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On-farm Mortality in Cattle

Analysis of on-farm mortality data for cattle for retrospective and prospective epidemiological surveillance

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SUMMARY

The present study was aimed at exploring if and on what extent on-farm mortality, which is regularly notified in national cattle databases in the EU, could be used to design an early warning system for emerging diseases.

The statistical analysis of mortality rates recorded in Italy in 2008 showed a clear influence by transport, age, sex and season.

Through spatial and spatio-clustering methods several geographic area with exceptionally high mortality rates were detected.

A more in-dept analysis of individual causes of mortality in the provinces of Trento and Bolzano showed that on-farm mortality was greatly influenced by management practices and economic conditions. In order to control some of the influencing management factors a model was created to compare for a given population the actual and expected mortality rates.

A conclusion of the study was that on-farm mortality regularly notified in national livestock databases could represent an important indicator for evaluating herd management practices. Further analysis and refinement of the applied models would be needed in order to establish a robust method for the detection of anomalous events with respect to the outbreaks of animal diseases.

1. INTRODUCTION

More than a decade ago the EU Member States started to build up national animal databases as one element to overcome shortcomings in animal traceability experienced during some major animal and public health threats such as BSE and FMD. Databases were first introduced for cattle with Community legislation in 1997, followed by requirements for central national databases for pigs, sheep and goats.

The potential risks of (re)introducing eradicated or unknown animal diseases into free regions in the EU brought up the question if the mortality data available in the national cattle databases in the EU could be a useful source for epidemiological surveillance and to develop an alert system for emerging diseases.

The present study was aimed at exploring if and on what extent the design of an early warning system could contribute to assess routinely faming management conditions.

For this purpose, JRC analysed individual holding mortalities, spatial and spatio-temporal clusters of high or low mortality and higher mortality. In addition to the statistical analysis a more detailed investigation was carried out in the Autonomous Provinces of Bolzano and Trento in Italy through a field surveys and interviews to farmers.

2. MATERIALS AND METHODS

2.1 Source data

The holding and animal data used for the analyses were exported from the Italian National Bovine database which is managed by the Istituto Zooprofilatico Sperimentale dell'Abruzzo e del Molise locate in Teramo (Italy). The data comprised notifications of individual animal movements between farms and cases of on-farm mortality in the year 2008. Additional attributes for each holding were the geographical location, type of holding (milk, beef, mixed farm, pasture, assembly centre, market, slaughterhouse), the average monthly animal population and for each animal: the breed, sex, date of birth, dates of movements and death.

2.2 Statistical methods

Mortality rates were calculated as the number of deaths notified in the database scaled to the size of the population, per unit time.
The calculations were performed at different level of spatial aggregation (holding, province, region and national) and at different temporal intervals (week, month and year).
Given the lack of daily population data the mortality rates were calculated on the basis of animals present at the beginning of each month.
The mortality rate for transported animals was calculated as the number of transported animals died within 30 days from the transport divided by the number of transported animals.

In order to identify cases of exceptionally high level of mortality the following two methods were considered:

- spatial clustering using Getis-Ord Gi* statistics (Getis and Ord., 1992) and Kernel density in ARCGIS and
- spatio-temporal scanning using SatSCAN (Kuldorff, 2001).

The modeling of mortality at national level was carried out using a Generalized Linear Model with negative binomial distribution in the system for statistical computation R.
In order to understand the procedures of notification, interviews were carried out with farmers and local official veterinarians in the provinces of Trento and Bolzano.
For the data on mortalities in the provinces of Bolzano and Trento, additional information was

received from the central veterinary services of the two provinces, their local veterinary services (Azienda Sanitaria Locale - ASL), private veterinarians and farm holding registers. This data comprised for each animal the cause of death as ascertained by the official veterinarians.

3. RESULTS

3.1 Mortality following transports to another farm

The national data for 2008 indicate an average monthly mortality rate of 0.26% and for transported animals an average mortality rate within 30 days from the transport of 0.50%.

Overall, the evolution of the number of transported animals died at destination after the date of transport shows a peak at the 2nd week and gradually decreases afterwards, indicating a clear influence by the transport event (figure 1).

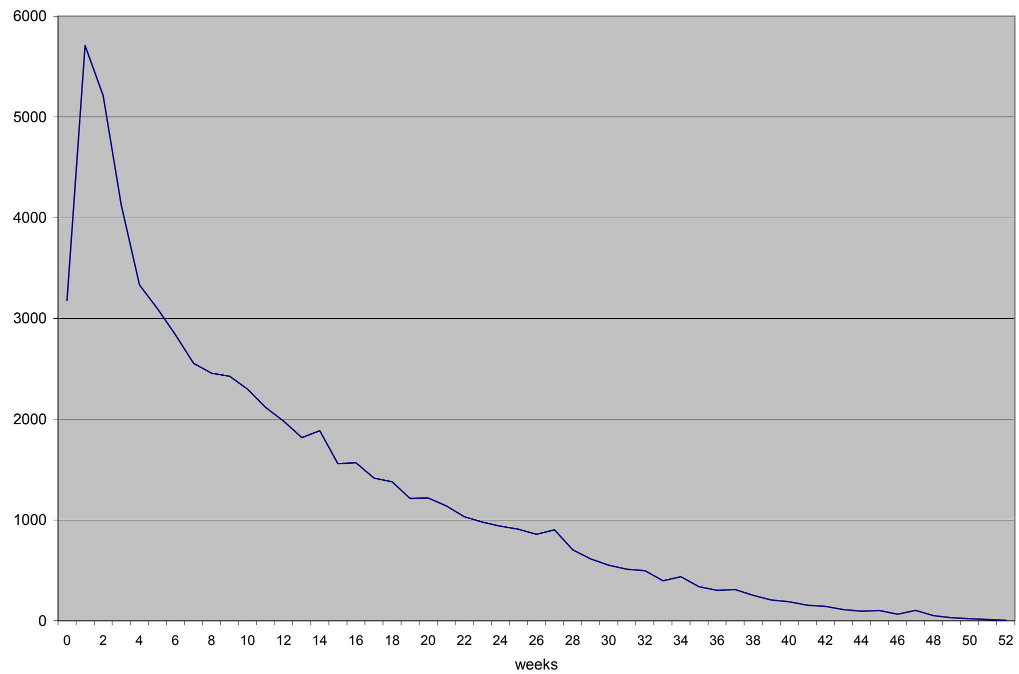

Figure 1 Number of transported animals died on farm of destination by time elapsed from the date of arrival

The mortality rates after transport were further analysed in relation to 4 different age groups of the transported cattle (< 6 months, 6-<12 months, 12 - < 20 months, ≥ 20 months of age at time of transport) (figure 2).

The mortality of the youngest group is the highest with a peak at the 2nd week after transport. At 30 days from transport the mortality rate for young animals reaches a level of 1.4%. The mortality of the second group has a peak around 2-4 week from the transport, but stays below 0.4%. For the 12-20 months old cattle the mortality rate is the lowest. For older animals above 20 months of age the mortality is increasing with a peak within the first week after transport.

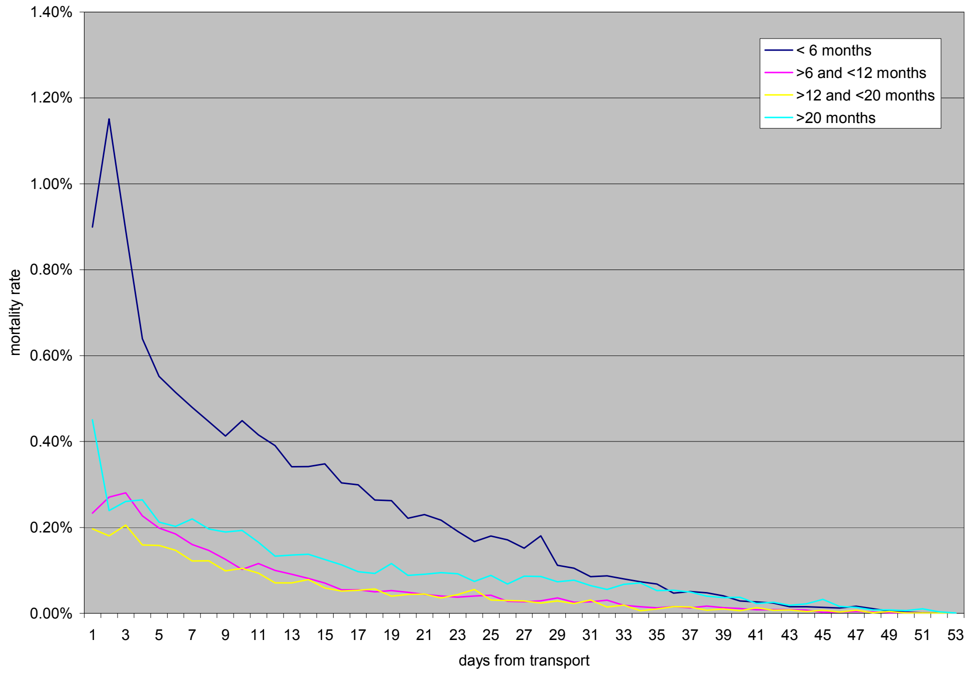

Figure 2 Mortality rates for 4 age categories of cattle after arrival at farm of destination by time elapsed from the date of arrival

Calves below 100 days of age present the largest group of cattle transported between farms, followed by animals between 200 and 400 days of age (figure 3). The highest numbers of dead on farm after arrival were recorded in very young calves and cattle of around 300 days of age. Differences in mortality rates in respect of duration of transports, seasons, holding of origin and holding of destination have not been observed.

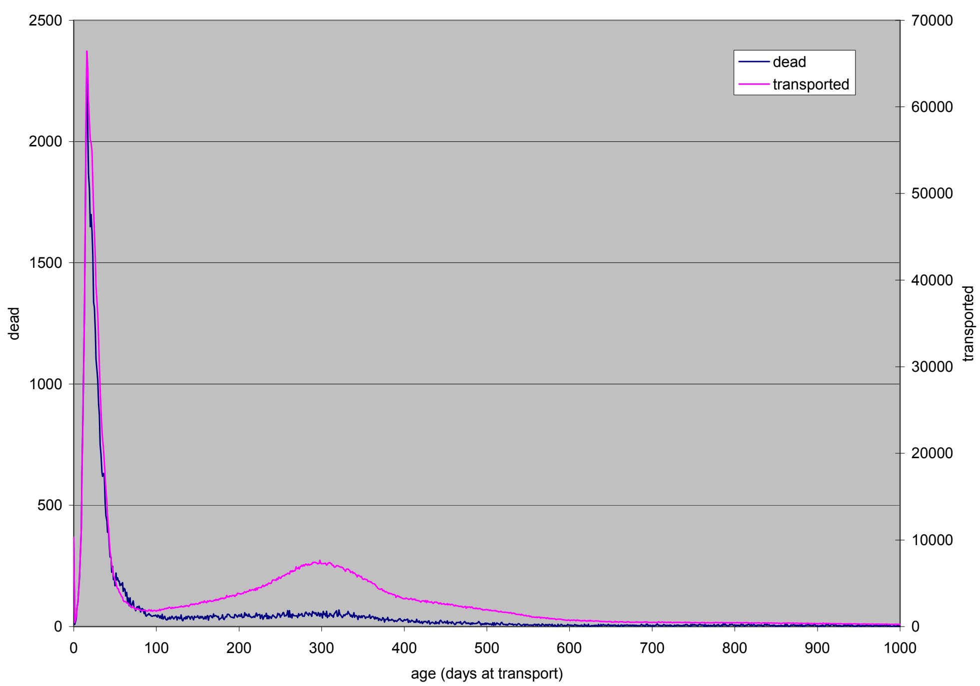

Figure 3 Number of animals transported to a farm and animals died on farm after transport in relation to the age at time of transport

3.2 National and regional on-farm mortalities

By comparing average monthly mortality rates in the different regions of Italy with the national mortality rates a sharp difference became evident between the provinces of Bolzano and Trento. The average monthly mortality rate of 0.27% in the province of Bolzano was very close to the national average of 0.28%, while the average monthly mortality rate in the province of Trento was more than double (0.58%).

3.2.1 Mortality rates by age, sex and production type

To analyse overall mortalities for Italy and the two autonomous provinces of Bolzano and Trento, data regarding populations, holding types and age groups were compared (figure 4).

At a national level, in 2008, cattle were kept for nearly equal proportions in milk and meat production holdings and in 10% in mixed production holdings. In both the provinces of Bolzano and Trento milk production was the predominant production type with around 85% of the cattle population. The province of Trento has the remaining 15% of the population in meat production holdings while the province of Bolzano in mixed production holdings.

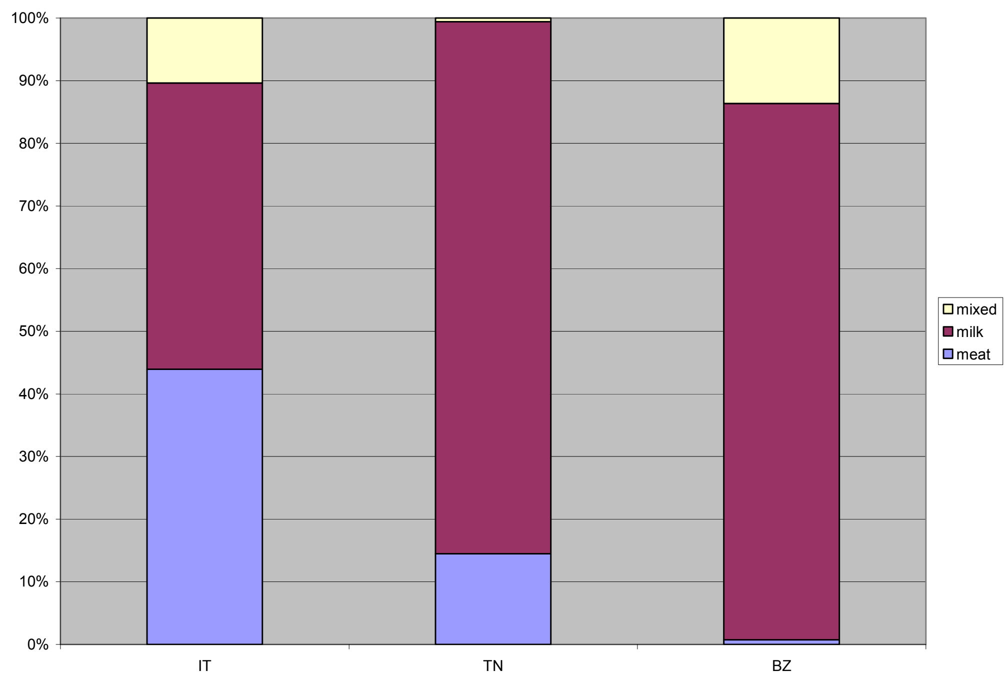

Figure 4 Distribution of the cattle population in farm holdings in 2008 by production type of farm holdings (mixed holdings, holdings for milk production, holdings for meat production) in Italy (first column), in the province of Trento (second column) and in the province of Bolzano (third column)

The structure of the cattle population by age groups in 2008 in Italy (figure 5) presented the highest percentage of animals in the young groups (0-12 months of age and between 12 and 24 months) and the lowest percentage in the age groups from 24 to 36 months and more than 96 months. The cattle populations in the two provinces followed a similar pattern, with lower values in the young groups and higher in the age groups 24-36 months, 36-60 months and 60-96 months (figure 5).

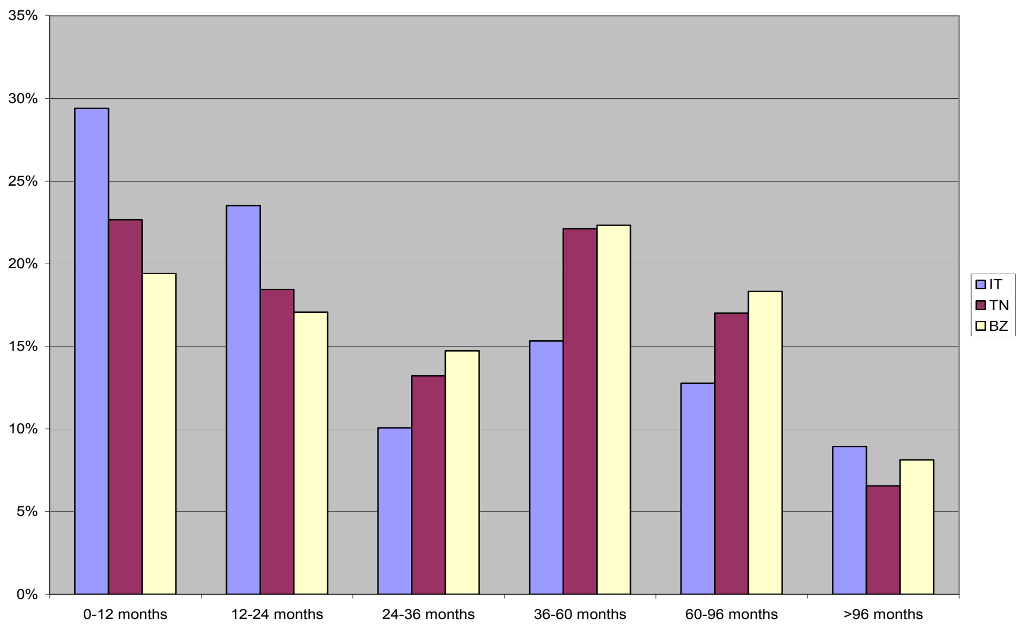

Figure 5 Distribution of the cattle population in 2008 by 6 age groups in Italy (first column), in the province of Trento (second column) and in the province of Bolzano (third column)

The mortality rates were clearly influenced by sex and age groups as shown in figure 6. The youngest age group has a nearly five fold mortality rate compared to the next group (1-2 years old). Male animals account for around 2/3 of the mortality in the youngest age group. Although far lower in absolute terms, in the age group of 12-24 months old, males represent still more than 50% of the mortality. For older age groups mortality is almost exclusively represented by female animals.

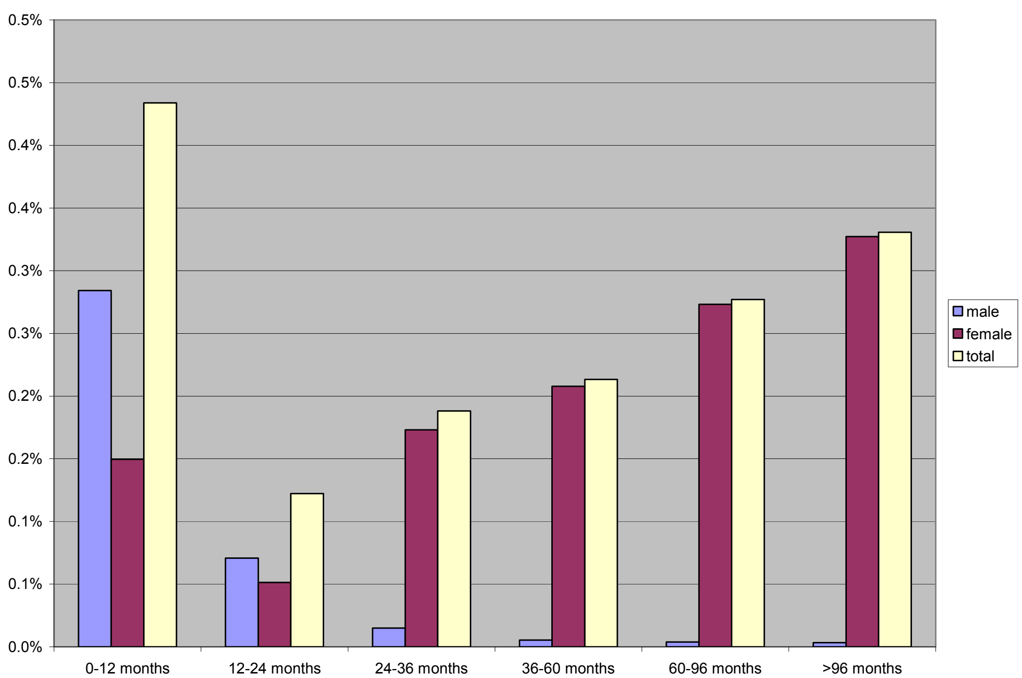

Figure 6 Average monthly mortality rates in cattle in farm holdings in 2008 in Italy by age groups and sex.

The mortality rates by age groups and production types show substantial differences for milk and meat producing holdings (figure 7). In the milk production holdings, mortality rates are higher in all age groups with the exception of the groups of 12-24 months and 24-36 months old animals. While after the highest rate in the youngest age group mortality rate in milk production holdings falls sharply for the 12-24 months old, it increases steadily for the following age groups. In meat producing holdings the mortality rate shows the highest rate in the youngest age group and the lowest in the 12-24 months old.

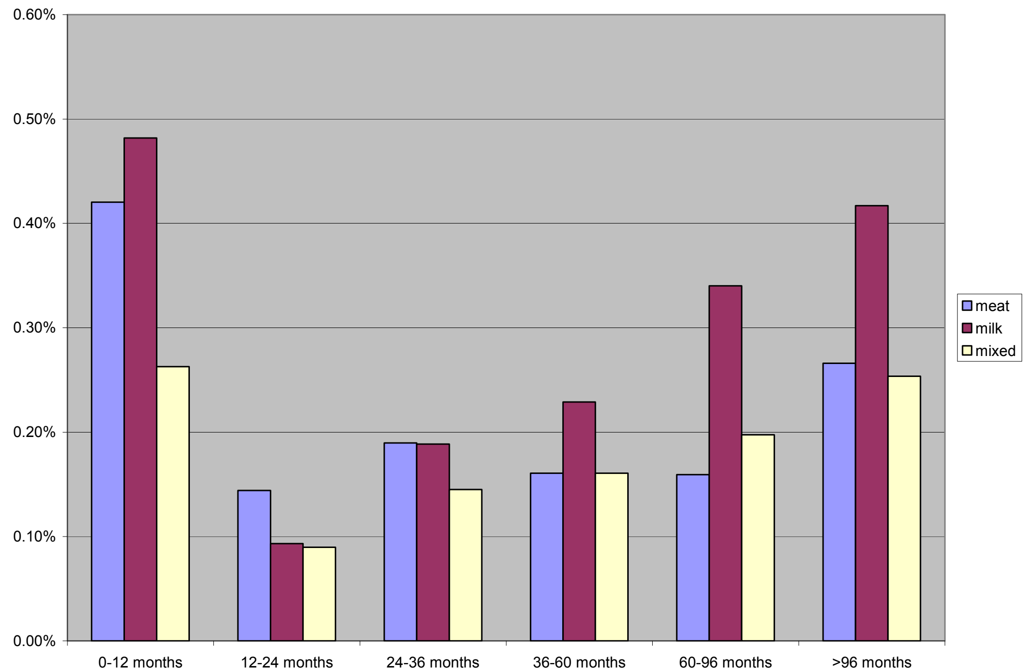

Figure 7 Distribution annual mortality rates by production type and age groups in Italy in 2008

3.2.2 Mortality rates over time series

Analysing the mortality cases notified in 2008 in Italy over weekly time series, a seasonal trend appeared, with the most cases occurring in the beginning, the middle and the end of the year. The low number of cases in the first week, the last two weeks of the year and the depression in the 29th, 30th and 33rd week could be attributed to low or delayed notification in correspondence to holiday times. A similar effect of under-reporting is also appearing on Sunday and Saturday considering daily rates of notifications; this effect has been reported also in another study for the UK cattle database (Robinson and Christley, 2006).

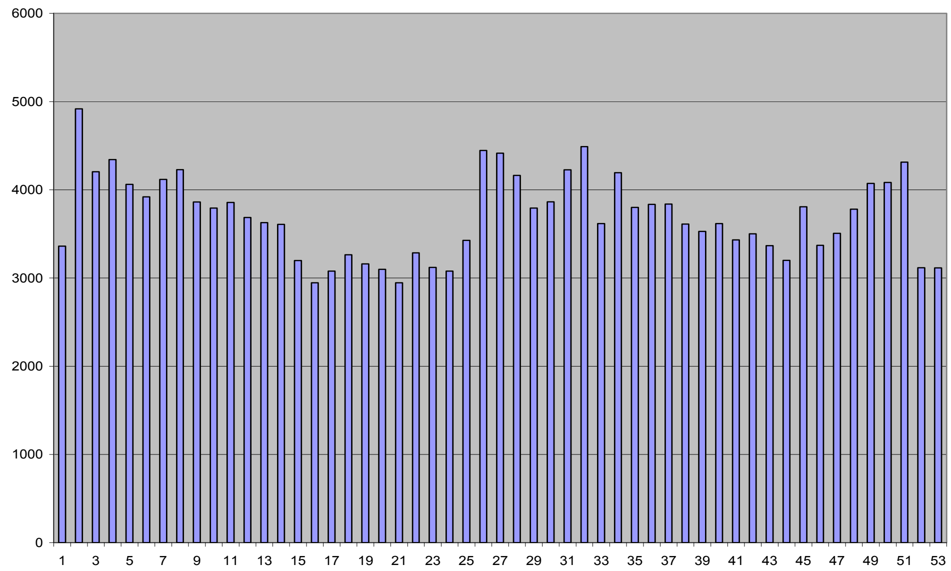

Figure 8 Distribution of the mortality cases in cattle in farm holdings in Italy in 2008 by week of death

Although having a very similar overall annual mortality rate, the time series of monthly rates in the province of Bolzano shows some differences in respect to the national one (figure 9). Starting from a lower level in the first months of the year, the rate for Bolzano increases more sharply between June and July. After a short period of lower mortalities, towards October it raises until the end of the year. The mortality rates for the province of Trento follow the same pattern, however with an overall higher level, with a more prominent decrease from January to May, an earlier peak in June and a later but sharper increase from November to the end of the year.

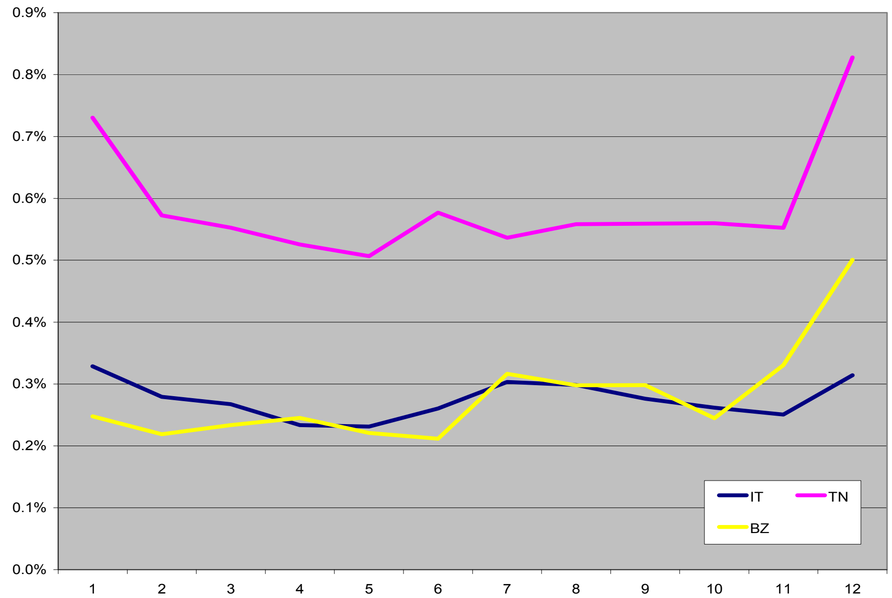

Figure 9 Distribution of the mortality rates in cattle in farm holdings in 2008 by month of death in Italy (blue line), in the province of Trento (magenta line) and in the province of Bolzano (yellow line)

Displaying the monthly mortality rates in Italy for the different age groups, the pattern of higher mortalities at the beginning, in the middle and at the end of the year remains for all 6 groups (figure 10). The groups of 12-24 months and the 24-36 months of age show a less pronounced fluctuation between seasons in respect of younger and older animals.

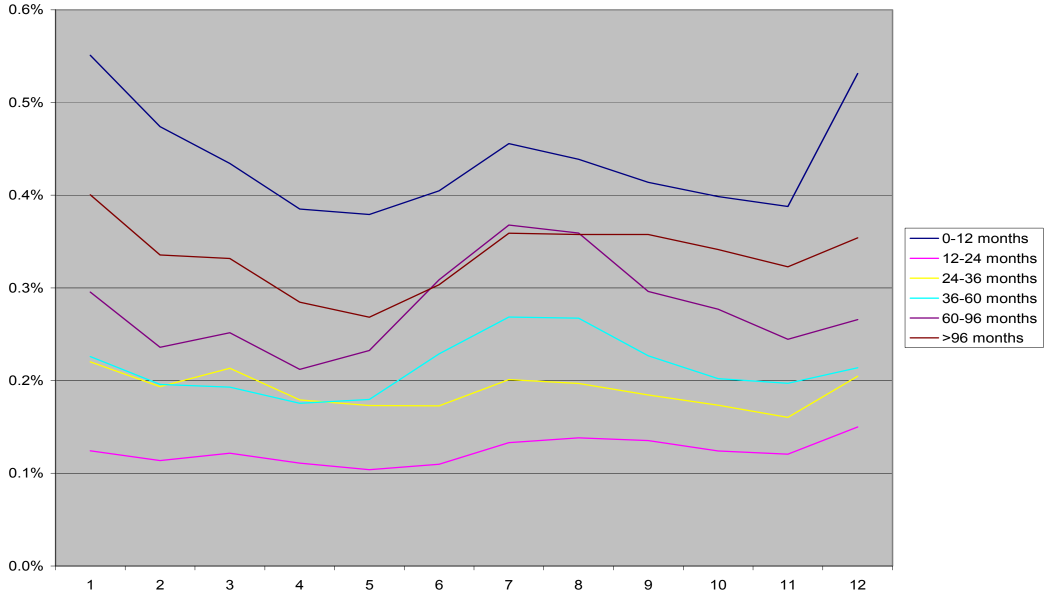

Figure 10 Distribution of the mortality rates in cattle in farm holdings in 2008 in Italy by age groups and month of death

Looking at monthly mortality rates by sex (figure 11) a more pronounced peak at the end of the year can be observed in males while in females the winter and summer peaks show similar mortality rates.

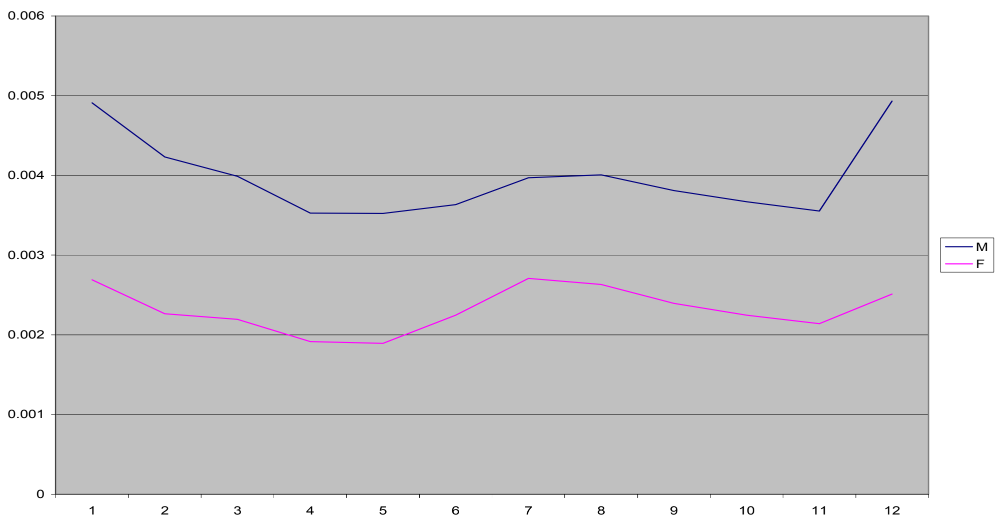

Figure 11 Distribution of the mortality rates in cattle in farm holdings in 2008 in Italy by sex (males - blue line, females - magenta line) and month of death.

3.2.3 Spatial and spatio-temporal clusters of elevated mortality rates

On the basis of the data for 2008 for the provinces of Bolzano and Trento, areas with a higher or lower mortality rate than the surrounding were identified. The analysis for identifying spatial clusters was carried out considering different spatial and spatio-temporal clustering methodologies described in the Materials and Methods paragraph.

Figure 12 represents areas with a higher mortality rate in darker blue and areas with lower mortality rate in light colour.

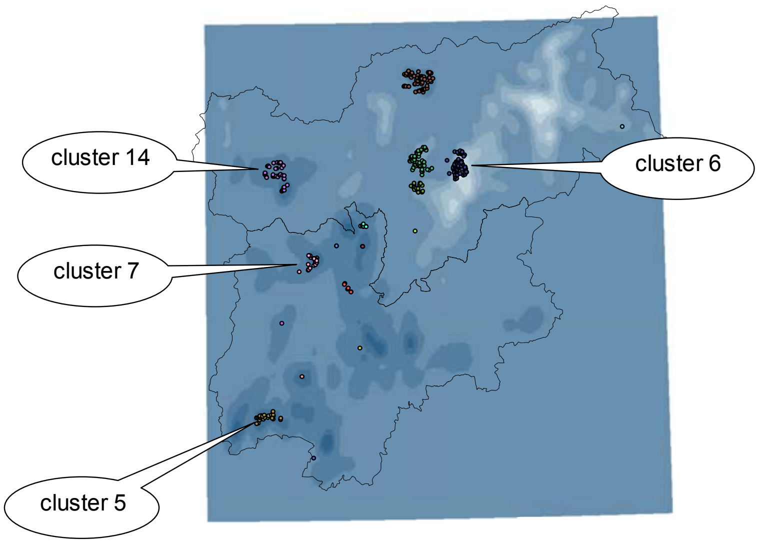

Figure 12 Geographical distribution of clusters in the provinces of Bolzano and Trento. Areas in dark blue indicate a high kernel density of positive Z scores of the Getis-Ord* statistics (hot spots). In these areas high mortality rates are found closer together than it would be expected from a random underlying spatial process. On the contrary areas in light blue (cold spots) are characterised by a high kernel density of negative Z scores. In these areas low mortality rate are found closer together than it would be expected. Clusters 14, 7, 5 and 6 represent relevant groups of holding with a higher mortality rate in specific periods of the year. Cluster 6 shows an unusual high mortality rate in a cold spot.

Using the Kuldorff 1997 spatio-temporal clustering method several significant clusters of high mortality in specific periods of the year were detected. Among those significant clusters 4 were selected for further investigations. The table below shows for the 4 clusters selected the details regarding the spatial dimension, the number of holdings forming the cluster, the time period with the abnormal mortality rate, the expected mortality rate and the factor for which the observed mortality rate exceeded the expected mortality rate. The clusters exhibit for periods of some weeks a number of dead animals four to five times higher than the surrounding areas.

Cluster	Province	Radius cluster (km)	Time period from-to		Number holdings in cluster	Expected deaths	Observed/ expected deaths
14	BZ	4.89	30/10	17/12	40	6.62	4.38
5	TN	4.29	01/01	20/02	27	6.41	5.31
6	BZ	4.88	20/11	31/12	79	11.07	3.79
7	TN	4.65	28/08	15/10	28	11.33	3.71

Table 1 List of 4 clusters in the provinces of Bolzano and Trento with a higher mortality than the surrounding areas in 2008

3.3 Cause analysis of mortality notifications

Field-investigations and interviews were carried out on the selected clusters in order to understand better the real causes of high mortality and explain possible reasons for clustering emerging from the statistical analysis.

Mortalities on a farm holding can be grouped in three main categories of death:

- animals died (e.g. caused by an accident or a disease);
- animals killed (e.g. euthanized downer cows or due to low value, end of productive live, accident, disease);
- animals slaughtered for own consumption.

The notification of death to the Italian national cattle database at the time of the analysis did not distinguish between the three categories and did not give a possibility to specify the death category. The data extracted from the national database included therefore animals died on farm, killed on farm and slaughtered on farm, all in a single group.

In the provinces of Bolzano and Trento for animals died or killed on a farm, the local veterinary services (ASL) issue a document which has to accompany the fallen stock to the rendering plant and which should state the cause of death. For on farm slaughter the municipalities issue an authorization. Both types of documents are kept in paper form in the office of the local veterinary services.

For all death notifications in 2008 in the province of Bolzano and for two spatio-temporal clusters with high mortality rates in the province of Trento (clusters 5 and 7) the causes of death indicated in the official documents were analysed and classified according to the following categories:

- accidents (e.g. on-farm, alps pasture);
- complications related to birth (e.g. downer cows);
- skeletal-muscular disorders other than related to birth;
- neonatal death (e.g. calves died during or shortly after birth);
- respiratory diseases;
- gastro-intestinal diseases;
- on-farm slaughter of own consumption;
- other specified causes of death (not fitting within one of the above categories);
- cause of on-farm death not specified.

For the province of Bolzano, the distribution of the causes of death for 4,783 animals notified in 2008 to the Italian national cattle database is shown in the table 2.

Category (causes of death, grouped from available documentation)	**% of cases**
Accidents	4%
Birth related	3%
Skeletal-muscular disorders other than related to birth	14%
Neonatal death	0%
Respiratory diseases	6%
Gastro-intestinal diseases	14%
On-farm slaughter for own-consumption	1%
Other-specified causes	6%
Other-none-specified causes	53%
	(4783) 100%

Table 2 Causes of death for a total of 4,783 animals died on-farm in the province of Bolzano in 2008 notified to the Italian national cattle database.

The distribution of the causes in two spatio-temporal clusters with high on-farm mortality in 2008 in the province of Trento is listed in the table 3.

Category (causes of death, grouped from available documentation)	cluster 5	cluster 7
Accidents	10%	10%
Birth related	6%	9%
Skeletal-muscular disorders other than related to birth	5%	7%
Neonatal death	0%	25%
Respiratory diseases	5%	4%
Gastro-intestinal diseases	15%	26%
On-farm slaughter for own-consumption	49%	7%
Other-specified causes	7%	6%
Other-none-specified causes	4%	6%
	(108) 100%	**(173) 100%**

Table 3 Two spatio-temporal clusters with high on-farm mortality notified in the province of Trento in 2008 to the Italian national cattle database sorted by mortality categories with their distribution (in brackets total number of death in each cluster)

The largest differences between clusters 5 and 7 regarding mortality rates can be seen for neonatal death and on-farm slaughter for own consumption. For cluster 5 the high mortality rate compared to the surrounding area was due to the high number of on-farm slaughter for own consumption in one municipality which applied the national rules less restrictively than surrounding municipalities. For cluster 7 the high mortality rate compared to the surrounding area was caused by a high number of notifications of neonatal death. Community and national legislation require identifying and notifying new born calves within 7 days after birth. As a result, calves which die within 7 days after birth and before identification are not notified by the farmers to the national database in most cases. On the contrary, in cluster 7, most of the farms followed a different procedure for identification and notification, identifying all new born and still born calves and notifying also their death to the national database.

When plotting the mortality cases notified in 2008 for the province of Bolzano by month of death and by sex as shown in the figure 13, in males the lowest number of cases can be observed in June with a sharp increase in the last quarter of the year and the highest number of cases in December. In females, the monthly differences in cases are less pronounced with two peaks, one around July-September and another in December.

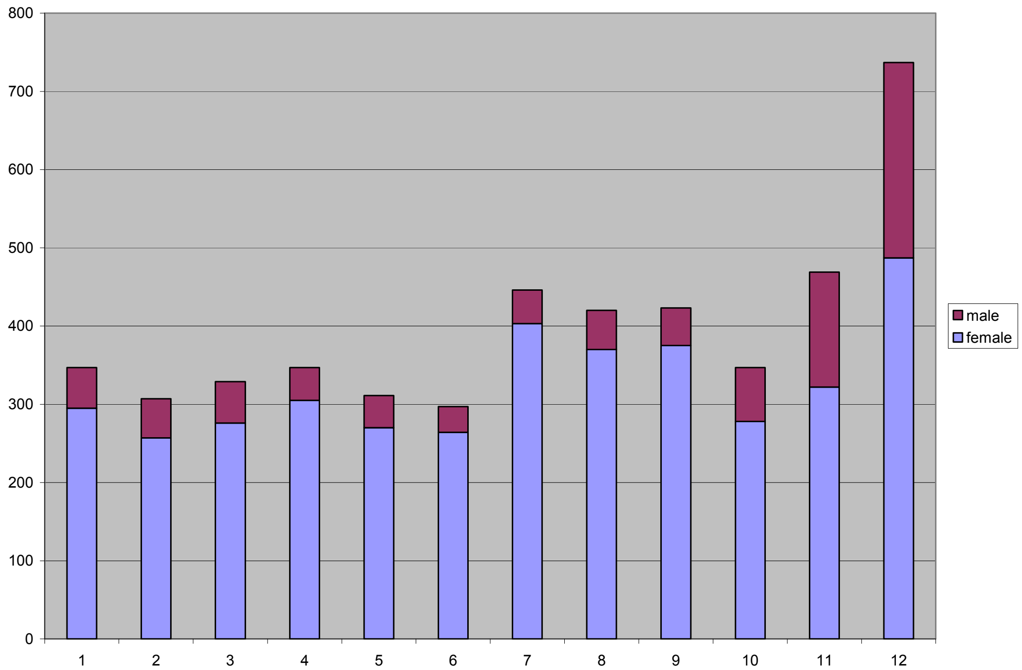

Figure 13 Cases of mortality in the province of Bolzano notified in 2008 plotted by month of death and sex (M= male, F = female, x-axis: months, y-axis: number of cases)

Plotting the mortality cases notified in 2008 for the province of Bolzano by month and category of death (figure 14), for most of the categories very little variation over the 12 months can be observed. An increase can be observed for accidents during summer, respiratory causes in January and February and own consumption and unspecified causes of death in the last two months of the year.

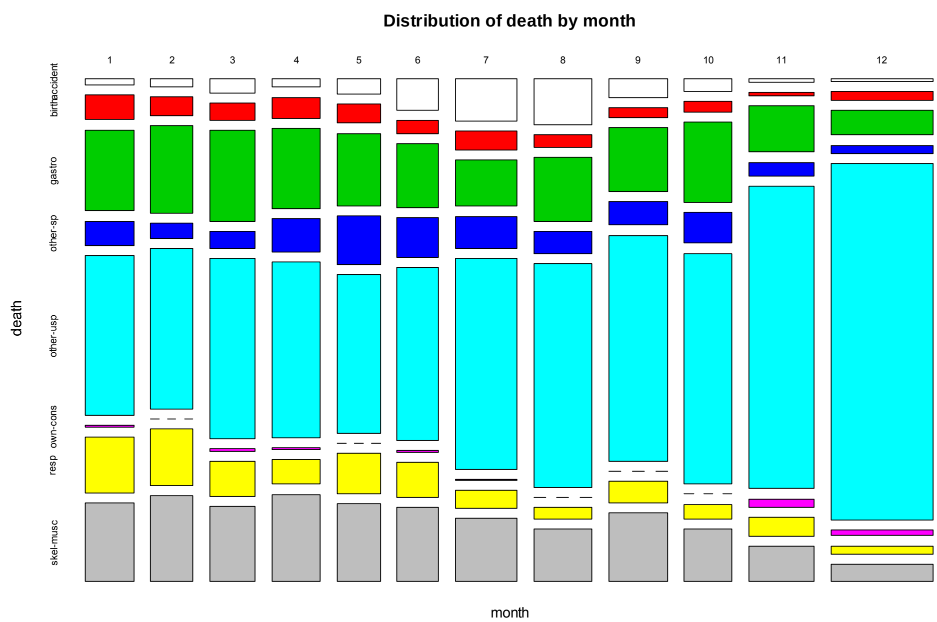

Figure 14 Cases of mortality in the province of Bolzano notified in 2008 plotted by month of death and category of death. The width of the bar denotes the relative proportion of the causes of death by month while inside each bar, the relative proportion denotes the distribution of causes of death within each month.

Sorting the mortalities notified in 2008 for the province of Bolzano by sex and age groups, a similar distribution pattern appear as described in figure 6. As seen in figure 15, the highest mortally rate relates to male calves of <12 months of age, whereas in females the mortality rate falls from the <12 months age group to the 12-24 months age group and afterwards it raises constantly reaching the highest rate in the cows >96 months of age.

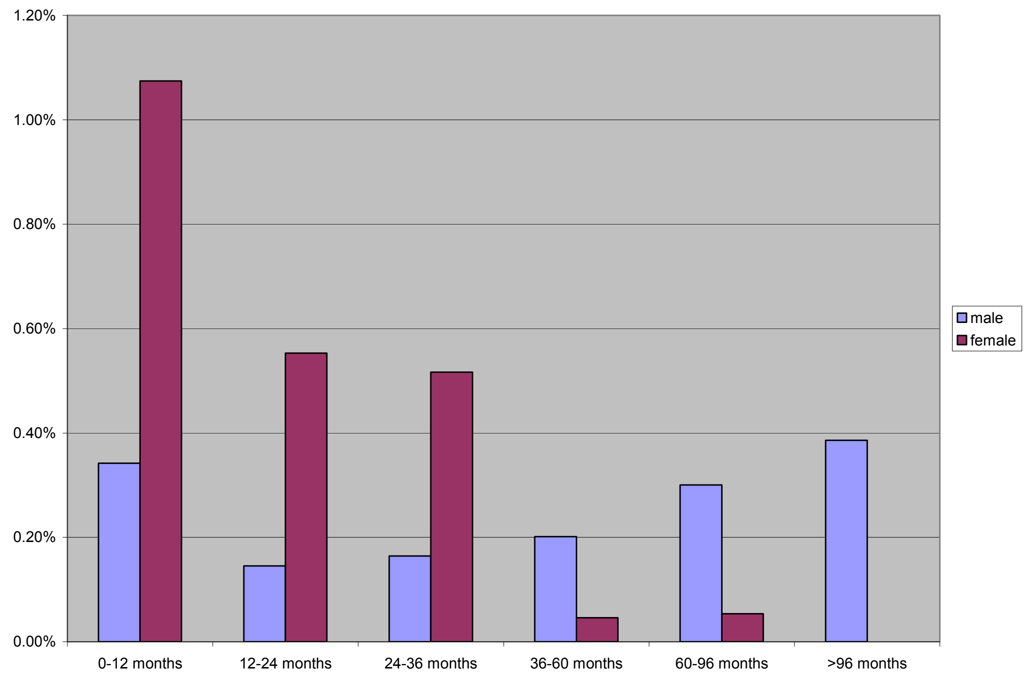

Figure 15 Monthly mortality rates in the provinces of Bolzano in 2008 by sex and age groups

3.4 Modelling on-farm mortality

Instead of comparing differences in mortality in an area with its surrounding area (clustering approach used in Kuldorff and in the Getis-Ord* methods) the recorded mortality in an area could be compared to its expected mortality rate (see expectation-based spatio-temporal clustering in Neill et al., 2005). An expected value of mortality would also be needed in order to establish a baseline for evaluating abnormalities using a time series analysis methods such as the CUSUM.

While in the clustering approach the sum of different factors influence the difference of an area with the outside, the modelling approach would exclude some external factors (e.g. differences in management, in administration) by taking into account differences within a given subset (e.g. holding, cluster, region, age group, holding type).

Using data at national level, mortality was modelled in reference to sex, age and month covariates using a Generalized Linear Model with negative binomial distribution to adjust for over-dispersion according to the following formula.

$$\log(E) = \alpha + \beta_{m1} Z_{m1} + \ldots \beta_{m6} Z_{m6} + \beta_{f1} Z_{f1} + \ldots \beta_{f6} Z_{f6} + \beta_s \sin(\frac{4\pi t}{12}) + \log(P)$$

Where
E = expected deaths in a sex/age category
t = month of the year (seasonality)
P = Population in the sex/age category for the month t
β = estimated parameter for sex/age category

Z = dummy variable (1 for the sex/age category considered, 0 for other sex/age categories)
m1 = male age group 1; all together 6 age groups: 1 = 0-12 months, 2 = 12-24 months, 3 = 24-36 months, 4 = 36-60 months, 5 = 60-96 months, 6 = >96 months of age
f1 = female age group 1 (same age groups as for males)

The estimated parameters for the model and their significance are indicated in table 4.

Coeffficient	Estimate	Std. Error	z value	Pr(>|z|)
α	-5.77305	0.005625	-1026.24	< 2e-16
β_{f2}	-1.2511	0.012106	-103.347	< 2e-16
β_{f3}	-0.53041	0.010555	-50.251	< 2e-16
β_{f4}	-0.37569	0.008674	-43.311	< 2e-16
β_{f5}	-0.10772	0.008454	-12.742	< 2e-16
β_{f6}	0.076611	0.008894	8.614	< 2e-16
β_{m1}	0.581689	0.006945	83.752	< 2e-16
β_{m2}	-0.59834	0.010731	-55.759	< 2e-16
β_{m3}	-0.04757	0.03082	-1.543	0.123
β_{m4}	-0.35994	0.041278	-8.72	< 2e-16
β_{m5}	-0.40706	0.053004	-7.68	1.59E-14
β_{m6}	-0.50866	0.068749	-7.399	1.37E-13
β_s	0.116892	0.003199	36.538	< 2e-16

Table 4 Estimated parameters for the expected mortality model. Coefficients are relative to the baseline of 1 for young females. According to the model a young male would have a probability of death exp(0.58) or 1.78 times greater than a young female.

The estimated mortality rates in farm holdings by sex/age groups and month of death are shown in figure 16. The graphical distribution over the year mimics the distribution shown in figures 10 and 11.

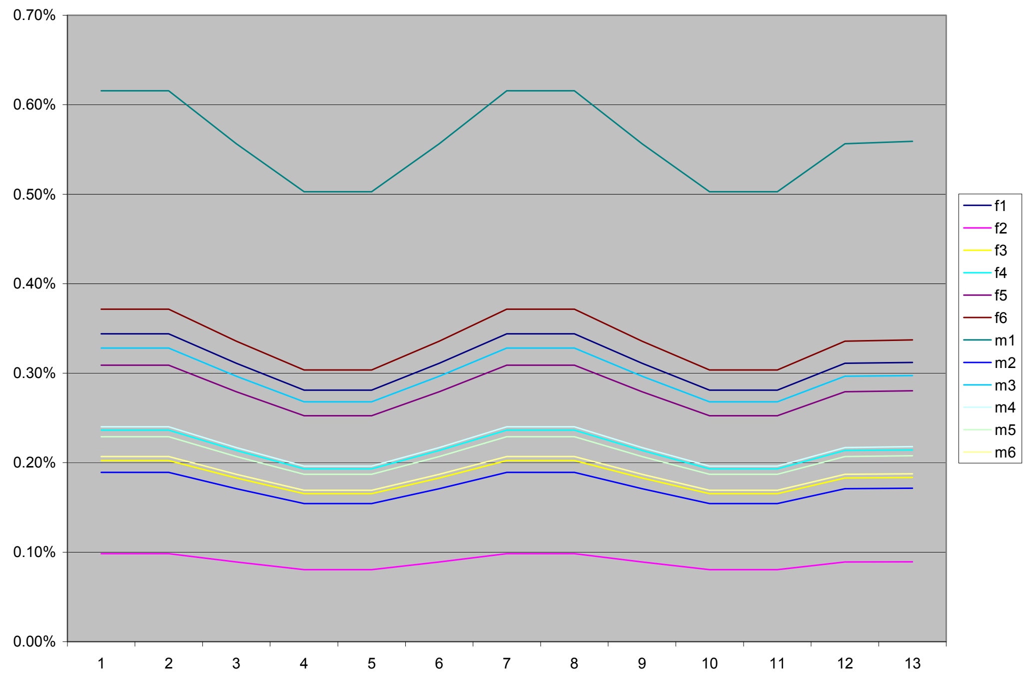

Figure 16: Estimated mortality rates in farm holdings by sex/age groups and month of death calculated with a generalised linear model on the basis of mortality data in Italy for 2008 ((M1-6 = male age groups, F1-6 = female age groups, where 1 = 0-12, 2 = 12-24, 3 = 24-36, 4 = 36-60, 5 = 60-96, 6 = >96 months of age, x-axis: months, y-axis: cases of mortality).

4. DISCUSSION

4.1 Mortality following transports to another farm

The analysis of mortality after transport identified the risks in terms of age and time after transport. A similar mortality curve has been already reported in literature for young cattle and mostly attributed to the Bovine Respiratory Disease complex (BRD) or shipping fever (Kelly and Janzen, 1986). The fact that the peak in mortality in calves < 6 months lies around 2 weeks after the transport can be considered as evidence that transport plays a substantial role in establishing stressing condition which favour the onset of an animal diseases. Animals > 20 months of age experience the second highest risk after transport, with a peak directly at the end of transport which could be attributed to injuries rather than to infections.

Differences in mortality rates in respect of duration of transports, seasons, holding of origin and holding of destination have not been observed.

Further analysis would be needed to understand if the national or regional mortality rates after transport, in particular of calves and older cows, could be use as indicators for assessing animal welfare during transport and transport management.

4.2 National and regional on-farm mortalities and cause analysis

Mortality rates show differences between provinces, farms, spatial and spatio-temporal clusters. Despite the differences between provinces, clusters and farms, all spatial subsets showed that the mortality rates are strongly related to age, sex and time of the year.

In none of the selected provinces, farms and clusters an elevated mortality rate was indicating the introduction of a specific disease but differences could be put in relation with a wide range of holding managements factors and different administrative procedures for the notification of events to the national livestock database.

Production types

In the provinces of Bolzano and Trento around 90% of cattle are kept for milk production, around double the percentage at national level, which causes differences in the composition in the age groups (due to the milk production, more cattle are represented in the groups from 2-8 years of age in respect to the national average).

Despite the differences in the composition of the cattle populations at national and regional level, the highest mortality rate is encountered in animals < 12 months of age. This rate is most likely even higher as dead born calves and calves which died within the first week after birth are normally not notified.

The mortality rates in male calves is around double as high as in females which could be explained with less care for male calves due to their lower value in the milk production.

Seasonal variations

In all age groups the mortality rates follow a “w” shaped pattern over the year, with higher mortalities at the beginning, in the middle and at the end of the year. In the age groups with higher mortality rates (young and old animals) the seasonal differences are more pronounced. The mortality rates in the provinces of Bolzano and Trento increase more sharply in the middle and the end of the year most likely in relation to a production system characterised by alpine summer pastures and predominant winter calving season.

Similar “w” shaped mortality curves are described also in humans with highest mortalities in winter and summer and the lowest values around spring and autumn.

Clusters

From the analysis of the higher mortalities in some clusters it emerged that differences were influenced by a combination of the following causes:

- areas where on-farm slaughtering is more common (distance to slaughterhouses, differences in issuing authorization between municipalities);
- insurance schemes which may render more profitable to kill an animal on farm than to send it for slaughter;
- differences in the notification practice, e.g. some farms identify and notify systematically dead born or newborn dead calves (first 7 days);
- low value of newborn male calves which implies low farmer interest to keep them alive, especially for pure milk breeds.

Provinces

For the difference in mortality rates between the provinces of Bolzano with a mortality rate close to the national and Trento with a mortality rate double as high, the following possible explanations emerged from the analysis and the in-field investigations:

- In Trento there are less rustic breeds. Calves from high performing breeds such as Holstein Frisians or Brown Swiss need more care in the first days from birth and if not supported they die within the first month. Their low economic value (~50-90 € at 15 days) does not justify any treatment or special care, in particular for male calves. The costs for disposal are fully covered by the public funding. The only cost for the farmer is linked to the death certificate and is around 6 €.
- The high insurance premiums paid for dead animals on farm for Trento may represent an incentive for not adopting good management practices and for replacing animals with low value trough euthanasia (e.g. in Trento fallen stock > 3 months of age is reimbursed to 80% of the value it would have at Bolzano market where prices are higher than in Trento).
- The increase of mortality at the end of the year may also be due to an economic decision of the farmers to reach the maximum insured level of 4% of animals and to kill the animals with the lowest value on farm. As shown for the province of Bolzano, especially the number of non-specified death increases towards the end of the year.
- During summer grazing, the problem for adapting to conditions in the alpine pastures is more evident for animals/breeds in the province of Trento which are less adapted to mountain conditions. Their higher nutritional demands of higher performing breeds are not always sufficiently covered at pasture. In the province of Bolzano preparation for transhumance is more gradual since in most cases animals are kept in free range already some weeks or months before moving to higher mountain areas.
- From the two high mortality clusters examined in Trento, one is due to the notification practice where calves died at birth or few days after are identified and than declared dead in the national database which was not encountered elsewhere. The other high mortality cluster seems to be associated to high slaughtering for own consumptions.

4.3 Modelling on-farm mortality

In order to analyse changes in mortality inside a population subset the developed model could provide the baseline for each farm for the detection of abnormalities independent of the high variation arising when comparing a subset with the surrounding area. The proposed model would take into account the observed variations regarding age and sex of the animals and time of the year.

The model could be refined by including data over several years from the Italian cattle database. To prove its usefulness the model should be verified against notified mortalities for different regions, clusters and years.

In applying the model for expected mortality rates, the acceptable variation between model and real values could be established when comparing the two for different years. This approach could allow finding cut-offs for abnormally high mortalities within a subset of a population.

5. Conclusions and Recommendations

Overall, the methods described for comparing mortality rates of regions, clusters or farm holdings with the surrounding area could provide suitable indicators for evaluating herd management. These indicators could be applied to:

- identify areas or holdings which have higher mortality rates, often symptoms of lower quality of the farming management system and possible animal welfare concerns;
- monitor improvements in management for both production and animal welfare aspects.

In addition, the described method provides evidence that transport conditions play a strategic role in establishing risky conditions for animal health and how to monitor corrective measures. As suggested in several scientific contributions, animal concentration during transport and /or adaptation at new environments (i.e. vehicles, collection centres where animals are grouped before dispatch, farm of destination) are the key points where to intervene to ensure that mortality rate due to transport is reduced at an acceptable level.

Mortality data from the national cattle databases could represent a useful source of information to establish indicators for national and regional policy and decision makers. Mortality rates could be routinely monitored for differences and changes between and in subpopulations.

The model developed for calculating expected mortality rates should be further refined and verified with data from the national cattle database for several years.

Further research could be directed towards including in an early warning system for emerging diseases additional information, such as birth data in the national cattle databases and data from rendering plants.

On-farm slaughter for own consumption should be considered as a distinctive category in the notification to national cattle databases in order to be able to analyse data for this group separately from animals died or killed on farm.

An obligatory notification of incoming fallen stock by the rendering plants to national cattle databases could be considered with information on holding of origin and individual identification or type of the animal.

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Abstract
The present study was aimed at exploring if and on what extent on-farm mortality, which is regularly notified in national cattle databases in the EU, could be used to design an early warning system for emerging diseases in cattle.
The statistical analysis of mortality rates recorded in Italy in 2008 showed a clear influence by transport, age, sex and season.
Through spatial and spatio-clustering methods several geographic area with exceptionally high mortality rates were detected.
A more in-dept analysis of individual causes of mortality in the provinces of Trento and Bolzano showed that on-farm mortality was greatly influenced by management practices and economic conditions. In order to control some of the influencing management factors a model was created to compare for a given population the actual and expected mortality rates.
A conclusion of the study was that on-farm mortality regularly notified in national livestock databases could represent an important indicator for evaluating herd management and animal welfare practices. Further analysis and refinement of the applied models would be needed in order to establish a robust method for the detection of anomalous events with respect to the outbreak of animal diseases

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