An epidemiological study of sheep pox in Tunisia (2008–2017)

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Summary

Sheep pox is a highly contagious disease causing significant economic losses on livestock farms, especially among young animals. Epidemiological analysis of retrospective data on sheep pox surveillance over ten years revealed the endemicity of the disease in Tunisia. Temporally, the prevalence of infected farms increased during the last five years analysed (2013–2017), despite control measures for the disease, which are based essentially on vaccination. Analysis of the seasonality of infection showed that most outbreaks occurred in autumn and winter. The geographical distribution and spatial analyses classified the governorate of Sidi Bouzid as the area most affected by sheep pox during the period of study. It was observed that vaccination coverage decreased below the recommended value (80%) in the last four years (2013–2016).

Keywords

Cluster – Evolution – Sheep pox – Spatial – Temporal – Tunisia – Vaccination.

Introduction

Sheep pox is a disease notifiable to the World Organisation for Animal Health (OIE), and is caused by a virus of the genus *Capripoxvirus* belonging to the family Poxviridae (1, 2). Clinically, skin lesions, inflammation of the mucous membranes of the eyes and nose, fever, lymphadenitis and pneumonia characterise sheep pox. It is enzootic in the Middle East, North Africa, the Indian subcontinent and countries of Central and Eastern Europe (3). Sheep pox is responsible for significant economic losses (high mortality among young animals, abortions, skin and wool damage) (4) and delays the development of livestock farming.

In the Maghreb region, the trade in livestock is enormous and complex, and occurs on many scales (at borders, between farms, at livestock markets, etc.). There are no intervening rules to control these movements and much of the trade is still based on bilateral agreements between countries. Consequently, sheep pox remains enzootic in Tunisia as for the other Maghreb countries (5, 6), with 'microepizootic' variations. Several factors (geographical location, incomplete identification of animals and uncontrolled movement of animals in neighbouring countries) increase the risk of introduction and spread of the disease (7).

Economic evaluation of the impact of sheep pox on sheep farms has shown that the resulting damage is significant, and losses can reach 2,478 Tunisian dinars per farm (equivalent to US $ 1,125) (8).

The geopolitical events observed in recent years (the Arab spring) influenced the epidemiological situation of animal diseases, including sheep pox. Indeed, the difficulties confronted by Veterinary Services in the application of disease control measures (acceptability to

farmers, financial and logistical deficiencies, etc.) have contributed to the persistence of the disease.

This study aims to describe the epidemiological situation of sheep pox in Tunisia over ten years (2008–2017), including its spatial and temporal evolution, in order to explain the enzootic profile of this disease and its persistence on Tunisian territory despite the control measures applied.

Materials and methods

Study area

Tunisia is a North African country. It is the smallest country in the Maghreb region, with an area of 163,610 km². It is bordered on the North and the East by the Mediterranean (1,148 km of coastline). Its western border opens on Algeria (965 km) and its South-eastern border on Libya (459 km). It is divided into 24 governorates (Fig. 1).

Fig. 1

Study area

Study population

Sheep husbandry in Tunisia 2008–2017

Information on the sheep population in Tunisia was collected from the annual report of the General Directorate for Studies and Agricultural Development (in French: *Direction générale des études et du développement agricole*). The sheep population is estimated at 6,955,000 head per year during the study period (2008–2017). The average number of sheep flocks is around 274,000 (9).

Data collection

According to the sheep pox surveillance in Tunisia, 'an outbreak of sheep pox' is defined as the occurrence of one or more cases on a farm, which constitutes the epidemiological unit. Cases were diagnosed based on clinical signs, i.e. fever >40°C, papules or nodules anywhere on the body, mucopurulent nasal discharge, swollen eyelids and enlarged prescapular lymph nodes.

Quantitative data on the number of outbreaks, cases and deaths recorded for the period from 2008 to 2017 were retrieved from annual reports of the General Directorate of Veterinary Services (DGSV – in French: *Direction générale des Services vétérinaires*), the OIE via the World Animal Health Information Database (WAHIS Interface) and the epidemiological bulletins of the Tunisian Veterinary Research Institute (IRVT – in French: *Institut des recherches vétérinaires de Tunis*).

The seasonal distribution of sheep pox was assessed by aggregating monthly outbreaks into four seasons: spring, summer, autumn and winter.

Data on sheep pox outbreaks for the second half of 2012 were not available.

Data analysis

The epidemiological parameters calculated to examine the dynamics and the impact of the disease included annual, monthly and seasonal prevalence, mortality rate, morbidity rate and vaccination coverage.

These parameters were calculated according to the following formulae:

- Annual prevalence = number of outbreaks per year / total number of flocks of sheep and goats during that year
- Mortality rate = number of deaths / total population of sheep and goats in the same year
- Morbidity rate = number of individual animal cases / total population of sheep and goats in the same year
- Vaccination coverage = total number of vaccinated sheep / the population of sheep during that year

The Local Moran index has been used to evaluate the existence of clusters in the spatial arrangement of a given variable and the similarity of the values of this variable, taking into consideration their geographical location (10, 11). A positive spatial autocorrelation indicates a spatial grouping of low or high values of the variable. Negative spatial autocorrelation indicates that a geographical unit tends to be surrounded by neighbours with very different values. The absence of spatial autocorrelation means that the spatial distribution of the values of the variable is random (12). As a result, governorates were categorised into five classes of spatial grouping:

- High–High: governorates with a high number of outbreaks of sheep pox that are surrounded by areas (governorates) with a high number of outbreaks
- Low–Low: governorates with a low number of outbreaks of sheep pox that are surrounded by areas (governorates) with a low number of outbreaks

– Low–High: governorates with a low number of outbreaks of sheep pox that are surrounded by areas (governorates) with a high number of outbreaks

– High–Low: governorates with a high number of outbreaks of sheep pox that are surrounded by areas (governorates) with a low number of outbreaks

– Non-significant: the number of outbreaks of sheep pox is randomly distributed (12).

In this study, the Anselin Local Moran index was calculated at the governorate level using the open source software R (version 3.2.3, www.r-project.org) by combining the data into five periods (period 1: 2008–2009; period 2: 2010–2011; period 3: 2012–2013; period 4: 2014–2015; period 5: 2016–2017).

Graphical representations were produced with the free software R. Joinpoint (version 4.7.0.0, Statistical Research and Applications Branch, National Cancer Institute, Bethesda, MD, United States of America [USA]) was used to perform trend analysis of the prevalence of sheep pox (13), to determine whether the prevalence increased or decreased over time. The annual percentage change (APC) was calculated to measure the speed at which the increase or decrease of the disease occurred. The Kruskal–Wallis test was performed to compare parameters. A significant difference was concluded when the *p*-value was below 0.05.

Results

Temporal distribution of sheep pox in Tunisia

Annual prevalence

During the period of study (2008–2017), the results showed that sheep pox occurred in all years, with a significant variation among years ($p < 0.0001$). In general, a low annual prevalence was observed over the ten years. Temporal distribution revealed the presence of a peak in 2016. The lowest yearly prevalence was recorded in 2011 (Fig. 2).

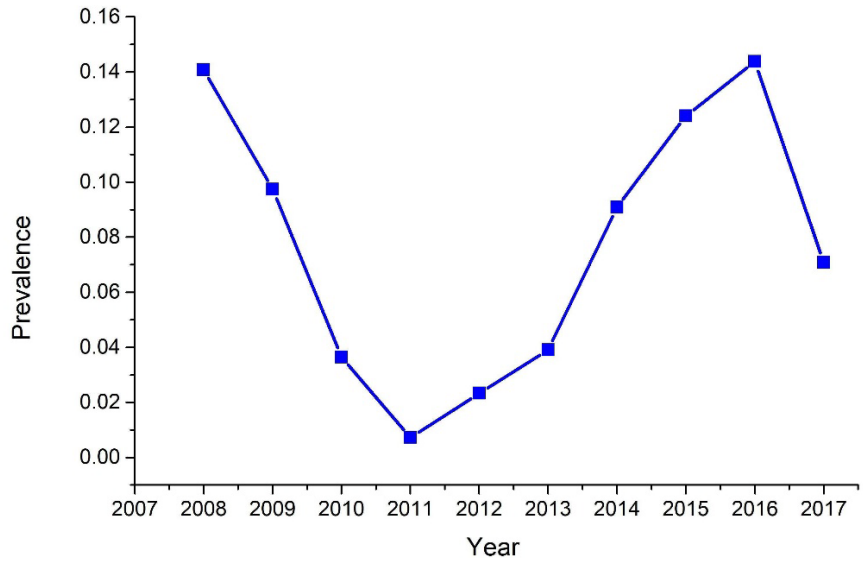

Fig. 2

Annual prevalence of flocks infected by sheep pox in Tunisia from 2007 to 2017

Trend analysis of the prevalence of sheep pox in Tunisia (2008–2017)

Figure 3 shows a graph of the trend of the prevalence of sheep pox outbreaks from 2008 to 2017. The APC values of the trend for the two segments are presented in the top right of the figure. For the prevalence values of sheep pox between 2008 and 2011, there was a downward trend of –41.28%. Between 2012 and 2017 there was an upward trend of 32.21% (Fig. 3).

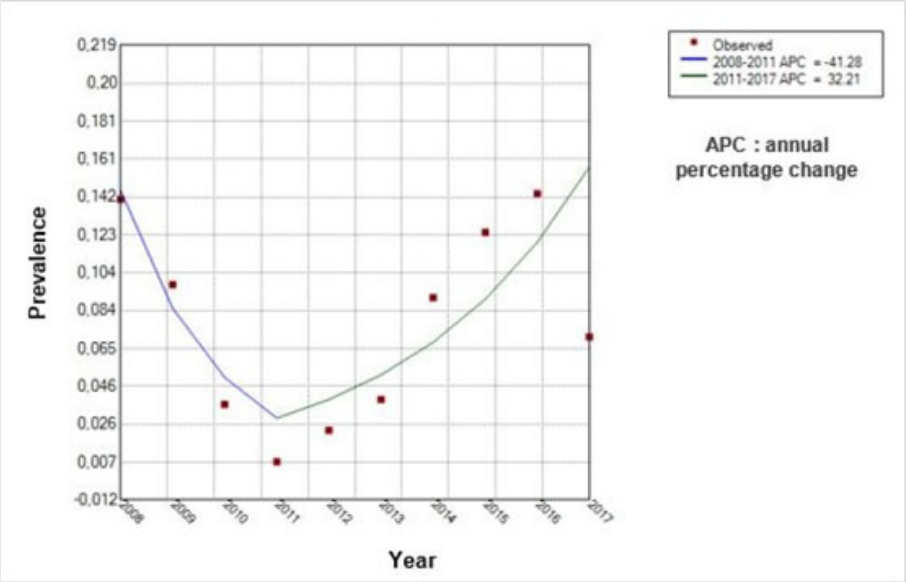

Fig. 3

Joinpoint regression lines for the prevalence of sheep pox in Tunisia (2008–2017)

APC: annual percentage change

Monthly prevalence

Sheep pox outbreaks were recorded throughout the year, with an average of 18 outbreaks per month for the ten years of the study. A statistically non-significant increase in outbreaks ($p = 0.26$) was observed during September, October, November, December, January, and February (Fig. 4). However, when analysed over the years, the monthly variation in the prevalence of sheep pox during the last four years of the study (2014 to 2017) was statistically significant ($p = 0.00000$) (Fig. 5). Indeed, a monthly average of 14 outbreaks was recorded during the first period (2008–2013), compared with 24 outbreaks per month in the second period (2014–2016).

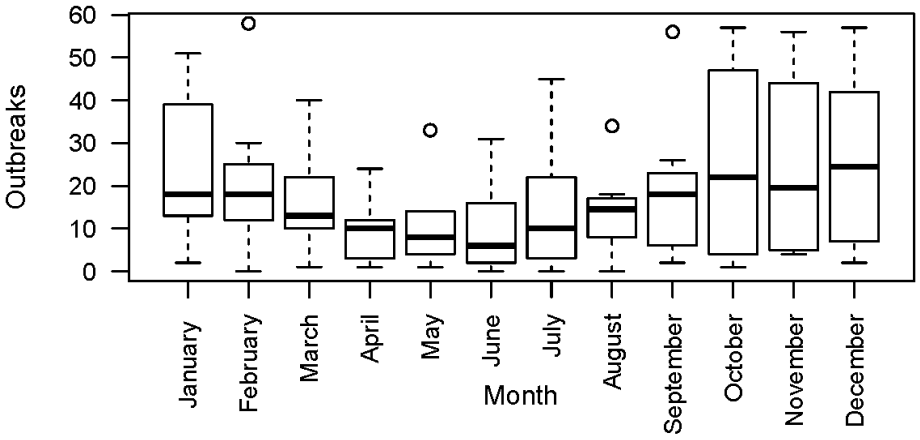

Fig. 4

Global monthly distribution of the prevalence of sheep pox in Tunisia (2008–2017)

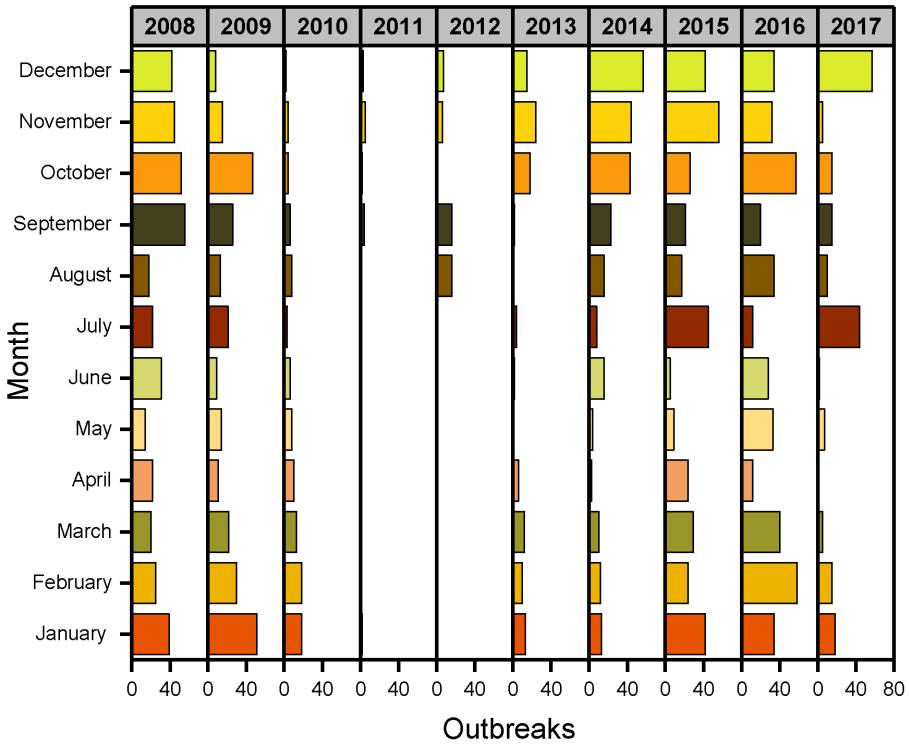

Fig. 5

Monthly distribution of the number of outbreaks of sheep pox in Tunisia (2008–2017)

Seasonal distribution

Data analysed on the basis of season show that sheep pox occurred during all seasons, but the highest number of outbreaks was recorded in the autumn and winter (Fig. 6). An average of 52 outbreaks per season was registered. However, the number of outbreaks recorded in autumn and winter (68 outbreaks) was almost twice as high as that in spring and summer (36 outbreaks) ($p = 0.0001$). Examining each year separately, the seasonal prevalence of sheep pox increased during autumn and winter in the last four years of the study (2014–2017) ($p = 0.0004$) (Fig. 7).

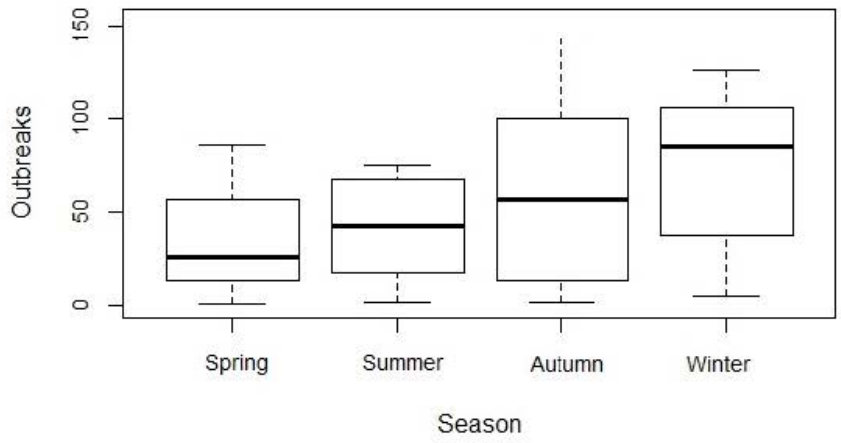

Fig. 6

Seasonal distribution of the number of outbreaks of sheep pox in Tunisia (2008–2017)

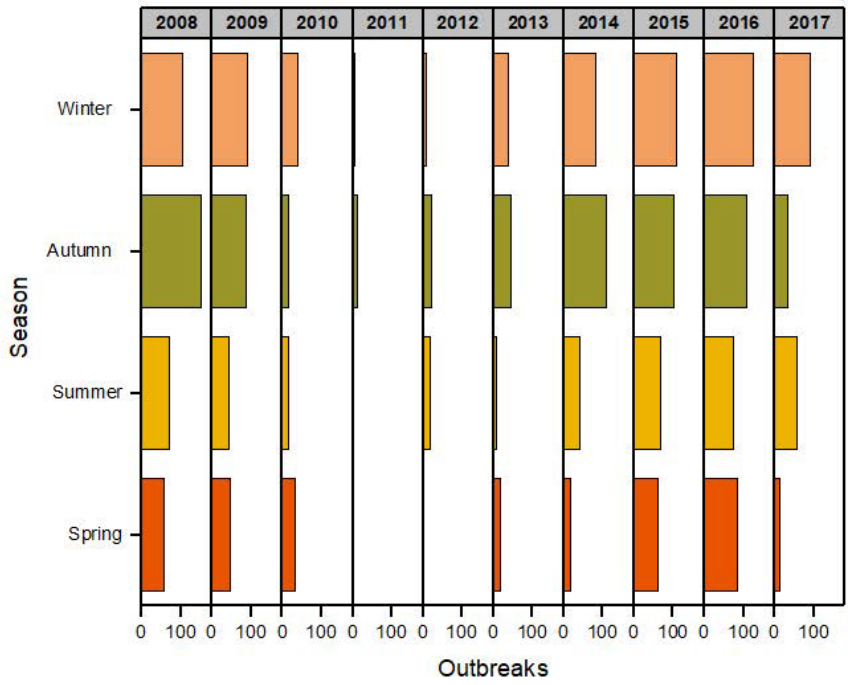

Fig. 7

Seasonal distribution of the number of outbreaks of sheep pox in Tunisia (2008–2017)

Mortality and morbidity rates

Morbidity and mortality rates of sheep pox calculated for the study period (2008–2017) are presented in Figure 8. The results show that mortality rate follows a stable trend with low values. However, the evolution of the morbidity rate fluctuated throughout the period of study. Indeed, a decline in the mortality rate was observed, from 0.033% in 2008 to 0.001% in 2011. From 2012 to 2017, a steady increase in the morbidity rate, reaching a maximum of 0.027% in 2016, was recorded (Fig. 8).

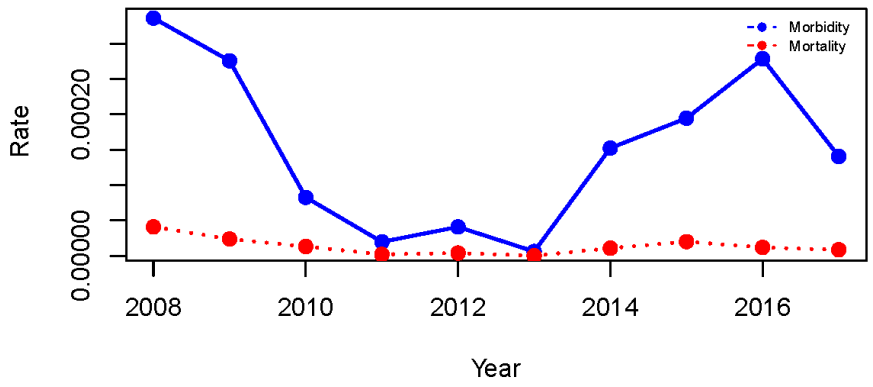

Fig. 8

Morbidity and mortality rates for sheep pox in Tunisia (2008–2017)

Spatial distribution of sheep pox in Tunisia

Geographical distribution

Figure 9 illustrates the geographical distribution of the prevalence of sheep pox in the 24 governorates from 2008 to 2017 and shows that the disease was widely distributed in Tunisia. Historically, sheep pox was reported in all governorates during the ten-year study period. However, it was more concentrated in the Midwest governorates (Sidi Bouzid, Kasserine and Kairouan). In 2008, the disease was reported in 23 governorates; no outbreaks were recorded in Monastir governorate. The governorates of Sidi Bouzid, Kairouan and Kasserine seem to be the most affected. A regular decrease in the number of outbreaks of sheep pox was noted from 2009, when the geographical extent of the disease reduced, but it was still restricted to the centre west governorates. No outbreaks were recorded in several governorates (Siliana, Beja and Medenine). The same distribution was observed in 2010 with limited infected areas. In the following three years (2011–2013), the epidemiological situation remained stable and Kairouan and Sidi Bouzid could be considered to be the most exposed areas with an important concentration of outbreaks. Nevertheless, the North-west, Midwest and a few governorates in the North-east did not experience the disease. During the second period of the study (2014–2017), a recurrence of sheep pox was highlighted and a high prevalence was observed, exceeding 100 outbreaks in 2015 and

200 outbreaks in 2016 in the Midwest governorates (Sidi Bouzid, Kasserine, Kairouan). The evolution of sheep pox in the other governorates was variable, specifically in the North part of the country where the disease was not detected (Fig. 9).

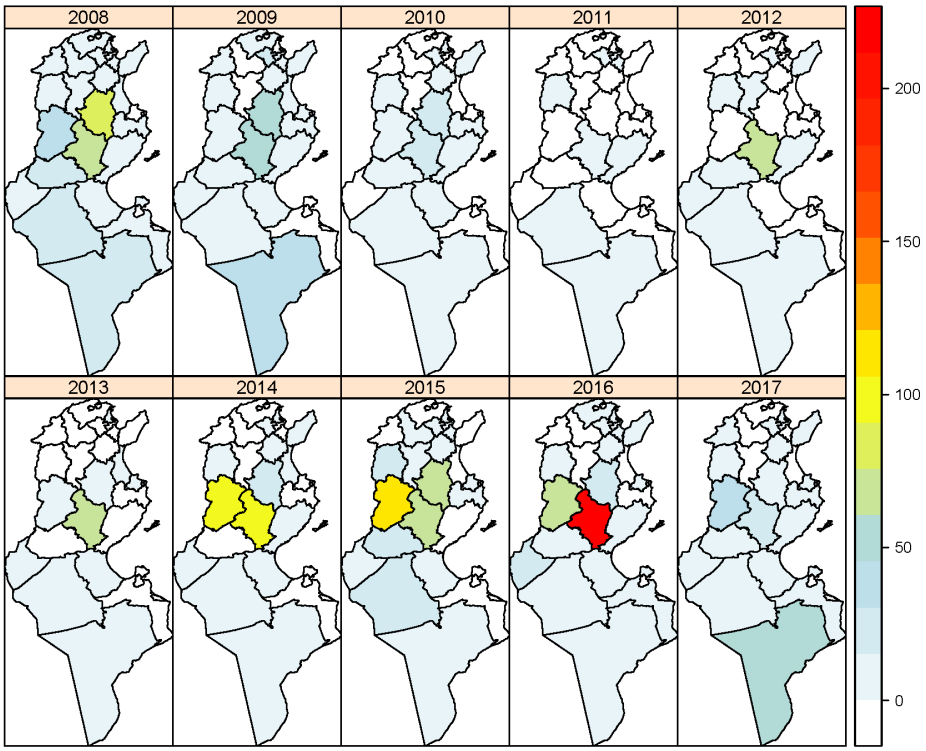

Fig. 9

Geographical distribution of the number of outbreaks of sheep pox in Tunisia (2008–2017)

Spatial autocorrelation

Local spatial autocorrelation analysis was performed for the five periods (A: 2008–2009; B: 2010–2011; C: 2012–2013; D: 2014–2015; E: 2016–2017). For the first period (2008–2009), it was noted that High–High gathering areas were mainly represented by the governorate of Sidi Bouzid (Centre of Tunisia) (Fig. 10A). For the second period (2010–2011), the High–High clusters of the disease were detected in the governorates of Sidi Bouzid and Kairouan (Centre of Tunisia) (Fig. 10B). Contrary to the first period, the governorate of Sidi Bouzid was classified as a High–Low cluster in

2012 and 2013 (Fig. 10C). For the remaining periods of the study (2014–2015 and 2016–2017), High–High clusters were always limited to the governorates of Sidi Bouzid and Kairouan (Figs 10D and 10E).

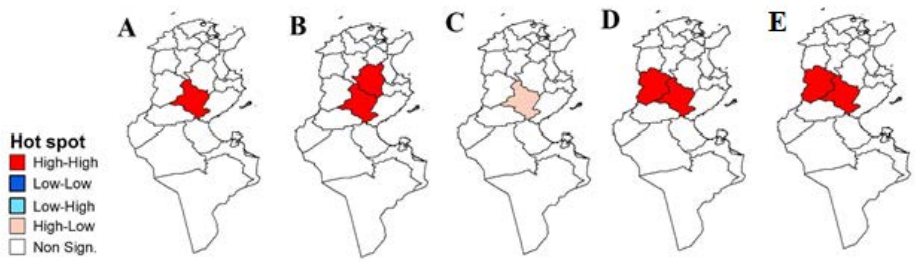

Fig. 10

Distribution of cluster and outlier analysis using the Anselin Local Moran Index for sheep pox in Tunisia for five periods (A: 2008–2009; B: 2010–2011; C: 2012–2013; D: 2014–2015; E: 2016–2017)

Non Sign: non-significant

Vaccination coverage for sheep pox in Tunisia between 2008 and 2016

Vaccination coverage was calculated by comparing the number of vaccinated animals to the population of sheep. As shown in Figure 11, a statistically non-significant variation in the vaccination coverage was observed. Coverage fluctuated between 61.1% in 2014 and 85.2% in 2011. From 2008 to 2011, a steady trend in the vaccination coverage was remarked. From 2012 to 2016, a decline was observed, and it remained below the threshold of 80% (recommended coverage) (Fig. 11).

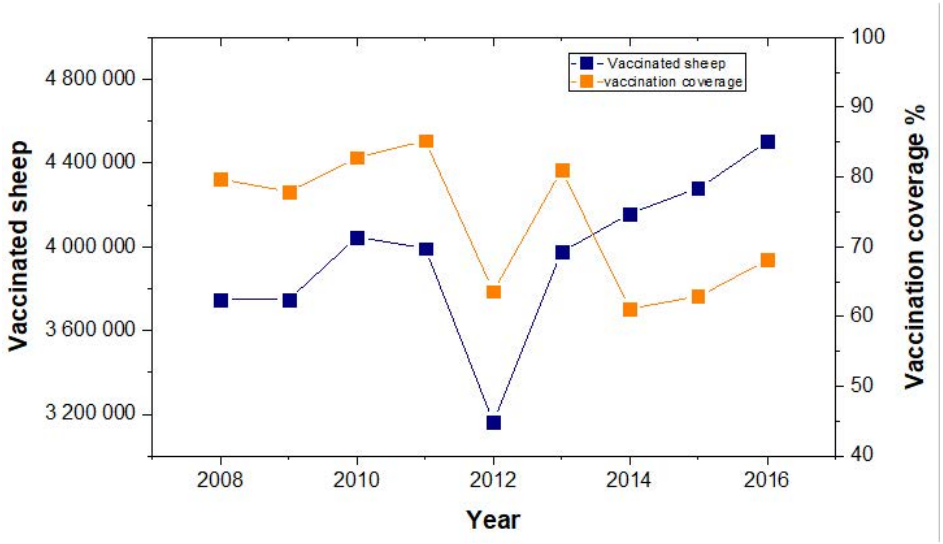

Fig. 11

Trends in vaccination coverage and number of sheep vaccinated against sheep pox in Tunisia (2008–2016)

Discussion

Sheep pox is a notifiable disease in Tunisia, and its diagnosis, as in other North African countries (Algeria, Libya) (8, 14, 15), is based mainly on detection of clinical signs. This study describes the epidemiological situation of sheep pox in Tunisia during a ten-year period (2008–2017). The results of this study have highlighted the enzootic profile of sheep pox and identified the governorates where the disease seems to persist.

The annual prevalence of sheep pox in Tunisia varied between 0.7% and 14%. However, the prevalence could be higher than reported because of under-reporting of the disease and absence of laboratory diagnosis. When diagnosis is based on clinical signs, the overlapping of several clinical manifestations with another disease commonly results in misdiagnosis of sheep pox. The significant decrease in the prevalence of sheep pox observed in 2011 may confirm this hypothesis. In addition, during the revolution (2010–2011), the Tunisian Veterinary Services experienced problems in implementing activities related to the surveillance and control of diseases. For these reasons, the decrease in the prevalence in 2011 should be analysed

with caution and not be interpreted as a true decrease in the number of outbreaks. Audu *et al.* observed that the situation of insecurity affected the reporting of disease cases and a large volume of recorded cases, for up to five months (May–September), was lost (16). After 2011, the available data indicate a significant increase in the prevalence of the disease in the last four years of the study (2013–2017), and APC was estimated at 32%. Recently, Ben Chehida *et al.* reported similar findings (8).

The presence of sheep pox throughout the period of study confirms the enzootic profile of the disease in Tunisia. Similarly to the current findings, sheep pox is enzootic in Algeria (17, 18), Morocco (18, 19) and in many other countries: Nepal, the People's Republic of China, Bangladesh, Ecuador, Iran, Turkey, Pakistan, Iraq, Afghanistan, the Indian subcontinent and Egypt (19, 20). One of the reasons for the persistence of sheep pox in Tunisia is the low vaccination coverage. The decrease in vaccination coverage in 2012 and during the last three years studied (2014–2016) could explain the observed increase of disease prevalence. It has been verified that vaccination against sheep pox induces permanent immunity in vaccinated animals and a single vaccination might be enough to stop the disease (21). In Tunisia, however, despite the implementation of annual vaccine campaigns for many years, sheep pox was not eradicated. This indicates that a significant fraction of the sheep and goat population are not reached by the vaccination efforts.

The monthly distribution of sheep pox in Tunisia shows that the disease occurs throughout the year but with a seasonal increase during the autumn and winter. This pattern is discernible throughout the ten years of the study. The seasonal nature of sheep pox in Tunisia has been confirmed in a previous study (8). In contrast to this finding, Eroksuz *et al.* reported that the majority of sheep pox outbreaks in Turkey are observed during spring (April–May) (22). The literature highlights the seasonal nature of the disease. However, climate variations from one country to another may explain the differences in observed peaks of infection (23, 24).

Mortality and morbidity rates varied over the ten years of the study, but remained below 0.03%. Lafar *et al.* reported lower values of mortality and morbidity rates for Morocco (19).

Historically, sheep pox has been widespread throughout Tunisia and it is present in all governorates (8), with a higher number of notified outbreaks in the Midwest governorates (Sidi Bouzid, Kairouan and Kasserine). The lowest number of outbreaks was observed in the Northern governorates specifically in the last five years (2013–2017). The spatial autocorrelation analysis identified Sidi Bouzid governorate as a hot spot (high incidence area) for the ten years of the study. In addition to Sidi Bouzid, Kairouan and Kasserine were recognised as a high–high cluster in 2010–2011 and 2014–2017, respectively. It can be concluded that the widespread distribution of sheep pox in these governorates (Sidi Bouzid, Kairouan and Kasserine) is likely to be due to the uncontrolled animal movements between Tunisia and neighbouring countries. It has been demonstrated in previous studies that the governorate of Sidi Bouzid and some border governorates may play an important role in the introduction of diseases via infected animals. They are considered as the most probable source of diseases. Indeed, animal mobility surveys in Tunisia carried out in 2016 showed that animal movements occurred throughout the whole country, but concentration of the flow is observed in the Midwest and Northern governorates. It has been shown that several livestock markets (Sidi Bouzid, Majel Bel Abbès [Kasserine], Gafsa) can play a major role in the large-scale spread of diseases and have qualified as 'super spreaders' (receivers and transmitters of infected animals) (25, 26). Studies have also highlighted the significant role of informal animal movements in the introduction and spread of the disease, and the highest incidence rates are always reported in areas with high levels of animal mobility (27, 28).

To better control and eradicate sheep pox, further studies on animal movements, risk factors related to disease persistence and the immunity induced by the sheep pox vaccine are recommended.

Conclusion

Despite the control programme for sheep pox in Tunisia, the disease is enzootic. The situation of insecurity during the revolution (2010–2011) influenced the epidemiological status of sheep pox and a significant increase in the prevalence has been observed since 2011. It is essential to improve vaccination coverage, particularly in the area with a high risk of occurrence of outbreaks. Animal movements must be controlled to reduce the risk of introduction and spread of sheep pox in Tunisia. The favourable evolution of the epidemiological situation of sheep pox in Tunisia and neighbouring countries requires a regional and harmonised control strategy. In the framework of the Food and Agriculture Organization of the United Nations (FAO)–OIE Peste des Petits Ruminants (PPR) Global Eradication Programme, which has among its objectives reducing the prevalence of other priority small ruminant diseases, the North African countries have decided to combine mass vaccination against PPR with sheep and goat pox vaccination. This could represent, if implemented, a significant step towards a better control of the disease in the North African region.

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