Published by Associazione Teriologica Italiana
Hystrix, the Italian Journal of Mammalogy
Volume 25 (1): 25–30, 2014
Available online at:
http://www.italian-journal-of-mammalogy.it/article/view/9460/pdf
doi:10.4404/hystrix-25.1-9460

Research Article

Spatial and temporal explorative analysis of sarcoptic mange in Alpine chamois (*Rupicapra r. rupicapra*)

Sara Turchetto[a,*], Federica Obber[a], Roberto Permunian[b], Stefano Vendrami[c], Monica Lorenzetto[d], Nicola Ferré[d], Laura Stancampiano[e], Luca Rossi[f], Carlo Vittorio Citterio[a]

[a] *Istituto Zooprofilattico Sperimentale delle Venezie - SCT2-Belluno, Via Cappellari 44/a, 32100 Belluno, Italy*
[b] *Parco Nazionale Gran Paradiso, Via della Rocca 47, 10123 Torino, Italy*
[c] *Provincia di Belluno, Via S. Andrea 5, 32100 Belluno, Italy*
[d] *Istituto Zooprofilattico Sperimentale delle Venezie, Viale dell'Università 10, 35020 Legnaro (PD), Italy*
[e] *Alma Mater Studiorum - Università di Bologna, Dipartimento di Scienze Mediche Veterinarie, Via Tolara di Sopra 50, 40064 Ozzano dell'Emilia (BO), Italy*
[f] *Università di Torino, Dipartimento di Scienze Veterinarie, Via L. da Vinci 44, 10095 Grugliasco (TO), Italy*

Keywords:
Sarcoptes
chamois
mange
epidemiology

Article history:
Received: 9 January 2014
Accepted: 30 May 2014

Acknowledgements
The present study has been partially funded by the Italian Ministry of Health - RC IZSVe 14/07.
The Authors are grateful to the Wildlife Management Office of Belluno Province and to the Belluno Hunting Preserves for their support. The Authors are also grateful to Isabella and Philip McGuinness for English supervision and to the two Anonymous Referees for their contribution in improving the manuscript.

Abstract

The sarcoptic mange epizootic affecting chamois in the Dolomites Alps since 1995 has risen considerable concern in a management and conservation perspective, due to its strong impact on chamois and ibex populations. A remarkable amount of data has been collected by different wildlife research and management institutions, in order to analyze mange patterns and develop possible strategies to control the disease. The present study is aimed at providing a population-related figure of the spatial and temporal dynamics of clinical sarcoptic mange in alpine chamois, proposing an approach in which relevant basic concepts and parameters, as the definition of the epidemic front and its spreading speed, can be estimated and framed. The epidemic front was referred to the different mountain massifs, corresponding to well established management units of the chamois in the study area; moreover, the mange-related mortality peak at the massif level was used (in substitution of the index case/s) for temporal analysis of the disease spreading. Two speeds of the front have been estimated: a first raw average speed of about 3.38 km/year, and a second refined speed of 4.64±3.12 km/year, more consistent to the variability in the field. The time series analysis showed that the impact of mange increases over the late winter months, reaching a peak in early spring.

Our results strengthen the conclusions of previous studies, proposing a new frame to include other studies in progress on the Alpine chamois-*Sarcoptes* interactions

Introduction

Sarcoptic mange is a cutaneous infection due to the burrowing mite *Sarcoptes scabiei*, worldwide distributed in domestic and wild mammals, and represents the most severe disease affecting population dynamics of wild alpine bovids, such as the alpine chamois (*Rupicapra r. rupicapra*) and the alpine ibex (*Capra ibex*). Mange can have serious consequences for endangered species, where the loss of even a few individuals can be critical for conservation (Pence and Ueckermann, 2002). Moreover, this disease raises concerns also in game species, inducing dramatic population decreases. Concerning wild bovids, the most known examples are probably the mange epizootics affecting the Spanish ibex (*Capra pyrenaica*) in the South-East of Spain (Pérez et al., 1997; León-Vizcaíno et al., 1999), the alpine chamois in Austria (Schaschl, 2003) and the alpine chamois and ibex in the North-Eastern Italian Alps (Rossi et al., 1995, 2006).

Different strategies have been applied in wildlife to manage sarcoptic mange, as isolation and treatment of infected individuals in highly endangered species (Pence and Ueckermann, 2002), or changes of hunting strategies, including hunting suspension according to the epidemiological situation, as happens for chamois in North-Eastern Italy, where the present study was conducted. Actually, in 1995, the chamois population of the Dolomites (North-Eastern Italy) was affected by mange originating from bordering Austria. Since then, the disease has progressively spread along a main south-west axis. "Oil spot"-like spread (average yearly advancement ranging between 2.4 and 4.5 km) of the mange cases was observed, together with apparent "jumps", followed by the filling of the rear gap (Rossi et al., 2007). As described in previous studies (Rossi et al., 1995), in the territories progressively involved by the disease, after 10-12 years from the occurrence of the first peak of mange cases, a second definitely lower peak was observed in chamois. Moreover, in this area mange spread involved and severely affected the sympatric alpine ibex herds (Rossi et al., 2006).

The occurrence and spread of this parasitic disease in the Eastern Italian Alps and the renewed attention by resource managers due to its demographic impact (estimated by some Authors even over 90% – Rossi et al. 1995; León-Vizcaíno et al. 1999), stimulated monitoring and research activities, from passive surveillance to the development of immunodiagnostic tests, from quantitative epidemiology to mathematical modeling, to genetic investigations on both parasite and hosts (Rossi et al., 1995; Guberti and Zamboni, 2000; Berrilli et al., 2002; Rossi et al., 2007; Rahman et al., 2010; Rasero et al., 2010; Cavallero. et al., 2012). Notwithstanding, additional research on mange in wildlife is deemed necessary at national and international level (Alasaad et al., 2011) to support sound conservation-oriented policies in infected areas and populations and, for this purposes, studies on the spatio-temporal distribution of sarcoptic mange could provide an useful support. Among the studies published on this topic in alpine chamois, Fuchs et al. (2000) and Fuchs and Deutz (2002) investigated on the presence of spatio-temporal clusters and critical spatial distances by mathematical and geostatistical methods in Styria (Austria), while Meneguz et al. (1996) and Rossi et al. (2007) described the spatial distribution of cases and estimated from the field data the spreading speed of the disease in North-Eastern Italy. In the present study, 15 years

*Corresponding author
Email address: sara.turchetto@izsvenezie.it (Sara Turchetto)

©2014 Associazione Teriologica Italiana
doi:10.4404/hystrix-25.1-9460

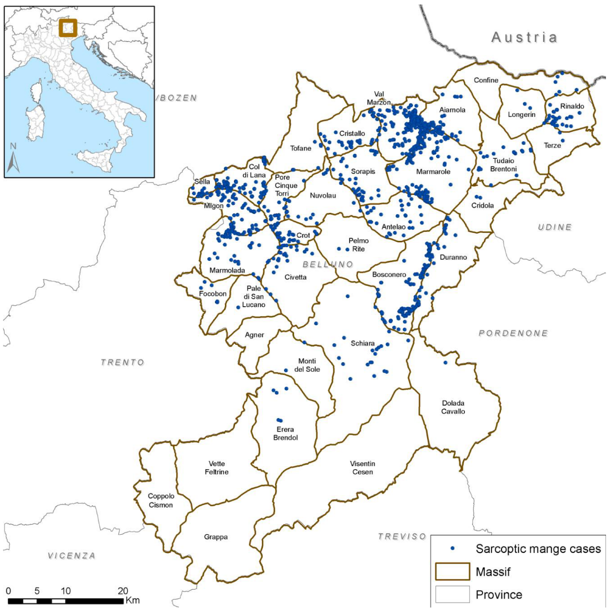

Figure 1 – Mountain massifs of the Belluno province and sarcoptic mange cases distribution (1162 scabietic chamois from 1995 to 2010).

of passive surveillance data, made available by the Province of Belluno (Dolomites Alps – North-Eastern Italy) and deriving from the expertise of field wildlife and wildlife health managers, were analyzed in a GIS framework in order to: i) characterize the spatial and temporal patterns of the mange-related mortality; ii) refine and standardize the definition of "epidemic front", then characterizing its speed accordingly.

Materials and methods

Origin of the data and term explication

The data here analyzed derive from passive surveillance on scabietic chamois cases conducted in the territory of the Belluno province (xMin, yMin 1706322.83, 5084653.24 - xMax, yMax 1787460.78, 5175653.84) from 1995 to 2010. The definition of "case" here includes both the finding of a dead scabietic chamois and the euthanasic culling of a chamois affected by severe mange. Cases were confirmed by microscopical examination of affected skin samples for *S. scabiei*, or clinically in the field by observing the typical lesions (whenever the environmental situation or the carcass status hampered a proper collection of a skin sample). Each case was then geo-referenced by means of GIS software, using the Coordinate Reference System (CRS) Rome 1940 / Italy zone 1 (Monte Mario /Italy 1).

It must be pointed out that, in this paper:

- we adopted the term "mortality" *sensu lato*, to mean the number of cases that were found in a specific area and/or in a specific period: in fact, since it would be impossible to find all the affected chamois carcasses in the field, we could not provide an estimate of the mortality as the ratio between the number of deaths due to mange and the number of chamois at risk in the population (Thrusfield, 2005). As well, since no data are available on possible recovery from clinical mange in alpine chamois, we could not provide an estimate of lethality (mortality in the infected individuals – Guberti et al. 2003);
- even if we were not dealing with isolated populations but with metapopulations with exchange of individuals and genes, for a better readability we used the term "population" instead of "metapopulation".

Data analysis

A quantitative description of case frequency was performed first by gender and age according to the following raw age classes: kids (less than 1 year old), yearlings (1 year old), adults (more than 1 year old). A time series analysis (by the software R ver. 2.10.1 Copyright ©2009 The R Foundation for Statistical Computing; using the libraries `tseries` and `ast`) was then performed, in order to detect possible temporal/seasonal mortality peaks.

Concerning spatial analyses, all were performed by Quantum Gis (Qgis-Tethys) ver. 1.5.0 and ESRI© ArcMap™ 10.0. Thematic maps were produced for exploratory analysis of the case distribution and of the epidemic front. To define the front and estimate its spreading speed we chose the mountain massif as the elementary graphical unit, instead of the single cases. Actually, the mountain massif represents the basic management unit, being an expression of a relatively closed population compared to other neighboring ones (Loison et al., 1999; Ramanzin, 2005): thus, we adopted the massif as the basic epidemiological unit, within which we assumed that the probabilities of intraspecific (chamois to chamois) contacts are significantly higher than those between chamois belonging to different massifs. According to this assumption, the front of the disease was no longer deemed corresponding to the first case observed in an individual previously naive massif (the so-called "index case" of the massif), rather to the time when the peak of mange-induced mortality was detected in that massif. Actually, this is the moment when the epidemic appears likely to spread, shifting from an affected to a neighboring still unaffected massif (in 65% of cases, within 1-2 years). Graphically, it has been evidenced by a series of maps as the moment when a mountain massif that has reached the peak of cases tends to "switch off", whereas one or more contiguous mountain groups concurrently "switch on".

The basic spatial parameters of the epidemic were then estimated as follows.

To evaluate the average distance of displacement of the mange cases,

- first, the mean center (MCr) of all cases, regardless of the massif, was calculated for each year. Mean center identifies the geographic center (or the center of concentration) for a set of features. Distances between consecutive MCrs were measured and added up to a raw estimate of the disease spread range in the 15 years of the study. MCrs were represented on a specific map;
- the obtained range was then divided for the number of years, in order to estimate the average yearly speed of the case displacement with the relative standard deviation. Since the focus of this study was mainly on the epidemic front facing mange-free chamois populations, data concerning the secondary wave of mange (observed since 2007 and still ongoing) were excluded from this procedure.

To evaluate the front spreading speed, defined as described above,

- the year showing the mange peak for each mountain massif was identified, and the centroid of each massif (massif centroid – MCd – calculated on the basis of the polygon represented by its borders) was evidenced;
- for each massif, the year of mange peak was chosen to measure kilometric pairwise distances between the relative MCd and the MCd of the adjacent others showing the highest mortality in the following years, thus estimating also a series of pairwise time intervals (in years);
- the raw average speed of the epidemic front spread was then estimated, adding up all the pairwise distances and dividing this sum by the sum of all the pairwise time intervals;
- finally, to refine the front spreading speed estimate, each distance was then divided by the time interval taken to be filled by the epidemic front, so obtaining a series of speeds, the mean and standard deviation of which represented a refined estimate of the average front speed, including its range.

Results

The distribution of the mange cases by year and mountain massif is reported in Tab. 1.

From 1995 to 2010, in the Belluno province 1162 scabietic chamois were found in the field (Fig. 1). Of these, 453 were males and 545 females, while no information about gender was available for the remaining 164 cases. Concerning age classes, 159 were kids, 173 yearlings and 788 adults, while age was not determined in 42 cases.

Table 1 – Distribution of sarcoptic mange cases in chamois by year and mountain massif in the Belluno province.

Massif	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
	Year																
Val Marzon	6	13	52	78	16	4	9	1	1	1			5	10	6	3	205
Aiarnola		4	8	26			9	1	3				1	1	5	2	60
Confine		2		5													7
Marmarole			4	6	4	5	44	33	10	3			1	4	6	6	126
Longerin				1		1	1	2	1			1					7
Cristallo					1	3	6	12	42		1			1	1		67
Col di Lana						1	3	22	16	19	6	3	2	1	1		74
Sorapis						1	5	2	67	14	1		1				91
Rinaldo							11	5	5	2	2	1					26
Migon							3	12	11	17	21	3	1				68
Antelao							1	7	19	7	1				1		36
Sella							1	7	5	1							14
Pore-Cinque Torri								1	8	3	2	2	1				17
Terze								1	2	2	1						6
Tudaio-Brentoni									8		1	4			2	2	17
Tofane									7	3	5	3					18
Nuvolau									5	5	4	1	1				16
Agner									1								1
Crot									2	4	17	6	4	3		1	37
Marmolada										29	20	6		2			57
Pelmo-Rite											2						2
Bosconero											1	10	65	45	2	3	126
Civetta												14	10	1		1	26
Duranno													4	9	7	7	27
Schiara													2		7	13	22
Focobon													1	1	3	1	6
Pale di S. Lucano														1			1
Cridola															1	1	2
Total	6	19	64	116	21	15	93	106	213	110	85	54	99	79	42	40	1162

The results of the time series analysis are shown in Figure 2. No evidence of any temporal trend appears from these data, but a seasonal pattern was observed, with the highest case frequency in late winter-early spring (Feb-Apr), and the lowest one in summer (Jul-Aug).

The graphical approach to spatial and temporal analyses is represented in Figure 4a-d.

Figure 3 represents the mange MCrs in the whole of Belluno province for each year and regardless of the massif, while Fig. 4 shows an example of the massif-related approach, by a series of maps evidencing the displacement of the mange peak through the years, when a mountain massif that has reached the peak of cases tends to "switch off", whereas one or more contiguous mountain groups concurrently "switch on".

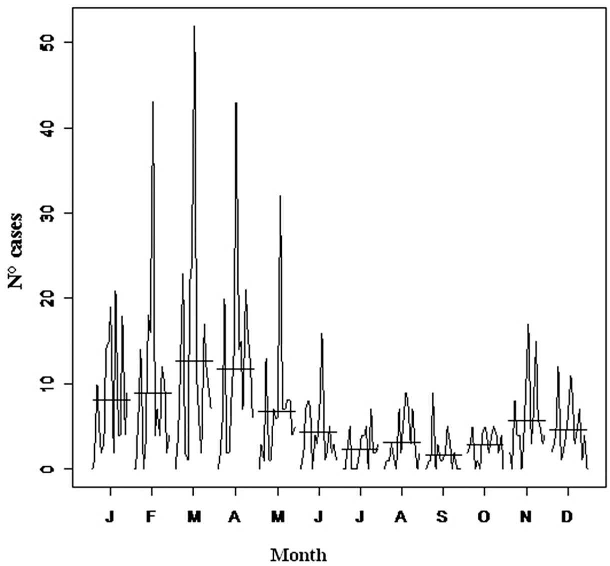

Figure 2 – Time series analysis of sarcoptic mange cases in chamois/month (monthplot) for the years 1995-2010 in Belluno province. Horizontal lines represent the monthly mean.

Table 2 shows the kilometric distances between consecutive MCrs. The disease has spread over 81.5 km in the space of 15 years, so that the average spreading speed of the cases was estimated in about 5.4±4.4 km/year.

Figure 5 shows the temporal distribution of the cases peaks in the mountain massifs, each one represented with its relative MCd.

Pairwise distances between the MCds of adjacent massifs with consecutive mortality peaks are shown in Tab. 3. The raw average speed

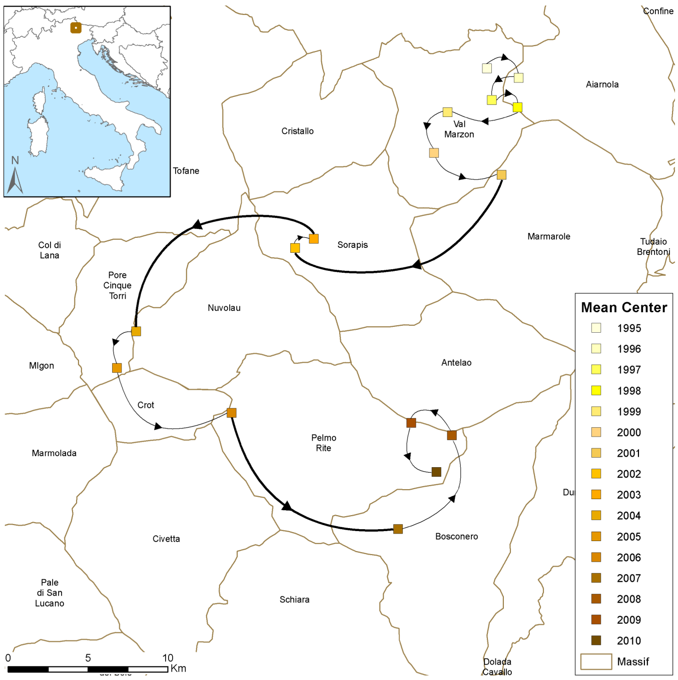

Figure 3 – The mean centers (MCrs) of sarcoptic mange cases in chamois in the whole Belluno province for each year of the study.

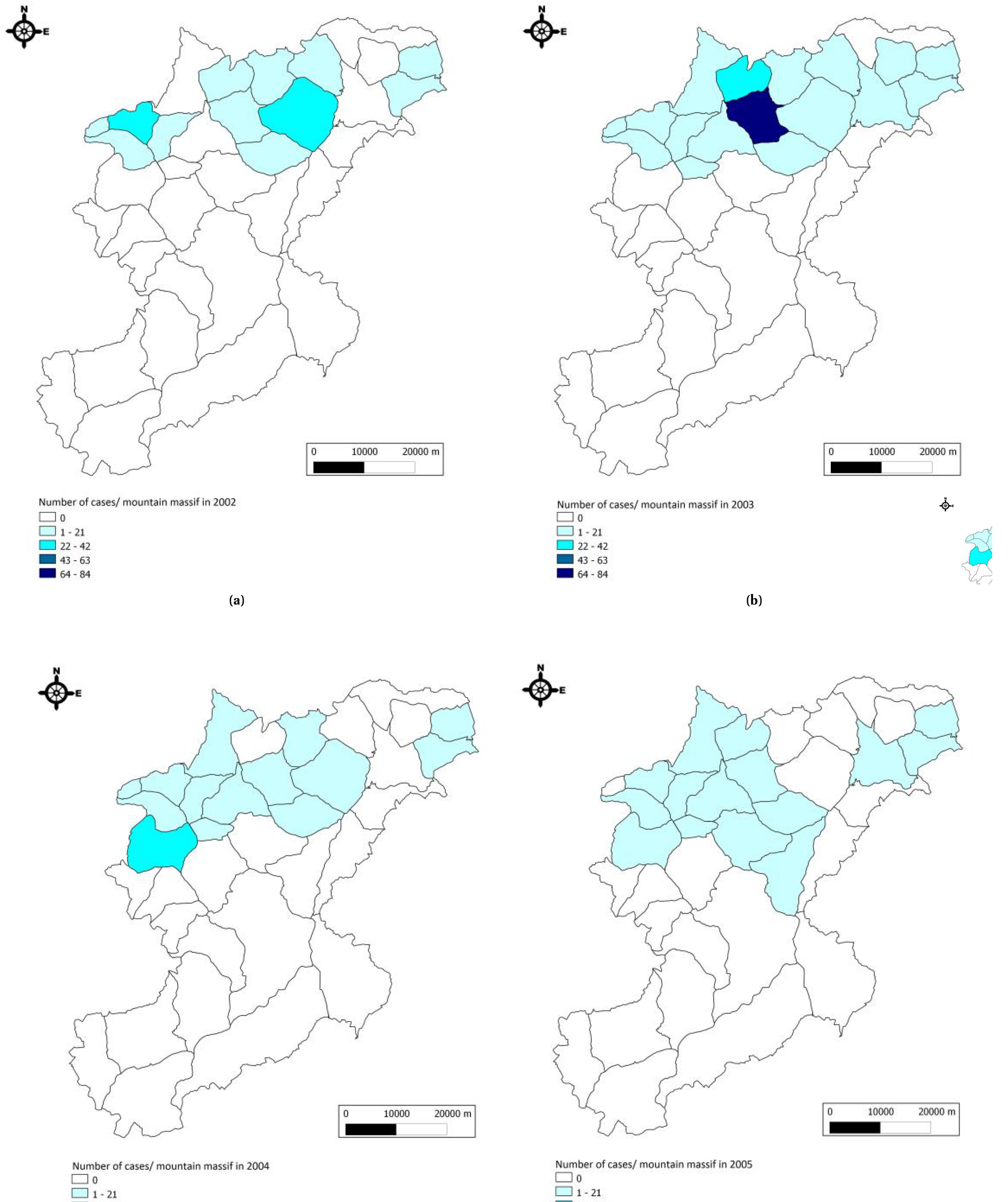

Figure 4 – Example of the epidemic spread of sarcoptic mange in chamois from 2002 to 2005. The maps show the moment at which a mountain massif that has reached the highest value of cases tends to "switch off", to "switch on" one or more contiguous mountain groups.

Table 2 – Kilometric distances between consecutive mean centers (MCrs) of sarcoptic mange cases in chamois of Belluno province.

Years	Distance between consecutive MCrs
1995-1996	2.1
1996-1997	2.2
1997-1998	1.8
1998-1999	4.5
1999-2000	2.8
2000-2001	4.5
2001-2002	13.9
2002-2003	1.2
2003-2004	12.4
2004-2005	2.5
2005-2006	7.8
2006-2007	12.9
2007-2008	6.8
2008-2009	2.7
2009-2010	3.4

of the epidemic front was estimated in 3.38 km/year, and the refined one was 4.64±3.12 km/year.

Discussion

The spread of sarcoptic mange in the chamois population mainly showed an "oil spot"-like expansion pattern from the north-eastern to the south-western massifs, as reported in Rossi et al. (2007).

The time series analysis confirmed the seasonality of clinical mange occurrence in chamois, as observed in previous studies (Arlian, 1989; Sokolova et al., 1989; Burgees, 1994; Rossi et al., 1995; Meneguz et al., 1996; Fernández-Morán et al., 1997; Rossi et al., 2007), identifying the seasonal cases peak in February-April and the lowest abundance in July-August.

No significant differences were observed in mortality by gender, as also evidenced by the sex ratio of mange mortality, confirming previous observations by Fernández-Morán et al. (1997) and Rossi et al. (2007). Likewise, the proportion of cases by age class was similar as previously reported (Rossi et al., 2007). However, it is important to point out that no information about possible different sensitivity to sarcoptic mange according to the age can be inferred from these data, since the field expertise clearly shows that carcasses of smaller individuals, as kids and yearlings, have a definitely lower probability to be found in the field compared to adult chamois (Morpurgo et al., 2014).

Table 3 – Pairwise distances between the centroids (MCds) of adjacent massifs with consecutive sarcoptic mange mortality peaks in chamois.

Source massif	Adjacent massif	Distance (km)	Time (years)	Speed (km/year)
Confine	Rinaldo	11	3	3.66
Longerin	Rinaldo	8.6	3	2.86
Confine	Tudaio-Brentoni	12.6	5	2.52
Longerin	Tudaio-Brentoni	7.8	5	1.56
Rinaldo	Tudaio-Brentoni	9.7	2	4.85
Aiarnola	Tudaio-Brentoni	15.1	5	3.02
Aiarnola	Marmarole	10.3	3	3.43
Val Marzon	Marmarole	9.8	3	3.26
Val Marzon	Cristallo	9	5	1.80
Val Marzon	Sorapis	10.2	5	2.04
Marmarole	Antelao	9.8	2	4.90
Tudaio-Brentoni	Cridola	10.7	6	1.78
Marmarole	Cridola	11.6	8	1.45
Marmarole	Duranno	15.8	7	2.25
Marmarole	Sorapis	12.2	2	6.10
Nuvolau	Pelmo-Rite	9.7	2	4.85
Nuvolau	Crot	7.5	2	3.75
Antelao	Bosconero	11	4	2.75
Antelao	Duranno	11.1	5	2.22
Antelao	Pelmo-Rite	9.7	2	4.85
Duranno	Cridola	13.4	1	13.40
Bosconero	Duranno	8.5	1	8.50
Bosconero	Schiara	15.7	3	5.23
Pelmo-Rite	Bosconero	10.3	2	5.15
Pelmo-Rite	Civetta	11.6	1	11.60
Pelmo-Rite	Schiara	19.4	5	3.88
Col di Lana	Pore-Cinque Torri	6.7	1	6.70
Col di Lana	Tofane	13.5	1	13.50
Col di Lana	Migon	5.6	3	1.86
Sella	Migon	6.7	3	2.23
Pore-Cinque Torri	Migon	8.7	2	4.35
Pore-Cinque Torri	Crot	7.3	2	3.65
Marmolada	Migon	7.2	1	7.20
Marmolada	Crot	10.5	1	10.50
Marmolada	Civetta	11.7	2	5.85
Marmolada	Focobon	8.9	5	1.78
Marmolada	Pale di S. Lucano	9.4	4	2.35
Civetta	Schiara	16.7	4	4.17
Civetta	Pale di S. Lucano	10.2	2	5.1
Total		415.2	123	

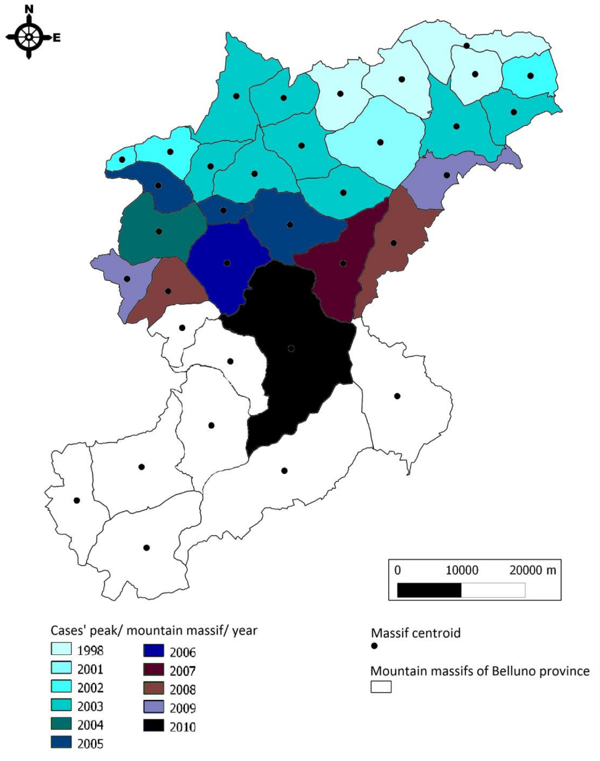

Figure 5 – Temporal distribution of sarcoptic mange mortality peaks in chamois in the mountain massifs, each one represented with the relative massif centroid (MCd).

Calculated spreading speeds were consistent with each other, and comparable to previous results obtained in the Eastern Alps, namely 3-6 km/year (Meneguz et al., 1996) and 2.4-4.5 km/year (Rossi et al., 2007). A similar spreading speed (about 6 km/year - Fernández-Morán et al. 1997) was also calculated for sarcoptic mange in cantabrian chamois (*Rupicapra pyrenaica parva*).

The MCrs-based average speed (5.4 km/year) slightly exceeds the front speed calculated on the basis of the MCds. Easy calculation might suggest the use of the former as a raw index, even though caution is recommended, since non homogeneous within- and between-massif distributions of chamois and their influence on disease spread cannot be taken into account. Moreover, MCrs-based speed from cases distributed in a wide area can be biased by the long distance between them, thus masking the real situation.

Actually, the massif-based (MCd) epidemic front appears as a better representation of the eco-epidemiological scenario, allowing a refinement of the estimates. A mountain massif becomes the epidemic front when it reaches the mange mortality peak (i.e. approximately 5 years after the earliest cases). Hence, it provides a more objective basis to standardize the spatial and temporal concepts when defining epidemic versus endemic areas, subsequent epidemic peaks and the epidemic front itself. In our opinion, such a basis may be helpful in a common framework for current and future interdisciplinary investigations on the *Sarcoptes*-chamois relationships, starting from host genetics and immunity to parasite molecular epidemiology. Moreover, such a knowledge may be helpful in the future in a chamois population management perspective. Namely, strategic management areas for chamois over a wide range, could/should be defined according to the results of the above mentioned interdisciplinary studies. However, it appears evident that all the results from the present and other studies should be first screened and validated based on wildlife managers' field knowledge on chamois ecology. Finally, the evolution of sarcoptic mange in other sensitive species (e.g. ibex) should also be taken into account since the population dynamics and distribution of such species could in some cases influence the basic spatial parameters of the disease, as hypothesized by some Authors (Fuchs et al., 2000; Schaschl, 2003). For these aims, work is in progress to widen our database with data from the neighboring Trento and Bolzano Provinces, to test our results on other datasets and areas.

References

Alasaad S., Walton S., Rossi L., Bornstein S., Abu-Madi M., Soriguer R.C., Fitzgerald S., Zhu X.Q., Zimmermann W., Ugbomoiko U.S., Pei K.J., Heukelbach J., *Sarcoptes*-World Molecular Network, 2011. *Sarcoptes*-World Molecular Network (*Sarcoptes*-WMN): integrating research on scabies. International Journal of Infectious Diseases 15: e294–297.

Arlian L.G., 1989. Biology, host relations and epidemiology of *Sarcoptes scabiei*. Annual Review of Entomology 34: 139–161.

Berrilli F., D'Amelio S., Rossi L., 2002. Ribosomal and mitochondrial DNA sequence variation in *Sarcoptes* mites from different hosts and geographical regions. Parasitology Research 88: 772–777.

Burgees I., 1994. *Sarcoptes scabiei* and Scabies. Advances in Parasitology 33: 235–292.

Cavallero S., Citterio C., Obber F., Bregoli M., Dellamaria D., Trevisiol K., D'Amelio S., 2012. Variability at MHC Class II in alpine chamois populations exposed to sarcoptic mange epidemics. Hystrix 23 (suppl.): 97.

Fernández-Morán J., Gomez S., Ballestreros F., Quiros P., Benito J.L., Feliu C., Nieto J.M., 1997. Epizootiology of sarcoptic mange in a population of cantabrian chamois (*Rupicapra pyrenaica parva*) in Northwestern Spain. Veterinary Parasitology 73: 163–171.

Fuchs K., Deutz A., Gressmann G., 2000. Detection of space-time clusters and epidemiological examinations of scabies in chamois. Veterinary Parasitology 92: 63–73.

Fuchs K., Deutz A., 2002. Use of variograms to detect critical spatial distances for the Knox's test. Preventive Veterinary Medicine 54: 37–45.

Guberti V., Zamboni L., 2000. Can the host resistance hypothesis explain the cyclic patterns observed in *Sarcoptes scabiei* in chamois (*Rupicapra rupicapra*)? Parassitologia 42: 72.

Guberti V., Zamboni L., Corrain R., 2003. Host depopulation and dynamic of infectious diseases in wildlife. Journal of Mountain Ecology 7 (suppl.): 75–84. [in Italian]

Loison A., Jullien J., Menaut P., 1999. Subpopulation structure and dispersal in two populations of chamois (*Rupicapra* sp.). Journal of Mammalogy 80: 620–932.

León-Vizcaíno L., Ruíz de Ybáñez M.R., Cubero M.J., Ortíz M.J., Espinosa J., Pérez L., Simón M.A., Alonso F., 1999. Sarcoptic mange in spanish ibex from Spain. Journal of Wildlife Diseases 35: 647–659.

Meneguz P.G., Rossi L., Sommavilla G., De Martin P., Rodolfi M., 1996. Sulla più temibile parassitosi della fauna alpina: la rogna sarcoptica del camoscio. Large Animals Review 2: 75–83. [in Italian]

Morpurgo L., Obber F., Turchetto S., Partel P., Ferraro E., Cassini R., Citterio C.V., 2014. Alpine chamois population dynamics and surveillance of sarcoptic mange in the Paneveggio-Pale di San Martino Natural Park (TN-Italy). Hystrix 25(suppl.): 53. doi:10.4404/hystrix-25.0-10096

Pence D.B., Ueckermann E., 2002. Sarcoptic mange in wildlife. Revue scientifique et technique de l'Office International des Epizooties 21(2): 385–398.

Pérez J.M., Ruiz-Martínez. I., Granados J.E., Soriguer R.C., Fandos P., 1997. The dynamics of sarcoptic mange in the ibex population of Sierra Nevada in Spain – influence of climatic factors. Journal of Wildlife Research 2: 86–89.

Rahman M.M., Lecchi C., Fraquelli C., Sartorelli P., Ceciliani F., 2010. Acute phase protein response in alpine ibex with sarcoptic mange. Veterinary Parasitology 168: 293–298.

Ramanzin M., 2005. Definizione di aree e modalità di gestione per camoscio (*R. rupicapra*) e fagiano di monte (*T. tetrix*) in provincia di Belluno. Relazione interna depositata presso l'Amministrazione provinciale di Belluno. Techincal Report. [in Italian]

Rasero R., Rossi L., Soglia D., Maione S., Sacchi P., Rambozzi L., Sartore S., Soriguer R.C., Spalenza V., Alasaad S., 2010. Host taxon-derived *Sarcoptes* mite in European wild animals revealed by microsatellite markers. Biological Conservation 143: 1269–1277.

Rossi L., Meneguz P., De Martin P., Rodolfi M., 1995. The epizootiology of sarcoptic mange in chamois *Rupicapra rupicapra* from the Italian Eastern Alps. Parassitologia 37: 233–240.

Rossi L., Menzano A., Sommavilla G.M., De Martin P., Cadamuro A., Rodolfi M., Coleselli A., Ramanzin M., 2006. Actions for the recovery of an alpine ibex herd affected by epidemic scabies: the Marmolada case, Italy. Proocedings of III International Conference on Alpine ibex, Pontresina, Switzerland, 12-14 October 2006.

Rossi L., Fraquelli C., Vesco U., Permunian R., Sommavilla G.M., Carmignola G., Da Pozzo R., Meneguz P.G., 2007. Descriptive epidemiology of a scabies epidemic in chamois in the Dolomite alps, Italy. European Journal of Wildlife Research 53: 131–141.

Schaschl E., 2003. Gamsräude. Österreichischer Jagd- und Fischer-eiverlag, Wien. 160. [in German]

Sokolova T.V., Radchenko M.I., Lange A.B., 1989. The seasonality of scabies morbility and the fertility of the itch mite *Sarcoptes scabiei* de Gea as an index of the activity of a population of the causative agent. Vestnik Dermatologii Venerologii 63(11): 12–25.

Thrusfield M., 2005. Veterinary Epidemiology. Third Edition. Blackwell Publishing.

Associate Editor: N. Ferrari