

On-line Appendix A Studies of measures of maternal condition or dominance in ungulates in relation to sex ratio, from which data for meta-analysis were extracted.

| Species | Test statistic in paper | Effect size (r) | N | Index of condition or dominance | Sampling time* | Status | Reference | Note |
|---|--------------------------|-----------------|-----|---------------------------------|----------------|-----------|-------------------------------|------|
| Fallow deer <i>Dama dama</i> | various | -0.017 | 61 | Morphological | Pre | Captive | Birgersson 1998 | 1 |
| Roe deer <i>Capreolus capreolus</i> | $c^2_1 = 5.40$ | -0.095 | 600 | Morphological | Post | Wild | Hewison and Gaillard 1996 | 2 |
| | $c^2_1 = 9.98$ | 0.367 | 74 | Body Mass | Post | Wild | Wauters et al. 1995 | |
| | $c^2_1 = 0.92$ | -0.134 | 51 | Body Mass | Post | Wild | Hewison et al. 1999 | |
| White-tailed deer <i>Odocoileus virginianus</i> | Calculated from paper | 0.0965 | 468 | Morphological | Post | Wild | Burke and Birch 1995 | 3 |
| Red deer <i>Cervus elaphus</i> | $c^2_1 = 9.92$ | 0.134 | 555 | Kidney fat index | Post | Wild | Kohlmann 1999 | 4 |
| | $G_2 = 6.59$ | 0.262 | 98 | Behavioral dominance | Pre | Wild | Clutton-Brock et al. 1984 | 5 |
| | $P = 0.0251$ | 0.249 | 62 | Kidney fat index | Post | Wild | Flint et al. 1997 | |
| Reeve's Muntjac <i>Muntiacus reevesi</i> | Calculated from paper | 0.096 | 135 | Body mass | Post | Wild | Chapman et al. 1997 | 6 |
| Moose <i>Alces alces</i> | $c^2_1 = 3.11$ | -0.134 | 173 | Dressed mass | Post | Wild | Nygen and Kojola 1997 | 7 |
| | Calculated from paper | 0.0531 | 39 | Morphological | Unspecified | Captive | Schwartz and Hundertmark 1993 | 8 |
| Reindeer <i>Rangifer tarandus</i> | $t = 2.47, df = 845$ | 0.085 | 847 | Morphological | Post | Semi-wild | Kojola and Eloranta 1989 | |
| | $F = +0.374, df = 1,233$ | 0.007 | 225 | Body mass | Pre | Semi-wild | Kojola 1993 | 9 |

| | | | | | | | | |
|--|-------------------------------------|--------|------|----------------------|-------------|-----------|---------------------------------|----|
| | Wilk's F = +0.181, df = 2,439 | 0.016 | 484 | Weight and back fat | Post | Semi-wild | Kojola and Helle 1994 | 10 |
| | Calculated from paper | -0.043 | 1525 | Morphological | Post | Semi-wild | Reimers and Lenvik 1997 | |
| | t = 1.36 | 0.0924 | 215 | Morphological | Post | Wild | Reimers 1999 | |
| | F-tests | 0.0217 | 1658 | Morphological | Post | Semi-wild | Weladji et al. (2003) | 11 |
| Cape mountain zebra <i>Equus zebra zebra</i> | $c^2_1 = 3.89$ | -0.547 | 13 | Behavioral dominance | Continuous | Wild | Lloyd and Rasa 1989 | |
| Bighorn sheep <i>Ovis canadensis</i> | Calculated from paper | 0.192 | 22 | Behavioral dominance | Continuous | Wild | Hass 1991 | 12 |
| Arrui <i>Ammotragus lervia</i> | $r^2 = 0.42, P = 0.04$ | 0.648 | 10 | Behavioral dominance | Post | Captive | Cassinello 1996 | |
| | $F_{4,28} = 3.1$ | 0.405 | 33 | Behavioral dominance | Pre | Captive | Cassinello and Gomendio 1996 | 13 |
| Bison <i>Bison bison</i> | $\chi^2 = 9.47$ | 0.340 | 82 | Lactation status | Pre | Wild | Rutberg 1986 | |
| | Calculated from paper | 0.4105 | 20 | Sex of previous calf | Pre | Wild | Wolff 1988 | 14 |
| | Calculated from paper | 0.1179 | 34 | Behavioral dominance | Post | Wild | Wolff 1988 | 15 |
| | $\chi^2 = 0.38$ | 0.0588 | 122 | Lactation status | Pre | Wild | Shaw and Carter 1989 | |
| | Calculated from paper | 0.0131 | 140 | Sex of previous calf | Pre | Wild | Wolff 1998 | 16 |
| Cuvier's gazelle <i>Gazella cuvieri</i> | t = -0.34, t = -1.07 | -0.159 | 21 | Weight and body size | Unspecified | Captive | Alados and Escos 1994 | 17 |
| | $F_{1,13} = 0.84$ | 0.200 | 15 | Behavioral dominance | Unspecified | Captive | Alados and Escos 1994 | 18 |
| Pronghorn <i>Antilocapra</i> | r = 0.90, P = 0.04 | 0.462 | 18 | Behavioral dominance | Unspecified | Wild | Byers 1997 | 19 |

| | | | | | | | | |
|--------------------------------------|-----------------|--------|------|----------------------|------|---------|----------------------------------|--------|
| <i>americana</i> | | | | | | | | |
| Domestic Horse <i>Equus caballus</i> | $\chi^2 = 4.09$ | 0.3049 | 44 | Sex of previous foal | Pre | Wild | Monard et al. 1997 | 20 |
| | $\chi^2 = 7.89$ | 0.242 | 77 | Body fat score | Pre | Wild | Cameron et al. 1999 | 21 |
| Domestic Pig <i>Sus scrofa</i> | $t_{84} = 4.66$ | 0.453 | 85 | Behavioral dominance | Pre | Captive | Meikle et al. 1996 | 22, 23 |
| <i>domesticus</i> | | | | | | | | |
| | | -0.377 | 22 | Behavioral dominance | Post | Captive | Mendl et al. 1995 | 24 |
| Wild boar <i>Sus scrofa</i> | $r = 0.032$ | 0.032 | 49.4 | Morphological | Post | Wild | Fernandez-Llario et al. 1999 | 25 |
| Mountain goat | See note 6 | 0.211 | 91 | Behavioral dominance | Pre | Wild | Cote and Festa-Bianchet 2001 | 26 |
| Soay sheep <i>Ovis aries</i> | $\chi^2 = 0.06$ | 0.0122 | 406 | Morphological | Pre | Wild | Lindström et al. 2002 | 27 |
| Mouflon <i>Ovis musimon</i> | $\chi^2 = 0.06$ | 0.0258 | 90 | Morphological | Pre† | Captive | Llandete-Castillejos et al. 2001 | 28 |

*Time of sampling to obtain measure of condition, relative to conception.

† Female condition determined at about the time of conception.

Notes: 1. Effect size is weighted mean of four separate t-tests comparing females that had sons and daughters; weighted by the number of hinds contributing to the analysis.

2. Sample size (number of females) not stated in paper; N = 600 assumed from mean litter size of approximately two.

3. Calculated from data in Tables 1-3.

4. Fitted relationship between sex ratio and KFI suggests an asymptote at a sex ratio of approximately 0.55.

5. Clutton-Brock et al. (1986) treats the same data as in Clutton-Brock et al. (1984), but uses a cohort specific measure of dominance.

6. Combination of results from first year and older breeders, yields effect of body mass on sex ratio: $\eta^2_1 = 1.25, P = 0.26$.
7. Sufficient information to calculate effect size for monoparous females only.
8. Calculated from data in Table 3.
9. Comparison of mean body mass of individuals producing a male calf or a female calf (direction of difference is for son producers to be heavier).
10. Test statistic is from a MANOVA with maternal weight and back fat as independent variables, and foetal sex as a predictor, in addition to herd; calculated assuming that one-tailed P testing hypothesis = 0.37.
11. Effect size is the weighted mean of three estimates from different age-classes of female.
12. Population in Montana; effect size calculated from Table IV.
13. Linear relationship between sex ratio and dominance calculated using quoted F-ratio and rank ordering of means versus expected, following Rice and Gaines (1994).
14. Effect of sex of previous calf on next one produced (Table 3 in Wolff 1988).
15. Dominance status of mother in paired interactions with respect to sex of calf (Table 4 in Wolff 1988).
16. Calculated from part of Table 5 in Wolff (1998).
17. Trend is for more males born to small and light females; effect size is the mean of the two reported tests.
18. Trend is for more males born to high-ranking females.
19. Analysis is a regression across 5 dominance quintiles. P-value assumed = 0.05, with N assumed 18 from other analyses of reproductive success in relation to dominance.
20. Paper also reports a non-significant effect of maternal rank on sex ratio, but insufficient data for calculation of an effect size.
21. Statistics based on treating foals as independent (N = 135); weighted by number of mares contributing foals (N = 77).
22. Data in Meikle et al. (1993) are a subset of the data here.
23. Test statistic is comparison of mean sex ratio of high and low ranking sows (paper also reports correlation between percentile dominance ranks and sex ratio as $r = 0.39, P < 0.03$).
24. Relevance of this study questioned by Meikle et al (1996) on the grounds that dominance ranks were not established until after conception.

25. Correlation coefficients and sample size means of five reported correlations between sex ratio and maternal condition.
26. Pers. comm. from S.D. Cote, August 2001.
27. Linear term for mother's weight.
28. Effect size taken from analysis of effect of body condition (scored on a five point scale); effect of body mass on sex ratio is positive: $\eta^2 = 4.10$, $P = 0.04$.

On-line Appendix B Compilation of all studies located by literature search as being potentially relevant to tests of whether individual sex ratios are related to maternal condition.

| Study | Species | Action | Reason for exclusion |
|------------------------------|-------------------------|----------|---|
| Alados & Escos 1994 | Cuvier's Gazelle | Included | |
| Barette & Vandal 1986 | Caribou | Excluded | No relevant data |
| Berube et al. 1996 | Bighorn sheep (Alberta) | Excluded | No relevant data |
| Birgersson 1998 | Fallow Deer | Included | |
| Braza et al. 2000 | Fallow Deer | Excluded | No relevant data |
| Burke & Birch 1995 | White-tailed Deer | Included | |
| Byers 1997 | American Pronghorn | Included | |
| Caley & Nudds 1987 | Odocoileus spp. | Excluded | Contains no primary data (commentary on other work) |
| Cameron et al. 1999 | Domestic Horse | Included | |
| Cassinello & Gomendio 1996 | Ammotragus lervia | Included | |
| Cassinello 1996 | Ammotragus lervia | Included | |
| Chapman et al. 1997 | Reeve's muntjac | Included | |
| Clutton-Brock et al 1986 | Red Deer | Excluded | Reports dominance corrected for age |
| Clutton-Brock et al. 1984 | Red Deer | Included | |
| Cote & Festa-Bianchet 2001 | Mountain goat | Included | |
| Degayner & Jordan 1987 | White-tailed deer | Excluded | Have not been able to obtain |
| Fernandez-Llario et al. 1999 | Wild Boar | Included | |
| Festa-Bianchet 1991 | Bighorn sheep (Alberta) | Excluded | Reports dominance corrected for age |
| Festa-Bianchet 1996 | - | Excluded | Contains no new primary data |
| Flint et al. 1997 | Red Deer | Included | |
| Green & Rothstein 1991 | Bison | Excluded | Not enough information to calculate effect sizes |
| Green & Berger 1990 | Bison | Excluded | Contains no data relating to sex ratio |
| Hass 1991 | Bighorn sheep | Included | |
| Hewison & Gaillard 1996 | Roe Deer | Included | |

| | | | |
|----------------------------------|----------------------------|------------------|--|
| Hewison et al. 1999 | Roe Deer | Included | |
| Hoefs & Nowlan 1994 | Six species | Excluded | No relevant data |
| Hogg et al 1992 | Bighorn sheep | Excluded | No relevant data |
| Kent 1995 | Domestic Sheep | Excluded | No relevant data |
| | Elk (C. elaphus in Oregon) | Included | |
| Kohlmann 1999 | | | |
| Kojola & Eloranta 1989 | Reindeer | Included | |
| Kojola & Helle 1994 | Reindeer | Included | |
| Kojola 1993 | Reindeer | Excluded | No relevant data |
| Kojola 1997a | Reindeer | Excluded | No relevant data |
| Kojola 1997b | General | Excluded | No primary data – a review of other work |
| Kojola 1998 | general | Excluded | No primary data – a review of other work |
| Kruuk et al. 1999 | Red Deer | Excluded | Dominance effect significant only in interaction |
| Kucera 1991 | Mule deer | Excluded | Analysis includes barren females with no sex ratio defined |
| Llandete-Castillejos et al. 2001 | | Included | |
| | Mouflon | | |
| Lindström et al. 2002 | Soay sheep | Included | |
| Lloyd & Rasa 1989 | Cape mountain zebra | Included | |
| Mansell 1974 | White-tailed Deer | Excluded | No relevant data |
| McCullogh 1979 | White-tailed Deer | Could not obtain | |
| Meikle et al. 1993 | Domestic swine | Excluded | Data are a subset of those in Meikle et al. (1996) |
| Meikle et al. 1996 | Domestic swine | Included | |
| Mendl et al. 1995 | Domestic swine | Included | |
| Mlikovsky 1988 | Przewalski horse | Excluded | Contains no relevant data |
| Monard et al. 1997 | Domestic horse | Included | |
| Novellie et al. 1996 | Cape mountain zebra | Excluded | Only reports relationship between age and sex ratio |
| Nygen & Kojola 1997 | Moose | Included | |
| Owen-Smith 1988 | Ceratotherium simum | Excluded | Reports only relationship between age and sex ratio |
| Pederson & Harper 1984 | White-tailed deer | Excluded | Comparison of different populations |
| Reimers & Lenvik 1997 | Reindeer | Included | |
| Reimers 1999 | Reindeer | Included | |
| Robinette et al. 1957 | Mule deer | Excluded | Generally comparisons between populations |
| Robinette et al. 1973 | Mule deer | Excluded | Comparison of herd on different diets |
| Rutberg 1986 | American bison | Included | |

| | | | |
|-----------------------------|---|----------|---|
| Saltz & Rubenstein 1995 | Wild ass | Excluded | No data on individual condition and sex ratio |
| Saltz 2001 | Asiatic wild ass | Excluded | Only data on age and sex ratio |
| | Persian fallow deer <i>Dama dama mesopotamica</i> | Excluded | Only data on age and sex ratio |
| Saltz 2001 | | | |
| San Jose et al. 1999 | Fallow Deer | Excluded | No relevant data |
| Schwartz & Hundertmark 1993 | Moose | Included | |
| Shaw & Carter 1989 | American bison | Included | |
| Skogland 1986 | Reindeer | Excluded | Comparison between populations |
| Smith et al. 1996 | Red deer | Excluded | Comparison between populations |
| Thomas et al. 1989 | Reindeer | Excluded | Insufficient detail presented for meta-analysis |
| Verme 1965 | White-tailed Deer | Excluded | Comparison of groups on different diets |
| Verme 1969 | White-tailed Deer | Excluded | Comparison of groups on different diets |
| Verme 1983 | <i>Odocoileus</i> spp (3) | Excluded | Review of other work |
| Verme 1985 | White-tailed Deer | Excluded | Comparison of groups on different diets |
| Verme 1989 | White-tailed deer | Excluded | Comparison of groups on different diets |
| Wauters et al. 1995 | Roe Deer | Included | |
| Weladji et al. 2003 | Reindeer | Included | |
| Wolff 1988 | American bison | Included | |
| Wolff 1998 | American bison | Included | |
| Woolf & Harder 1979 | deer sp | Excluded | No relevant data |
| Yang et al. 1989 | Pig | Excluded | No relevant data |

On-line Appendix C Life-history data for ungulates used in meta-analysis

| Species | Litter Size | Gestation | Ad m mass | Ad f mass | Mating system | Social Organization | Sources |
|---|-------------|-----------|-----------|-----------|-----------------------|---------------------|---------|
| Fallow Deer <i>Dama dama</i> | 1 | 235.5 | 68 | 44.6 | lek | Herd | 1 |
| White-tailed Deer <i>Odocoileus virginianus</i> | 1.8 | 203.5 | 110 | 55 | single female defence | solitary | 1 |
| Red Deer <i>Cervus elaphus</i> | 1 | 235 | 185.1 | 140.2 | rut | Herd | 1 |
| Roe Deer <i>Capreolus capreolus</i> | 2.14 | 294 | 24.2 | 23.4 | single female defence | solitary | 1, 7 |
| Reeve's Muntjac <i>Muntiacus reevesi</i> | 1 | 210 | 14.7 | 11.8 | male dom poly | solitary | 1 |
| Moose <i>Alces alces</i> | 1.4 | 245 | 510.2 | 358.8 | Rut | solitary | |
| Reindeer <i>Rangifer tarandus</i> | 1 | 225 | 145 | 85.8 | harem poly | Herd | 1 |
| Cape Mountain Zebra <i>Equus zebra zebra</i> | 1 | 365 | 255 | 234.3 | harem poly | Herd | 8 |
| Arrui <i>Ammotragus lervia</i> | 1.18 | 160 | 111.8 | 51.6 | harem poly | Herd | 1 |
| Bison <i>Bison bison</i> | 1 | 285 | 795.3 | 452.8 | rut | Herd | 1 |
| Cuvier's Gazelle <i>Gazella cuvieri</i> | 1.4 | 170 | 29.4 | 20.4 | harem poly | Herd | 5 |
| Pronghorn <i>Antilocapra americana</i> | 2 | 250 | 56.2 | 49.8 | Rut | Herd | 1,2 |
| Horse <i>Equus caballus</i> | 1 | 337 | 265 | 235 | Harem poly | Herd | |
| Pig <i>Sus scrofa</i> | 6 | 115 | 200 | 130 | male dom poly | Herd | 1 |
| Mountain Goat <i>Oreamnos americanus</i> | 1 | 180 | 95.9 | 61 | unknown | Herd | 1,6 |
| Bighorn Sheep <i>Ovis canadensis</i> | 1.5 | 175 | 83.4 | 58.7 | male dom poly | Herd | 1 |
| Soay Sheep <i>Ovis aries</i> | 1.15 | 165 | 32.6 | 22 | rut | Herd | 10 |
| Mouflon <i>Ovis musimon</i> | 1.33 | 170 | 42.5 | 27.5 | male dom poly | Herd | 9 |

Sources: 1. McDonald (2001). 2. Byers (1997). 3. Nowak (1999). 4. Perez-Barberia and Gordon (2000). 5. Olmedo et al. (1985). 6. Cote and Festa-Bianchet (2001). 7. Andersen and Linnell (1997) Variation in maternal investment in a small cervid: the effects of cohort, sex, litter size and time of birth in roe deer (*Capreolus capreolus*). 8. Skinner and Smithes (1990). 9. Llandete-Castillejos et al. (2001). 10. Lindström et al. 2002. 11. Pelabon et al. (1995). Note: Took the midpoint of quoted ranges, if no mean was indicated.

Literature Cited for on-line Appendices

- Alados, C.L., and J.M. Escos. 1994. Variation in the sex ratio of a low dimorphic polygynous species with high levels of maternal reproductive effort: Cuvier's gazelle. *Ethology, Ecology and Evolution* 6:301-311.
- Andersen, R., and J.D.C. Linnell. 1997. Variation in maternal investment in a small cervid: the effects of cohort, sex, litter size and time of birth in roe deer (*Capreolus capreolus*) fawns. *Oecologia* 109:74-79.
- Barrette, C., and D. Vandal. 1986. Social rank, dominance, antler size and access to food in snow-bound wild woodland caribou. *Behaviour* 97:118-146.
- Bérubé, C.H., M. Festa-Bianchet, and J.T. Jorgenson. 1996. Reproductive costs of sons and daughters in Rocky Mountain bighorn sheep. *Behavioral Ecology* 7:60-68.
- Birgersson, B. 1998. Adaptive adjustment of the sex ratio: more data and considerations from a fallow deer population. *Behavioral Ecology* 9:404-408.
- Braza, F., C. San Jose, and S. Aragon. 2000. Variation of male-biased female investment in fallow deer (*Dama dama*). *Journal of Zoology* 250:237-241.
- Burke, R.L. and J.M. Birch. 1995. White-tailed deer vary offspring sex-ratio according to maternal condition and age. *Ecological Research* 10:351-357.
- Byers, J.A. 1997. American pronghorn: social adaptations and the ghosts of predators past. University of Chicago Press, Chicago.
- Caley, M.J., and T.D. Nudds. 1987. Sex ratio adjustment in *Odocoileus* – does local resource competition play a role? *American Naturalist* 129:452-457.

- Cameron, E.Z., W.L. Linklater, K.J. Stafford, and C.J. Veltman. 1999. Birth sex ratios relate to mare condition at conception in Kaimanawa horses. *Behavioral Ecology* 10:472-475.
- Cassinello, J. 1996. High-ranking females bias their investment in favour of male calves in captive *Ammotragus lervia*. *Behavioral Ecology and Sociobiology* 38:417-424.
- Cassinello, J., and M. Gomendio. 1996. Adaptive variation in litter size and sex ratio at birth in a sexually dimorphic ungulate. *Proceedings of the Royal Society of London, Series B: Biological Sciences* 263:1461-1466.
- Chapman, N.G., M. Furlong, and S. Harris. 1997. Reproductive strategies and the influence of date of birth on growth and sexual development of an aseasonally-breeding ungulate: Reeve's muntjac (*Muntiacus reevesi*). *Journal of Zoology* 241: 551-570.
- Clutton-Brock, T.H. 1991. *The evolution of parental care*. Princeton University Press, Princeton.
- Clutton-Brock, T.H., S.D. Albon, and F.E. Guinness. 1984. Maternal dominance, breeding success, and birth sex ratios in red deer. *Nature* 308:358-360.
- Côté, S.D., and M. Festa-Bianchet. 2001. Offspring sex ratio in relation to maternal age and social rank in mountain goats (*Oreamnos americanus*). *Behavioral Ecology and Sociobiology* 49:260-265.
- Degayner, E.J., and P.A. Jordan. 1987. Skewed fetal sex ratios in white-tailed deer: evidence and evolutionary speculations. Pages 178-188 in C.M. Wemmer, ed. *Biology and management of the cervidae*. Smithsonian Institution Press, Washington.
- Fernandez-Llario, P., J. Carranza, and P. Mateos-Quesada. 1999. Sex allocation in a polygynous mammal with large litters: the wild boar. *Animal Behaviour* 58:1079-1084.

- Festa-Bianchet, M. 1991. The social system of bighorn sheep: grouping patterns, kinship and female dominance rank. *Animal Behaviour* 42:71-82.
- Festa-Bianchet, M. 1996. Offspring sex ratio in studies of mammals: does publication depend upon the quality of the research or the direction of the results? *Écoscience* 3:42-44.
- Flint A.P.F., S.D. Albon, and S.I. Jafar. 1997. Blastocyst development and conceptus sex selection in red deer *Cervus elaphus*: Studies of a free-living population on the Isle of Rum. *General and Comparative Endocrinology* 106:374-383.
- Green, W.C.H., and J. Berger. 1990. Maternal investment in sons and daughters: problems of methodology. *Behavioral Ecology and Sociobiology* 27:99-102.
- Green, W.C.H., and A. Rothstein. 1991. Sex bias or equal opportunity? Patterns of maternal investment in bison. *Behavioral Ecology and Sociobiology* 29:373-384.
- Hass, C.C. 1991. Social status in female bighorn sheep (*Ovis canadensis*) – expression, development and reproductive correlates. *Journal of Zoology* 225:509-523.
- Hewison, A.J.M., R. Andersen, J.-M. Gaillard, J.D.C. Linnell, and D. Delorme. 1999. Contradictory findings in studies of sex ratio variation in roe deer (*Capreolus capreolus*). *Behavioral Ecology and Sociobiology* 45:339-348.
- Hewison, A.J.M., and J.-M. Gaillard. 1996. Birth sex ratios and local resource competition in roe deer, *Capreolus capreolus*. *Behavioral Ecology* 7:461-464.
- Hoefs, M., and U. Nowlan. 1994. Distorted sex ratios in young ungulates: the role of nutrition. *Journal of Mammalogy* 75:631-636.

- Hogg, J.T., C.C. Hass, and D.A. Jenni. 1992. Sex-biased maternal expenditure in Rocky Mountain bighorn sheep. *Behavioral Ecology and Sociobiology* 31:243-251.
- Kent, J.P. 1995. Birth sex ratios in sheep over nine lambing seasons: years 7-9 and the effects of ageing. *Behavioral Ecology and Sociobiology* 36:101-104.
- Kohlmann, S.G. 1999. Adaptive fetal sex allocation in the elk: evidence and implications. *Journal of Wildlife Management* 63:1109-1117.
- Kojola, I. 1993. Early maternal investment and growth in reindeer. *Canadian Journal of Zoology* 71:753-758.
- Kojola, I. 1997a. Behavioural correlates of female social status and birth mass of male and female calves in reindeer. *Ethology* 103:809-814.
- Kojola, I. 1997b. Social status and physical condition of mother and sex ratio of offspring in cervids. *Applied Animal Behaviour Science* 51:267-274.
- Kojola, I. 1998. Sex ratio and maternal investment in ungulates. *Oikos* 83:567-573.
- Kojola, I., and E. Eloranta. 1989. Influences of maternal body weight, age and parity on sex ratio in semi-domesticated reindeer. *Evolution* 43:1331-1336.
- Kojola, I., and T. Helle. 1994. Offspring sex ratio adjustment in reindeer, *Rangifer tarandus*. *Annales Zoologici Fennici* 31:405-410.
- Kruuk, L.E.B., T.H. Clutton-Brock, S.D. Albon, J.M. Pemberton, and F.E. Guinness. 1999. Population density affects sex ratio variation in red deer. *Nature* 399:459-461.
- Kucera, T.E. 1991. Adaptive sex ratio variation in sex ratios of offspring in nutritionally stressed mule deer. *Journal of Mammalogy* 72:745-749.

- Llandete-Castillejos, T., A. Garcia, S. Langton, I. Inglis, L. Gallego, and J. Garde. 2001. Opposing offspring sex ratio variations with increasing age and weight in mouflon mothers. *Acta Veterinaria Hungarica* 49:257-268.
- Lindström, J., T. Coulson, L. Kruuk, M.C. Forchhammer, D.W. Coltman, and T. Clutton-Brock. 2002. Sex-ratio variation in Soay sheep. *Behavioral Ecology and Sociobiology* 53:25-30.
- Lloyd, P.H., and O.A.E. Rasa. 1989. Status, reproductive success and fitness in Cape mountain zebra (*Equus zebra zebra*). *Behavioral Ecology and Sociobiology* 25:411-420.
- Mansell, W.D. 1974. Productivity of white-tailed deer in Bruce Peninsula, Ontario. *Journal of Wildlife Management* 38:808-814.
- McCullough, D.R. 1979. The George Reserve deer herd: population ecology of a K-selected species. The University of Michigan Press, Ann Arbor.
- McDonald, D. (ed) 2001. The Encyclopedia of Mammals. Oxford University Press.
- Meikle, D.B., L.C. Drickamer, S.H. Vessey, T.L. Rosenthal, and K.S. Fitzgerald. 1993. Maternal dominance rank and secondary sex ratio in domestic swine. *Animal Behaviour* 46:79-85.
- Meikle D.B., L.C. Drickamer, S.H. Vessey, R.D. Arthur, and T.L. Rosenthal. 1996. Dominance rank and parental investment in swine (*Sus scrofa domesticus*). *Ethology* 102: 969-978.
- Mendl, M., A.J. Zanella, D.M. Broom, and C.T. Whitemore. 1995. Maternal social status and birth sex ratio in domestic pigs: an analysis of mechanisms. *Animal Behaviour* 50:1361-1370.

- Mlikovsky, J. 1988. Secondary sex ratio in the Przewalski horse *Equus przewalskii*. International Journal of Mammalian Biology 53:92-101.
- Monard, A.M., P. Duncan, H. Fritz, and C. Feh. 1997. Variations in the birth sex ratio and neonatal mortality in a natural herd of horses. Behavioral Ecology and Sociobiology 41:243-249.
- Novellie, P.A., P.S. Millar, and P.H. Lloyd. 1996. The use of VORTEX simulation models in a long term program of re-introduction of an endangered large mammal, the Cape mountain zebra (*Equus zebra zebra*). Acta Oecologia 17:657-671.
- Nowak, R.M. (1999) Walker's Mammals of the World, Sixth Edition. Johns Hopkins Univ Press, Baltimore.
- Nygén, T., and I. Kojola. 1997. Twinning and fetal sex ratio in moose: effects of maternal age and mass. Canadian Journal of Zoology 75:1945-1948.
- Olmedo, J.E., J. Escos, and M. Gomendio M. 1985. Reproduction de gazella cuvieri en captivite. Mammalia 49, 501-507
- Owen-Smith, R.N. 1988. Mega-herbivores. Cambridge University Press, Cambridge.
- Pederson, J.C., and K.T. Harper. 1984. Does summer range quality influence sex ratios among mule deer fawns in Utah? Journal of Range Management 60:508-517.
- Pélabon, C., J.-M. Gaillard, A. Loison, and C. Portier. 1995. Is sex-biased maternal care limited by total maternal expenditure in polygynous ungulates? Behavioral Ecology and Sociobiology 37:311-319.
- Perez-Barberia, F.J., and I.J. Gordon. 2000. Differences in body mass and oral morphology between the sexes in the Artiodactyla: evolutionary relationships with sexual segregation. Evolutionary Ecology Research 2:667-684.

- Reimers, E. 1999. Foetal sex ratios in wild reindeer *Rangifer tarandus* in relation to maternal condition and age. *Wildlife Biology* 5:49-54.
- Reimers, E., and D. Lenvik. 1997. Fetal sex ratio in relation to maternal mass and age in reindeer. *Canadian Journal of Zoology* 75:648-650.
- Rice, W.R., and S.D. Gaines. 1994. Extending non-directional heterogeneity tests to evaluate simply ordered alternative hypotheses. *Proceedings of the National Academy of Sciences of the USA* 91, 225-226.
- Robinette, W.L., J.S. Gashwihler, J.B. Low, and D.A. Jones. 1957. Differential mortality by sex and age among mule deer. *Journal of Wildlife Management* 21:1-16.
- Robinette, W.L., C.H. Baer, R.E. Pilmore, and C. Knittle. 1973. Effects of nutritional change on mule deer. *Journal of Wildlife Management* 37:312-326.
- Rutberg, A.T. 1986. Lactation and foetal sex ratios in American bison. *American Naturalist* 127:89-94.
- Saltz, D. 2001. Progeny sex ratio variation in ungulates: maternal age meets environmental perturbation of demography. *Oikos* 94:377-384.
- Saltz, D., and D.I. Rubenstein. 1995. Population dynamics of a reintroduced asiatic wild ass (*Equus hemionus*) herd. *Ecological Applications* 5:327-335.
- San José, C., F. Braza, and S. Aragón. 1999. The effect of age and experience on the reproductive performance and prenatal expenditure of resources in female fallow deer (*Dama dama*). *Canadian Journal of Zoology* 77:1717-1722.
- Schwartz, C.C., and K.J. Hundertmark. 1993. Reproductive characteristics of Alaskan moose. *Journal of Wildlife Management* 57:454-468.

- Skinner J.D., and R.H.N. Smithes. 1990. The Mammals of the Southern Africa Sub-region. Univ. of Pretoria, Pretoria, South Africa.
- Skogland, T. 1986. Sex ratio variation in relation to maternal condition and parental investment in wild reindeer. *Oikos* 46:417-419.
- Shaw, J.H., and T.S. Carter. 1989. Calving patterns among American bison. *Journal of Wildlife Management* 53:896-898.
- Smith, B.L., R.L. Robbins, and S.H. Anderson. 1996. Adaptive sex ratios: another example? *Journal of Mammalogy* 77:818-825.
- Thomas, D.C., S.J. Barry, and H.P. Kilian. 1989. Fetal sex ratios in caribou: maternal age and condition effects. *Journal of Wildlife Management* 53:885-890.
- Verme, L.J. 1965. Reproductive studies on penned white-tailed deer. *Journal of Wildlife Management* 29:74-79.
- Verme, L.J. 1969. Reproductive patterns of white-tailed deer related to nutritional plane. *Journal of Wildlife Management* 33:881-887.
- Verme, L.J. 1983. Sex ratio variation in *Odocoileus*: a critical review. *Journal of Wildlife Management* 47:573-582.
- Verme, L.J. 1985. Progeny sex ratio relationships in deer: theoretical vs. observed. *Journal of Wildlife Management* 49:134-136.
- Verme, L.J. 1989. Maternal investment in the white-tailed deer. *Journal of Mammalogy* 70:438-442.
- Wauters, L.A. et al. 1995. Do female roe deer in good condition produce more sons than daughters? *Behavioral Ecology and Sociobiology* 37:189-193.

Weladji, R.B., O. Holand, G. Steinheim, and D. Lenvik. 2003. Sex-specific pre-weaning maternal care in reindeer (*Rangifer tarandus*). Behavioral Ecology and Sociobiology, in press.

Wolff, J.O. 1988. Maternal investment and sex ratio adjustment in American bison calves. Behavioural Ecology and Sociobiology 23:127-133.

Wolff, J.O. 1998. Breeding strategies, mate choice, and reproductive success in American bison. Oikos 83:529-544.

Wolf, A., and J.D. Harder. 1979. Population dynamics of a white-tailed deer herd with emphasis on reproduction and mortality. Wildlife Monographs 67.

Yang, H., P.R. Eastham, P. Phillips, and C.T. Whitemore. 1989. Reproductive performance, body weight and body condition of breeding sows with differing body fatness at parturition, differing nutrition during lactation, and differing litter size. Animal Production 48:181-201.