Factors correlated with the presence of rodents on outdoor pig farms in Denmark and suggestions for management strategies

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Abstract

The correlation between farm characteristics and the occurrence and importance of rodent pests on outdoor pig farms in Denmark was explored in an extensive questionnaire survey. Mice occurred on most farms but were only rarely considered a problem, as opposed to rats, which were controlled on more than half of the farms. A series of trapping studies showed a high small-mammal diversity in and around the pigsties. The presence of rats was positively correlated with farm size, the presence of straw stacks near the pigsties and the use of automatic feeders. Rats were considered a problem more often when open drinking basins were used or when feed was stored near the pigsties. The environment of the farm did not play an important role except to some extent the proximity of hedges. Recommendations for preventative rodent management include avoiding conditions indicated previously, frequent mucking out and movement of huts, keeping feed in rodent-proof containers, avoid spillage of fodder, and general cleanliness. Direct control methods include application of rodenticides with proper consideration for the risk of unintended poisoning of production animals, the use of traps, keeping dogs or cats, and possibly shooting.

Additional keywords: *Rattus*, rat, mouse, vole, organic farming, rodent management

Introduction

The past decade has experienced a growth in extensive pig farming, both in Denmark and elsewhere in Western Europe. A common characteristic of such a production system, whether in an organic or a conventional farming setting, is the access of pigs to outdoor areas during at least some period in the production cycle. Systems in use

are diverse, ranging from sows that are outdoors throughout the year and that are moved between parcels of land with small movable huts for cover, to fattening pigs that are kept in permanent stables with access to outdoor pens (Hermanssen, 2000). In these systems the production animals may come into contact – albeit to a varying extent – with the wild fauna. This may facilitate the transmission of diseases from wild to production animals, from farm to farm or from one herd to the next one on the same farm.

Rodents are known to be a reservoir for a variety of pathogens that may affect pigs, e.g. the bacteria *Erysipelothrix rhusiopathiae* and several species of *Salmonella*, *Leptospira* and *Yersinia*, protozoa like *Toxoplasma gondii*, helminths like *Trichinella* spp. and *Echinococcus multilocularis* (Gratz, 1994; Feenstra *et al.*, 2000). Such pathogens can pose a health problem to the pigs themselves (like infection with *Leptospira pomona* that causes abortion) or – like Toxoplasmosis – they may constitute a zoonotic risk for humans eating poorly prepared pork. Moreover, rodents may cause direct damage by destroying infrastructure, eating and spoiling stored feed or disturbing the pigs. If they are present in large numbers, they may attract predators that also prey on young piglets as experienced by some Danish farmers (e.g. Gjedsig, 2003).

In traditional pig farming with pigs in stables, rodents occurring inside the buildings are relatively easily controlled with rodenticides or traps and rodent proofing of the buildings is a valuable means to reduce rodent access. This is not possible in outdoor settings, which because of their open nature and the easy access to food and water may be sites that actually attract rodents. At present, anticoagulants are still allowed in organic farming in Denmark, but only for rat control. According to the basic concept of organic farming, however, any use of chemicals should be avoided. So there is a desire – and in the not too distant future probably even a need – to develop non-chemical methods and strategies to control rodent problems.

In this paper we assess the extent of rodent presence in outdoor pig farms in Denmark, try to answer the question whether variation in rodent presence is related to farm characteristics and present an outline of how that information can be used to formulate rodent management strategies.

Materials and methods

General set-up

The large variation in outdoor pig production systems, in farm infrastructure and management and in farm surroundings, required a large number of farms to be investigated in order to identify factors that may be related to variation in the presence of rodents. We therefore opted for a broad survey using a questionnaire, thus increasing the number of farms about which information was collected.

The information from the questionnaire was supplemented with bimonthly trapping sessions between December 2001 and December 2003 with capture-recapture studies and telemetric work on two farms near Ringsted and Gørløse on Zealand.

The results of this work will be published elsewhere; in this paper we only report the overall species composition of the small mammals that were trapped.

Selection of farms

Farm addresses were obtained from different sources. The Danish Plant Directorate had a register with 251 organic pig farmers. The Danish Central Register for Production Animals had a database containing information on 123 organic pig farmers and 1119 conventional farmers that kept pigs outdoors. We furthermore included 110 members of Friland Food, a professional association of outdoor pig farmers. These databases were merged and updated for incomplete addresses and duplicates. We then selected 428 farms, which included all organic pig farms from the merged database, and a number of conventional outdoor pig farms distributed throughout the country. The 428 farms represented a range of farm sizes. A pilot version of the questionnaire was sent to 20 farms in July 2001, followed up by telephone contact where necessary and adjusted on the basis of their reactions. In August 2001, the final version was sent to the remaining 408 farms.

The questionnaire

The questionnaire consisted of several parts. We collected information on the type of pig production and farm size, on internal conditions about farm organization, pig housing, feeding and drinking provisions, and on characteristics of the external conditions around the farm. This information was treated as the explanatory variables in our analysis. We furthermore asked how often pest animals were observed in the pigsties, and how problematic that was considered to be. For these questions we grouped animal species that look superficially similar and that farmers would be unlikely to tell apart during occasional observations (e.g. many farmers classify different small murids and microtids as 'mice'). We asked for the presence of rodents (rats, mice, water voles) but also included other potential mammal pests like foxes, birds and arthropods. Four answers were possible for each of these animal groups: never, rarely, regularly in specific seasons, and regularly throughout the year. Finally we asked for the applied pest management methods for each of these groups. A detailed overview of the final information obtained is presented in the Appendix.

Statistical analysis

The results from the questionnaire were analysed, as a first step, by calculating the correlation between the possible explanatory variables on the one hand, and the presence of rodents or the perceived problems they cause on the other. Because values were categorical, we used a Gamma Rank correlation, and a Bonferroni-adjusted α-level for significance in order to minimize the chance of including spurious correlations. Using 2×4 contingency tables we investigated whether the presence or absence of different environmental factors had an effect on the distribution of farms over the

four groups representing different levels of rodent occurrence. Interactions between the explanatory factors were explored in a Generalized Linear Model (GLM) with four levels of rat occurrence as response variable and different combinations of second-order interactions as factors in the model (Anon., 1998). The data set not being large enough, no higher-order interactions were investigated.

The results from the questionnaire showed that production types and feed and water provision systems rarely differed between seasons, as sometimes is the case due to Danish winter conditions. The few farms with such a seasonal difference were disregarded. So in the analysis we only compared farms where a practice was applied during the whole year with farms where that practice was never applied.

Results

The survey

The response to the questionnaire was high: 277 of the 428 questionnaires were returned. However, of these 277 only 158 (57%) confirmed to have outdoor pig production at the time of the survey, and 98 of these were organic farmers. Farm size ranged from 1 to 500 sows, or from just a few slaughter pigs to about 10,000. Organic farms were over-represented among the smaller farms (Figure 1).

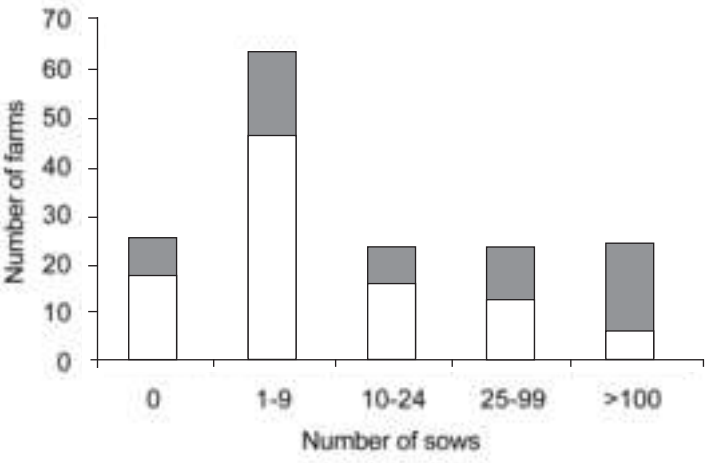

Figure 1. Size distribution of the organic (non-shaded columns) and the conventional (shaded columns) outdoor pig farms that participated in the study.

The observed presence, the perceived problems, and the application of pest control measures are summarized in Table 1. On 39% of the participating farms rats were seen regularly whereas mice were observed on 69% of the farms. The presence of rats was perceived as problematic by 26% of the respondents and 53% performed rat

Table 1. Summarized responses from questionnaire about presence, importance and control of potential pest animals in outdoor pigsties. Blank answers have been excluded.

Potential pest	Presence observed			Importance perceived			Control measures taken		
	No	Rarely	Regularly	Never	In some years	Every year	No	Sometimes	Permanently
Mammals									
Rats	56	38	60	98	17	17	70	38	42
Mice	38	9	103	115	5	7	102	14	20
Water voles	95	22	25	112	5	3	121	2	6
Foxes	44	23	86	77	27	30	79	16	44
Minks	117	17	9	107	2	4	124	3	3
Martens	117	19	6	113	1	0	130	0	2
Hares	46	23	78	120	2	0	122	3	8
Other	33	3	14	55	0	1	72	1	0
Birds									
Raven	59	18	65	85	12	23	120	8	5
Rooks	36	15	89	74	12	36	105	16	14
Crows	11	8	135	61	18	50	99	22	20
Pigeons	21	15	111	106	5	10	126	5	2
Starlings	18	9	124	101	7	17	128	4	3
Gulls	30	20	101	87	14	28	114	11	9
Raptors	28	20	93	100	12	8	124	3	2
Other	17	1	33	54	1	3	71	1	0
Arthropods									
Flies	21	8	122	87	17	18	121	5	10
Mosquitoes	49	21	79	110	10	4	131	1	1
Tabanid flies	67	22	59	106	8	5	132	0	1
Ticks	105	13	29	108	2	3	130	0	1
Lice	129	15	4	116	5	0	126	3	2
Scab mites	124	21	3	110	13	1	119	8	4
Other	61	1	5	83	1	0	93	2	0

control regularly. Only 9% considered the presence of mice problematic but 25% regularly controlled mice. Of the other potential mammal pests, clearly most important were the foxes, with a regular presence on 56% of the farms, though only 43% of the respondents considered them problematic and a similar percentage applied control measures. Several bird species were often considered problematic.

A number of farmers provided information about the rodent control methods they used. Although this information was not collected in a quantitative way, it is worth

reporting the strategies that farmers mentioned. A number of strategies focused on reducing population size by killing rodents: poisoning (under feeding stations, in bait stations, in special tubes under straw); trapping (snap-traps, live-traps, mouse live-traps with poison inside); shooting; keeping cats or dogs to catch rodents, sometimes of specialized breeds. Other strategies focused on reducing attractiveness and living conditions for rodents: frequently mucking out the pig huts because the rodents live in the litter; frequently moving huts; storing fodder in rodent-proof containers; avoiding fodder spillage; general cleanliness; avoiding nearby feeding stations for game animals.

Statistical analysis

A statistically significant and positive correlation was found between the presence of rats on the one hand and farm size, use of automatic feeders and the presence of straw stacks in the pigsties on the other (see Table 2 for Gamma- and *P*-values). There was a negative correlation between the presence of rats and the presence of other production animals outdoors. However, median farm size was significantly different between farms with and farms without other production animals outdoors (Mann-Whitney U = 1522, Z = –4.97, n = 158, $P < 0.0001$) and the presence of other production animals had no effect within the group of large farms and the group of small farms. The presence of rats was positively correlated with the presence of mice (Gamma = 0.40, Z = 4.78, n = 125, $P < 0.0001$) and foxes (Gamma = 0.31, Z = 3.19, n = 131, $P = 0.0014$) but not with other potential pest species. The presence of mice was correlated with the same explanatory factors as the presence of rats, except for the presence of other production animals and the use of automatic feeders.

The contingency tables showed statistically significant effects on rat occurrence for automatic feeders ($\chi^2 = 9.17$, df = 3, $P = 0.027$), drinking basins ($\chi^2 = 8.61$, df = 3, $P = 0.035$) and straw stacks in the pigsties ($\chi^2 = 9.17$, df = 3, $P = 0.027$). The effects were not always straightforward. For example, the presence of automatic feeders was related to a higher proportion of farms with regular seasonal rat occurrence but not throughout the year (Figure 2). Other factors had no statistically significant effect. The GLM analysis confirmed farm size and the presence of automatic feeders as statistically significant main effects but not as interaction effects.

Rats were less often considered a problem by organic than by conventional farmers (Table 2). Perception of rats as a pest problem was correlated with the observed presence of rats (Gamma = 0.81; Z = 8.53; n = 122; $P < 0.0001$), and thus also with the factors that were correlated with this presence. Moreover, problems with rats were also (borderline) significantly associated with the use of open drinking basins and with feed storage near pens. Mouse problems were not correlated with the presence of mice, or with any of the factors investigated.

Trapping results

The captures yielded a total of 1247 small mammals, belonging to 8 rodent and

Table 2. Gamma Rank correlation coefficients with associated *P*-values, between the observed presence of rats and the perceived rat problems on the one hand and the explanatory factors investigated through the questionnaire on the other.

Explanatory factors	Presence of rats				Perceived rat problems			
	n	Gamma	Z	*P*	n	Gamma	Z	*P*
Organic farming	143	–0.11	–1.17	0.2434	132	–0.38	–3.16	0.0016*
Number of sows	143	0.27	4.02	0.0001*	132	0.42	4.56	0.0000*
Number of fattening pigs	143	0.16	2.45	0.0144	132	0.28	2.99	0.0028
Other production animals outdoors	143	-0.38	–4.08	0.0000*	132	–0.38	–3.10	0.0019*
Lactating sows outdoors	134	0.33	2.59	0.0096	122	0.55	2.56	0.0106
Pregnant sows outdoors	132	0.13	1.18	0.2376	121	0.10	0.65	0.5128
Walking pens outdoors	136	0.12	1.25	0.2117	125	0.05	0.35	0.7233
Fattening pigs outdoors	115	0.05	0.52	0.6050	106	–0.15	–1.07	0.2853
Feed on the ground	128	0.34	3.01	0.0026	118	0.23	1.58	0.1143
Feed in trough	121	–0.30	–2.78	0.0055	112	–0.05	–0.36	0.7186
Automatic feeder	134	0.41	4.19	0.0000*	123	0.42	3.46	0.0005*
Drinking basin	130	0.29	2.10	0.0359	120	0.75	3.07	0.0022
Drinking nipples	138	0.10	0.39	0.6988	127	–0.10	–0.27	0.7858
Drinking cups	137	–0.23	–1.41	0.1598	126	–1.00	–2.63	0.0085
Straw huts	143	–0.03	–0.31	0.7539	132	0.01	0.07	0.9414
Family pen tents	143	0.54	2.00	0.0451	132	0.26	0.68	0.4995
Straw stacks on/near field	143	0.32	3.44	0.0006*	132	0.40	3.34	0.0008*
Huts of soft material	139	–0.11	–1.11	0.2671	128	–0.05	–0.37	0.7143
Huts with floor	143	0.31	1.21	0.2246	132	0.30	1.05	0.2917
Cattle in same pens	143	–0.15	–0.98	0.3271	132	0.12	0.65	0.5160
Cattle nearby	143	–0.11	–1.06	0.2909	132	0.00	0.03	0.9779
Neighbouring animal farm	143	0.02	0.18	0.8548	132	0.10	0.77	0.4433
Feed storage nearby	143	0.11	1.18	0.2395	132	0.57	4.65	0.0000*
Pond nearby	142	0.06	0.58	0.5614	131	0.16	1.17	0.2428
Woodland nearby	141	0.21	2.20	0.0277	130	–0.01	–0.07	0.9409
Hedges nearby	143	0.52	2.77	0.0056	132	0.60	2.01	0.0448
Motor- or railway nearby	143	–0.18	–0.62	0.5324	132	–0.10	–0.26	0.7931

* Statistically significant at $\alpha = 0.05$ (Bonferroni-adjusted $\alpha = 0.0019$).

2 shrew species (Table 3). The most commonly trapped animals were wood mice (*Apodemus sylvaticus)* and field voles (*Microtus agrestis*). The commensal Norway rat (*Rattus norvegicus*) and the house mouse (*Mus musculus*) constituted 8.0 and 4.6%, respectively, of the trapped animals.

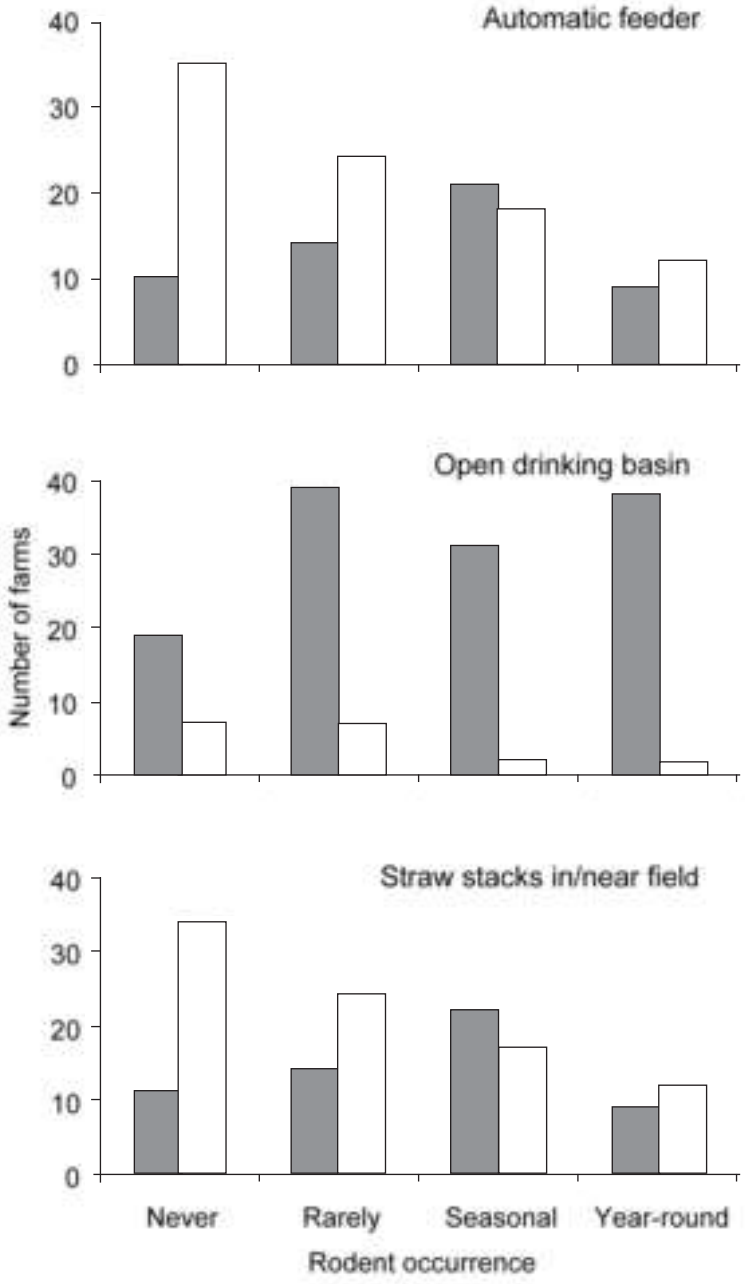

Figure 2. Number of farms where rodents were observed in relation to the presence (shaded columns) or absence (non-shaded columns) of automatic feeders, open drinking basins or straw stacks in or near the field.

Table 3. Overall composition of the small mammal species (n = 1247) captured on two outdoor pig farms in the years 2001–2003.

Common name	Scientific name	%
Wood mouse	*Apodemus sylvaticus*	34.2
Field vole	*Microtus agrestis*	24.8
Common shrew	*Sorex araneus*	13.1
Norway rat	*Rattus norvegicus*	8.0
Yellow-necked mouse	*Apodemus flavicollis*	6.7
House mouse	*Mus musculus*	4.6
Harvest mouse	*Micromys minutus*	4.6
Bank vole	*Clethrionomys glareolus*	3.8
Water vole	*Arvicola terrestris*	0.2
Pigmy shrew	*Sorex minutus*	0.2

Discussion

Rodent presence and diversity

Farmers appear to consider rodents an important issue. The results from the questionnaire confirmed that the presence of rodents is common in outdoor pig farming and that rats are often considered a problem, more so than mice. Remarkably, rats were less often considered problematic by organic than by conventional farmers, even though there was no difference in rat occurrence between the two production systems. It was also surprising to learn that the different address databases of outdoor pig farmers were rather disparate, and maybe even more so that almost half of the responding farmers indicated that they did not (or no longer) have outdoor pig production activities. A formal analysis of this problem falls beyond the scope of this paper, but it would be advisable to consider an improved registration system.

The small mammals trapped in and around the pigsties show a species diversity that corresponds to what can be encountered in the surrounding natural or semi-natural environment (Muus, 1991). Flying or subterranean mammals were obviously not encountered in our trapping study. The considerable diversity we observed is important since it shows that pigs may have direct or indirect contact with most of the small mammals that occur in the environment and that may be carrying pathogens. Furthermore, outdoor living *R. norvegicus* can move over large distances (Taylor & Quy, 1973) and thus be a carrier of pathogens from nearby areas to a pig farm. In other parts of Denmark than where our trapping study was carried out, the wild rodent fauna also includes the common vole (*Microtus arvalis*) and the striped field mouse (*Apodemus agrarius*). The latter is particularly relevant when it occurs together with pigs because it is the natural reservoir for *Leptospira pomona,* which may cause abortion in sows (Friis *et al.,* 2000). However, not all wild rodent species need to be considered as pests

and since a basic concept in organic farming is to operate in an environment with a high biodiversity, rodent management strategies must be as specific against target species as possible.

House mice and a variety of other small rodent species and shrews of similar size occur around the pigsties. So the questionnaire responses about the presence of mice most likely concern the combined presence of these small mammals. On the other hand, where 'rats' are reported, these can be classified exclusively as *Rattus norvegicus*, because roof rats (*Rattus rattus*) are very rare in Denmark and are only known from a few indoor localities far away from agricultural land (J. Lodal, unpublished results). Water voles (*Arvicola terrestris*), though large, are quite distinctive from murid rats and were captured only very rarely.

Farm characteristics and preventative rodent control

Our study was correlative and thus any causal interpretation must be treated with caution. Nevertheless, the combination of the questionnaire results and existing knowledge about rodent biology strongly suggests factors that could be important in explaining rodent presence on outdoor pig farms. Farm size and the presence of other production animals outdoors were important factors explaining differences in rodent occurrence. Larger farms offer more opportunities for rats to settle and the farmers probably also spend more time around their pigsties and thus are more likely to notice rodents. The presence of other production animals appeared to have a negative effect on rodent presence, but this factor is actually significantly negatively correlated with farm size and thus not independent. Farmers with just a few pigs outdoors are more likely to have other production animals outdoors as well.

Several aspects of farm design were important and provide suggestions for preventative rodent control. However, it is clear that controlled experiments are needed before these suggestions are turned into direct recommendations. Straw stacks near the pigsties offer very good shelter to rodents and clearly improve the attractiveness of an area. Storing straw well away from the pigsties will be advantageous and can be planned already when designing the layout of an outdoor production system. The relation with feeding installations is less straightforward. Feeding on the ground had a positive effect on rodent presence and feeding in troughs a negative, although the statistical significance of this difference depended on how strict the need for a Bonferroni adjustment of *P*-values is considered (Moran, 2003). Surprisingly, the presence of automatic feeders was very strongly correlated with rat presence. We assume that the pigs in a short time always finish the feed in troughs, leaving very little for rats. Automatic feeders, however, provide feed for a longer time and if rats can get inside, they can feed freely without being disturbed. The types of automatic feeder that are on the market have to be improved with regard to rodent proofing and should be made less attractive to rodents. It may also help to reduce the rodents' access to the automatic feeders by placing them on a raised platform, as we observed on one farm. Clearly, storing feed such that rodents have no or limited access should be a key issue in rodent management strategies. Similarly, it is a good practice to place game feeding stations well away from the pigsties.

On farms with open drinking basins, rats were considered more of a problem, even though the presence of such basins was not correlated with rat occurrence as such. This is justified, however, as contamination of drinking water with rat urine containing, for example, leptospires (e.g. Zieris, 1992), is easier in open basins than when drinking nipples or cups are used. A somewhat similar phenomenon was the effect of feed storage near the pigsties. Although it did not affect (perceived) rat occurrence, it was correlated with rat problems, likely because damage to the stored feed was visible. Finally, the environment of the farms appeared to have little effect on rodent occurrence, except perhaps the presence of hedges. So a distance of more than 100 m is worthwhile to consider when planning an outdoor production system. It is interesting to note that the farmers who mentioned preventative strategies in the questionnaire, focused largely on other aspects than the ones we discussed in this paragraph, except the access to feed. It is possible that the currently applied strategies are not very relevant for rodent control, but it is more likely that they sound so evident and are therefore so commonly applied that our study did not pick them up as relevant.

In conclusion, rodent problems on outdoor pig farms appear to be correlated with relatively few factors, several of which farmers could control by changing the design or organization of their farms. This opens opportunities for alternative rodent management strategies.

Direct methods for rodent control

Notwithstanding attempts for preventative strategies, it can be expected that under some circumstances direct control may be required. Although our study did not focus on this aspect, it is relevant to review the available information.

Rodenticides were often mentioned in the questionnaire reactions as the method for the direct control of rodents. Very few farmers described what active ingredient or what type of formulation they used. In Denmark only anticoagulant rodenticides are allowed for rat control, whereas for control of mice also chloralose is available. Anticoagulant rodenticides are characterized by being slow-acting and causing internal haemorrhage. They generally are well accepted by rodents. An important property of the first-generation anticoagulants (e.g. warfarin and coumatetralyl) is that they are not sufficiently toxic to rodents to cause death after a single exposure. In order to be successful it is necessary that each target animal has continuous access to poisonous bait over a period of several days. Second-generation anticoagulants have been developed in response to resistance to first-generation anticoagulants, which was first reported in Scotland in 1958 for Norway rats (Buckle, 1994). Occurrence of resistance in rats is well documented for first- and some second-generation anticoagulants in Denmark (Lodal, 2001), England (Kerins *et al.,* 2001) and Germany (Pelz, 2001).

If anticoagulants are used, the active ingredient chosen is very important. There are large differences as to the risk of unintended poisoning of pigs as can be seen by comparing the acute oral LD_{50} values for the different anticoagulants in Norway rats, house mice and pigs (Table 4) (Lodal & Hansen, 2002). The acute oral LD_{50} values are of interest here because unintended accidental poisoning often occurs after just one meal. Table 4 shows that a single dose of the first-generation anticoagulant warfarin is

Table 4. Acute oral LD_{50} values for rats, mice and pigs, of first- and second-generation anticoagulant rodenticides. Source: Lodal & Hansen (2002).

Rodenticide	Norway rats	House mice	Pigs
	– – – – – – – – –	(mg per kg body weight)	– – – – – – – – – –
First generation			
Warfarin	10	374	1
Coumatetralyl	16.5	> 1000	unknown
Second generation			
Bromadiolone	0.65	0.99	3
Difenacoum	1.8	0.8	80
Brodifacoum	0.2	0.4	0.5
Flocoumafen	0.25	0.79	60
Difethialone	0.55	1.29	2

actually more toxic to pigs than to rats and mice. The second-generation anticoagulants are generally more toxic to the target rodents than the first-generation ones, with difenacoum and flocoumafen presenting the lowest risk of serious poisoning. The standard concentration in ready-to-use baits for difenacoum and flocoumafen is 0.005%. This means that a pig needs to consume 1600 g of difenacoum bait or 1200 g of flocoumafen bait per kg body weight in order to have an intake equal to the LD_{50} value. On the other hand, if bromadiolone is used, only 60 g of ready-to-use bait per kg body weight are necessary to give an intake equal to the LD_{50} value.
Chloralose is a narcotic with a rapid effect. Buckle (1994) describes that it slows down a number of essential metabolic processes such as brain activity, heart rate and respiration, leading to hypothermia and eventually to death. So in practice chloralose is most effective against small rodents like mice, which have a high surface to volume ratio. There is no risk of poisoning pigs consuming a portion of chloralose bait. Cool conditions are most favourable and in Denmark its use against mice is recommended at temperatures below 16 °C. Toxicity symptoms occur within an hour after intake (Lund, 1988). It is rapidly metabolized and hence non-cumulative (Tomlin, 1997). So chloralose is rather safe to use in pigsties but only for mouse control and only in colder seasons.

Using traps is in good accordance with the concept of organic farming. Traps have to be set often and as soon as rodents or signs or tracks of the animals are observed. As mentioned by some respondents the method may be time-consuming if live-traps are used. No farmer mentioned the use of monitoring systems. Different types of traps can be used as monitoring tools to find out which species are involved. Apart from traps, a simple monitoring system may consist of (bait) boxes with non-poisonous material and placed at critical points. Rodents may show their presence by taking or gnawing the non-poisonous material. Such a monitoring system or devices like tracking plates for footprints and video cameras may be useful for determining where to

place rodenticides or set traps for direct control. Shooting rodents may be problematic but if practised where it can be done legally and in a safe way, the method may be satisfactory to keep populations of rodents at a low level.

Dogs, often of special breeds, may be good in destroying small colonies of rodents. Keeping cats that have to find their own food may contribute to reducing the number of rodents within their hunting territories but several cats are needed to attain a satisfactory effect. However, there may be a drawback of keeping cats for rodent control in organic farming because the cat is the final host of the protozoon *Toxoplasma gondii*. Infected cats shed oocysts in their faeces and ingestion of these oocysts may cause Toxoplasmosis in rodents, pigs and human beings, a disease that under certain circumstances can become fatal (Frenkel, 1973). Rodents act as intermediate hosts and although they do not shed oocysts, they will pass on the infection to predators, including pigs (Frenkel *et al.*, 1970; Work, 1971). Human beings may also become infected by handling or eating raw or undercooked infected pork (Work, 1967; 1968). Dogs only act as intermediate hosts for *T. gondii* and do not shed oocysts. So in order to avoid undesirable *Toxoplasma* infections in the production animals, dogs are to be preferred to cats.

The use of chemical repellents, of so-called non-poisonous chemicals, sound-emitting or electromagnetic devices, or improvement of the environment with the purpose of practising biological control were measures not mentioned in the questionnaires. Such methods seem to fit in well with the concept of organic farming and therefore we will briefly discuss them below.

To our knowledge there is no chemical repellent that can be used against rodents in outdoor production systems.

In some European countries, but not in Denmark, rodent control products are marketed that are made entirely of natural vegetable food-grade materials. These products are presented as a food source and as a non-poisonous solution, though the effect claimed is the killing of rodents, especially rats and mice. As they seem to fit in very well with the basic concept of organic farming, such products may appeal to the organic farmer. A preliminary test with such a product, which mainly contained cellulose, against Norway rats at the Danish Pest Infestation Laboratory did not show convincing results (Lodal, 2002). The rats did not accept the product very well and no rats died, not in no-choice nor in choice tests. Ultrasonic devices, low-frequency sound generators and electromagnetic devices have one attractive quality in common: they are non-poisonous. However, none of these devices seems to have a satisfactory effect on the target animals even when used under the most optimal conditions (Bohills *et al.*, 1979; Iglisch & Ising, 1985; Lodal, 1988; 1994; 1995).

Also the idea of biological control, i.e., making use of mammal predators, birds of prey and owls to maintain the rodent populations at a low level, fits in very well with the basic concept of organic farming. The predators could be attracted by setting up artificial foxholes and by setting up perches and nest boxes for the birds. A very serious disadvantage mentioned by several farmers is that foxes and birds of prey take piglets and disturb and stress the sows. With these negative effects in mind, such biological control methods cannot be recommended.

Conclusions

Our study has provided a number of suggestions for preventative rodent control on outdoor pig farms. Whether these correlative observations indeed are due to causal relations needs to be established in specific and controlled experiments. In the meantime, a number of recommendations appear reasonable. We expect reduced rodent occurrence and problems when farmers avoid automatic feeders (unless redesigned), open drinking basins, stacks of straw nearby, open feed storage or game feeding stations nearby. If possible, a distance longer than 100 m between pigsties and between pigsties and hedges has to be taken into account. Commonly applied methods already include mucking out and moving huts frequently, avoiding rodent access to spilled or stored feed and general cleanliness. Preventive measures are considered of paramount importance, reason why they should have highest priority. Direct control methods are to be considered only when problems do arise in spite of indirect measures. Our study did not compare direct control techniques, but if anticoagulants are used, they need to be carefully selected and applied. Trapping and keeping dogs or, less so cats, seem the most useful non-poisonous techniques.

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Appendix

Information collected through the questionnaire. In most cases the answers had to be chosen from a limited number of possibilities.

Identification (open answers)
- Name, address and contact details
- Annual production of the farm: no. of sows, no. of pigs sold at 30 kg, no. of slaughter pigs produced
- Presence of other production animals (indoors, outdoors) on the farm
- Farm registered as an organic farm?

Pig production system (possible answers: year-round, summer or winter)
- Lactating sows outdoors
- Pregnant sows outdoors
- Mating or insemination pens outdoors
- Fattening pigs in stables with outdoor access
- Fattening pigs outdoors
- Fattening pigs outdoors but on hard underground
- Weaned pigs up to 30 kg outdoors
- Weaned pigs up to 30 kg in huts or stables with outdoor access.
- Other

Feed provision (possible answers: year-round, summer or winter)
- Directly onto the ground
- In open trough
- From automatic feeder
- Other

Drinking water (possible answers: year-round, summer or winter)
- Open drinking basin
- Bite nipples
- Drinking cups
- Other

Outdoor conditions and surroundings (possible answers: yes or no)
- Huts, tents or straw packs in the pigsties
- Family pens with tents in rotation crops
- Straw storage in the field
- Huts made of soft material (plastic, wood, etc.)
- Huts have a floor
- Cattle grazing in pigsties
- Cattle grazing within 500 m from pigsties
- Less than 500 m from neighbouring farm with production animals

Appendix (cont'd)

Less than 100 m from central food storage
Less than 500 m from waterhole, pond, swampy area or watercourse
Less than 500 m from forest
Less than 100 m hedge
Less than 100 m from motorway or railway

Observed presence of potential pest species in the pigsties (possible answers: do not know, never, rarely, regularly in some seasons, or regularly throughout the year)
Listed animal groups:
Mammals: rats, mice, water voles, foxes, minks, stone martens, hares, other mammals
Birds: ravens, rooks, crows, pigeons, starlings, gulls, raptors, other birds
Arthropods: flies, mosquitoes, tabanid flies, ticks, lice, scab mites, other arthropods

Importance of particular pest problems in the pigsties (possible answers: do not know, never, in some years or every year)
The same animal groups as listed above

Control measures against particular pests in the pigsties (possible answers: no, sometimes or permanent)
Type of control or preventive action
The same animal groups as listed above