MORTALITY PATTERNS IN NONDOMESTIC HOOFSTOCK (OVIS ORIENTALIS LARISTANICA, CAPRA AEGAGRUS, CAPRA IBEX NUBIANA) INDICATE SPECIES-SPECIFIC DIFFERENCES IN DISEASE SUSCEPTIBILITY IN SMALL RUMINANTS

DEISS R[1], HAMMER C[2], MÜLLER DWH[1], DEB A[2], CLAUSS M[1], HAMMER S[2]

[1]Clinic for Zoo Animals and Exotic Pets, Vetsuisse Faculty, University of Zurich, Winterthurerstrasse 260, CH-8057, Zurich, SWITZERLAND; ramonadeiss@msn.com, mclauss@vetclinics.uzh.ch
[2]Al Wabra Wildlife Preservation, P.O. Box 44069, Al Wabra, Doha, STATE OF QATAR

Summary

A retrospective evaluation was performed regarding cause of death in 91 Laristan mouflons (Ovis orientalis laristanica), 32 wild goats (Capra aegagrus) and 31 Nubian ibex (Capra ibex nubiana) at Al Wabra Wildlife Preservation (AWWP) between 2001 and 2008. The Capra spp. (i.e. wild goat and Nubian ibex) were strongly affected by an outbreak of contagious caprine pleuropneumonia in April 2004, whereas the mouflon remained mainly unaffected. Of the mouflon, 12 % (eleven animals) died with icterus as main pathological finding, and only in mouflon tick infection was reported. In one case a Theileria sp. infection was confirmed, suggesting it to be the etiologic agent also in the other icteric animals. Although parasites, including coccidia, were identified in all species. Coccidia had a major involvement in cases of macroscopic gastrointestinal lesions only in mouflons, but not goat species. In mouflons only animals with a birth weight over 1.5 kg reached an age over 2.5 years. As the mouflon and goat species were held in immediate proximity, the reported disease patterns at AWWP indicate distinct differences in disease susceptibility between wild Capra and Ovis spp. In this context, the common zoo practice to present closely related taxa in close spatial vicinity, as the C. aegagrus and C. ibex in this case, will favour the spread of certain infectious diseases.

Introduction

Wild sheep and goat are in the order Artiodactyla, familiy Bovidae and subfamily Caprinae (FOWLER, 2005). Nubian ibex and wild goats are stated as “vulnerable” in the IUCN red list (IUCN, 2009). These species and the Laristan mouflon have been bred successfully in AWWP for many years. The native habitats of these species are arid to semiarid inhospitable mountainous regions. Nubian ibex occur in Egypt, east of Nile, along the east cost of the Red Sea (Saudi Arabia, Oman) and north-eastern Sudan (FOWLER, 2005). Laristan mouflon are restricted to Iran (VALDEZ et al., 1978), and wild goats are native to Greece, southern and eastern Turkey, eastern Caucasus, Middle East, southern Turkmenistan, Afghanistan and south-western Pakistan (MITCHELL et al., 1999). These species are all adapted to climbing. Optimal enclosures should provide opportunities to climb, which aids in keeping the rate of necessary hoof trims low. Hoof overgrowth is a continual problem in captive wild Caprinae and periodic trimming is still necessary. Wild sheep and goats are mostly intermediate feeders, and in captivity may be maintained on grass or alfalfa hay (FOWLER, 2005). According to GAREL et al. (2005), twin pregnancy in *Ovis orientalis* occurs more often under good environmental conditions. Due to the taxonomic proximity we assume this to also be true for Laristan mouflons and probably as well for the *Capra* spp.

Free-ranging wild Caprinae are susceptible to a variety of diseases often transmitted by domestic animals, such as foot rot in free-ranging mouflon (VOLMER et al., 2008), as well as for infectious keratoconjunctivitis and other diseases of Alpine ibex (CAPRAIBEX, 2008). Lungworms may cause serious problems in endemic areas and *Psoroptes ovis* has been particularly troublesome in free-ranging bighorn sheep and may even be associated with population declines in some areas. Hemoparasites have been described in bighorn sheep but so far not in other free-ranging wild sheep or goat species (KOCAN and WALDRUP, 2001).

Wild Caprinae in captivity have demonstrated a similar susceptibility to diseases as domestic small ruminants. Protozoal parasites are not common in free-ranging wild Caprinae, but coccidiosis is prevalent in captive populations of wild Caprinae (FOWLER, 2005). Additionally, after ECKERT et al. (2005) sheep and goats are generally susceptible to *Babesia ovis* and *Babesia motasi* as well as to *Theileria hirci (*Syn.: *Theilieria lesoquardi), Theileria recondita* and *Theileria ovis*. The crucial factor is the presence of vector ticks. So far Mycoplasma were not believed to be of relevance in Caprinae kept in zoos; they are not even mentioned in FOWLER's (2005) respective book chapter. This situation might change as the first outbreak of contagious caprine pleuropneumoniae caused by *Mycoplasma capricolum* subsp*. capripneumoniae* has been reported at AWWP (ARIF et al., 2007). At the same time, several outbreaks of this disease have occurred in domestic sheep and goats of Africa (BÖLSKE et al., 1995; HOUSHAYIMI et al., 2002; SHIFERAW et al., 2006), from where lifestock is regularly imported into Qatar.

The aim of this study was to detect main causes of death in wild sheep and goats held at AWWP. In addition we put special emphasis on reproductive parameters such as twin pregnancy and birth weight.

Materials and methods

This investigation included 2 *Capra* species, i.e. Nubian ibex (31 animals) and wild goats (32 animals) and 1 *Ovis* species, i.e. Laristan mouflon (91 animals), kept at Al Wabra Wildlife Preservation (AWWP). The different herds were held adjacent to each other in enclosures, which measure, on average, 1,820 m^2. An average mouflon group consisted of 1 adult male and 7 to 8 females plus juvenile offspring. During birth peak periods, i.e. March/April till late autumn, this resulted in mean herd sizes of up to 30 animals. Later, groups were split. Due to the small Nubian ibex population, not more than 5 adult females and 1 male plus juvenile offspring were held together. In wild goats, mean group size was 2 adult males and 5 adult and subadult females with 10 juveniles in 1 enclosure. During peak periods mouflon herds had 2 enclosures at their disposal to accommodate offspring. Surplus animals were held in non-breeding groups, which consisted of only male or only female animals, or were culled.

The diet consisted of local herbivore pellets and wheat bran (relation 3:1) supplemented by an imported vitamin/mineral mixture. Additionally fresh lucerne was offered daily. Animals always had free access to grass hay, water and mineral licks.

Animals that died were submitted to in-house post mortem examinations at AWWP, the results of which are evaluated here. In mouflon we found a similar pattern (general icterus, hepatomegaly and splenomegaly) for 11 animals, which we summed up as "icterus". For animals in which the coccidia status at death had been investigated, the frequency of coccidia-positive and coccidia-negative results were compared between animals with and without a macroscopic diagnosis of gastrointestinal (GIT) disorder. Special emphasis was put on evaluating neonatal mortality (up to 30 days) in mouflon due to expected population effects given the high population numbers at AWWP.

Results

Wild goat and Ibex

The population size of both species showed a remarkable decline in 2004 (Fig. 1ab). In this year, an outbreak of contagious caprine pleuropneumonia occurred in AWWP (ARIF et al., 2007). In wild goats, the herd size was reduced from 17 animals at the end of 2003 to 4 animals at the end of 2004. Since then, the herd has been increasing again up to 15 animals at the end of 2008. In Nubian ibexes, the population collapsed from 14 animals at the end of 2003 to 8 animals at the end of 2004, and increased by only one individual to 9 animals at the end of 2008. To date 2 females are left and in addition, the majority of newborns happened to be males. To restore the population it is planned to import animals.

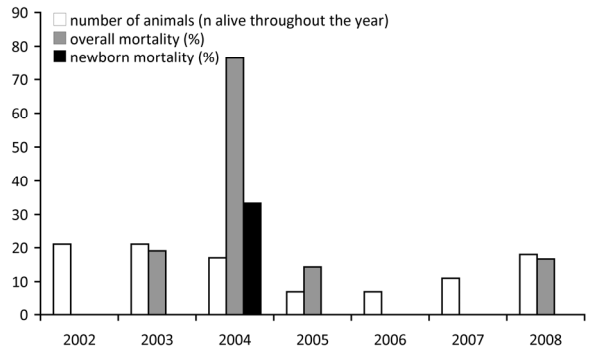


Figure 1a: Population development and mortality in wild goats from 2002 – 2008.

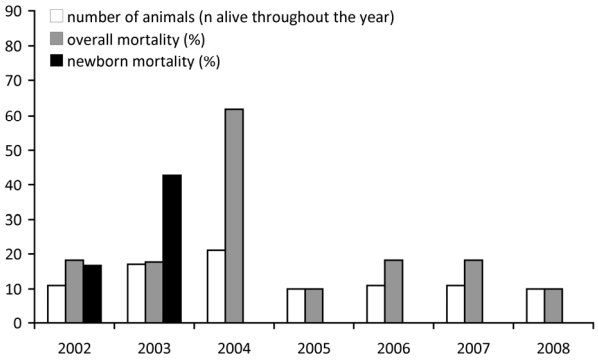


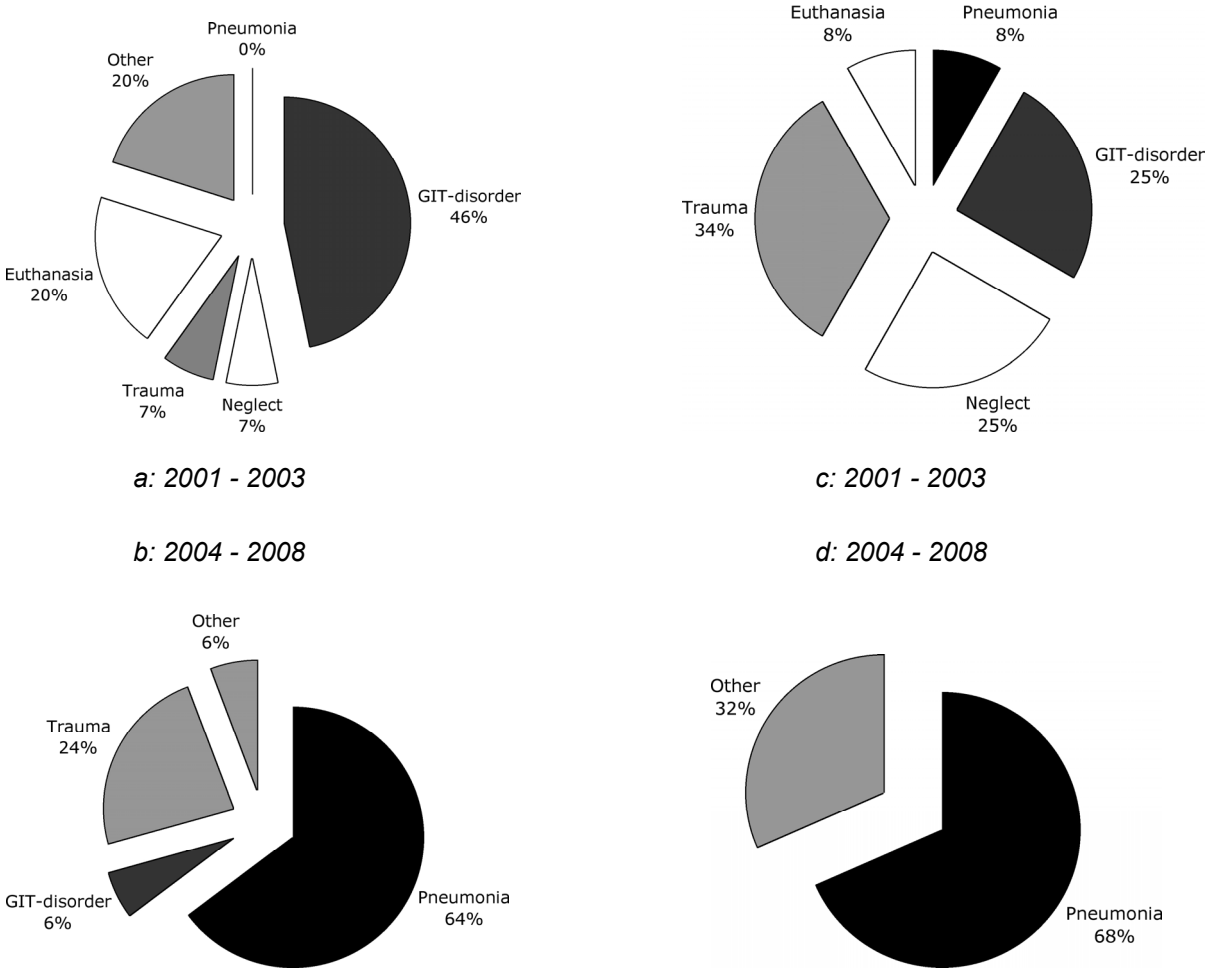
Figure 1b: Population development and mortality in Nubian ibex from 2002 – 2008.

These events are reflected in the overall mortality patterns. Basically, there were hardly any cases of pneumonia from 2001-2003 in wild goats and ibex. In this period, 47 % (7 animals) of wild goats died of gastrointestinal disorders (Fig. 2a). Nubian ibexes died from a greater variety of causes like trauma (33 %, 4 animals), neglect (25 %, 3 animals) and gastrointestinal disorders (25 %, 3 animals) (Fig. 2c). After 2004 pneumonia was the overruling cause of death in both species (Fig. 2bd); as part of this epidemic, all but 2 ibex females were lost. No ticks were observed in goat species, and there was no pathologic pattern that included icterus. Due to the generally small number of animals, no pattern with respect to newborn mortality could be described. Coccidia-positive individuals occurred with similar frequency in wild goats and ibex with or without GIT disorders (Fig. 3). Note that for many animals (18 wild goats and 22 ibex) the coccidia status at death was not investigated.

Laristan mouflon

The population of Laristan mouflon increased steadily over the years. Up to 2005, overall and newborn mortality increased with population size, possibly indicating a density-dependent process; however, from 2006-2008 both overall and newborn mortality decreased although the population kept growing (Fig. 4). There was no single major cause of death in Laristan mouflon, but animals died due to a variety of reasons (Fig. 5). The proportion of pneumonia as cause of death is, at 14.6 % (13 animals), remarkably smaller than in the goat species. For eleven animals, common pathologic findings such as generalized icterus, hepatomegaly and splenomegaly were noted. In one case *Theileria* sp. was confirmed. Ticks had been found on 17 individual dead mouflons from as early as 2001 on. Icterus was first noted in 2005, with 2 - 4 cases per year since. Coccidia-positive individuals were more prominent among mouflon with GIT disorders as compared to animals without GIT disorders (Fig. 3). In both

twins and singletons, no animal with a birth weight of less than 1.5 kg (9 twins and 15 singletons) reached an age of more than 2 years. Birth weight was positively correlated with age at death (Spearman's R = 0.306, p = 0.022, n = 56). Overall, singletons (1.83 ± 0.40 kg; n = 63) tended to be heavier at birth than twins (1.68 ± 0.33 kg; n = 34; t-test, p = 0.070).



a: 2001 - 2003

b: 2004 - 2008

c: 2001 - 2003

d: 2004 - 2008

Figure 2: Causes of death in wild goat from a) 2001 - 2003 and b) 2004 - 2008; and for Nubian ibex from c) 2001 - 2003 and d) 2004 - 2008; euthanasia performed for overgrown hooves. 'Other' causes include autolysed carcasses or singular occurrences.

Discussion

This investigation included 2 *Capra* and 1 *Ovis* species. So far not many investigations have evaluated differences in the susceptibility to clinical disease between goats and sheep, although there are several examples for differing disease patterns. One example of the latter is the Caprine arthritis encephalitis virus and maedi-visna (lately summed up under the name "small ruminant lentivirus"). Although both, domestic sheep and goats can become infected, the clinical outcome is not the same,

with goats showing more arthritis and sheep tending to pneumonia and encephalitis (PETERHANS et al., 2004). Estimated mortality rates up to 30 % have been reported in free-ranging Caprinae (ibex and chamois) in Switzerland due to infection with *M. conjunctivae* and resulting blindness. 90 % of Swiss sheep flocks are seropositive with animals only sporadically clinical showing signs, and there is experimental evidence for possible transmission from domestic sheep to wild-ranging ibex and chamois (NICHOLAS et al., 2008). It is unclear whether the different clinical relevance is an effect of different circumstances (e.g., impaired eyesight may not be noted in domestic sheep, and they do not fall off a cliff as might happen in wild animals), of the different exposition pattern (in domestic sheep the agent is supposed to circulate all year round, whereas free-ranging hoofstock is probably only exposed during presence of domestic herds on the alps), or really of a different disease susceptibility, as a result of "spill-over" of a disease from domestic to immunologically naive wild populations.

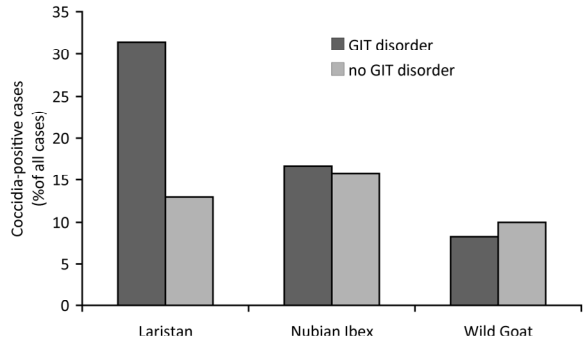


Figure 3: Proportion of Coccidia-positive cases in individuals with and without GIT disorder in 3 ruminant species.

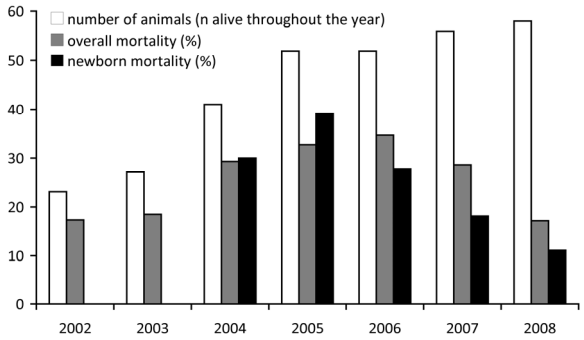


Figure. 4: Population development and mortality in Laristan mouflon from 2002 - 2008.

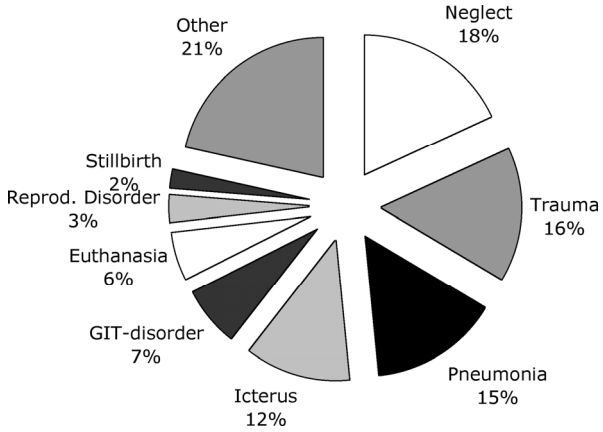


Figure 5: Causes of death in Laristan mouflon between 2001 - 2008; euthanasia performed for overgrown hooves or in surplus males. 'Other' causes include autolysed carcasses or singular occurences.

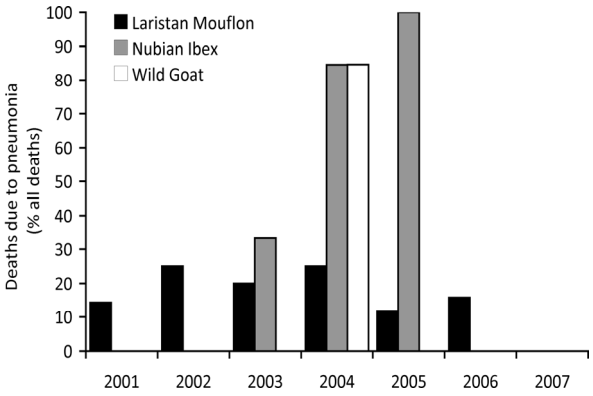


Figure 6: Mortality due to pneumonia (in % of all mortality) in 3 ruminant species from 2001 - 2007. Note the even distribution in Laristan mouflon and the peak-like occurrence in Nubian ibex and wild goat.

Here, we present an example of highly different disease outcome with another mycoplasma species as causative agent. In April 2004 there was a severe outbreak of caprine contagious pleuropneumonia (CCPP) in AWWP (ARIF et al., 2007). This is a respiratory disease caused by *M. capricolum subsp. capripneumoniae,* which is supposed to be mainly present in Africa and Asia (NICHOLAS et al., 2008). Common pathological findings that were observed in the wild goats and ibex, like a trachea full of froth, serosanguineous pleural effusion, fibrinous pleuropneumonia and pericarditis, are consistent with the diagnosis of CCPP (ROLLE and MAYR, 2007). The rapid progression of the disease is documented in the fact that in most animals a good body condition was noted at death. The population increase of the wild goats after 2004 reflects the effort in the detection of the etiologic agent and development of a vaccine (ARIF et al., 2007).

Pneumonia was the most important cause of death in the wild goats and Nubian ibex from 2001 to 2008, and both populations were reduced dramatically in 2004 (Fig. 1), typical for a serious epidemic. In the *Capra* spp. the mortality due to pneumonia in proportion of all mortalities had a peak between 2002 and 2006 with a considerable increase from 0 % to 90 - 100 %; in contrast, the mortality due to pneumonia in Laristan mouflon seemed to decrease from 20 % to 0% over the years with no evident peak (Fig. 6). Different reports from the literature exist on species-specific differences in disease susceptibility in small ruminants. In another outbreak of CCPP in domestic goats and sheep in Afar Region, Ethiopia, morbidity did not differ between species, but mortality was significantly higher in goats than in sheep (SHIFERAW et al., 2006). The authors confirmed infection with *M. capricolum* subsp. *capripneumoniae* in goats only. This difference indicates species-specifity of the infectious agent and offers the possibility that sheep could act only as carriers. The hypothesis of sheep as a reservoir had already been suggested by HOUSHAYMI et al. (2002), when seropositive results for *M. capricolum subsp. capripneumoniae* were found in sheep. Several sources (BÖLSKE et al., 1995; HOUSHAYMI et al., 2002; SHIFERAW et al. 2006; ARIF et al., 2007) have now reported the clinical occurrence of CCPP in sheep and some have also isolated the causative agent. There were also some individual mouflon at AWWP that died during the outbreak of CCPP with diagnosis of *M. capricolum* subsp. *capripneumoniae* (ARIF et al., 2007). BÖLSKE et al. (1995) even reports an outbreak in which as many domestic sheep as goats died. These results are in contrast to the work of MCMARTIN et al. (1980), which described that CCPP does not cause disease in sheep, neither spontaneously nor experimentally. However, experimental studies to test Koch‘s postulates are still lacking in sheep.

One of the disease patterns observed in mouflon but never found in goats was characterised by general icterus, splenomegaly and hepatomegaly, which is consistent with piroplasmosis (ECKERT et al., 2005). At the same time, ticks were only reported in sheep; these observations are consistent with *Theileria* infection in all cases. A crucial factor for infection is the presence of vector ticks, which – for unknown reasons - have never been reported in goat species. However, there is limited additional evidence that Theileriosis might affect goats less than sheep. In an experiment where 4 domestic goats and sheep each were deliberately infected with *Theileria lestoquardi*, all animals seroconverted, piroplasm parasitemia and positive blood PCR results were obtained for all sheep, but parasitemia and a positive PCR was only observed in 1 of the goats (KIRVAR et al., 1998). In a survey on *Theileria* infections in small ruminants in Turkey, ALTAY et al. (2007) found a distinctively higher prevalence in domestic sheep than in domestic goats.

One more species difference was found with respect to parasites. Coccidia are frequent gut parasite in faecal samples investigated at AWWP. They were not differentiated any further, but according to ECKERT et al. (2005) there are at least 13 different pathologic agents for cattle, sheep and goats, which all belong to the taxon *Eimeria*. Clinical disease mainly occurs up to the age of 1.5 years; usually an enzootic stability develops due to the early achievement of a protecting immunity (ECKERT et al., 2005). At AWWP the mouflons seemed to be more susceptible to pathological manifestations than the goat species, as a higher proportion of animals with gastrointestinal disorders had Coccidia-positive

faeces. In this context, it is, however, also important to mention that coccidiosis is an illness to which factors like crowding, stress, climate and others can contribute - and Laristan mouflon always had the largest herd size.
The mouflon population in AWWP was continuously increasing. As long as the animals have a fixed amount of space available, the expected consequence would be an increasing newborn mortality due to crowding (density-dependent) effects. Although this trend appeared to occur in 2004 and 2005, it was reversed in 2006, most likely because of additional enclosure space for the mouflon herd – an indirect effect of the dramatic population declines in wild goats and Nubian ibex.
As for reproduction, a good feeding management during pregnancy might have considerable importance. No newborn lighter than 1.5 kg could be observed to get older than 2.5 years. For example, KEEN et al., (1997) investigated the effect of birth weight in sheep and found low birth weight to be one of the cumulative factors that decrease productivity in infected animals. Similar effects of birth weight on survival have been demonstrated in free-ranging populations of wild sheep (CLUTTON-BROCK et al., 1992); the same study also documents that twins are usually of lower birth weight than singletons. An interesting question is whether twin births, which lead to lower birth weights, can be avoided by restrictive feeding around ovulation, but high birth weight assured by more intensive feeding during pregnancy. Experimental evidence for effects of feeding on twinning rates in sheep are controversial and probably differ between species and breeds (HOEFS, 1978; LASSOUED et al., 2004; ROBINSON et al., 2006).
It is a common pattern in many zoos to exhibit closely related species in adjoining exhibits. Actually, it may be considered a desired strategy to keep animals that are susceptible to the same diseases in spatial vicinity, in order to make logistics of hygiene or emergency procedures (such as fencing off during a notifiable epidemic) easier. Based on the experiences with mouflon and *Capra* spp. at AWWP in this study, however, it appears that the opposite strategy could also have epidemiological advantages – to keep closely related species spatially separate, to avoid disease spread in all susceptible species.

Acknowledgments

This investigation was possible because of the kindness of Sheikh Saoud Mohammed Bin Ali Al-Thani and his support of the Zoo Research Camp (ZRC) 2009 organised by AWWP and the Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich. The ZRC 2009 was also supported by the Vetsuisse Faculty and the Society of Swiss Veterinarians.

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