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Possible windborne spread of bluetongue to Portugal, June–July 1956

R. F. SELLERS
Animal Virus Research Institute, Pirbright, Woking, Surrey
D. E. PEDGLEY AND M. R. TUCKER
Centre for Overseas Pest Research, London W8 5SJ

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SUMMARY

The possible sources for the epidemic of bluetongue in Portugal at the beginning of July 1956 were examined. Introduction through authorized importation of domestic or wild ruminants was not feasible, since no cattle, sheep or goats were imported and the wild ruminants were confined to Lisbon Zoo, which was too far from the initial outbreaks. Weather maps were examined to see if the wind could have carried infected *Culicoides* midges from North Africa. On 21 June 1956 infected midges in Morocco could have been taken offshore by southeast winds and then carried by south winds unusual at that time of year to the south coast of Portugal. The 200–300 km sea crossing would have taken some 10 h and been by day when air temperatures near the sea surface were about 18–20 °C. Bluetongue had not been reported at that time in Morocco, and the possibility of the presence of the virus in Moroccan animals without clinical signs is discussed.

INTRODUCTION

In the second half of 1956 there was an epidemic of bluetongue in southern Portugal and south western Spain which resulted in extensive losses among the sheep and which also affected some cattle (Manso-Ribeiro *et al.* 1957; Campano, 1957). Bluetongue had not previously been seen in Europe and how the disease was introduced into Portugal was never discovered (Manso-Ribeiro, 1958). In a recent paper the spread of African horse sickness (AHS) was examined and it was shown that dispersal of the disease by infected midges on the wind was feasible (Sellers, Pedgley & Tucker, 1977). It was therefore decided to see if bluetongue could have been introduced into Portugal by infected midges carried on the wind from Africa.

HOST AND VECTOR

The disease is found primarily in sheep, although cattle and goats may also be affected (Howell, 1963; Erasmus, 1975). Among sheep, Merino and European breeds are more susceptible than other breeds. Breeds of sheep in endemic areas are rarely affected, but on the border between endemic and epidemic areas there may be considerable variation in the clinical disease depending on the strain of

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virus responsible for the disease. Cattle and goats are regarded as reservoirs or carriers of the virus in endemic areas (Nevill, 1971; Luedke, Jones & Walton, 1977).

The incubation period of bluetongue in sheep for type 10 virus (the strain responsible for the outbreak in Portugal and Spain) varies from 6 to 10 days with a mean of 8 days (Goldsmit, Barzilai & Tadmor, 1975), although the period could be longer. Virus to a titre of 10^4 per ml or greater is present in the blood from about 4 days before the appearance of disease to 4 days afterwards and during this period there is sufficient virus to infect a midge.

The disease is transmitted by *Culicoides* species. In Northern America the vector is *C. variipennis*, and in Africa and Asia *C. imicola* (*C. pallidipennis*). Other species (*C. milnei*, *C. tororoensis*, *C. schultzei*, *C. cornutus*, *C. puncticollis* and *C. zuluensis*) may also act as vectors (Walker, 1977).

The life cycle of the midge *C. imicola* was described in a previous paper (Sellers *et al.* 1977). In summary, the adults take a blood meal after emergence and subsequently will take blood meals every 3 to 4 days depending on the temperature. If the blood meal is infective the bluetongue virus multiplies in the midge and reaches a high titre ($10^{5.5}$ to 10^6 per ml) on the sixth day. The titre remains high for the rest of the midge's life of up to 70 days (Jochim & Jones, 1966). The midge can transmit virus from between 4 days (embryonated eggs – Jones & Foster, 1966) and 10 days (sheep – Foster, Jones & McCrory, 1963) after feeding and subsequently. As with African horse sickness, a midge infected at the first bite could have transmitted the virus on the 8th day of its life (assuming an incubation period of 7 days) and as many as five times by the 20th day. With an observed daily survival rate of 0·8, 1·8% of a given population would have survived to 18 days (Walker, 1977).

With an incubation period in sheep of 8 days (range 6–10 days) and a minimum incubation period in midges of 7 days, the shortest period between a midge biting an affected animal and the disease being seen later in a sheep bitten by that midge could be from 13 to 17 days with a mean of 15 days.

Movement of host and vector

Bluetongue spreads by movement of host or vector. With cattle, sheep and goats, movement would be on foot over short distances, but by vehicle, ship or aircraft over longer distances.

In the previous paper, it was shown that a major method of transport of AHS over long distances could be the movement of infected midges on the wind (Sellers *et al.* 1977). Inferred flight endurance varied up to at least 20 h and flight range up to 700 km. Temperatures at the time of inferred flight were likely to have been in the range 15 to 25 °C if flight was at night, or 20 to about 40 °C if it was by day.

The initial outbreak in Portugal

The first case of bluetongue disease in sheep was brought to the attention of the veterinary authorities on 10 July 1956 (Boino de Azevedo & Alface Reis, 1956). The sheep originated from a farm in the district of Alcacer do Sal (38° 20′ N; 8° 30′ W) (Fig. 1). The number of sheep affected (11 out of 88) and the description

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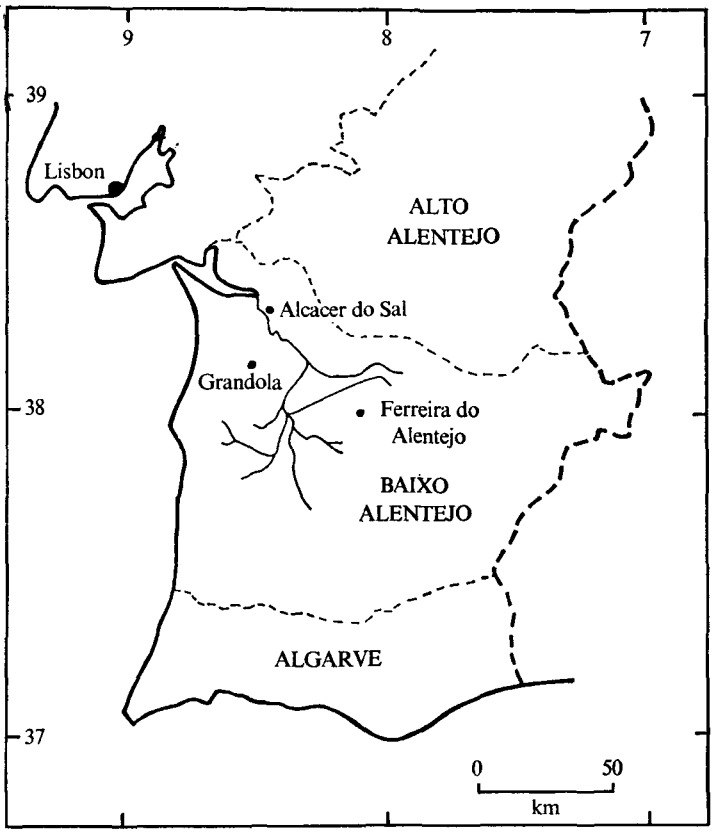

Fig. 1. Location map showing outbreaks of bluetongue in Portugal, July 1956.

of the lesions suggest that the sheep had suffered the disease for a few days, possibly from 6 July at the latest. About the same time outbreaks were reported from Grandola and Ferreira do Alentejo (38°–38° 10′ N; 8° 10′–8° 35′ W) (Estrella é Silva, 1956; Manso-Ribeiro *et al.* 1957). The latter authors concluded that the disease would have begun in the district of Alcacer do Sal on 1 July, Grandola on 5 July and Ferreira do Alentejo on 12 July (Table 1). Seventeen farms were affected in the first half of July and 114 in the second half; in August, 382 during the first half and 586 during the second half.

The area where the disease was reported (Lower Alentejo) is one of the chief sheep producing areas in Portugal. Lower and Upper Alentejo together have 38 % of the sheep population. There are few sheep in the Algarve (Mason, 1967). Merino and Meriono varieties are the breeds found in the area of the disease.

Introduction of disease

The number of farms affected in the first half of July and the dates put forward for the start of the disease in the three districts imply that a number of farms were infected within 5 to 11 days of each other. This period is less than the minimum for a sheep-midge-sheep cycle (13 days) and suggests a common source for the outbreaks, which could be either host or vector.

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Table 1. *Outbreaks of bluetongue in Portugal – July* 1956

	Date of outbreak	Possible dates of infection of sheep	Latest possible dates of infection of midge
Alcacer do Sal	1 July*	20–24 June	13–17 June
	6 July*	26–30 June	19–23 June
	10 July†	30 June–4 July	23–27 June
Grandola	5 July*	25–29 June	18–22 June
	18 July†	8–12 July	1–5 July
Ferreira do Alentejo	12 July*	2–6 July	25–29 June
	19 July†	9–13 July	2–6 July

* Suggested date. † Date reported.

If introduction of animals was reponsible, the infected sheep, cattle or goat(s) would have to have been in the district by 17 June. There had been no reports of disease in Portugal before 1956, and therefore the animals would have to have been imported. According to the records no authorized importation of cattle, sheep or goats took place. Wild ruminants had been imported into Lisbon zoo during the twelve months before July 1956, but were unlikely to have been responsible as there were no outbreaks near Lisbon. If the bluetongue was introduced through animals, it could have been by illicit import of carrier cattle, sheep or goats from Africa to the district near Grandola, but there is no means of verification.

If *Culicoides* were responsible for the introduction of the outbreak they would have bitten the sheep at Alcacer do Sal by 24 June if 1 July is accepted as the date of the outbreak or 30 June if 6 July is accepted (Table 1). Boino de Azevedo & Alface Reis (1956) suggested the transport of *Culicoides* in aircraft or on ship as a possible source of infection, but pointed out that there were no outbreaks near Lisbon, where the first cases might have been expected.

Weather maps were used to see if the wind could have carried infected midges to Portugal from a source in Africa. Surface maps were drawn for the period 19–22 June, based on 0600 and 1800 GMT data published in the Daily Weather Reports of Portugal, Spain and Morocco. The 0600 GMT maps were taken to be more representative of the broad-scale wind flow than the 1800 GMT maps, for sea breezes are likely to have been blowing along most coasts from about 0900 until after 1800 GMT. Such sea breezes would have almost certainly reversed any offshore broad-scale wind, thereby preventing midges from being carried out to sea at heights below about 500 m. Published ship data for 1200 GMT, from the Northern Hemisphere Data Tabulations of the United States Weather Bureau, were used to help the 0600 GMT analyses over the open sea, where diurnal changes in winds were almost certainly small.

The maps show that 0600 GMT surface winds over the outbreak area in Portugal veered from north on 19 and 20 June, through east on the 21st, to south on the 22nd. Earlier in June they had been between west and north-east, and after the

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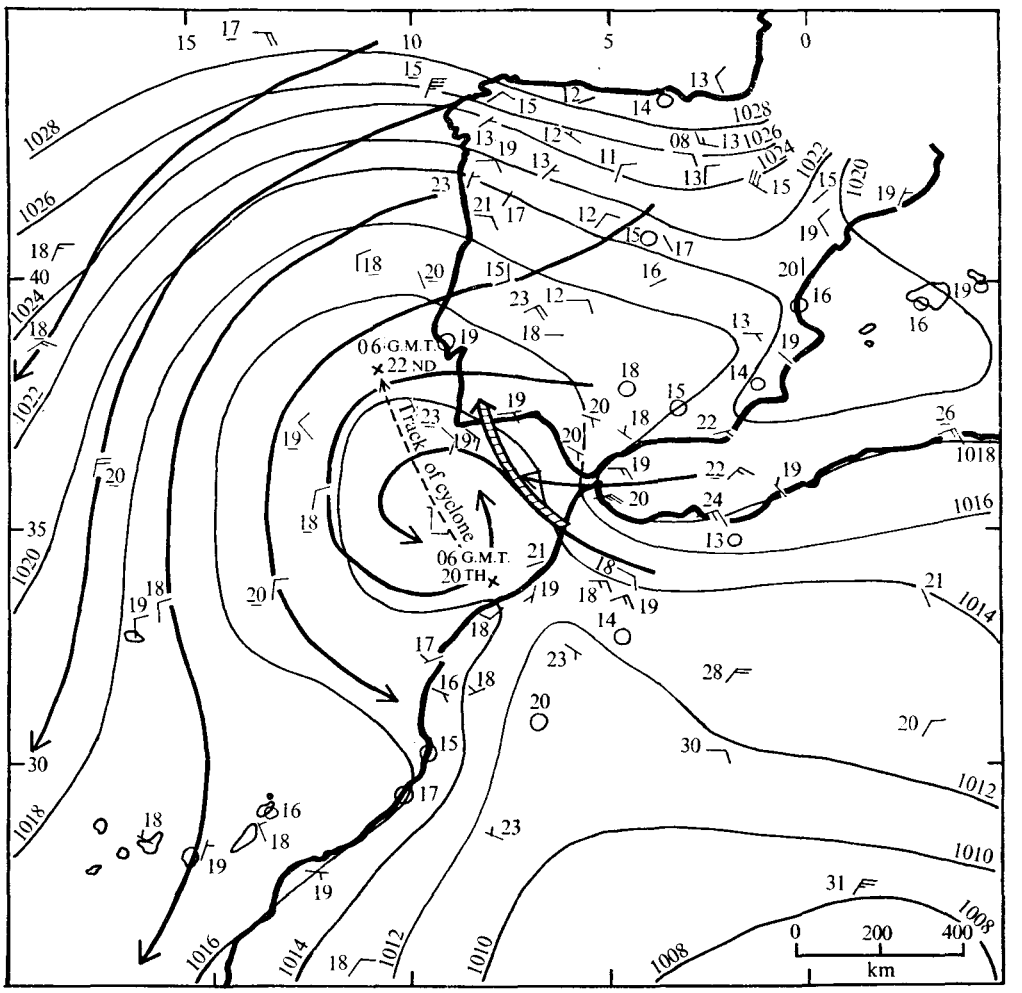

Fig. 2. Surface weather map for 0600 GMT, 21 June 1956, showing likely track taken by midges flying from Morocco to Portugal.— Symbols on surface chart:

18 0600 GMT temperature;

18 1200 GMT temperature;

1026 surface isobar;

streamline;

likely track of midges between about 0600 and 1800 GMT;

wind speed 2·5 m s^{-1};

wind speed 5 m s^{-1}.

22nd they stayed light and variable until the end of the month. This short spell of unusual south winds was part of a cyclonic wind circulation that formed near the coast of northern Morocco on the 19th and 20th, and then intensified as it moved north-west to become centred about 38° N 11° W by the 22nd. Thereafter the circulation drifted to about 40° N but had faded away by the 25th. Fig. 2

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shows the map for 0600 GMT, 21 June 1956, with positions of the centre a day earlier and a day later.

Windborne midges could have come to Portugal from Morocco only on the 21st, when south-east winds over Morocco between about 34 and 36° N would have taken midges off-shore and carried them the 200–300 km to the south coast of Portugal (Fig. 2) and then to Alcacer do Sal. The time taken for this sea crossing was likely to have been of the order of 10 h, because winds over the sea were almost certainly in the range 5–10 m s^{-1} (18–36 km h^{-1}). The maps show it was unlikely that the midges reached Portugal early on the 21st because winds over the sea would have been blowing from the east. Midges most likely left the coast of Morocco between about 0300 and 0900 GMT on the 21st, and early in that period if flight over land is by night. Over the sea, however, much of the flight would have been by day, with air temperatures near the sea surface about 18–20 °C. There was a similar wind circulation at greater height with speeds increasing to 10–15 m s^{-1} by 3 km above sea level. However, temperatures were less than 20 °C above about 1·5 km, so midge flight was probably confined to below that height.

From Table 1 it can be seen that 21st June is within a period of 6 to 17 days before the suggested dates of the first outbreak at Alcacer do Sal. This is the most likely period for midges to have been brought in on the wind if one allows an incubation period of 7 days in the midge and 6–10 days in the sheep.

DISCUSSION

By 1950, outbreaks of bluetongue had been reported on several occasions in West Africa: in Senegal, Upper Volta, Ivory Coast and Chad, 1923–31 (Curasson, 1936); Ghana, 1918 (Curasson, 1936) and 1933 (Stewart, 1933); and Nigeria 1943 (Henderson, 1945) and 1945 (Mettam, 1947). However, clinical disease was not reported in sheep in Morocco until October 1956 after it had been present in Portugal and Spain (Placidi, 1957; Barbaud, Herault & Placidi, 1957), but it was admitted that sporadic outbreaks could have been present before that time.

The outbreaks in Morocco in October were in the north of the country near Larache (35° 10′ N; 6° 10′ W). The main breed of sheep in that area is the Beni Ahsen, which have the finest wool in Morocco, and it has been suggested that they carry Merino (or proto-Merino) blood (Mason, 1967). Merino sheep are susceptible to bluetongue (Howell, 1963) and the sheep at Larache would have shown signs of disease, whereas the coarse wooled sheep in other parts of the country would not.

The possible carriage of midges to Portugal on 21 June suggested that infected midges were present in Morocco in June. It is possible that the cattle, goats and sheep of breeds other than the Beni Ahsen were infected at that time but did not show the disease. In a study of Moroccan midges, it was found that in subtropical zones *Culicoides* are present from April to December and in the arid zones there is a peak in numbers during June at the end of the rainy season and before the beginning of the hot season (Bailly-Choumara & Kremer, 1970). Thus infected midges could have been present.

In a description of the spread of African horse sickness (also transmitted by

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C. imicola) northwards in Morocco in 1966, Laaberki (1969) reported that it reached north of Meknes and Fes (34° 45′ N) by the end of May and beginning of June, remained in the area during July and August and did not move further north until September. It was reported around Tanger (35° 30′ N) at the end of September (Montilla & Marti, 1968). The dying down of bluetongue during the hot season and the reduction of numbers of *Culicoides* has been reported in June and July in Israel (Braverman & Galun, 1973). Thus, in Morocco, infection of animals with bluetongue virus could have been as far north as 34° 45′ N by June, but because of the fall in numbers of *Culicoides*, infection did not move north until September and became apparent as bluetongue disease at the beginning of October among the susceptible sheep around Larache. Having reached as far as 34° 45′ N, midges would have been taken to Portugal only on the 21st June, a date consistent with the first outbreak. It is therefore suggested that the evidence strongly favours the taking of bluetongue to Portugal by midges carried on the wind from Morocco.

Daily weather reports for June 1956 were kindly supplied by the French Meteorological Office (Morocco and Portugal) and by the Spanish Meteorological Office (Spain).

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