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African swine fever in Mozambique: Review, risk factors and considerations for control

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ABSTRACT

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African swine fever (ASF) is the most important disease that constrains pig production in Mozambique. Until 1994 it was apparently restricted to the central and northern provinces, but since 1994 outbreaks have been experienced throughout the country. ASF causes severe economic losses both in the small commercial sector and among the large numbers of small-scale producers in the family sector in rural and peri-urban areas. The history of ASF in Mozambique since its first confirmation in 1960 is briefly reviewed, recent outbreaks are reported, and the available information on the virus genotypes that have been responsible for some of the outbreaks is presented. Epidemiological factors that contribute to ASF outbreaks and strategies for limiting the negative effects of the disease in the different pig farming sectors in Mozambique, including raising farmer and community awareness, are discussed.

Keywords: African swine fever, Mozambique

INTRODUCTION

African swine fever (ASF) is one of the most serious limiting factors for pig production in sub-Saharan Africa (El Hicheri, Gomez-Tejedor, Penrith, Davies, Douati, Edoukou & Wojciechowski 1998; Penrith, Thomson & Bastos 2004a; Penrith, Thomson, Bastos, Phiri, Lubisi, Botha, Esterhuysen, Du Plessis, Macome & Pinto 2004b) owing to the high mortality rate and lack of a vaccine. In Mozambique, the commercial pig industry is small and has suffered considerable and repeated setbacks due to ASF. However, more than 90 % of the pigs in Mozambique belong to so-called family sector farmers, most of whom are very poor. Figures of the Livestock Directorate for 2001 show that the greatest concentration of pigs in Mozambique exists in the northern part of the country, where there is almost no commercial pig farming (Fig. 1). These pigs are important to their owners not only as a source of protein but mainly as a source of income. Census figures for 2003 indicated 1.3 million pigs in Mozambique (F. Rodrigues, personal communication 2006), an increase of more than 80 % over the figure for 2000 (Annual Report of the Livestock Directorate 2001), mostly in the family sector, indicating that pig farming is considered a worthwhile occupation. The ravages of ASF are felt at least as keenly in the family and smallholder sectors as in the commercial sector.

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It is likely that ASF has killed domestic pigs in Mozambique since their introduction to that country, probably from Portugal in the 19th century (Morgado 2004). The confirmation of ASF in Mozambique for the first time only in 1960 (Abreu, Valadão, Limpo Serra, Ornelas Mário & Sousa Montenegro 1962), although earlier cases were suspected on clinical evidence (Mendes 1971), was probably due to the interest roused in the disease by its introduction into the Iberian peninsula in 1957 from Africa, probably Angola, and its subsequent establishment there (Picard 1989; Wilkinson 1989; Edwards & Wilkinson 1990; Davies 1994; Manelli, Sotgia, Patta, Oggiano, Carboni, Cossu & Laddomada 1998). Before that ASF had been treated more as a colonial curiosity than as a major economic threat, although it was described from Angola as early as 1932 (Gago de Camâra 1932; Leitão & Martins 1998).

Investigators in Mozambique believed that the disease originated from contact between domestic pigs and warthogs (Abreu *et al* 1962; Ruiz 1969; Valadão 1969a, b; Mendes 1971), and the apparent absence of ASF from the area south of the Save River was attributed to the paucity of warthogs in that area (Abreu *et al.* 1962; Ruiz 1969), as well as lack of southward trade of pigs. The appearance of ASF for the first time south of the Save River in 1994 is generally believed to have been due to movement of people and livestock following the establishment of peace in 1992.

The ASF situation in Mozambique is particularly interesting but there is relatively little epidemiological information for most of the country. The existence of the sylvatic cycle in warthogs and tampans is probable but has not been reported. However, maintenance of the virus occurs in domestic pigs in an area adjacent to the endemic area in Malawi described by Haresnape, Lungu & Mamu (1985, 1987). The source of infection for commercially farmed pigs appears to be movement of infected pigs from rural areas where large numbers of pigs are produced in traditional systems based on allowing the pigs to roam freely, offering opportunities for contact between pigs of different owners as well as warthogs in some areas. Until 1994, ASF was apparently restricted to the provinces north of the Save River (Fig. 2), but since that time outbreaks have occurred frequently throughout the country. A recent study of samples from a number of outbreaks that have occurred in Mozambique since 1960 demonstrated the involvement of four genotypes of ASF virus (Bastos, Penrith, Macome, Pinto & Thomson 2004). Viruses belonging to two of these genotypes were isolated from the same outbreak of ASF in the Angónia District of Tete Province in 1998 (Bastos *et al.* 2004).

Despite the frequent ASF outbreaks, pigs remain a species of considerable socio-economic importance in Mozambique. Unfortunately, the occurrence of the disease results in negative perceptions of pig production among development agencies, which are reluctant to support pig farming in spite of its popularity and potential for income generation.

It is certain that ASF in Mozambique is, and always has been, considerably under-reported, with the majority of outbreaks among family sector pigs escaping official attention. Many more suspected outbreaks are never confirmed in the laboratory. The purpose of the present paper is to document the known occurrence of ASF in Mozambique since 1994, discuss the relationships of the viruses involved in recent outbreaks as determined by genetic characterization, evaluate the information in terms of identification of factors that contribute to the occurrence and spread of the disease, and explore the options for limiting the effects of this devastating disease under the circumstances that prevail in the country.

MATERIALS AND METHODS

The information about the outbreaks is derived from published material and data obtained from the Epidemiological Unit (UEV) of the former National Directorate of Livestock, Ministry of Agriculture (DINAP), the Provincial Livestock Services (SPP), and the Central Veterinary Laboratory (CVL), Directorate of Animal Sciences, Agricultural Research Institute of Mozambique (IIAM).

African swine fever was diagnosed at the CVL using the fluorescent antibody test as described in the OIE Manual for Diagnostics and Vaccine Production (2000). Sequencing of the *p72* gene of viruses was performed at the Exotic Diseases Division of Onderstepoort Veterinary Institute, South Africa, as described by Bastos, Penrith, Crucière, Edrich, Hutchings, Roger, Couacy-Hymann & Thomson 2003.

RESULTS

1960–1993 (Fig. 2)

The first confirmed outbreak of ASF in Mozambique occurred in what is now the Mutarara District of Tete Province, close to the Malawi border, in 1960 (Abreu *et al.* 1962). The disease spread among pigs farmed

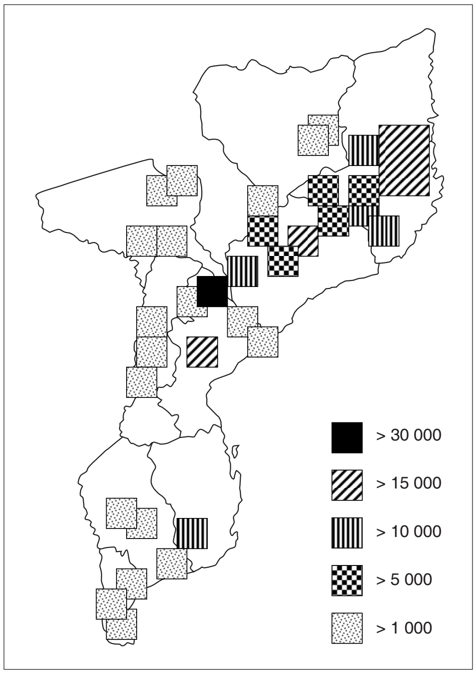

FIG. 1 Distribution and density of domestic pigs in Mozambique (2003 census figures)

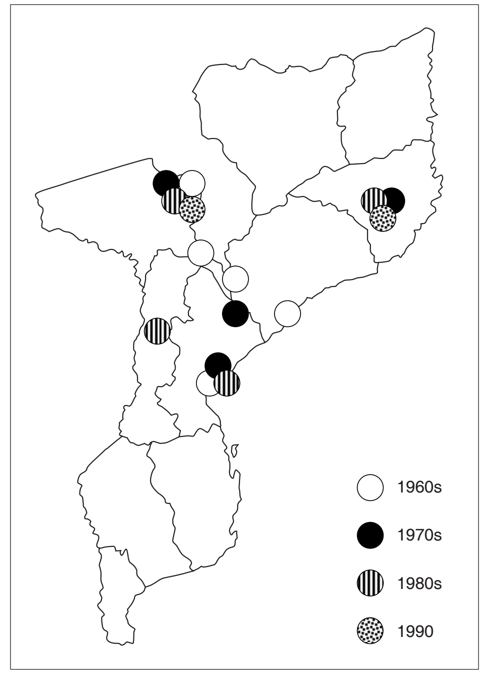

FIG. 2 Distribution of African swine fever outbreaks in Mozambique 1954–1993

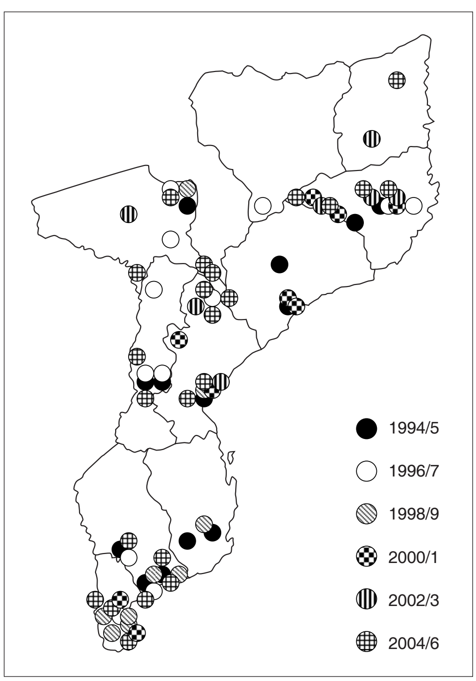

FIG. 3 Distribution of African swine fever outbreaks in Mozambique 1994–2006

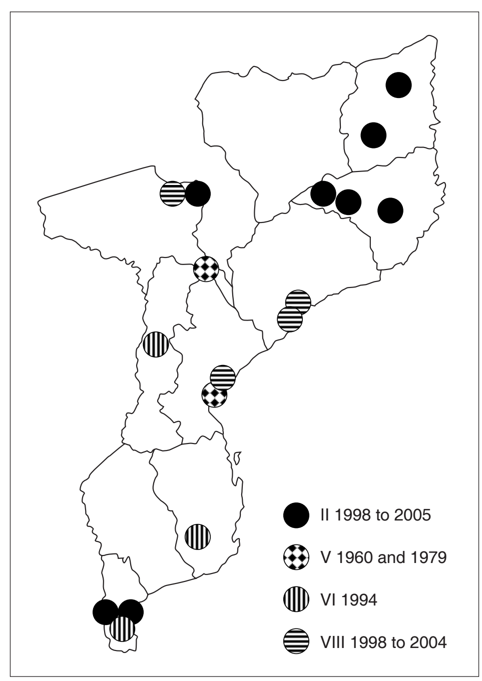

FIG. 4 Spatial and temporal distribution of outbreaks of African swine fever in Mozambique for which virus sequence data are available

on both sides of the Zambezi River to Morrumbala district in Zambézia Province (Abreu *et al.* 1962; Valadão 1969a). Previous suspected outbreaks had occurred in Tete Province in the Angónia District and around the city of Beira in 1954 (Mendes 1971). Outbreaks were reported to the Office International des Épizooties (OIE) with increasing frequency, the majority of which occurred in Tete Province, but the

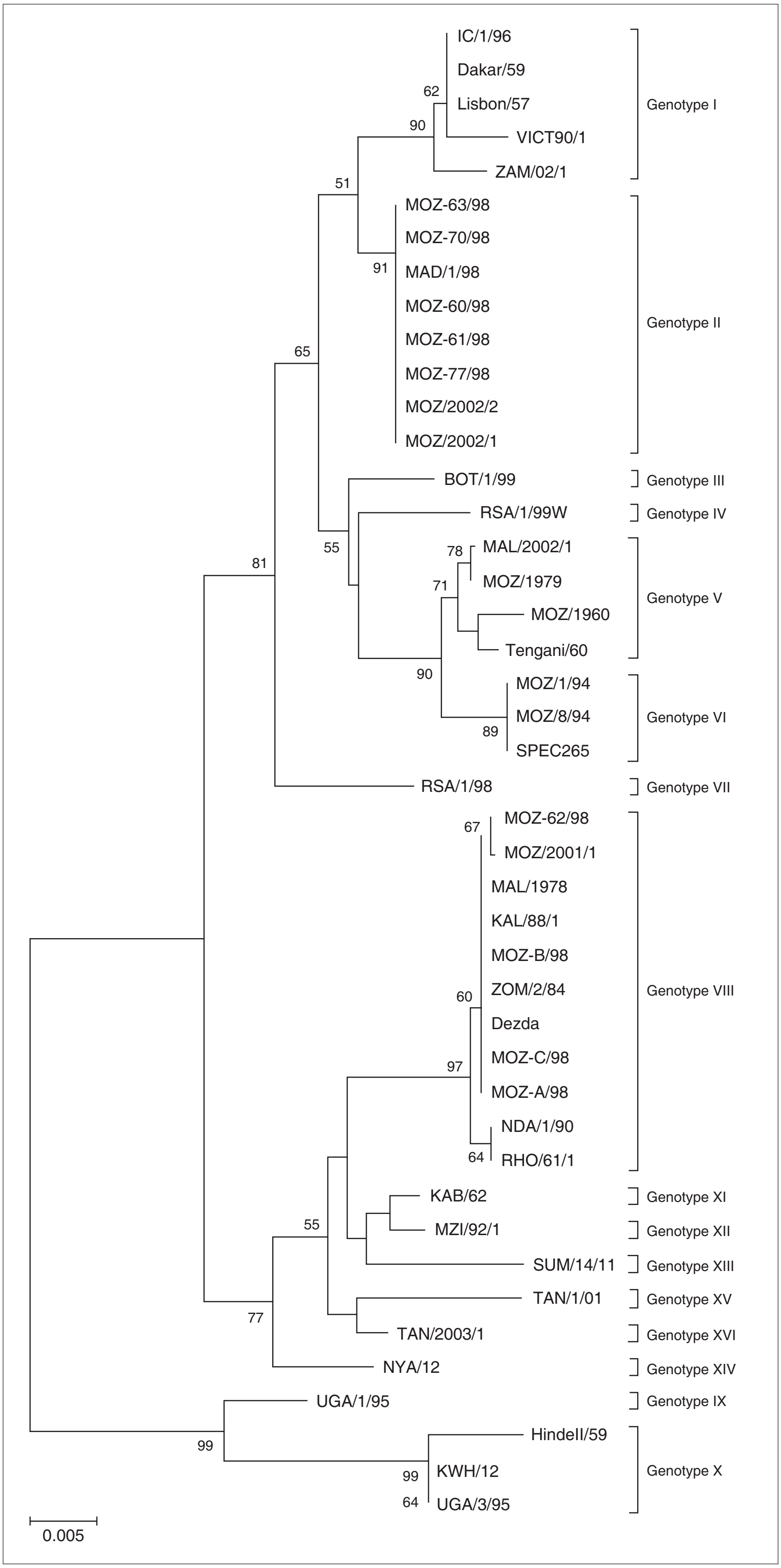

FIG. 5

Neighbour-joining tree depicting *p72* gene relationships of African swine fever viruses from Mozambique and neighbouring countries. The 17 presently recognised genotypes are denoted I–XVII. Bootstrap values >50 and based on 10 000 replications are indicated next to the relevant node (supplied by Dr A.D.S. Bastos, Department of Zoology and Entomology, University of Pretoria)

TABLE 1 African swine fever oubreaks in Mozambique 1994–2005: number of localities affected per province. Figures in parentheses indicate number of reports or samples

Year	Maputo	Gaza	Inhambane	Sofala	Manica	Tete	Zambézia	Nampula	Cabo Delgado	Niassa
1994	18 (60)	3 (4)	3	3	3	0	0	0	0	0
1995	8 (9)	2	0	2 (3)	0	1	2 (3)	3	0	0
1996	3 (4)	3 (4)	0	1	0	0	0	0	0	1
1997	2 (3)	0	0	0	4 (8)	2 (3)	0	0	0	0
1998	3	1	0	1 (2)	0	1 (8)	0	0	0	0
1999	11 (20)	3	1	0	0	0	0	0	0	0
2000	2 (4)	0	0	1	0	0	0	0	0	0
2001	1 (3)	0	0	1	0	0	7 (9)	3	0	0
2002	0	0	0	2	0	0	0	3 (4)	0	0
2003	0	0	0	0	0	1	0	1	1[a] (2)	0
2004	9	0	0	3	0	8	0	3	2	0
2005	8 (14)	3 (4)	0	1	0	0	0	0	0	0

[a] High mortality in pigs occurred in three districts over a period of 11 months

TABLE 2 African swine fever outbreaks in Mozambique 1994–2006 for which more detailed information is available

Date	Province	Observations	Source
1994	Manica	Outbreaks among commercially farmed pigs around the city of Chimoio: Source of infection was probably pigs moved from Tete Province, where ASF had affected pigs in the Cahora Bassa District and around the city of Tete (these outbreaks were apparently not officially reported)	Morgado 2004
1995–1996	Nampula	Outbreak first noted in Morrupula District with deaths of 400 pigs in the family sector, followed by 79 commercially farmed pigs in Nampula city by December 1995; 362 pigs in the family sector and 82 commercially farmed pigs died in Monapo District in February 1996	Dr C. Linha, SPP Nampula, personal communication 2003
1998	Tete: Angónia	An outbreak occurred in a quarantine facility at the Estação Zootécnica e Agronómica, Ulongué, shortly after 25 pigs from a number of different villages in the district had been brought to the facility and mixed; eight pigs died	Bastos *et al.* 2004; Penrith *et al.* 2004b
2001	Sofala: Gorongosa	Severe and unprecedented outbreak in pigs in the Gorongosa District around Vila de Gorongosa; attributed to movement of pigs southward from Caia District due to construction of a new road	Pig producers, Vila de Gorongosa, interviewed September 2005
2001	Zambézia	Deaths of 500 pigs in the family and smallholder sector in Namacurra and Nicoadala Districts from February to May 2001	Dr H. Elizeu, SPP Zambézia, personal communication 2003
2001–2002	Nampula	From October to December 2001, 903 family sector pigs died in the Malema District, followed by 302 in the Ribaué District; 1 786 commercially farmed pigs around Nampula city died in January and February 2002	Dr C. Linha, SPP Nampula, personal communication 2003
2003	Cabo Delgado, Nampula	Deaths in family sector pigs in Balamo and Namuna Districts from February 2003, ASF confirmed in family sector pigs in Montepuez District in October 2003; deaths of 2000 pigs to December 2003; subsequent spread to other districts, with outbreak in Mueda District in September 2004	CVL field investigation, December 2003; SPP Cabo Delgado
2004	Nampula	Deaths of commercial pigs near city in February 2004 attributed to purchase of pigs from Chiure District, Cabo Delgado	Dr C. Linha, SPP Nampula, personal communication 2004
2005	Sofala	ASF was diagnosed on clinical grounds in the Caia District in the family sector	SPP Beira, personal communication 2005
2006	Manica	In February 2006 ASF occurred among commercial pigs at Catandica, Barué District, as well as on a farm of the same owner at Nhamatiquite, Sussundenga District	LRV Manica, Chimoio

Bulletins of the OIE also reflect repeated outbreaks in pigs around the cities of Beira (1967, 1968, 1979, 1981, 1989) and Nampula (1972, 1986, 1987, 1990). Outbreaks also occurred in Zambézia Province in Morrumbala in 1970 and near Quelimane in 1969, and in Manica Province near the city of Chimoio in 1988 (Fig. 2). It appears that most of the outbreaks reported until 1974 occurred in pigs that belonged to Portuguese settlers, although not necessarily all were farmed under intensive conditions.

1994–2005 (Tables 1 and 2, Fig. 3)

The appearance of ASF south of the Save River in 1994 was a major event. Outbreaks in 1994–1995 decimated pigs in the commercial sector around Maputo (unpublished data, DINAP, CVL). The first cases were diagnosed in pigs belonging to the Veterinary Faculty of the Eduardo Mondlane University, but it is believed that the event started with an outbreak in the Inhambane Province in 1993. From 1994–2001 numerous outbreaks occurred in all three provinces south of the Save River, as well as in the central and northern provinces (Table 1, Fig. 3). Information is available about only a few of the outbreaks, and is summarized in Table 2. It is noteworthy that commercially farmed pigs were involved in most of the outbreaks for which more detailed information was available.

In September 2004, ASF reappeared south of the Save River (Table 1), apparently starting with an outbreak in a village near the city of Maputo, followed by continuous outbreaks in the environs of Maputo city until the time of writing (2006).

Outbreak viruses (Fig. 4 and 5)

Genetic information is available from 21 outbreak localities in eight provinces over a period of 25 years (Fig. 4). Bastos *et al.* (2004) described four genotypes of ASF virus from Mozambique (Table 2, Fig. 4 and 5). Genotype V was closely related to the Tengani virus isolated from an outbreak in Malawi in the same year (Bastos *et al.* 2004). Genotype VI is so far known only from Mozambique (Bastos *et al.* 2004; Lubisi, Bastos, Dwarka & Vosloo 2005). Genotype II, apart from outbreaks in Mozambique, was recovered from the outbreaks of ASF in Madagascar that have occurred since 1997 (Bastos *et al.* 2004) and an outbreak in Zambia (Lubisi *et al.* 2005). Genotype VIII viruses have been recovered from outbreaks in Malawi, Mozambique, Zambia and Zimbabwe (Bastos *et al.* 2004). The co-circulation of genotype II and VIII viruses in a single outbreak in Angónia in 1998 has been described elsewhere (Bastos *et al.* 2004; Penrith *et al.* 2004b). One or other of these two viruses has been retrieved from all the outbreaks since 1998 for which material was available for sequencing (Dwarka, Mtshali, Lubisi, Phiri, Penrith, Nhamusso, Banze, Masambu & Vosloo 2006).

DISCUSSION

Control of ASF poses a complicated problem that is compounded by the lack of a vaccine. Historically, the identification of risk factors has proven useful in designing preventive and control measures. Knowledge of the association of ASF virus with warthogs and argasid ticks (*Ornithodoros* spp.) (Montgomery 1921; De Kock, Robinson & Keppel 1940; De Tray 1963; Sanchez-Botija 1963; Plowright, Parker & Pierce 1969) enabled ASF to be controlled by adequate separation between domestic pigs and warthogs in Africa and treatment of infected premises wherever tick-associated ASF occurred (Pérez-Sánchez, Astigarraga, Oleaga-Pérez & Encinas-Grandes 1994; Plowright, Thomson & Neser 1994). However, sporadic outbreaks of ASF in individual herds in the ASF control zone in South Africa in the present decade (OIE Handistat II 1995–2004) demonstrate that there is no guarantee that the legal measures will be effectively applied. We explored the extent to which the information that exists about ASF outbreaks in Mozambique, including the limited genetic information, could assist in identifying risk factors to support control strategies in that country.

It is likely that factors that permit maintenance of the virus in domestic pigs are more important than association with warthogs as a cause of outbreaks of ASF in most parts of Mozambique. Studies on pigs in Angónia District of Tete Province, close to the Malawi border, demonstrated that, as Haresnape *et al.* (1985, 1987) described in the adjacent Mchinje District of Malawi, ASF is endemic in domestic pigs (Penrith *et al.* 2004b). These endemic areas are characterized by frequent outbreaks that cause lower than expected mortality and many healthy and normal pigs (sometimes more than 50 %) may be serologically positive for antibodies to ASF virus (Haresnape *et al.* 1985, 1987; Penrith *et al.* 2004b). Unlike the case in Malawi, the way in which ASF is maintained in domestic pigs in Angónia has not been clarified, since to date association with ticks of the *Ornithodoros moubata* species complex has not been confirmed (Penrith *et al.* 2004b). It appears unlikely that healthy recovered pigs act as long-term carriers of the virus, since these pigs rapidly become virologically negative and are unable to infect susceptible pigs (Penrith *et al.* 2004b; Valadão 1969b). However, movement of pigs and their products from Tete Province has long been recognized as a probable source of ASF outbreaks in Mozambique (Morgado 2004).

The available information on outbreaks of ASF in Mozambique is unlikely to reflect the full spectrum of outbreaks that occur there. ASF in commercial pigs is much more likely to be reported than in family sector pigs, because commercial pigs have a relatively high economic value and are usually produced close to cities where the veterinary services are well represented, enabling the owners to seek assistance when their animals are ill. Thus, ASF appears to occur more frequently in the cities of Beira, Nampula, Chimoio, and, after 1994, Maputo (Table 1, Fig. 2 and 3) than in more remote areas, where the veterinary services are poorly represented. Because each family keeps only a few pigs, losses are not spectacular and are often spread out over a period of months, as observed in Cabo Delgado in 2003. Fear of being prevented from selling pigs may also play a role in poor reporting of ASF. In Maputo Province, where family sector pig production is largely represented by peri-urban backyard piggeries, the animal health officers are likely to become aware of the situation even if attempts are made to conceal it. Thus, the lack of outbreaks in Maputo Province from the beginning of 2002 until September 2004 is likely to be real, whereas the apparent lack of outbreaks in Tete from 1999 to 2002 (Table 1) is almost certainly due to lack of reporting. The 1998 outbreak in Angónia (Bastos *et al.* 2004) was probably only reported because it affected pigs that were involved in a research project (Penrith *et al.* 2004b). The dearth of reports of ASF from Niassa Province and from Cabo Delgado prior to 2003 can probably be ascribed to the virtual absence of commercial pig farming in those provinces. Relatively low pig numbers may contribute to the apparently low number of outbreaks in Gaza, Manica and Niassa, but outbreaks have also been infrequently reported from Inhambane, where there are large numbers of family sector pigs (Fig. 1). Gaps between reported outbreaks among commercial sector pigs in Beira, Nampula, and Chimoio probably do reflect periods of freedom from ASF in that sector. Beira is more frequently afflicted than the other cities; in fact, according to local information, periods when ASF does not occur among commercial pigs in Beira represent an absence of pigs after severe outbreaks. The frequency of outbreaks in Beira is likely to result from movement of infected pigs from the interior of the province. An established trade route exists between the Gorongosa District and the city of Beira. Traders usually buy live pigs from a number of suppliers along the route and transport them to Beira to sell in the informal market. Pigs that die *en route* may be sold during the journey or on arrival in Beira. Although interviews with pig farmers indicated that ASF is a rare event in most of Gorongosa district, a massive outbreak in 2001 being the only one in living memory, farmers in the buffer zone surrounding the Gorongosa National Park informed us that they regularly suffer outbreaks of ASF. This is not surprising since there are large numbers of warthogs in the park, which is currently not fenced. Another possible source of infection for pigs in Beira may be the Caia District, which is situated on the Zambezi River adjacent to the Mutarara District of Tete Province, where outbreaks are fairly frequently reported (Fig. 2 and 3), and where there may even be an endemic situation similar to that in Angónia. The 2001 outbreak in Gorongosa District was attributed to movement of pigs from Caia in response to the completion of an excellent road linking the two districts. Since it makes economic sense to sell pigs before they die once an outbreak has started, and since pigs may shed virus for up to 48 hours before showing clinical signs of disease (Plowright *et al.* 1994), it is likely that infected pigs reach Beira or are sold along the way if they die.

Using information about the genetic relationships between viruses to assist in control has been explored for various diseases (Vilcek & Paton 1998; Bastos, Haydon, Sangare, Boshoff, Edrich & Thomson 2002; Bastos *et al.* 2003, 2004). Genetic studies have shown that a single genotype was involved in the outbreaks of ASF that occurred outside Africa from 1959 to 1981 (Wesley & Tuthill 1984), as well as in all the outbreaks studied in West Africa, including the pandemic that began in 1996 (Bastos *et al.* 2003; Phologane, Bastos & Penrith 2005). A study of eastern African viruses (Lubisi *et al.* 2005) demonstrated that ASF in southern and eastern Africa has been caused by a number of genotypes, which the authors pointed out appears to be the case wherever the sylvatic cycle for ASF virus has been confirmed.

Three of the four genotypes of ASF virus (II, V and VIII) described from Mozambique (Bastos *et al.* 2004) have been associated with outbreaks in Tete Province (Fig. 4 and 5). Although a link with Tete is not supported by genetic evidence, the 1994 outbreak in Chimoio associated with genotype VI was ascribed to movement of infected pigs from areas in Tete affected by outbreaks at the time (Morgado

2004; Table 2). It is possible that the occurrence of multiple genotypes in Tete may in part be due to the free cross-border movement of pigs between Malawi and Angónia, since two of the four genotypes are shared with Malawi (Bastos *et al.* 2004; Lubisi *et al.* 2005). Only one genotype (II) has been associated with outbreaks that occurred in Nampula and Cabo Delgado Provinces from 2002–2004 and in Maputo and Gaza Provinces in 2004–2006, while another genotype (VIII) was retrieved from outbreaks in Zambézia Province in 2001 and Beira in 2004. Three samples from the wave of outbreaks that swept through the south of Mozambique in 1994 all yielded genotype VI, while the only two earlier outbreaks from which virus was available for characterization, both yielded genotype V. The genetic evidence appears to support the significance of the endemic area in Tete Province as one possible source of infection for other areas. It is of interest that the recent outbreaks in Maputo Province were due to a new introduction and not to the occult presence of the virus involved in the 1994–2001 outbreaks, supporting evidence from limited serological surveys carried out by the CVL and DINAP that ASF did not become endemic in the environs of Maputo as a result of its introduction in 1994.

Populations of free-ranging pigs appear to provide one mechanism for maintenance of the virus (Penrith *et al.* 2004b). Outbreaks of ASF usually dissipate when no more susceptible pigs are left to infect, but in a large and widely distributed population of free-ranging pigs this may never happen, given the rapid reproductive rate of pigs and the fact that sows with young litters are often separated and confined, thus escaping infection. The genetic studies provided evidence that a virus was circulating in a number of districts in Nampula and Cabo Delgado for at least 2 years (late 2002 until late 2004), in spite of killing more than 2 000 pigs between September and December 2003 (SPP, Cabo Delgado, personal communication 2003). One of the highest concentrations of domestic pigs in Mozambique is found in this region (Fig. 1). In an endemic area such as Angónia maintenance is likely to be facilitated by the relatively low mortality rate. In comparison with the interior of Nampula and Cabo Delgado, the number of pigs in Angónia is relatively small (Fig. 1), but a high proportion of these pigs have antibodies to ASF, demonstrating that they have survived the pathogenic effects of the virus (Penrith *et al.* 2004b). This resistance enables the number of pigs to remain relatively stable, in spite of repeated outbreaks of ASF, and allows subsistence level pig farming to be sustainable. The mechanism for resistance is unknown, since an experimental study demonstrated that it is not a matter of simple inheritance (Penrith *et al.* 2004b), and is deserving of further study. It is noteworthy that, unlike in Cabo Delgado, in Angónia sows with piglets do not appear to be confined except at night, and it may be that early exposure of piglets with maternal antibodies to ASF contributes to the observed resistance.

When considering how to control ASF in a country like Mozambique, it is necessary to consider the needs and options of the different sectors of the pig industry, rather than adopting a conventional approach to control. It is an incontrovertible fact that the existence of the family sector is a major risk for the commercial sector, but both sectors have the right to survive and to produce pigs in order to enjoy a better quality of life. The challenge is therefore to devise measures that will provide an appropriate level of protection for each sector and allow them to co-exist without threatening one another.

Movement control is one of the conventional control measures for animal diseases that is doomed to failure because it is impossible to implement in the informal sector. In addition to trade along established routes, movement of pigs and pig meat is determined by unpredictable events such as family ceremonies and visits. Owing to the dispersion of populations that took place during the war for independence and the subsequent civil disturbances, as well as the economic pressures that cause people to move to the cities, such visits can encompass the length and breadth of the country. As an example, anecdotal evidence of movement of people and goods, supported by the genetic evidence, suggested that the virus isolated from outbreaks around Maputo in 2004 and 2005 may have been introduced from Cabo Delgado (SPP, Maputo, personal communication 2004), at least 1 500 km away, although the possibility that the virus was introduced from Angónia, where deaths were reported among pigs in July and August 2004, could not be excluded. These movements could not have been predicted or prevented. However, contact between commercially farmed pigs and infected pigs or pork, whatever the source, can be prevented relatively easily. Because ASF virus is directly transmitted, the rigorous application of adequate sanitary measures by commercial pig farmers is sufficient to protect their herds against ASF. In addition to the formal commercial sector, there are increasing numbers of smallholder pig farmers who are raising pigs for profit in rural and peri-urban areas who would benefit considerably from protecting their pigs, since they are investing in feed to support better production. Many of the farmers in both these sectors do not sufficiently understand either the disease or the measures that they need to apply to prevent it. A continuing education programme for farmers, community leaders and agricultural extension officers is therefore a vital element in the prevention and control of ASF. Such a programme should include information about management and general health care, as well as housing and alternative feeds for pigs. Poor management and nutritional deficiencies were identified as major constraints even for commercial pig production in Mozambique (Garcês, Casey & Otto 1998). The higher the expected returns from the pigs, the more likely farmers will be to apply the necessary level of biosecurity to prevent ASF. Access to micro-finance to assist with facility improvement and bridging funds until the pigs become profitable would be a valuable incentive to encourage farmers to put the necessary measures in place.

The problem of how to manage ASF in traditional pig farming areas is complex. There is no doubt that traditional pig farming and ASF have co-existed for centuries, and that a delicate balance has been established in at least some pig populations. To upset this balance could potentially worsen the situation by replacing a partially resistant population of pigs with a fully susceptible population that would suffer close to 100% mortality in an outbreak. This is a danger in Angónia and possibly other border districts, because the circulation of ASF among domestic pigs in the adjacent parts of Malawi and the frequent cross-border traffic would ensure a persistent source of infection.

During fieldwork and participatory workshops in connection with a research project in Mozambique, the attitudes of family sector pig farmers to ASF in the district of Angónia have been explored. The farmers are unanimous in their desire to be rid of the feared disease, but in general lack of feed is regarded as an even greater threat. This is generally true throughout the country, and therefore the recommendation to family sector pig farmers to keep pigs permanently confined is unlikely to be widely accepted because it will cost too much to feed them. However, there are approaches that might help to reduce the negative effects of the disease in the long term. Increasing awareness among farmers of the ways in which ASF is transmitted would enable those who wish and can afford to do so to protect their pigs, but farmers choosing to confine their pigs permanently would need to understand that their pigs, even if of local breed, would probably lose the partial immunity currently observed, and that their protective measures would therefore need to be rigorously and consistently applied. Increasing profitability of pig production would encourage family sector farmers to move towards more formal production systems in order to obtain better prices for their pigs. Pigs in Mozambique are kept for commercial rather than purely domestic purposes, and the farmers themselves suggested that slaughter facilities with meat inspection should be established within the rural areas where pigs are produced, to improve the safety of the meat and reduce the movement of infected pigs. The construction of excellent roads in several provinces, in particular Tete, Manica and Sofala, offers greater opportunities to rural pig producers to access city markets, and a constructive approach is required to ensure that saleable pigs, rather than ASF, will reach the cities. On the other hand, increasing the value of pigs in areas like Angónia would ensure an increased flow of cheaper pigs from Malawi and raise the level of threat of ASF.

Research in support of managing ASF in Mozambique should include (1) the continued genetic characterization of outbreak viruses, (2) defining the extent of the area(s) in which ASF is endemic in domestic pigs, (3) exploring the potential for market expansion and improved market access for family sector farmers, as well as identifying factors such as price differentials that could increase the danger of cross-border ASF, and (4) identifying alternative sources for pig feed in Mozambique.

Preventing and controlling ASF under the conditions that prevail in Mozambique is challenging, and is unlikely to be achieved by conventional measures, since these, if they could be applied, would be more likely to eradicate pig production. Alternative measures that take into account epidemiological factors such as the situation in Angónia, involve the pig farmers at all levels in protecting their own herds, and at the same time encourage them to achieve improvement in their enterprises, could allow pig production to realize its potential to alleviate poverty and improve the quality of life in Mozambique.

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REFERENCES

ABREU, E.F. DE, VALADÃO, F.G., LIMPO SERRA, J.J.B., ORNELAS MÁRIO, R. & SOUSA MONTENEGRO, A. 1962. Peste suína africana em Moçambique. *Anais dos Serviços Veterinárias de Moçambique,* 8:105–123.

ANNUAL REPORT OF THE DIRECTORATE OF LIVESTOCK, MOZAMBIQUE 2001.

BASTOS, A.D.S., HAYDON, D.T., SANGARE, O., BOSHOFF, C.I., EDRICH, J.L. & THOMSON, G.R. 2002. The implications of viral diversity within the SAT-2 serotype for control of foot-and-mouth disease in sub-Saharan Africa. *Journal of general Virology*, 84:1595–1606.

BASTOS, A.D.S, PENRITH, M.-L., CRUCIÈRE, C., EDRICH, J.L., HUTCHINGS, G., ROGER, F., COUACY-HYMANN, E. & THOMSON, G.R. 2003. Genotyping field strains of African swine fever virus by partial p72 gene characterisation. *Archives of Virology*, 148:693–706.

BASTOS, A.D.S., PENRITH, M.-L., MACOME, F., PINTO, F. & THOMSON, G.R. 2004. Co-circulation of two genetically distinct viruses in an outbreak of African swine fever in Mozambique: no evidence for individual infection. *Veterinary Microbiology*, 103:169–182.

DAVIES, G. 1994. Eradication of epidemic pig diseases in the European Union. *Veterinary Record*, 135:567–568.

DE KOCK, G., ROBINSON, E.M. & KEPPEL, J.J.G. 1940. Swine fever in South Africa. *Onderstepoort Journal of Veterinary Science and Animal Industry*, 14:31–93.

DE TRAY, D.E. 1963. African swine fever. *Advances in Veterinary Science and Comparative Medicine*, 8:299–333.

DWARKA, R.M., MTSHALI, N., LUBISI, B.A., PHIRI, O.C., PENRITH, M.-L., NHAMUSSO, A.E., BANZE, J, MASAMBU, J. J.G. & VOSLOO, W. 2006. Molecular comparisons of African swine fever outbreak viruses from Mozambique and Tanzania for the period 2001–2005. *Paper presented at the 14th Biennial Congress of the South African Society for Microbiology (SASM), CSIR International Conference Centre, Pretoria, 9–12 April 2006*.

EDWARDS, S. & WILKINSON, P.J. 1990. Hog cholera and African swine fever in Europe. *Pig Veterinary Journal*, 25:9–16.

EL-HICHERI, K, GOMEZ-TEJEDOR, C., PENRITH, M.-L., DAVIES, G., DOUATI, A., EDOUKOU, G.J. & WOJCIECHOWSKI, W. 1998. L'épizootie de peste porcine africaine de 1996 en Côte d'Ivoire. *Revue scientifique et technique, Office International des Épizooties,* 17:660–673.

GAGO DA CÂMARA, N.J. 1932. História da peste suína em Angola. *Pecuária*, 1:25–40.

GARCÊS, A., CASEY, N.H. & OTTO, F. 1998. Factors limiting pig breeding in Maputo, Mozambique. *Israel Journal of Veterinary Medicine*, 53:21–24.

HARESNAPE, J.M., LUNGU, S.A.M. & MAMU, F.D. 1985. A four-year survey of African swine fever in Malawi. *Journal of Hygiene, Cambridge*, 95:309–323.

HARESNAPE, J.M., LUNGU, S.A.M. & MAMU, F.D. 1987. An updated survey of African swine fever in Malawi. *Epidemiology and Infection*, 99:723–732.

LEITÃO, A. & MARTINS, C.L.V. 1998. Algumas considerações sobre a infecção pelo vírus da peste suína africana (VPSA). *Revista Portuguesa de Ciências Veterinárias*, 93:3–24.

LUBISI, B.A., BASTOS, A.D.S., DWARKA, R.M. & VOSLOO, W. 2005. Molecular epidemiology of African swine fever in East Africa. *Archives of Virology,* 150:2439–2452.

MANELLI, A., SOTGIA, S., PATTA, C., OGGIANO, A., CARBONI, A., COSSU, P. & LADDOMADA, A. 1998. Temporal and spatial patterns of African swine fever in Sardinia. *Preventive Veterinary Medicine*, 35:297–306.

MENDES, A.M. 1971. Algumas doenças dos animais em Angola e Moçambique e sua importância na hygiene das carnes. *Revista Portuguesa das Ciências Veterinárias*, 66:271–286.

MONTGOMERY, R.E. 1921. On a form of swine fever occurring in British East Africa (Kenya Colony). *Journal of Comparative Pathology*, 34:159–191; 243–262.

MORGADO, F. DE P. 2004. *A Pecuária no Centro de Moçambique. As Províncias no Centro : Zambézia, Tete, Manica e Sofala.* Portugal: Nova Vega.

PENRITH, M.-L., THOMSON, G.R. & BASTOS, A.D.S. 2004a. African swine fever, in *Infectious diseases of livestock*, 2nd ed., edited by J.A.W. Coetzer & R.C. Tustin. Cape Town: Oxford University Press.

PENRITH, M.-L., THOMSON, G.R., BASTOS, A.D.S., PHIRI, O.C., LUBISI, B.A., BOTHA, B., ESTERHUYSEN, J., DU PLESSIS, E.C., MACOME, F. & PINTO, F. 2004b. An investigation into natural resistance to African swine fever in domestic pigs from an endemic area in southern Africa. *Revue scientifique et technique, Office International des Épizooties,* 23:665–677.

PÉREZ-SÁNCHEZ, R., ASTIGARRAGA, A., OLEAGA-PÉREZ, A. & ENCINAS-GRANDES, A. 1994. Relationships between the persistence of African swine fever and the distribution of *Ornithodoros erraticus* in the province of Salamanca, Spain. *Veterinary Record*, 135:207–209.

PHOLOGANE, S.B., BASTOS, A.D.S. & PENRITH, M.-L. 2005. Intra- and inter-genotypic size variation in the central variable region of the *9RL* open reading frame of diverse African swine fever viruses. *Virus Genes*, 31:357–360.

PICARD, M. 1989. Les pestes porcines en France et en Europe en 1988. *Epidemiologie et Santé Animale*, 16:27–32.

PLOWRIGHT, W., PARKER, J. & PIERCE, M.A. 1969. The epizootiology of African swine fever in Africa. *Veterinary Record*, 85:668–674.

PLOWRIGHT, W., THOMSON, G.R. & NESER, J.A. 1994. African swine fever, in *Infectious diseases of livestock, with special reference to southern Africa*, 1st ed., edited by J.A.W.

Coetzer, G.R. Thomson & R.C. Tustin. Cape Town: Oxford University Press.

RUIZ, R. 1969. Alguns aspectos da peste suína nas variants "clássica" e "africana". *Anais dos Serviços Veterinárias de Moçambique*, No 15, 1967 (1969): 317–327.

SANCHEZ-BOTIJA, A.C. 1963. Reservorios del virus de la peste porcina africana. Investigación del virus de la PPA en los artrópodos mediante la prueba de la hemoadsorción. *Bulletin Office International des Epizooties,* 60:895–899.

VALADÃO, F.G. 1969a. Nota previa sobre algumas tentativas para atenuação do virus da peste suína africana. *Anais dos Serviços Veterinárias de Moçambique*, No 12/14, 1964–1966 (1969): 91–94.

VALADÃO, F.G. 1969b. Notas sobre alguns ensaios realizados em porcos sobreviventes de peste suína africana. *Anais dos Serviços Veterinárias de Moçambique*, No 12/14, 1964–1966 (1969): 95–100.

VILCEK, S. & PATON, D.J. 1998. Application of genetic methods to study the relationship between classical swine fever outbreaks. *Research in Veterinary Science*, 65:89–90.

WESLEY, R.D. & TUTHILL, A.E. 1984. Genome relatedness among African swine fever virus isolates by restriction endonuclease analysis. *Preventive Veterinary Medicine*, 2:53–62.

WILKINSON, P.J. 1989. African swine fever virus, in *Virus infections of porcines*, edited by M.C. Pensaert. Amsterdam: Elsevier.