Introduction

Infectious keratoconjunctivitis (IKC) is recognised worldwide as a common condition affecting the eyes of domestic sheep and goats (36, 61). In the European Alps, IKC also occurs frequently in free-ranging Alpine chamois (Rupicapra r. rupicapra) and Alpine ibex (Capra i. ibex) (27). In addition, IKC has been described in other wild Caprinae species, such as Pyrenean chamois (Rupicapra p. pyrenaica) in the Pyrenees (10, 52), European mouflon (Ovis o. musimon) in France (12, 55, 59), and Himalayan thar (Hemitragus jemlahicus) in New Zealand (13). Infectious keratoconjunctivitis is a specific ocular disease characterised by inflammation of the conjunctiva and cornea. In the most advanced stages, the cornea is opaque or even perforated (45). The principal single cause of IKC in chamois, ibex, and other Caprinae species (including domestic sheep and goats) is Mycoplasma conjunctivae (3).
The first reported outbreak of IKC in wild Caprinae (Eine infektiöse Kerato-Conjunktivitis bei Gemen) dates from 1916 and refers to chamois in the Austrian Alps (58). Since then, numerous outbreaks have been described in other alpine countries, including Switzerland (1, 9, 15, 23, 38, 53), Italy (6, 11, 32, 41), France (29, 33, 42) and Slovenia (62). However, the origin of outbreaks of IKC remains unclear in most cases, and description of disease progression is usually incomplete due to the difficulty of recognising mild IKC symptoms in remote segments of the habitat. Furthermore, habitats of wild Caprinae populations are often politically subdivided (24), and collaboration among administrative units at the population level, essential for complete IKC records, is not yet common.

Importance for animal health

Infectious keratoconjunctivitis caused by M. conjunctivae is an inflammatory condition of the conjunctiva and cornea in domestic and wild Caprinae. In the early stages, the disease presents as a unilateral or bilateral conjunctivitis with hyperaemia of the vessels. Untreated cases may progress to mucopurulent conjunctivitis and corneal ulceration resulting in opaque corneas and transient blindness. In domestic Caprinae (sheep and goats), IKC is a nuisance to farmers since animals require treatment and some nursing to reduce the period of blindness (17).

The impact of IKC on sheep health is comparatively low; in infected sheep herds, symptoms are moderate or absent in adults, and in lambs, M. conjunctivae is generally only mildly pathogenic. Outbreaks associated with severe symptoms are usually observed when the agent is introduced into naive herds by infected animals purchased from other flocks (2, 46).

While IKC usually provokes mild symptoms in domestic sheep and goats, the consequences in wildlife can be fatal. Blind chamois and ibex face particularly treacherous circumstances in steep rocky areas and affected animals may fall from cliffs. In wild Caprinae, the disease may also progress to ruptured corneas (Fig. 1) and lead to death due to starvation if perforation is bilateral. In particular situations, mortality can reach 30% and have a marked impact on demography.

Aetiology

The term IKC is used to describe a clinical condition which is not always ascribable to the same infectious agent (36). Aetiology of IKC in chamois and other wild Caprinae species has been a matter of debate for a long time (30). Several agents, including Branhamella ovis, Chlamydia psittaci, Corynebacterium pyogenes, M. conjunctivae, Richettsia (Colesiota) conjunctivae and Staphylococcus aureus have been suspected as aetiological agents of IKC (21). However, in domestic sheep, pathogenicity has been demonstrated for only two of the micro-organisms which have been isolated from the eyes, namely: C. psittaci and M. conjunctivae (36, 37, 63). Pathogenicity of M. conjunctivae has also been demonstrated in the domestic goat (61), Alpine ibex (25) and European mouflon (59), and in addition, this agent has been implicated as the aetiological agent of IKC in Alpine chamois (15, 32, 50). Mycoplasma conjunctivae is now generally agreed to be the principal single cause of IKC in domestic and wild Caprinae (3). Phylogenetically, M. conjunctivae belongs to the Mycoplasma neurolyticum cluster of the hominis group, and this agent is closely related to M. bovoculi and M. ovipneumoniae (51).

The first isolation of M. conjunctivae from sheep eyes was performed by Surman in Australia in 1968. The agent was described and named by Barile et al. in 1972 (5). Mycoplasma conjunctivae has been isolated from domestic sheep and goats in North America, Europe, South Africa, Saudi Arabia and Australia (39, 63). In most countries, seroprevalence in domestic Caprinae is unknown. Therefore, further epidemiological studies are required to elucidate the extent of the infection.

Klingler et al. first isolated M. conjunctivae from chamois in 1969 (38). The strains were identified six years later by Nicolet and Frendt (50). More recently, M. conjunctivae has been detected in two other wild Caprinae species, namely: Alpine ibex (44) and European mouflon (59). However, M. conjunctivae is also likely to be present in other species of Caprinae, such as Himalayan thar and Pyrenean

Fig. 1
Right eye of a chamois (Rupicapra r. rupicapra) affected by infectious keratoconjunctivitis
The cornea has perforated and presents a cicatrix. Blindness is irreversible in this case
chamois. Presumably, *M. conjunctivae* is specific for Caprinae in general (i.e. goats, sheep and their relatives).

**Laboratory diagnosis**

In wild Caprinae, the occurrence of several animals showing bilateral keratoconjunctivitis in a distinct region within a short period is likely to be associated with an *M. conjunctivae* infection. However, diagnosis of mycoplasmal IKC requires detection of *M. conjunctivae* or of specific *M. conjunctivae* antibodies in affected animals.

The classical method for the diagnosis of *M. conjunctivae* infections is isolation of the organism by culture and subsequent identification by immunological methods (18, 48). For culture, eye swabs are dipped into Transwab® transport medium and processed within 24 h of collection. Culture is performed on standard mycoplasma broth medium enriched with 20% horse serum, 2.5% yeast extract and 1% glucose (4).

Culture of *M. conjunctivae* is cumbersome and requires specialised technical experience. Therefore, a specific polymerase chain reaction (PCR) assay was recently developed for the rapid direct detection of this pathogen in clinical material (26). For detection of *M. conjunctivae* by PCR, conjunctival swabs are dipped in tubes without transport medium and stored at –18°C until analysis. Nested PCR is based on unique sequences of the *rrs* genes (16S ribosomal ribonucleic acid [rRNA]) of *M. conjunctivae*. Sensitivity of nested PCR is usually higher than that obtained by cultivating the mycoplasma. Furthermore, identification of *M. conjunctivae* by nested PCR does not require special care in the transportation of the samples. This method plays a central role in the diagnosis of IKC in Caprinae.

An indirect enzyme-linked immunosorbent assay (ELISA) method based on the Tween 20 extracted fraction of *M. conjunctivae* strain HRC/581 has recently been developed to detect *M. conjunctivae* antibodies in sera of domestic sheep (7). For the analysis of the sheep sera, serum is diluted 1/10, applied to the plates and analysed using a commercially-available monoclonal antibody directed against ruminant immunoglobulin G (IgG) conjugate to horseradish peroxidase, according to the instructions provided by the manufacturer. The optical densities are measured with a photometer at a wavelength of 405 nm. The value of each sample is expressed as a percentage of a positive reference standard, taking a negative reference serum as zero value. The cut-off level (37%) was set 3 standard deviations higher than the mean value for negative controls according to the test validation (7). At present, studies are being performed to develop and evaluate an ELISA to be used in Alpine chamois (28).

**Clinical manifestations and pathology**

The first visible signs of IKC are hyperaemic conjunctiva and congestion of conjunctival vessels associated with serous or mucous effusions (Fig. 2). In the initial stages of infection, the conjunctiva is infiltrated with mononuclear cells (2, 36, 45). Conjunctivitis can persist for some weeks without any sign of keratitis, but the disease may progress to more severe forms. Mild keratitis is characterised by either oedema with accompanying infiltration of neutrophils or by perilimic neovascularisation with mostly mononuclear inflammatory infiltration. Perlimbic neovascularisation can occur without preceding corneal oedema in the vertex area when keratitis is mild (45). Vascularisation occurs in response to a variety of cytokines released by damaged corneal epithelium, stromal keratocytes, or immigrant leukocytes, rather than as a response to the oedema (19). Superficial oedema is variable in the more advanced cases, but is always severe, either with marked neovascularisation or necrosis. Corneal ulceration may occur in severe cases, and mixed cellular infiltration is present when neovascularisation extends to the ulcerated area. According to Wilcock, ulcerated epithelia lead to infiltration with neutrophils, and neutrophils may be present in response to secondary bacterial infection (64). In the most severe cases, cornea may perforate. Ruptured corneas show anterior synchia and melanin deposits forming staphyloma (45). The stages are progressive, but healing may commence at any time, unless the cornea is ruptured.

![Fig. 2](image-url)

**Infectious keratoconjunctivitis in domestic sheep: lamb showing reddened, swollen eyelids and sero-mucous ocular effusion**

Infectious keratoconjunctivitis caused by *M. conjunctivae* is a non-generalised, specific ocular disease. The other organs, including lungs, show no alterations suggestive of changes induced by *M. conjunctivae*. The absence of
pathological changes in the brain of blind ibex and chamois presenting circling movements suggests that in wild Caprinae affected by IKC, changes in behaviour are not necessarily a consequence of cerebral lesions. Such changes may simply be due to disorientation and stress in totally blind animals (15, 45).

**Biology of infection**

In IKC, the period of incubation after experimental infection with *M. conjunctivae* is short (two to four days) (8, 25, 37, 63). In individual animals, clinical signs last two weeks to two months. However, after the disappearance of symptoms, animals can act as healthy carriers of *M. conjunctivae*. The eyes of sheep without clinical signs of IKC were nevertheless found to be infected with the agent of IKC (35, 37, 40, 46). However, persistence of *M. conjunctivae* infection in individual animals does not exceed three to six months (35). Similar to the situation in sheep, bacteriological results in Alpine ibex suggest a temporary persistence of *M. conjunctivae* only (25).

In Caprinae, immune response to *M. conjunctivae* infections appears to be strong. In experimental infections, specific antibodies, as detected by immunoblot analysis, appeared two to four weeks post infection (16). Immunoblot analysis allowed identification of the principal specific immunogenic proteins of *M. conjunctivae* in naturally- and experimentally-infected chamois, ibex and domestic sheep (Fig. 3). Major immunogenic proteins using sera had molecular masses of 175, 83, 68, 60, 50, 42, 36 and 33 kDa. Antibodies to the 175, 73, 68, 60 and 33 kDa antigens appeared to be specific to *M. conjunctivae*. Naturally-infected animals demonstrated much stronger immune reactions than those infected experimentally (16). However, little is known about the protective effect of acquired immunity. Although preliminary results in domestic sheep indicate that clinical signs may be weaker in the course of a second *M. conjunctivae* infection, the immunity acquired is insufficient to resist natural infections.

In outbreaks of IKC in chamois and ibex, spontaneous recovery is the most prevalent course of the disease (20). Mortality is usually low (<5%), and in most reports, less than fifty dead chamois were recorded during the course of an IKC epidemic. However, in particular situations mortality can reach 30%. Examples associated with a high mortality in chamois are outbreaks of IKC in the Gran Paradiso (Italy) and Vanoise (France) National Parks from 1981 to 1983 (33, 41), in the Aosta Valley (Italy) in 1998 (32), and in the Simmental-Gruyère-Region (Switzerland) from 1997 to 1999 (15). In Simmental-Gruyère, a total of 420 chamois died of the consequences of IKC (Fig. 4). This is the highest number of deaths reported during an IKC outbreak since 1919, when the first epidemic in chamois was described in the Alps by Stroh (58). The reason for differences in mortality is still open to question; those suggested are differences in virulence of distinct *M. conjunctivae* strains, particular predisposition of hosts (e.g. genotype, health condition, overcrowding), secondary infections or environmental predisposing factors (e.g. ultraviolet-irradiation) (47). Recovery of demographic parameters in the post-epidemic period is rapid or occurs within a time lag of five to six years (42), depending on the mortality rate observed.

In wild Caprinae, mortality has been associated with IKC, especially in females and juveniles (10, 15, 21, 28, 53). The number of affected adult males recorded is usually low, possibly reflecting a lower percentage of this sex/age-class within populations of chamois. This would not be surprising, since in some regions the number of old male
The hunted chamois is disproportionately high compared to other sex/age-classes (22). Furthermore, sexual segregation of adult males and solitary living during most of the year could lower the probability of infection with \textit{M. conjunctivae} (56).

**Epidemiology of infection**

**Transmission of \textit{Mycoplasma conjunctivae}**

Mycoplasmal IKC is highly contagious within herds (2); the agent, \textit{M. conjunctivae}, is excreted in ocular effusions. Given that mycoplasmal organisms do not survive for a long time in the environment, transmission must occur through direct contact or after a short delay. According to recent publications, mycoplasmas can be spread via aerosol (43, 57) and by eye-frequenting insects (14, 31). However, intraspecific transmission of \textit{M. conjunctivae} does not require vectors and occurs predominantly or exclusively by contact (40).

On alpine meadows in Switzerland, IKC occurs at the same time in the same regions in several host species (23, 50), and short-distance encounters between free-ranging individuals of different Caprinae species, domestic and wild, are not uncommon events in the Alps (M.-P. Ryser-Degiorgis, P. Ingold, H. Tenhu, A.M. Tébar, A. Ryser and M. Giacometti, unpublished data). Therefore, interspecific transmission of \textit{M. conjunctivae} between domestic and wild Caprinae species is likely to occur. However, interspecific body contacts are rare, and the probability of interspecific transmission of infectious agents by physical contact appears to be rather low. For IKC, encounters can nevertheless be considered as a predisposing factor for the interspecific transmission of \textit{M. conjunctivae}; aerosol infection or transmission by eye-frequenting insects (Fig. 5) are possible, and the probability of interspecific transmission increases as distance between animals decreases. Excessive lachrymation is an attractive source of proteins, salt and water for insects (49, 65), and the feeding habits of flies include constant changing of hosts grazing.

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**Fig. 4**

_Distribution of 420 chamois (\textit{Rupicapra r. rupicapra}) which died of the consequences of infectious keratoconjunctivitis from 1997 to 1999 in the Simmental-Gruyères region of the north-western Swiss Alps_.

Different colours are used for different time periods (all three months, except for the first and the last time periods which lasted two months each). Brown triangles represent mountain peaks, black squares represent villages, and rivers are presented in blue.
close to each other. Four genera of Muscidae were identified as potential vectors of *M. conjunctivae*, namely: *Hydrotaea*, *Musca*, *Morellia* and *Polietes* (14). Flies are likely to play a role as accessory vectors, but their role might be of primary importance in interspecific transmission of *M. conjunctivae* on alpine meadows.

In chamois, epidemics of IKC progress at an average speed of 15 km/year (15), which is three to four times faster than the progression reported for sarcoptic mange in chamois in the eastern Italian Alps (54). This may be associated with differences in host density, social organisation and habitat morphology, but the highly contagious character of IKC may play the most important role in faster progression. In some outbreaks of IKC, intraspecific transmission of *M. conjunctivae* occurs throughout the year (15). However, losses due to IKC in chamois are more frequent during the summer and autumn (28). This coincides with the presence of domestic sheep grazing on summer pastures.

Treatment and prevention

In free-ranging Caprinae, identification of affected animals in remote segments of the habitat is difficult. Spillover of *M. conjunctivae* from domestic Caprinae may have occurred several weeks before the first affected animal is observed in a particular area, and the *M. conjunctivae* infection is then likely to have already spread within the whole herd. In addition, spontaneous recovery is the most prevalent course of the disease. Therefore, culling all animals affected with IKC, regardless of the severity of IKC signs, is an inappropriate method of disease control.

A special effort should be made to minimise unnecessary human disturbance in affected areas (e.g. cross-country-walks and uncontrolled hunting), to avoid putting animals to flight (which could lead to falls and injury or death), and to prevent long-distance movements of infected animals. Migrating animals could transmit *M. conjunctivae* to neighbouring, non-infected herds and widen the diseased area. Individuals which either present irreversible ocular lesions (corneal perforation) or are in poor general condition and/or injured should be shot by professional gamekeepers to prevent suffering. Treatment of affected free-ranging chamois or ibex should not be attempted.

Prevention of IKC in wild Caprinae should therefore focus on hindering the spillover of *M. conjunctivae* from livestock. Thus, use of salt licks should be restricted to a minimum to reduce the frequency of encounters between the domestic sheep population in Switzerland (35). At least one positive animal was detected in 89% of the herds, and in positive herds, 57% of the individual animals tested positive. Risk factors for maintenance of *M. conjunctivae* infections in domestic sheep have not yet been studied. In Switzerland, herd size did not appear to play an important role, but regional differences were not particularly relevant. The mixing of sheep for grazing, shows and markets, the introduction of new animals to a flock, as well as the presence of (susceptible) lambs during most of the year appear to enable maintenance of *M. conjunctivae* infection within the national sheep population. Importantly, the disease can be spread to other flocks by infected sheep which are clinically healthy. In contrast, the interrelationship with wild Caprinae does not appear to be a condition of maintaining infection, as shown by studies in Switzerland. In sheep, IKC occurs in winter, at which time these animals are housed and no encounters with chamois and ibex occur. In addition, *M. conjunctivae* infections in sheep occur in countries where free-ranging susceptible wild Caprinae species are absent, such as the Netherlands (39), the United Kingdom (34) and South Africa (63).

**Maintenance of *Mycoplasma conjunctivae* in host populations**

Persistence of infections in animal populations is principally determined by the potential of the pathogen to maintain its life cycle in the host and by characteristics of the host population such as number of individuals, percentage of susceptible animals within the population and interaction between animals (60). A recent study in the eastern Swiss Alps (28) indicated that *M. conjunctivae* infection is not self-maintained in alpine chamois. This may be due to the limited contact between chamois from different herds and to the fact that persistence of infection in individual animals does not exceed three to six months, as shown in sheep (35).

In contrast to the situation in wild Caprinae, *M. conjunctivae* infection is endemic and self-maintained in the domestic sheep population in Switzerland (35). At least one positive animal was detected in 89% of the herds, and in positive herds, 57% of the individual animals tested positive. Risk factors for maintenance of *M. conjunctivae* infections in domestic sheep have not yet been studied. In Switzerland, herd size did not appear to play an important role, but regional differences were not particularly relevant. The mixing of sheep for grazing, shows and markets, the introduction of new animals to a flock, as well as the presence of (susceptible) lambs during most of the year appear to enable maintenance of *M. conjunctivae* infection within the national sheep population. Importantly, the disease can be spread to other flocks by infected sheep which are clinically healthy. In contrast, the interrelationship with wild Caprinae does not appear to be a condition of maintaining infection, as shown by studies in Switzerland. In sheep, IKC occurs in winter, at which time these animals are housed and no encounters with chamois and ibex occur. In addition, *M. conjunctivae* infections in sheep occur in countries where free-ranging susceptible wild Caprinae species are absent, such as the Netherlands (39), the United Kingdom (34) and South Africa (63).
individuals of different Caprinae species. Domestic sheep showing ocular effusion should be treated before being moved to alpine meadows during the summer. Topical treatments in domestic sheep should use broad spectrum antibiotics such as oxytetracycline or chlortetracycline, in either ointment or powder form. Several treatments are often necessary in severe cases and relapses commonly occur. Systemic (intramuscular) treatments may be applied alternatively or additionally. Penicillin or streptomycin are ineffective (36). Unfortunately, no vaccine exists against infections with M. conjunctivae in sheep.

Perspectives

Infection with M. conjunctivae is an exotic emerging disease of Caprinae. Infectious keratoconjunctivitis is probably not self-maintained in wild Caprinae populations, and spillover of the agent from domestic sheep living in proximity during the summer may be the origin of point-source epidemics in wildlife. However, little is known about the occurrence of IKC in sheep sharing pastures with wild Caprinae species. Therefore, studies are required to evaluate the distribution of M. conjunctivae infection in domestic sheep in several countries and to assess the risk of IKC spillover from domestic animals to wildlife. For this purpose, new molecular and serological methods have recently been developed for the rapid and specific detection of M. conjunctivae infections (7, 26). In addition, further studies are needed to improve understanding of mechanisms of interspecific transmission of the pathogen and to evaluate infection maintenance in both domestic and wild Caprinae populations. In wild Caprinae, mortality following IKC outbreaks can reach 30%, and blind chamois and ibex face particularly treacherous circumstances in steep rocky areas. The authors therefore suggest further epidemiological and immunological studies be undertaken to develop tools which could lead to the control of M. conjunctivae infections in domestic sheep. This includes molecular studies on pathogenesis and development of effective and safe vaccines for immunoprophylaxis in sheep.

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La kérato-conjonctivite infectieuse du bouquetin, du chamois et d’autres Caprinae

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Résumé

La kérato-conjonctivite infectieuse due à Mycoplasma conjunctivae est une infection oculaire très contagieuse, fréquente chez les ovins et caprins domestiques. Dans les Alpes européennes, la kérato-conjonctivite infectieuse est souvent observée chez le chamois des Alpes (Rupicapra r. rupicapra) et chez le bouquetin des Alpes (Capra i. ibex), mais la maladie a également été décrite chez d’autres Caprinae sauvages dans les Pyrénées et en Nouvelle-Zélande. L’infection se caractérise par une inflammation de la conjonctive et de la cornée ; aux stades les plus avancés, il se produit une opacité, voire une perforation de la cornée. Chez les chamois et les bouquetins atteints de kérato-conjonctivite infectieuse, une guérison spontanée est l’issue la plus courante de la maladie. Cependant, la mortalité peut occasionnellement atteindre 30%. Des études récentes effectuées dans l’est de la Suisse montrent que l’infection due à
M. conjunctivae n’est pas auto-entretenue chez les chamois. En revanche, la maladie est endémique et auto-entretenue chez les ovins domestiques. Le contact avec l’agent excrété par des ovins vivant à proximité pendant l’estive peut être à l’origine d’épidémies ponctuelles chez les Caprinae sauvages. Les mouches jouent probablement un rôle majeur dans la transmission interspécifique de M. conjunctivae dans les prairies alpines. Lorsque la kérato-conjonctivite infectieuse se déclare chez les animaux sauvages, il faut veiller tout particulièrement à limiter les dérangements anthropogènes superflus dans les zones atteintes. Toutefois, les animaux présentant des lésions oculaires irréversibles doivent être abattus par les garde-chasse pour leur éviter de souffrir. La prévention de la kérato-conjonctivite infectieuse chez les Caprinae sauvages consiste essentiellement à empêcher la propagation de M. conjunctivae par les animaux domestiques. Cependant, des études doivent être faites pour analyser la répartition de l’infection due à M. conjunctivae chez les ovins domestiques dans plusieurs pays et pour évaluer le risque de transmission de la kérato-conjonctivite infectieuse des animaux domestiques à la faune sauvage. De plus, des études immunologiques doivent être effectuées pour développer des outils permettant de lutter contre l’infection due à M. conjunctivae chez les ovins domestiques.

Mots-clés

Queratoconjuntivitis infecciosa del íbice, la gamuza y otros Caprinae

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Resumen
La queratoconjuntivitis infecciosa causada por Mycoplasma conjunctivae es una infección ocular extremadamente contagiosa que afecta con frecuencia a ovejas y cabras domésticas. En los Alpes europeos, la enfermedad se observa a menudo en la gamuza alpina (Rupicapra r. rupicapra) y el íbice alpino (Capra i. ibex), aunque también está descrita en otros Caprinae salvajes de los Pirineos y Nueva Zelanda. Esta infección se caracteriza por la inflamación de la conjuntiva y de la córnea, que en las fases más avanzadas se vuelve opaca o incluso se perfura. En la gamuza y el íbice, el desenlace más frecuente de los brotes infecciosos es la recuperación espontánea. Sin embargo, la mortalidad puede alcanzar a veces tasas de hasta un 30%. Estudios recientes efectuados en el Este de Suiza pusieron de manifiesto que la infección por M. conjunctivae no se autoentiene en la gamuza. En las poblaciones de ovejas domésticas, en cambio, es endémica y automeutante. La propagación del agente a partir de ovejas trasladadas a pastos de altura en verano podría ser la fuente de brotes de tipo localizado entre Caprinae salvajes. Las moscas son seguramente el principal vehículo de transmisión interspécífica de M. conjunctivae en las praderas alpinas. Cuando se declaren brotes de queratoconjuntivitis infecciosa entre la fauna salvaje, hay que hacer lo posible por evitar toda intrusión humana innecesaria en las zonas afectadas. No obstante, conviene que los guardas forestales sacrifiquen a los ejemplares con lesiones oculares irreversibles a fin de evitarles sufrimientos.
Para prevenir la aparición de la enfermedad en Caprinae salvajes es preciso ante todo evitar que *M. conjunctivae* se propague a partir de animales domésticos. Pero para ello se requieren estudios que determinen la distribución de la infección en ovejas domésticas de diversos países y evalúen el riesgo de propagación de la fauna doméstica a la salvaje. Convendría además llevar a cabo estudios inmunológicos que sirvan para elaborar técnicas aplicables a la lucha contra la infección en la oveja doméstica.

**Palabras clave**

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**References**


