	150	143	144	112	91	78	63	56	55	23	11	6	8	6.2
2001	11	132	145	148	148	132	133	90	70	81	62	44	41	26	14	6	6.5
2002	5	138	144	162	158	149	128	128	100	81	63	36	37	24	25	14	6.6
2003	3	102	157	119	110	119	129	94	77	60	53	35	28	24	15	16	6.6
2004	2	80	105	118	103	82	93	69	90	66	47	46	29	24	7	12	6.9
2005	3	115	161	152	156	123	103	84	90	81	45	39	29	15	7	18	6.4
2006	3	95	150	158	132	124	119	83	75	48	58	42	23	19	14	14	6.5
2007	5	78	84	99	140	98	106	75	53	56	46	36	26	12	12	7	6.7
2008	7	85	94	88	97	113	87	60	57	46	40	28	23	18	4	9	6.5
2009	2	80	89	101	92	89	85	68	74	44	38	25	19	16	7	15	6.6
2010	2	62	81	109	84	81	82	101	51	46	40	30	16	10	6	6	6.6
2011	1	53	66	68	95	81	64	63	81	59	22	16	20	12	9	5	6.9
2012	–	62	63	74	99	97	97	60	63	52	45	31	29	9	9	9	7.0
2013	1	53	70	87	94	90	93	64	52	73	54	37	21	13	11	3	7.0

Continue...

Year	age of females in year																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	≥ 16	Avg
2014	3	42	66	69	91	52	75	82	81	54	48	47	31	18	13	10	7.5
2015	2	61	57	71	85	63	70	63	60	50	41	24	29	26	14	9	7.2
2016	–	43	53	52	53	54	55	52	54	49	31	30	21	21	12	10	7.5
2017	–	23	30	35	30	23	33	22	30	11	21	14	9	11	5	4	7.2
2018	–	1	3	5	2	2	1	1	3	3	2	2	–	–	–	–	6.8
Total	5373	5869	6767	6023	5369	4490	3949	3054	2538	1887	1450	1038	689	446	265	236	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 54 in 1969, 3 females were in their second parity while in 1973, 5 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	11	12
1949	3	–	–	–	–	–	–	–	–	–	–	–
1951	6	–	–	–	–	–	–	–	–	–	–	–
1953	5	–	–	–	–	–	–	–	–	–	–	–
1954	1	–	–	–	–	–	–	–	–	–	–	–
1955	4	–	–	–	–	–	–	–	–	–	–	–
1957	2	–	–	–	–	–	–	–	–	–	–	–
1958	3	–	–	–	–	–	–	–	–	–	–	–
1959	1	–	–	–	–	–	–	–	–	–	–	–
1960	2	–	–	–	–	–	–	–	–	–	–	–
1961	3	–	–	–	–	–	–	–	–	–	–	–
1962	5	–	–	–	–	–	–	–	–	–	–	–
1963	2	–	–	–	–	–	–	–	–	–	–	–
1964	7	–	–	–	–	–	–	–	–	–	–	–
1965	8	–	–	–	–	–	–	–	–	–	–	–
1966	15	1	–	–	–	–	–	–	–	–	–	–
1967	19	–	–	–	–	–	–	–	–	–	–	–
1968	19	1	–	–	–	–	–	–	–	–	–	–
1969	24	3	–	–	–	–	–	–	–	–	–	–
1970	35	–	–	–	–	–	–	–	–	–	–	–
1971	41	2	–	–	–	–	–	–	–	–	–	–
1972	109	2	–	–	–	–	–	–	–	–	–	–
1973	644	20	5	1	–	–	–	–	–	–	–	–
1974	795	89	5	1	–	–	–	–	–	–	–	–
1975	531	130	21	1	–	–	–	–	–	–	–	–
1976	373	101	33	4	2	–	–	–	–	–	–	–
1977	462	125	32	10	1	–	–	–	–	–	–	–
1978	1464	155	48	14	5	–	–	–	–	–	–	–
1979	1287	240	51	19	5	1	–	–	–	–	–	–
1980	1098	272	60	18	11	3	1	–	–	–	–	–
1981	1009	309	66	22	8	3	–	1	1	1	1	–
1982	1118	317	90	19	6	2	–	–	–	–	–	1
1983	830	265	85	19	11	–	–	–	–	–	–	–
1984	918	307	108	21	5	3	–	–	–	–	–	–
1985	997	348	87	39	10	4	1	–	–	–	–	–
1986	999	435	131	47	10	4	1	–	–	–	–	–

Continue...

Year	parity number											
	1	2	3	4	5	6	7	8	9	10	11	12
1987	1053	415	168	36	17	4	–	–	–	–	–	–
1988	892	417	166	51	12	9	–	–	–	–	–	–
1989	769	367	146	56	12	3	4	–	–	–	–	–
1990	587	306	125	53	19	3	3	1	–	–	–	–
1991	612	247	121	59	22	6	–	2	1	–	–	–
1992	648	293	109	50	25	5	2	–	–	–	–	–
1993	740	274	127	48	18	13	1	–	–	–	–	–
1994	688	323	124	51	16	9	3	1	–	–	–	–
1995	647	349	131	47	19	7	4	1	–	1	–	–
1996	573	296	129	45	24	9	2	3	–	–	–	–
1997	505	263	112	57	19	4	4	–	–	–	–	–
1998	561	267	146	54	28	8	2	–	–	–	1	1
1999	646	323	132	61	27	8	7	1	–	–	–	–
2000	696	314	142	55	19	15	4	–	–	–	–	–
2001	693	345	136	63	29	9	6	3	–	–	–	–
2002	733	380	167	57	33	15	6	1	1	–	–	–
2003	592	312	143	53	23	7	7	3	1	1	–	–
2004	472	253	150	53	23	17	3	4	1	1	–	–
2005	691	318	122	59	22	5	7	–	1	–	–	–
2006	650	283	128	56	25	10	3	1	–	1	1	–
2007	499	246	120	48	13	5	2	2	–	–	–	–
2008	474	223	97	32	19	4	4	2	1	–	1	–
2009	481	204	96	40	11	8	1	2	1	–	–	–
2010	448	220	86	33	17	3	1	–	1	–	–	–
2011	398	184	77	35	13	6	2	1	–	–	–	–
2012	480	193	88	24	10	1	3	–	–	–	–	–
2013	472	205	84	36	12	5	3	–	–	–	–	–
2014	418	239	78	28	11	6	2	1	–	–	–	–
2015	405	191	81	30	9	4	2	2	1	–	–	–
2016	314	181	58	20	12	5	1	1	1	–	–	–
2017	173	69	37	11	5	3	2	1	–	–	–	–
2018	14	7	1	2	–	1	–	–	–	–	–	–
Total	30863	11629	4449	1638	638	237	94	34	11	5	4	2

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 54 breed the Generation interval (average age of parents when their selected offspring were born) for the selection path between sire to son (ss) was 6.3 year in 1966. This values was calculated based on the avarage ages of 7 selected sons, born during 1966. 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 6.7, 3.3 and 2.0 year, respectively. During 1966, the generation interval for the males was 6.5 year and 2.5 year for the female born during this year. The generation interval in 1966 for all four selection paths together, or for the population in total (pop), was 4.5 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 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, Nfemale=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
1949	2.0	2	2.0	2	2.0	2	2.0	1	2.0	4	2.0	3	2.0	4
1951	2.0	5	2.0	3	2.0	3	2.0	3	2.0	8	2.0	6	2.0	8
1953	2.0	2	2.0	4	2.0	2	2.0	3	2.0	6	2.0	5	2.0	6
1955	2.6	3	3.9	1	2.0	3	2.0	1	3.0	4	2.0	4	2.5	4
1957	2.0	1	2.0	2	2.0	1	2.0	1	2.0	3	2.0	2	2.0	3
1958	2.0	1	2.0	2	2.0	1	2.0	2	2.0	3	2.0	3	2.0	3
1960	2.0	1	3.9	1	2.0	1	2.0	1	3.0	2	2.0	2	2.5	2
1961	3.6	2	2.0	1	3.9	2	2.0	1	3.1	3	3.3	3	3.2	3
1962	2.0	1	5.0	3	2.0	1	2.0	3	4.3	4	2.0	4	3.1	4
1963	3.6	4	3.5	4	2.0	1	15.8	1	3.5	8	8.9	2	4.0	8
1964	8.4	4	8.1	5	2.7	4	2.0	3	8.2	9	2.4	7	6.1	9
1965	8.5	5	2.0	3	2.0	5	2.0	3	6.1	8	2.0	8	3.8	9

Continue...

Year	Generation interval and number of animal													
	ss	Nss	sd	Nsd	ms	Nms	md	Nmd	male	Nmale	female	Nfemale	pop	Npop
1966	6.3	7	6.7	10	3.3	6	2.0	10	6.5	17	2.5	16	4.5	17
1967	6.0	13	7.6	9	2.2	10	2.0	9	6.6	22	2.1	19	4.4	23
1968	6.2	12	5.2	12	1.9	10	2.1	9	5.7	24	2.0	19	4.2	24
1969	7.8	11	4.7	20	2.0	9	2.2	18	5.8	31	2.2	27	4.3	31
1970	8.7	9	3.7	27	2.0	7	2.0	26	4.9	36	2.0	33	3.5	37
1971	7.9	11	4.5	33	2.9	8	2.0	31	5.4	44	2.2	39	4.1	44
1972	9.7	7	4.0	87	1.9	8	2.1	82	4.4	94	2.1	90	3.3	95
1973	10.5	42	5.8	306	2.5	42	2.2	304	6.3	348	2.2	346	4.3	348
1974	10.5	68	7.3	413	2.7	68	2.4	411	7.7	481	2.4	479	5.1	481
1975	10.0	53	7.3	309	3.0	53	3.0	307	7.7	362	3.0	360	5.3	362
1976	10.6	41	7.4	234	4.7	41	3.3	235	7.9	275	3.5	276	5.7	276
1977	8.0	54	6.7	310	4.5	54	3.7	314	6.9	364	3.8	368	5.3	369
1978	6.1	58	6.6	717	4.1	58	3.1	879	6.6	775	3.1	937	4.5	939
1979	6.4	52	6.8	760	4.9	52	3.3	885	6.7	812	3.4	937	4.8	940
1980	6.1	59	6.8	742	5.3	59	3.7	803	6.8	801	3.8	862	5.2	864
1981	6.6	49	7.0	698	5.5	49	4.3	794	6.9	747	4.3	843	5.5	843
1982	6.1	63	6.7	749	5.6	64	4.5	862	6.7	812	4.6	926	5.5	926
1983	6.0	60	6.0	582	5.3	60	5.0	624	6.0	642	5.0	684	5.5	686
1984	5.1	58	6.0	657	5.5	60	5.2	703	5.9	715	5.2	763	5.5	764
1985	6.0	83	5.7	632	5.7	83	5.5	712	5.7	715	5.6	795	5.6	801
1986	5.5	98	5.8	641	5.5	98	5.7	691	5.8	739	5.7	789	5.7	791
1987	6.2	102	5.6	747	5.6	102	6.0	787	5.7	849	5.9	889	5.8	891
1988	5.7	68	5.3	719	6.2	68	6.0	730	5.3	787	6.0	798	5.7	798
1989	5.6	89	5.0	664	5.7	89	6.0	671	5.1	753	6.0	760	5.5	760
1990	5.9	65	5.0	610	5.6	65	6.0	617	5.1	675	5.9	682	5.5	683
1991	4.1	91	4.6	574	5.9	91	6.0	580	4.5	665	6.0	671	5.3	671
1992	4.1	68	4.6	598	6.5	68	6.2	605	4.5	666	6.3	673	5.4	676
1993	4.6	97	4.6	616	5.9	97	6.1	627	4.6	713	6.1	724	5.4	726
1994	4.5	75	4.8	646	6.5	75	6.5	651	4.8	721	6.5	726	5.6	726
1995	4.5	79	4.8	622	6.4	79	6.6	627	4.7	701	6.6	706	5.7	708
1996	3.9	57	4.6	627	6.9	57	6.8	633	4.6	684	6.8	690	5.7	691
1997	4.9	83	4.8	515	6.5	83	6.7	517	4.9	598	6.7	600	5.8	600
1998	4.9	82	4.9	562	7.2	82	7.1	567	4.9	644	7.1	649	6.0	650
1999	5.2	77	5.3	617	6.2	77	7.1	622	5.3	694	7.0	699	6.1	701
2000	5.0	81	5.4	582	6.2	81	6.7	592	5.4	663	6.7	673	6.0	674
2001	7.0	75	5.5	581	7.2	75	7.2	594	5.6	656	7.2	669	6.4	670
2002	7.7	61	5.8	620	7.1	61	7.2	626	6.0	681	7.2	687	6.6	688
2003	5.2	49	5.6	496	7.8	49	7.1	505	5.6	545	7.2	554	6.4	555
2004	5.4	51	5.6	424	7.1	51	7.5	425	5.6	475	7.5	476	6.5	476
2005	5.8	87	5.7	490	6.4	87	7.1	492	5.7	577	7.0	579	6.3	579
2006	5.1	70	5.7	480	7.0	70	7.0	480	5.6	550	7.0	550	6.3	554
2007	6.9	54	5.9	351	6.9	54	7.3	354	6.0	405	7.3	408	6.6	408
2008	6.5	64	6.0	307	7.5	64	6.8	306	6.1	371	6.9	370	6.5	371
2009	8.9	62	6.2	275	6.2	62	7.0	276	6.7	337	6.9	338	6.8	339
2010	10.9	49	7.2	261	7.0	49	7.2	260	7.8	310	7.1	309	7.5	310
2011	10.0	58	6.0	177	6.5	58	6.9	176	7.0	235	6.8	234	6.8	236
2012	8.1	54	6.4	148	6.4	54	7.3	148	6.9	202	7.1	202	7.0	202
2013	6.7	45	7.3	98	7.1	45	7.4	98	7.1	143	7.3	143	7.2	143

Continue...

Year	Generation interval and number of animal													
	ss	Nss	sd	Nsd	ms	Nms	md	Nmd	male	Nmale	female	Nfemale	pop	Npop
2014	9.4	23	8.0	50	7.8	23	7.3	50	8.5	73	7.5	73	8.0	73
2015	6.5	10	11.2	7	7.9	10	5.9	7	8.4	17	7.1	17	7.8	17
Total	6.3	-	5.7	-	5.9	-	5.6	-	5.8	-	5.7	-	5.7	-

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 ($N_e = 1/2\Delta F$ where N_e 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
1947	2	1.3	1	1.0	2	1.3	1	1.0	1	1.0	1	1.0	1	1.0	1	1.0
1949	3	1.3	1	1.0	2	1.1	1	1.0	1	1.0	1	1.0	1	1.0	1	1.0
1951	13	4.4	1	1.0	13	4.4	1	1.0	6	2.3	1	1.0	7	3.3	1	1.0
1953	5	3.0	1	1.0	5	3.0	1	1.0	4	2.5	1	1.0	1	1.0	1	1.0
1954	2	2.0	-	-	2	2.0	-	-	1	1.0	-	-	1	1.0	-	-
1955	336	201.3	3	2.3	206	127.3	3	2.0	50	36.3	1	1.0	156	91.0	2	2.0
1956	1	1.0	-	-	1	1.0	-	-	1	1.0	-	-	-	-	-	-
1957	27	13.3	3	1.8	18	10.0	3	1.5	2	1.5	1	1.0	17	9.0	2	1.3
1958	1	1.0	4	4.0	1	1.0	4	3.5	1	1.0	1	1.0	-	-	3	3.0
1959	20	7.3	2	1.3	10	4.0	1	1.0	1	1.0	1	1.0	10	10.0	1	1.0
1960	19	5.8	2	1.2	17	6.7	2	1.3	6	2.7	1	1.0	11	6.0	2	1.3
1961	3	1.3	1	1.0	3	1.3	1	1.0	1	1.0	1	1.0	2	1.3	-	-
1962	2	2.0	2	1.3	2	2.0	2	1.2	1	1.0	2	1.3	2	1.5	1	1.0
1963	100	27.0	4	1.3	50	14.5	3	1.2	8	3.5	1	1.0	42	22.0	2	1.3
1964	232	52.0	6	1.9	144	28.7	5	1.7	7	3.6	3	1.5	137	30.8	2	1.2
1965	93	14.9	5	1.9	42	8.8	5	1.8	5	2.7	2	1.2	38	10.2	3	1.5
1966	586	67.8	5	1.7	338	40.8	3	1.4	18	9.0	2	1.1	320	39.6	2	1.3
1967	114	21.9	4	1.6	65	12.5	4	1.4	9	2.5	2	1.3	56	11.7	4	1.2
1968	520	38.0	5	1.3	292	21.3	5	1.3	51	8.6	2	1.1	241	19.6	3	1.2
1969	110	17.5	6	1.4	61	10.0	6	1.4	6	2.8	5	1.7	55	9.6	3	1.2
1970	111	12.5	5	1.4	75	8.7	4	1.3	15	3.1	2	1.3	60	8.0	3	1.2
1971	43	6.6	7	1.4	28	4.3	6	1.3	4	1.7	3	1.2	27	3.8	6	1.2
1972	105	12.5	7	1.4	73	9.3	7	1.3	7	2.5	3	1.1	66	8.3	5	1.3
1973	80	6.9	12	1.4	48	4.8	7	1.3	10	2.6	4	1.2	38	4.4	7	1.3
1974	474	19.2	7	1.5	238	12.9	5	1.3	7	2.3	4	1.3	231	12.6	5	1.3

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
1975	302	18.1	7	1.6	171	12.1	6	1.5	15	2.7	3	1.2	156	11.4	5	1.4
1976	540	23.7	6	1.4	285	15.4	5	1.3	21	3.9	3	1.3	264	16.0	5	1.2
1977	104	16.3	7	1.4	59	11.1	6	1.3	16	4.0	3	1.2	58	10.0	4	1.2
1978	469	21.6	7	1.5	225	13.4	5	1.3	26	5.1	4	1.3	199	12.4	4	1.3
1979	534	18.5	8	1.5	256	12.2	8	1.4	28	4.0	5	1.3	228	11.4	8	1.3
1980	184	20.8	12	1.6	107	12.5	11	1.4	20	4.2	5	1.2	92	11.1	6	1.3
1981	111	15.3	8	1.7	58	9.3	7	1.5	16	3.1	4	1.4	42	8.9	5	1.5
1982	125	16.5	7	1.7	65	9.8	6	1.5	9	2.6	3	1.2	62	8.9	6	1.4
1983	173	15.7	8	1.7	92	9.4	8	1.5	9	2.6	4	1.3	87	8.4	5	1.4
1984	604	26.1	7	1.6	284	14.2	6	1.4	29	4.4	3	1.2	255	13.3	6	1.4
1985	195	10.2	8	1.7	111	7.6	8	1.5	17	3.1	4	1.3	94	6.6	7	1.4
1986	55	8.9	10	1.8	38	6.4	9	1.5	4	1.8	4	1.3	38	6.2	6	1.4
1987	367	14.8	7	1.7	192	9.3	5	1.5	18	3.7	3	1.2	174	8.4	5	1.4
1988	362	15.3	8	1.9	209	10.8	8	1.6	32	4.7	4	1.3	177	9.8	6	1.5
1989	464	20.1	11	1.9	236	13.5	11	1.6	30	4.6	5	1.4	206	11.7	6	1.5
1990	194	12.7	9	1.9	110	8.6	9	1.6	9	2.8	7	1.5	101	8.0	6	1.5
1991	191	13.7	7	1.9	90	8.5	6	1.6	27	3.0	4	1.4	79	7.9	6	1.5
1992	230	18.8	8	1.9	139	10.9	8	1.6	33	4.4	5	1.3	106	9.6	6	1.5
1993	100	13.3	11	1.8	61	8.4	9	1.5	11	3.2	4	1.2	50	7.6	6	1.4
1994	97	13.5	9	1.9	50	8.3	9	1.5	5	2.0	5	1.3	48	7.8	6	1.4
1995	333	23.8	7	1.8	197	13.3	6	1.5	43	4.3	3	1.2	154	12.1	5	1.4
1996	45	10.8	8	1.8	34	6.7	8	1.5	12	2.4	4	1.4	22	6.4	5	1.3
1997	127	13.9	9	1.8	67	8.1	9	1.4	18	3.4	5	1.4	49	7.1	4	1.3
1998	153	17.5	7	1.8	77	9.7	6	1.5	23	3.8	3	1.2	54	8.6	5	1.4
1999	55	11.8	7	1.6	23	6.0	5	1.3	8	1.6	3	1.2	23	5.7	4	1.3
2000	110	12.4	6	1.7	42	6.2	5	1.3	13	2.6	4	1.2	29	5.6	4	1.2
2001	204	17.5	9	1.7	126	10.1	6	1.4	46	6.7	5	1.5	80	8.5	4	1.3
2002	127	16.1	9	1.7	60	7.0	8	1.3	10	2.0	2	1.1	50	6.5	8	1.3
2003	138	18.2	7	1.6	56	8.3	6	1.3	21	3.7	4	1.2	42	7.0	4	1.2
2004	103	12.2	7	1.5	49	5.1	4	1.2	11	2.4	2	1.2	38	4.7	4	1.2
2005	122	12.0	5	1.6	42	4.0	3	1.2	9	1.8	3	1.1	33	3.6	3	1.2
2006	133	11.8	6	1.5	50	4.7	3	1.2	16	3.1	2	1.2	34	3.9	3	1.1
2007	178	15.3	6	1.5	49	5.0	4	1.1	12	2.7	2	1.1	37	3.9	2	1.1
2008	33	8.5	7	1.4	8	2.3	3	1.2	5	1.8	3	1.2	6	1.9	2	1.1
2009	85	9.6	6	1.4	17	2.9	3	1.1	9	2.5	2	1.1	8	2.4	2	1.0
2010	33	9.5	5	1.3	9	2.2	2	1.1	3	1.9	2	1.1	6	1.9	1	1.0
2011	22	6.2	4	1.2	6	1.5	2	1.1	3	1.4	1	1.0	3	1.3	1	1.0
2012	13	4.2	3	1.2	1	1.0	1	1.0	1	1.0	-	-	-	-	1	1.0
2013	17	4.1	2	1.1	1	1.0	-	-	1	1.0	-	-	-	-	-	-
2014	13	3.0	2	1.0	-	-	-	-	-	-	-	-	-	-	-	-
2015	2	1.3	1	1.0	-	-	-	-	-	-	-	-	-	-	-	-
Total	604	14.8	12	1.6	338	9.2	11	1.4	51	3.3	7	1.3	320	8.5	8	1.3

Figure 1: Dams with the most Progeny in the Population

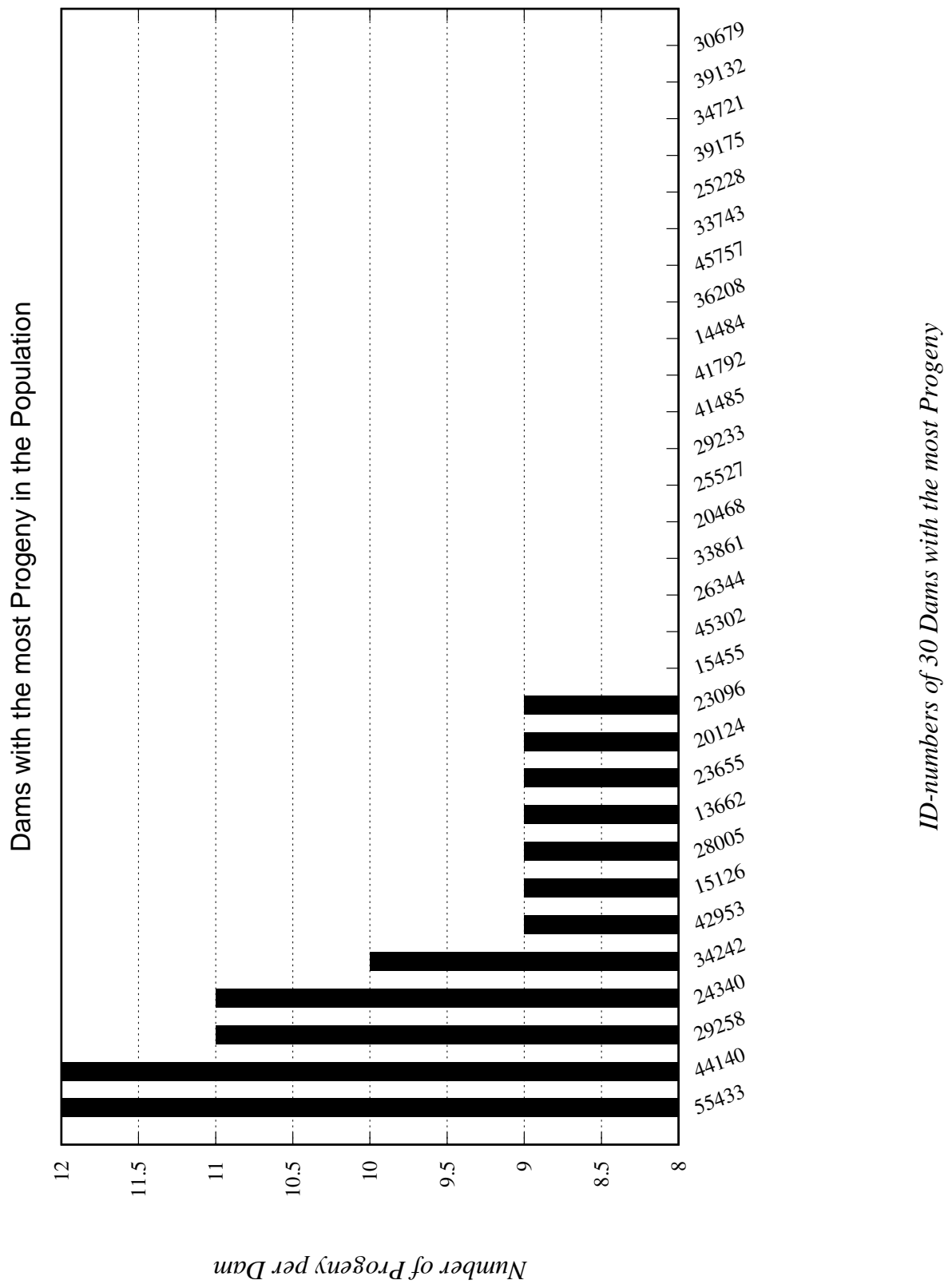


Figure 2: Number of Progeny per Dam

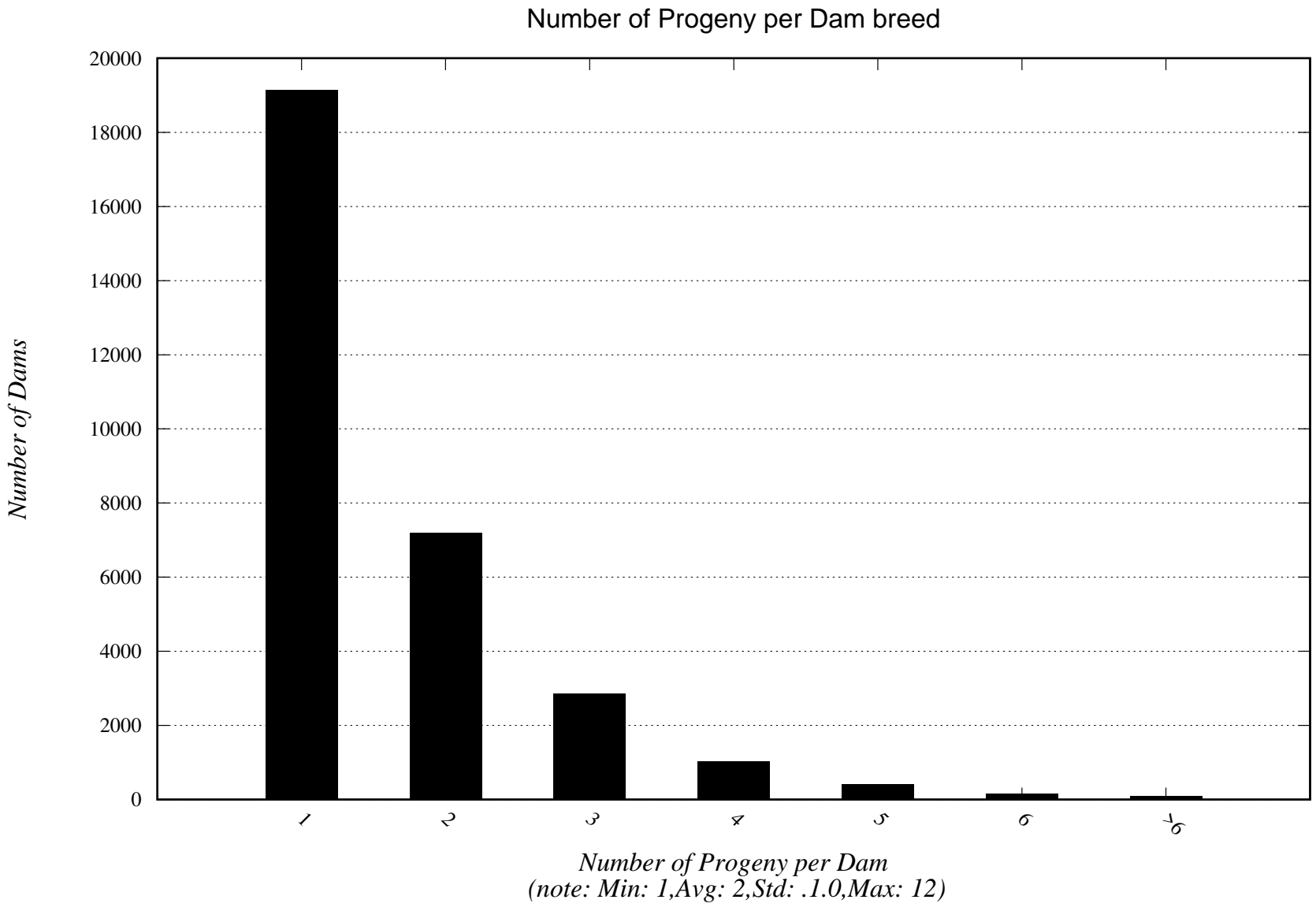


Figure 3: Sires with the most Progeny in the Population

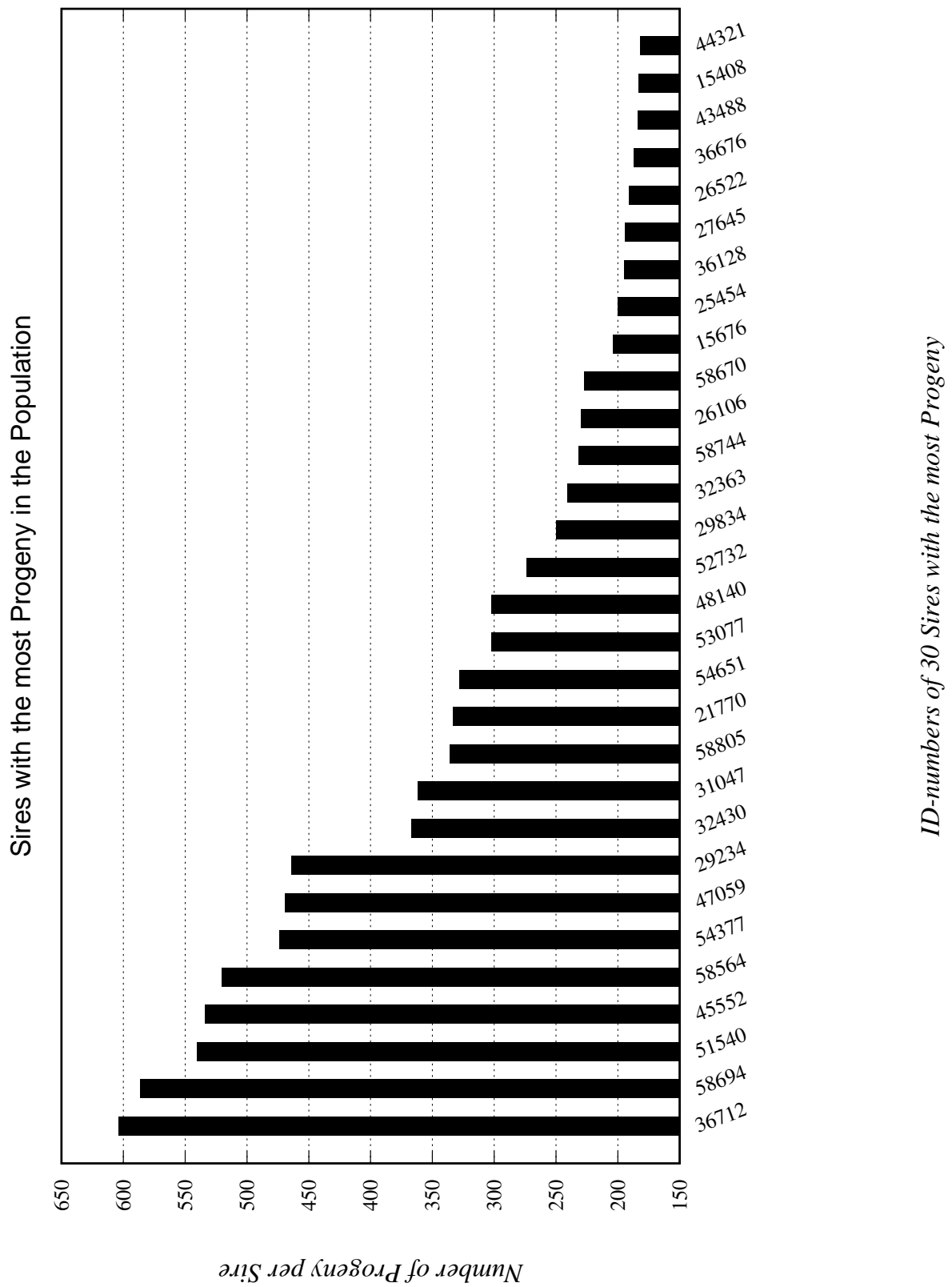


Figure 4: Number of Progeny per Sire

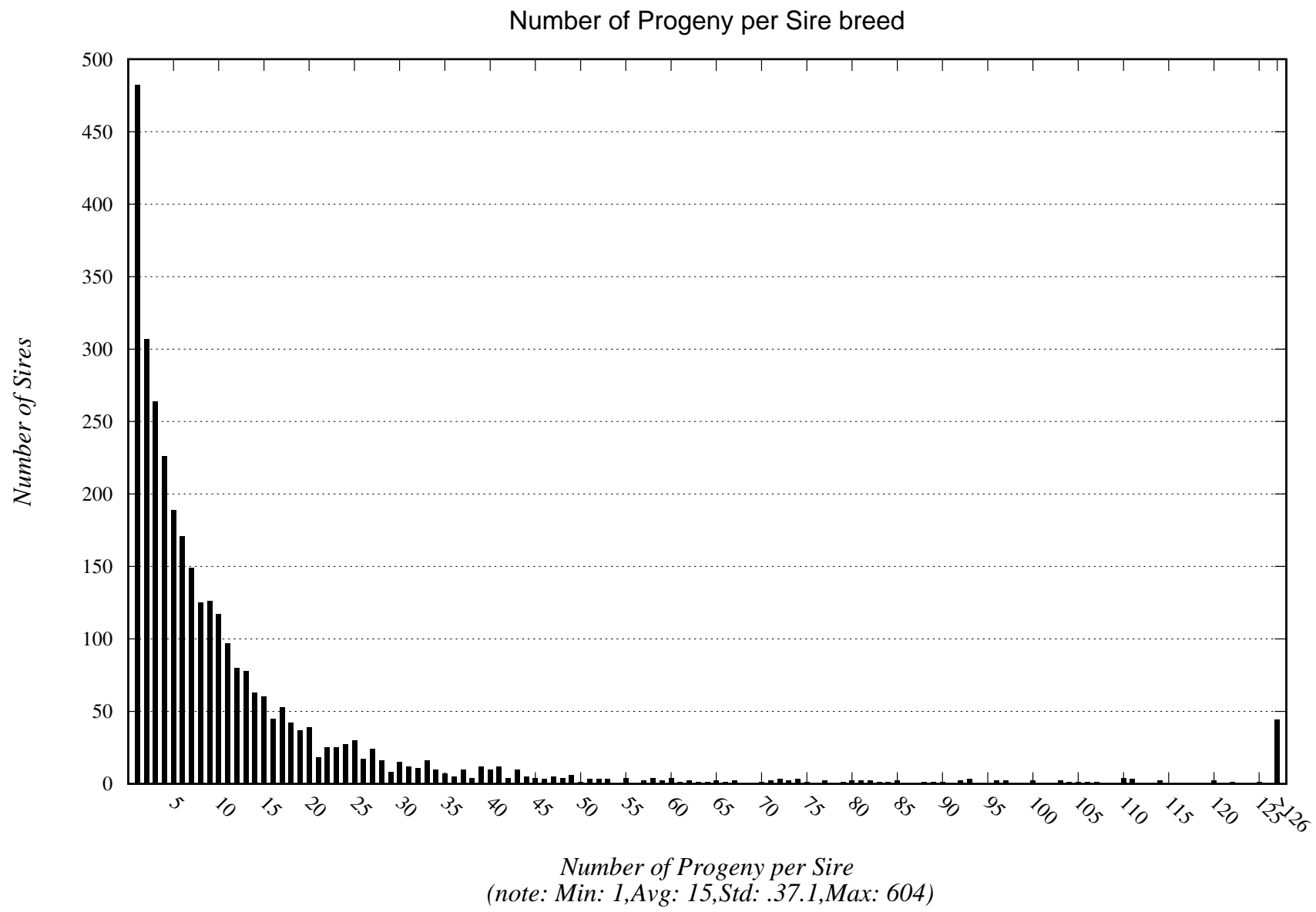


Figure 5: Dams with the most Selected Progeny in the Population

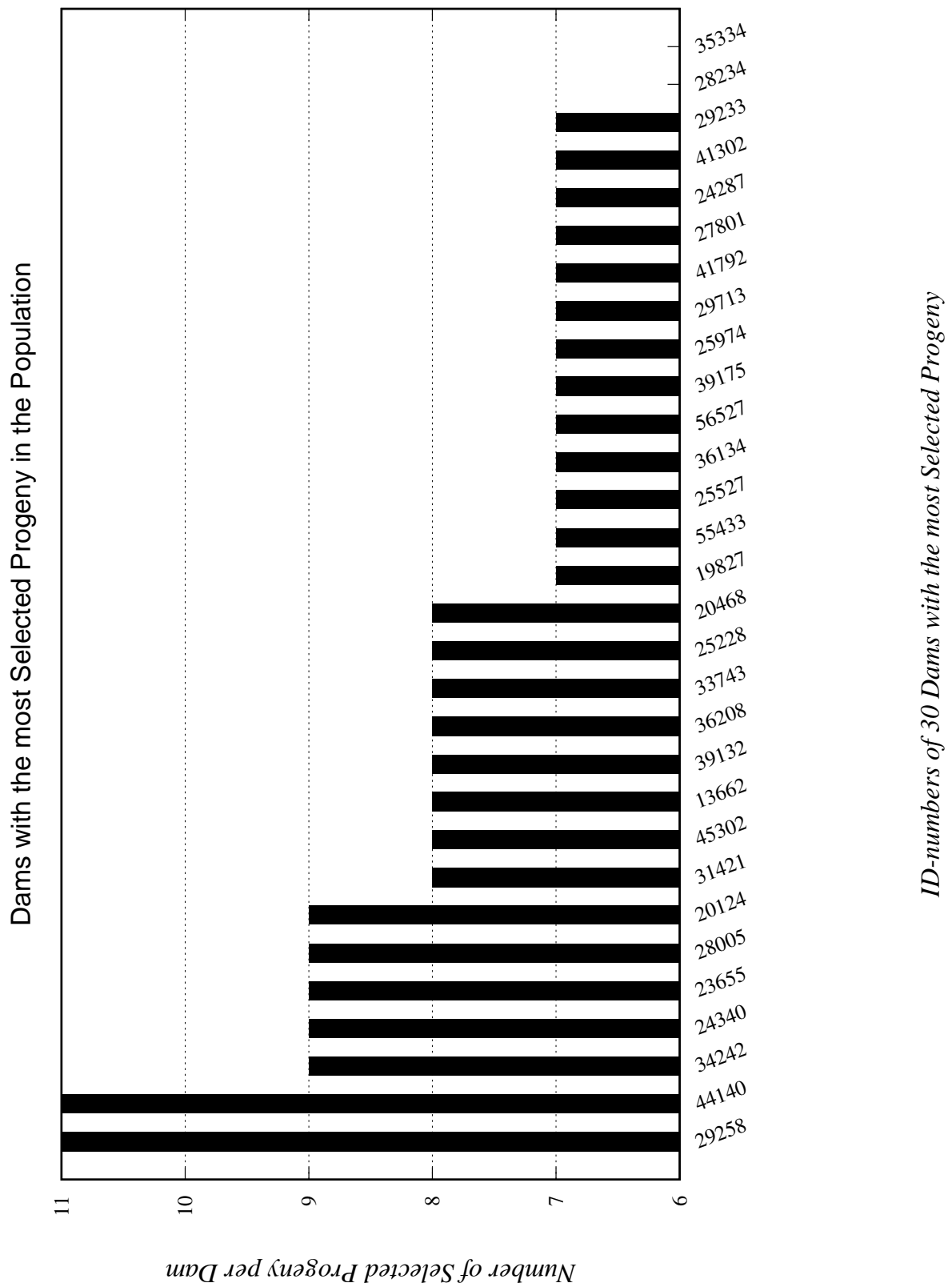


Figure 6: Number of Selected Progeny per Dam

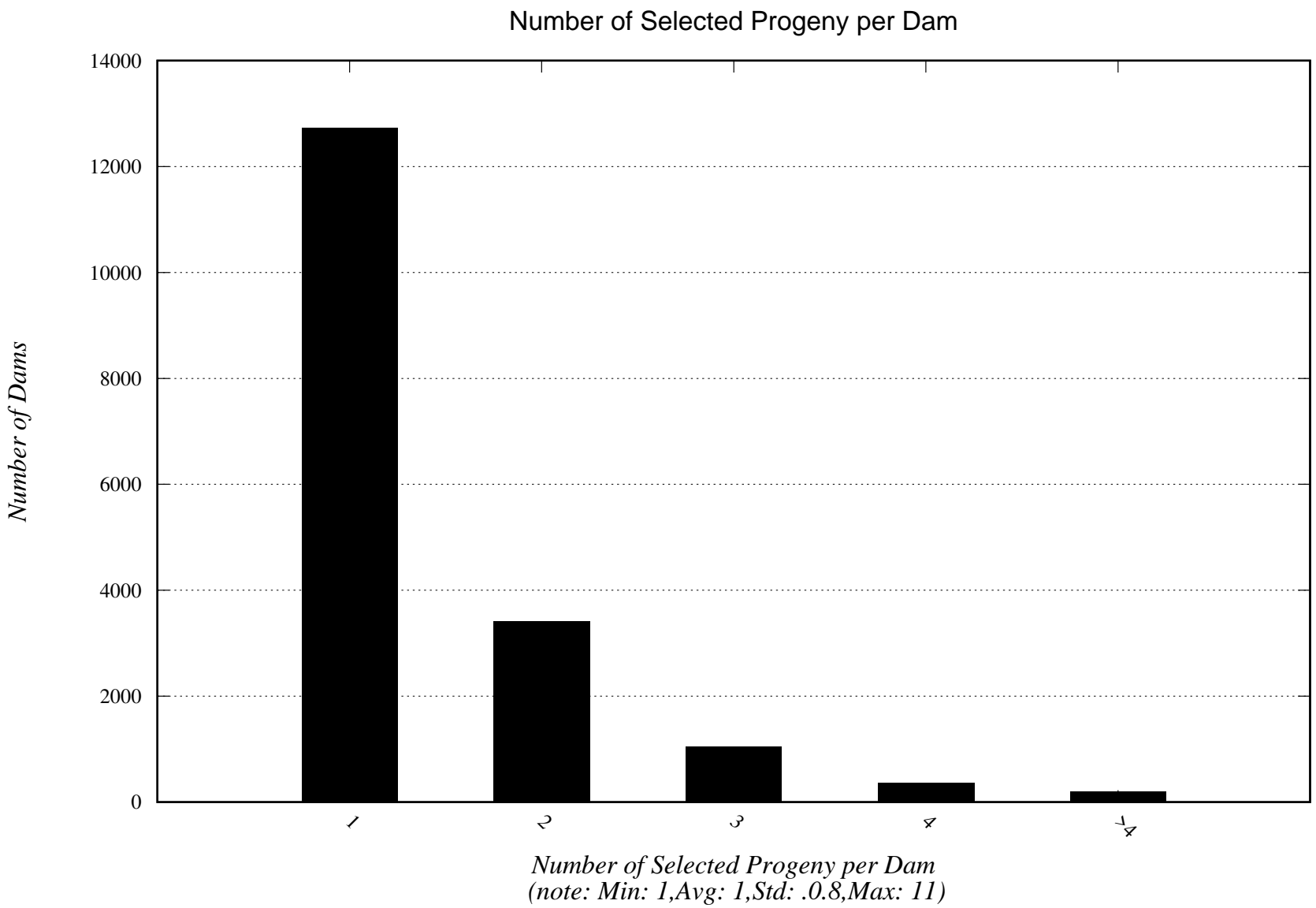


Figure 7: Sires with the most Selected Progeny in the Population

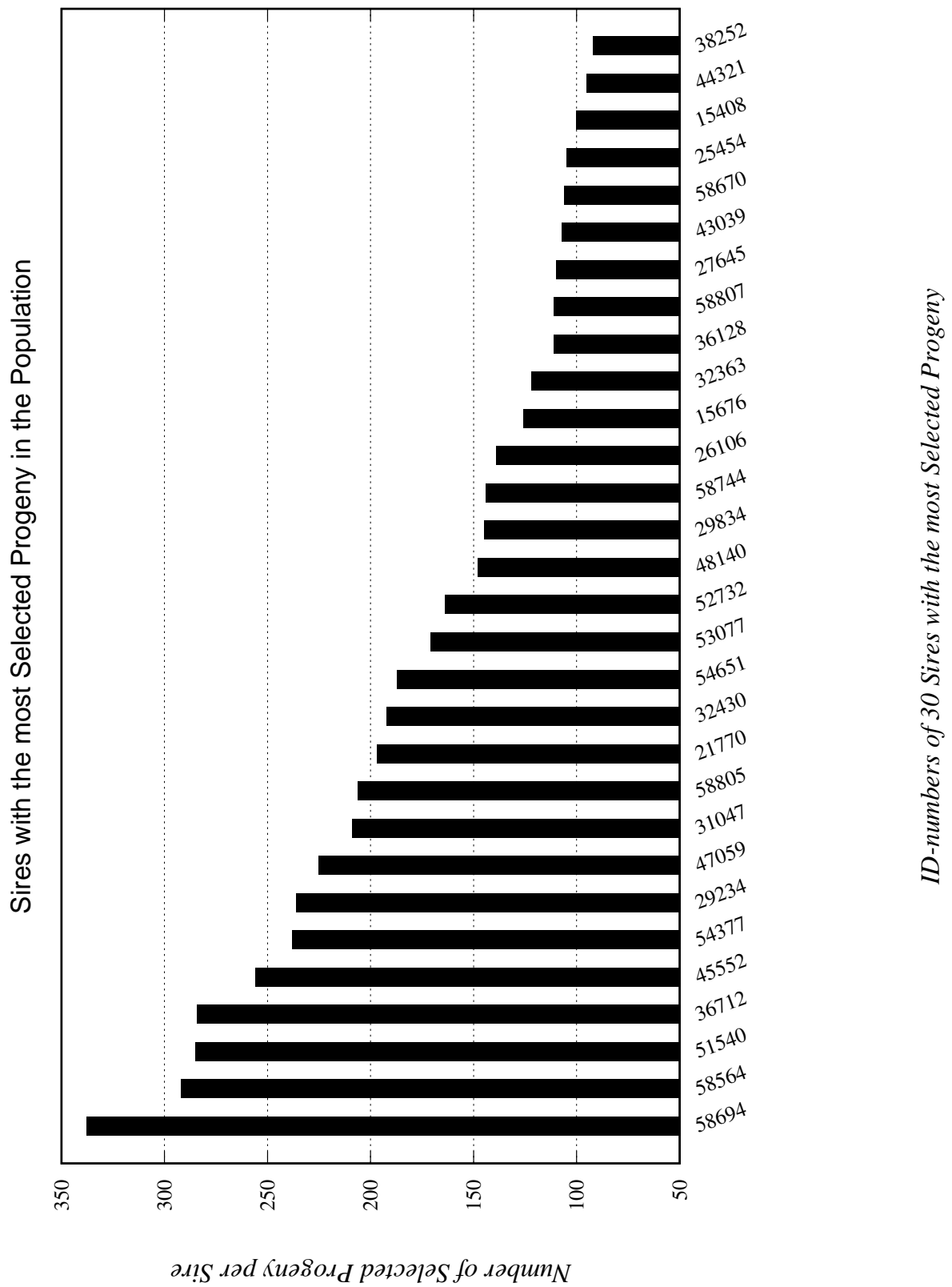


Figure 8: Number of Selected Progeny per Sire

