Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Veterinary Medicine and Animal Science
Department of Animal Breeding and Genetics

Inbreeding and its effect on fitness traits in captive populations of North Persian leopard and Mhorr gazelle

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ABSTRACT

In this study, linear mixed model analyses was conducted to assess inbreeding depression, purging and founder heterogeneity in relation to fitness traits (survival traits and litter size) in captive populations of North Persian leopard and Mhorr gazelle. *"Old"* and *"new"*, ancestral, partial and partial ancestral inbreeding coefficients were included in the models as finer scale measurements in addition to the classical inbreeding coefficient. In North Persian leopard, possible inbreeding depression for survival at days 7 and 30 after birth and weaning age (90 days) is associated with individual/ litter classical inbreeding, further attributed mainly to *"old"* inbreeding. However, a sign of purging can be observed because increased dam inbreeding corresponds with an increased probability for survival of the offspring. Detailed analyses revealed that this effect is significantly associated with the *"new"* inbreeding of the dam. Inbreeding depression is also expressed as litter size reduction. Ancestral inbreeding significantly reduces litter size but has no effect on survival traits. Therefore, no purging could be detected using ancestral inbreeding coefficients. On the other hand, individual classical and *"new"* inbreeding increases the mortality of Mhorr gazelle at weaning (day 180). Sire inbreeding significantly increases mortality at days 7, 30 and 180 which is further associated with *"old"* and *"new"* inbreeding. In both species, there is unbalanced founder contribution of alleles causing inbreeding depression and purging in fitness traits as shown in the results from the analyses including partial and partial ancestral inbreeding coefficients. The study shows that the magnitude of response to inbreeding differs between species and fitness traits.

TABLE of CONTENTS

Contents	Page Number
Title page	
Abstract	
List of Figures	i - ii
List of Tables	iii
List of Appendices	iv
1 Introduction	**1**
2 Literature Review	**3**
2.1 *Species biology*	3
2.1.1 North Persian leopard *(Panthera pardus saxicolor)*	3
2.1.2 Mhorr gazelle *(Gazella dama mhorr)*	4
2.2 Pedigree analysis	5
2.3 Inbreeding depression and purging	6
2.4 Founder heterogeneity	10
2.5 Measures of inbreeding	11
3 Materials and Methods	**13**
3.1 *Data*	13
3.2 *Pedigree analysis for genetic variability*	13
3.3 *Inbreeding coefficients*	14
3.3.1 Classical inbreeding	14
3.3.2 *"Old"* and *"new"* inbreeding	14
3.3.3 Ancestral inbreeding	15
3.3.4 Partial inbreeding	15
3.3.5 Partial ancestral inbreeding	16
3.4 General linear mixed models	16
3.4.1 Mortality risk at days 7, 30 and 90/ 180 (weaning age)	17
3.4.2 Litter size	20
4 Results and Discussion	**21**
4.1 *North Persian leopard*	21

4.1.1 Pedigree analysis 21
4.1.2 Mortality risk at days 7, 30 and 90 (weaning age) 22
4.1.3 Litter size 37
4.1.4 Effects of sex, parity and birth type 43
4.2 *Mhorr gazelle* 44
4.2.1 Pedigree analysis 44
4.2.2 Mortality risk at days 7, 30 and 180 (weaning age) 45
4.2.3 Effects of sex and parity 51
5 Summary and Conclusions **52**
5.1 North Persian leopard 52
5.2 Mhorr gazelle 53
6 Literature Cited **55**
Appendices **60**

List of figures

Figure Number	Title	Page Number
1	North Persian leopard	3
2	Mhorr gazelle	4
3	Mortality risk of an individual at days 7, 30 and 90 (weaning age) with total inbreeding of the individual, sire and dam	24
4	Mortality risk of a litter at days 7, 30 and 90 (weaning age) with total inbreeding of the litter, sire and dam	24
5	Mortality risk of an individual at days 7, 30 and 90 (weaning age) with *"old"* and *"new"* inbreeding coefficients of an individual	26
6	Mortality risk of a litter at days 7, 30 and 90 (weaning age) with *"old"* and *"new"* inbreeding coefficients of a litter	27
7	Mortality risk of an individual at days 7, 30 and 90 (weaning age) with *"old"* and *"new"* inbreeding coefficients of a dam	28
8	Mortality risk of a litter at days 7, 30 and 90 (weaning age) with *"old"* and *"new"* inbreeding coefficients of a dam	29
9	Mortality risk of an individual at days 7, 30 and 90 (weaning age) with ancestral inbreeding coefficient	30
10	Mortality risk of a litter at days 7, 30 and 90 (weaning age) with litter ancestral inbreeding coefficient	30
11	Mortality risk of an individual at days 7, 30 and 90 (weaning age) with partial inbreeding coefficients of founder and founder groups	33
12	Mortality risk of a litter at days 7, 30 and 90 (weaning age) with partial inbreeding coefficients of founder and founder groups	33
13	Mortality risk of an individual at days 7, 30 and 90 (weaning age) with partial inbreeding coefficients of dam founder and founder groups	34

3. The effect of *"old"* and *"new"* inbreeding of litter on litter size.

Inbreeding coefficient	f*"old"*_litter	f*"new"*_litter
0.00	0.00	0.00
0.05	-0.09	0.01
0.10	-0.18	0.03
0.15	-0.27	0.04
0.20	-0.36	0.05
0.25		0.07
0.30		0.08
0.35		0.09
0.40		0.10

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001; **f"old"_litter** = old inbreeding coefficient of the litter; **f"new"_litter** = new inbreeding coefficient of the litter*

4. Mortality risk of an individual at days 7, 30 and 90 with *"old"* and *"new"* inbreeding coefficients of the dam.

Inbreeding coefficient	*f"old"*_ dam_d7	*f"new"*_ dam_d7**	*f"old"*_ dam_d30	*f"new"*_ dam_d30**	*f"old"*_ dam_d90	*f"new"*_ dam_d90**
0.00	0.23	0.23	0.23	0.23	0.21	0.21
0.05	0.27	0.19	0.26	0.20	0.25	0.18
0.10	0.32	0.16	0.30	0.17	0.29	0.15
0.15	0.37	0.14	0.34	0.14	0.34	0.12
0.20		0.11		0.12		0.10
0.25		0.10		0.10		0.09
0.30		0.08		0.09		0.07
0.35		0.07		0.07		0.06
0.40		0.05		0.06		0.05

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001; **f"old"_dam**= old inbreeding coefficient of the dam; **f"new"_dam** = new inbreeding coefficient of the dam; **d7**= day 7; **d30**= day 30; and **d90**= day 90*

5. Mortality risk of a litter at days 7, 30 and 90 with *"old"* and *"new"* inbreeding coefficients of the dam.

Inbreeding coefficient	*f"old"*_ dam_d7	*f"new"*_ dam_d7**	*f"old"*_ dam_d30	*f"new"*_ dam_d30***	*f"old"*_ dam_d90	*f"new"*_ dam_d90***
0.00	0.26	0.26	0.27	0.27	0.26	0.26
0.05	0.28	0.22	0.28	0.23	0.30	0.23
0.10	0.29	0.19	0.28	0.19	0.33	0.21
0.15	0.31	0.16	0.29	0.16	0.37	0.18
0.20		0.13		0.14		0.16
0.25		0.11		0.11		0.14
0.30		0.09		0.09		0.12
0.35		0.08		0.08		0.11
0.40		0.06		0.06		0.09

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.00; **f"old"_dam**= old inbreeding coefficient of the dam; **f"new"_dam** = new inbreeding coefficient of the dam; **d7**= day 7; **d30**= day 30; and **d90**= day 90*

6. The effect of *"old"* and *"new"* inbreeding of dam on litter size.

Inbreeding coefficient	**f*"old"*_dam**	**f*"old"*_dam***
0.00	0.00	0.00
0.05	-0.11	-0.05
0.10	-0.21	-0.10
0.15	-0.31	-0.16
0.20	-0.42	-0.21
0.25		-0.26
0.30		-0.31
0.35		-0.36
0.40		-0.42

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001*

f"old"_dam*= old inbreeding coefficient of the dam;* ***f"new"_dam*** *= new inbreeding coefficient of the dam*

7. The effect of *"old"* and *"new"* inbreeding of sire on litter size.

Inbreeding coefficient	**f*"old"*_sire**	**f*"new"*_sire**
0.00	0.00	0.00
0.05	-0.16	0.01
0.10	-0.31	0.01
0.15	-0.47	0.02
0.20	-0.62	0.02
0.25		0.03
0.30		0.04
0.35		0.04
0.40		0.05

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001*

f"old"_sire*= old inbreeding coefficient of the dam;* ***f"new"_sire*** *= new inbreeding coefficient of the dam*

APPENDIX 1C- ANCESTRAL INBREEDING

1. Mortality risk of an individual at days 7, 30 and 90 with ancestral inbreeding coefficients.

Inbreeding coefficient	ancestral f_d7	f_d7	ancestral f_d30	f_30*	ancestral f_d90	f_d90***
0.00	0.20	0.20	0.22	0.22	0.20	0.20
0.05	0.21	0.22	0.21	0.24	0.20	0.23
0.10	0.21	0.23	0.21	0.26	0.19	0.27
0.15	0.21	0.25	0.21	0.28	0.19	0.30
0.20	0.21	0.27	0.21	0.30	0.18	0.34
0.25	0.21	0.28	0.20	0.33	0.18	0.38
0.30	0.21	0.30	0.20	0.35	0.17	0.42
0.35	0.22	0.32	0.20	0.38	0.17	0.47
0.40	0.22	0.34	0.20	0.41	0.16	0.51
0.45	0.22		0.19		0.16	

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001*

***ancestral f**= ancestral inbreeding coefficient; **f**= total inbreeding coefficient; **d7**= day 7; **d30**= day 30; and **d90**= day 90*

2. Mortality risk of a litter at days 7, 30 and 90 with litter ancestral inbreeding coefficients.

Inbreeding coefficient	ancestral_f _d7	litter_f _d7	ancestral_f _d30	litter_f _d30	ancestral_f _d90	litter_f _d90
00.00	0.25	0.25	0.26	0.26	0.26	0.26
0.05	0.24	0.25	0.25	0.26	0.26	0.27
0.10	0.24	0.25	0.25	0.27	0.25	0.29
0.15	0.24	0.26	0.25	0.28	0.25	0.30
0.20	0.24	0.26	0.25	0.28	0.25	0.31
0.25	0.24	0.27	0.25	0.29	0.25	0.33
0.30	0.24	0.27	0.25	0.30	0.25	0.34
0.35	0.24	0.28	0.24	0.31	0.24	0.36
0.40	0.24	0.28	0.24	0.32	0.24	0.37
0.45	0.24		0.24		0.24	

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001*

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001*

***ancestral_f**= ancestral inbreeding coefficient of the litter; **litter_f**= total inbreeding coefficient of the litter; **d7**= day 7; **d30**= day 30; and **d90**= day 90*

3. The effect of ancestral inbreeding of litter on litter size.

Inbreeding coefficient	litter_f	ancestral_f**
0.00	0.0000	0.00
0.05	0.0008	-0.04
0.10	0.0015	-0.09
0.15	0.0023	-0.13
0.20	0.0030	-0.17
0.25	0.0038	-0.21
0.30	0.0046	-0.26
0.35	0.0053	-0.30
0.40	0.0061	
0.45	0.0068	

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001*

ancestral_f*= ancestral inbreeding coefficient of the litter;* ***litter_f****= total inbreeding coefficient of the litter;* ***d7****= day 7;* ***d30****= day 30; and* ***d90****= day 90*

APPENDIX 1D- PARTIAL INBREEDING

1. Mortality risk of an individual at days 7, 30 and 90 with partial inbreeding coefficients.

Inbreeding coefficient	g1_ d7	g2_ d7	g3_ d7	f222_ d7	g1_ d30	g2_ d30**	g3_ d30	f222_ d30	g1_ d90	g2_ d90*	g3_ d90	f222_ d90***
00.00	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.22	0.21	0.21	0.21
0.05	0.22	0.27	0.25	0.32	0.22	0.28	0.26	0.32	0.21	0.27	0.26	0.30
0.10	0.20	0.30	0.26	0.42	0.20	0.34	0.28	0.42	0.20	0.34	0.30	0.39
0.15	0.19	0.34	0.28	0.53	0.19	0.40	0.30	0.53	0.19	0.41	0.35	0.50
0.20	0.18	0.38	0.30	0.64	0.18	0.46	0.33	0.63	0.18	0.48	0.41	0.60
0.25	0.17	0.42	0.32	0.73	0.17	0.52	0.35	0.72	0.17	0.56	0.46	0.70
0.30		0.46	0.33	0.81		0.59	0.38	0.80		0.63	0.52	0.78
0.35		0.51				0.65				0.70		
0.40		0.55				0.70				0.76		

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001*

g1*= partial inbreeding coefficient of founder group g1;* ***g2****= partial inbreeding coefficient of founder group g2;* ***g3****= partial inbreeding coefficient of founder group g3;* ***f222****= partial inbreeding coefficient of founder animal 222;* ***d7****= day 7;* ***d30****= day 30; and* ***d90****= day 90*

2. Mortality risk of a litter at days 7, 30 and 90 with litter partial inbreeding coefficients.

Inbreeding coefficient	g1_ d7	g2_ d7	g3_ d7	f222_ d7	g1_ d30	g2_ d30**	g3_ d30	f222_ d30	g1_ d90	g2_ d90***	g3_ d90	f222_ d90
0.00	0.27	0.27	0.27	0.27	0.28	0.30	0.28	0.28	0.28	0.28	0.28	0.28
0.05	0.26	0.30	0.27	0.30	0.28	0.33	0.28	0.30	0.27	0.34	0.29	0.30
0.10	0.26	0.34	0.27	0.33	0.27	0.38	0.29	0.32	0.26	0.41	0.31	0.32
0.15	0.25	0.37	0.27	0.37	0.27	0.44	0.30	0.34	0.25	0.49	0.32	0.34
0.20	0.25	0.41	0.27	0.41	0.26	0.50	0.30	0.37	0.24	0.56	0.34	0.36
0.25	0.24	0.45	0.27	0.44	0.26	0.56	0.31		0.23	0.64	0.35	
0.30		0.50	0.28	0.48		0.62	0.31			0.70	0.37	
0.35		0.54				0.67				0.76		
0.40		0.58				0.72				0.81		

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001*

g1*= partial inbreeding coefficient of founder group g1;* ***g2****= partial inbreeding coefficient of founder group g2;* ***g3****= partial inbreeding coefficient of founder group g3; partial inbreeding coefficient of* ***f222****= founder animal 222;* ***d7****= day 7;* ***d30****= day 30; and* ***d90****= day 90*

3. Mortality risk of an individual at days 7, 30 and 90 with partial inbreeding coefficients of the dam.

Inbreeding coefficient	dam_ g1_d7	dam_ g2_d7	dam_ g3_d7**	dam_ f222_d7	dam_ g1_d30	dam_ g2_d30	dam_ g3_d30*	dam_ f222_d30	dam_ g1-d90	dam_ g2_d90	dam_ g3_d90*	dam_ f222_d90
0.00	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.22	0.22	0.22	0.22
0.05	0.11	0.26	0.20	0.67	0.13	0.26	0.21	0.53	0.15	0.23	0.19	0.33
0.10	0.05	0.27	0.17	0.93	0.07	0.29	0.18	0.80	0.10	0.23	0.16	0.46
0.15	0.02	0.28	0.14		0.03	0.31	0.15		0.06	0.24	0.13	
0.20	0.01	0.30	0.11		0.02	0.34	0.12		0.04	0.24	0.11	
0.25	0.00	0.31	0.09		0.01	0.36	0.10		0.02	0.25	0.09	
0.30		0.33	0.08			0.39	0.09			0.25	0.07	

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001*

dam_g1*= partial inbreeding coefficient of dam founder group 1 ;* ***dam_g2****= partial inbreeding coefficient of dam founder group 2;* ***dam****_g3= partial inbreeding coefficient of dam founder group 3;* ***dam_f222****= partial inbreeding coefficient of dam founder 222;* ***d7****= day 7;* ***d30****= day 30; and* ***d90****= day 90*

4. Mortality risk of a litter at days 7, 30 and 90 with partial inbreeding coefficients of the dam.

Inbreeding coefficient	dam_ g1_d7	dam_ g2_d7	dam_ g3_d7**	dam_ f222_d7	dam_ g1_d30	dam_ g2_d30*	dam_ g3_d30**	dam_ f222_d30	dam_ g1_d90	dam_ g2_d90	dam_ g3_d90	dam_ f222_d90
0.00	0.28	0.28	0.28	0.28	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
0.05	0.18	0.34	0.22	0.51	0.22	0.37	0.23	0.35	0.24	0.35	0.24	0.29
0.10	0.11	0.40	0.17	0.73	0.16	0.45	0.18	0.41	0.20	0.41	0.21	0.29
0.15	0.06	0.46	0.13		0.11	0.53	0.14		0.16	0.48	0.18	
0.20	0.03	0.52	0.10		0.08	0.61	0.10		0.13	0.55	0.15	
0.25		0.58	0.08			0.69	0.08			0.62	0.12	

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001*

dam_g1*= partial inbreeding coefficient of dam founder group 1 ;* ***dam_g2****= partial inbreeding coefficient of dam founder group 2;* ***dam_g3****= partial inbreeding coefficient of dam founder group 3;* ***dam_f222****= partial inbreeding coefficient of dam founder 222;* ***d7****= day 7;* ***d30****= day 30; and* ***d90****= day 90*

APPENDIX 1E- PARTIAL ANCESTRAL INBREEDING

1. Mortality risk of a litter at days 7, 30 and 90 with partial ancestral inbreeding coefficients.

Inbreeding coefficient	g1_a _d7	g2_a _d7	g3_a _d7	fa_178 _d7	fa_222 _d7**	g1_a_ d30	g2_a_ d30**	g3_a_ d30	fa_178_ d30	fa_222_ d30	g1_a _d90	g2_a _d90*	g3_a _d90	fa_178 _d90	fa_222 _90
0.00	0.19	0.19	0.19	0.19	0.19	0.20	0.20	0.20	0.20	0.20	0.22	0.22	0.22	0.22	0.22
0.05	0.12	0.23	0.19	0.20	0.30	0.12	0.25	0.20	0.23	0.28	0.14	0.26	0.22	0.24	0.26
0.10	0.07	0.27	0.18	0.21	0.43	0.07	0.30	0.19	0.25	0.36	0.09	0.30	0.22	0.25	0.31
0.15	0.04	0.31	0.18		0.58	0.04	0.36	0.18		0.46	0.05	0.34	0.21		0.36
0.20		0.36	0.18				0.43	0.17				0.39	0.21		
0.25		0.41	0.17				0.49	0.17				0.44	0.21		
0.30		0.46	0.17				0.56	0.16				0.49	0.21		

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001; **g1_a**= partial ancestral inbreeding coefficient of founder group 1 ; **g2_a**= partial ancestral inbreeding coefficient of founder group 2; **g3_a**= partial inbreeding coefficient of founder group 3; **fa_178**= partial ancestral inbreeding coefficient of founder 178; **fa_222**= partial ancestral inbreeding coefficient of founder 222; **d7**= day 7; **d30**= day 30; and **d90**= day 90*

2. Effects of different levels of partial ancestral inbreeding on litter size

Inbreeding coefficient	g1_a	g2_a*	g3_a	fa_178	fa_222
0.00	0.00	0.00	0.00	0.00	0.00
0.05	-0.07	-0.09	-0.03	-0.06	-0.01
0.10	-0.14	-0.19	-0.06	-0.11	-0.01
0.15	-0.21	-0.28	-0.08		-0.02
0.20		-0.38	-0.11		
0.25		-0.47	-0.14		
0.30		-0.57	-0.17		

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001 **g1_a**= partial ancestral inbreeding coefficient of founder group 1; **g2_a**= partial ancestral inbreeding coefficient of founder group 2; **g3_a**= partial inbreeding coefficient of founder group 3; **fa_178**= partial ancestral inbreeding coefficient of founder 178; **fa_222**= partial ancestral inbreeding coefficient of founder 222; **d7**= day 7; **d30**= day 30; and **d90**= day 90*

APPENDIX 2 - MHORR: Inbreeding coefficients, mortality risk and effect on litter size

APPENDIX 2A – TOTAL INBREEDING

Mortality risk of an individual at days 7, 30 and 180 with total inbreeding coefficients of individual, sire and dam.

Inbreeding coefficient	f_d7	f_s_d7	f_d_d7	f_d30	f_s_d30**	f_d_d30	f_d180*	f_s_d180	f_d_d180
0.00	0.05	0.05	0.05	0.06	0.06	0.06	0.12	0.12	0.12
0.05	0.06	0.06	0.05	0.07	0.08	0.06	0.14	0.12	0.12
0.10	0.06	0.06	0.06	0.08	0.09	0.05	0.17	0.13	0.12
0.15	0.07	0.07	0.06	0.10	0.11	0.04	0.20	0.14	0.12
0.20	0.08	0.08	0.07	0.11	0.14	0.04	0.23	0.14	0.12
0.25	0.09	0.09	0.07	0.13	0.16	0.03	0.27	0.15	0.12
0.30	0.10	0.10	0.07	0.15	0.19	0.03	0.31	0.16	0.12
0.35	0.11	0.11	0.08	0.17	0.23	0.03	0.35	0.16	0.11
0.40	0.12	0.12	0.08	0.19	0.27	0.02	0.40	0.17	0.11
0.45	0.13	0.13	0.09	0.22	0.32	0.02	0.45	0.18	0.11
0.50	0.14	0.14	0.10	0.25	0.37	0.02	0.50	0.19	0.11

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001*

***f** = Individual inbreeding coefficient; **f_s**= sire inbreeding coefficient; **f_d**= dam inbreeding coefficient; **d7**= day 7; **d30**= day 30; and **d180**= day 180*

APPENDIX 2B – *'OLD"* AND *'NEW'* INBREEDING

1. Mortality risk of an individual at days 7, 30 and 180 with *"old"* and *"new"* inbreeding coefficient of the individual.

Inbreeding coefficient	f"old" _d7	f"new" _d7	f"old" _d30	f"new" _d30	f"old" _d180	f"new" _d180**
0.00	0.05	0.05	0.05	0.05	0.09	0.09
0.05	0.06	0.06	0.05	0.06	0.09	0.10
0.10	0.06	0.06	0.05	0.07	0.10	0.12
0.15	0.07	0.07	0.05	0.08	0.11	0.15
0.20	0.07	0.08	0.05	0.09	0.11	0.17
0.25	0.08	0.09	0.05	0.11	0.12	0.21
0.30	0.09	0.10	0.05	0.12	0.13	0.24
0.35	0.09	0.11	0.05	0.14	0.14	0.28
0.40	0.10	0.12	0.05	0.16	0.15	0.32

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001*
f"old" *= old inbreeding coefficient of the individual;* ***f"new"*** *= new inbreeding coefficient of the individual;* ***d7****= day 7;* ***d30****= day 30; and* ***d180****= day 180*

2. Mortality risk of an individual at days 7, 30 and 180 with *"old"* and *"new"* inbreeding coefficient the sire.

Inbreeding coefficient	f"old"_ sire_d7	f"new"_ sire_d7	f"old"_ sire_d30*	f"new"_ sire_d30*	f"old"_ sire_d180	f"new"_ sire_d180
0.00	0.15	0.15	0.03	0.03	0.07	0.07
0.05	0.16	0.15	0.05	0.04	0.08	0.07
0.10	0.18	0.16	0.07	0.05	0.10	0.08
0.15	0.20	0.16	0.11	0.06	0.13	0.08
0.20	0.21	0.16	0.16	0.08	0.16	0.09
0.25	0.23	0.17	0.23	0.10	0.20	0.09
0.30	0.25	0.17	0.32	0.12	0.24	0.10
0.35		0.17		0.15		0.10

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001*
f"old"_sire*= old inbreeding coefficient of the dam;* ***f"new"_sire*** *= new inbreeding coefficient of the dam;* ***d7****= day 7;* ***d30****= day 30; and* ***d180****= day 180*

APPENDIX 2C – ANCESTRAL INBREEDING

Mortality risk of an individual at days 7, 30 and 180 with ancestral inbreeding coefficients of the individual.

Inbreeding coefficient	f_d7	ancestral f_d7*	f_d30	ancestral f_d30	f_d180	ancestral f_d180
0.00	0.06	0.06	0.07	0.07	0.12	0.12
0.05	0.06	0.06	0.08	0.08	0.14	0.13
0.10	0.06	0.07	0.09	0.09	0.17	0.13
0.15	0.06	0.08	0.09	0.10	0.19	0.14
0.20	0.07	0.09	0.10	0.10	0.22	0.14
0.25	0.07	0.11	0.11	0.11	0.25	0.15
0.30	0.07	0.12	0.12	0.12	0.28	0.15
0.35	0.08	0.14	0.13	0.13	0.32	0.16
0.40	0.08	0.16	0.14	0.15	0.36	0.17
0.45	0.08	0.18	0.15	0.16	0.40	0.17
0.50	0.09	0.20	0.16	0.17	0.44	0.18
0.55	0.09	0.22	0.17	0.19	0.48	0.18
0.60	0.09	0.25	0.19	0.20	0.53	0.19
0.65	0.10		0.20		0.57	

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001*

***Ancestral f**= ancestral inbreeding coefficient; **f**= total inbreeding coefficient; **d7**= day 7; **d30**= day 30; and **d190**= day 180*

APPENDIX 2D – PARTIAL INBREEDING

Mortality risk of an individual at days 7, 30 and 180 with partial inbreeding coefficient of sire founder group 1.

Inbreeding coefficient	sire_g1_d7	sire_g1_d30**	sire_g1_d180
0.00	0.05	0.08	0.13
0.05	0.06	0.08	0.13
0.10	0.06	0.08	0.13
0.15	0.07	0.08	0.14
0.20	0.08	0.09	0.14
0.25	0.09	0.09	0.14
0.30	0.10	0.09	0.14
0.35	0.11	0.09	0.14
0.40	0.12	0.09	0.14
0.45	0.13	0.09	0.14
0.50	0.14	0.09	0.14

** p <0.10, ** p <0.05, *** p <0.01, **** p <0.001*
sire_g1*= partial inbreeding coefficient of dam founder group* ***d7****= day 7;* ***d30****= day 30; and* ***d180****= day 180*