EFFICACY OF HUNTING, FEEDING, AND FENCING TO REDUCE CROP DAMAGE BY WILD BOARS

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Abstract: Since 1980, populations of wild boar (*Sus scrofa*) have increased over the species' entire European range. This increase has led to conflicts because wild boars cause crop damage amounting to several million U.S. dollars every year. Wildlife management agencies promote and financially support 3 major methods to reduce the loss: (1) intensive harvest, (2) supplemental feeding in forests to bait animals for easier shooting and to distract them from agricultural fields, and (3) building electrical fences around crops at risk. Our objective was to investigate how effective these methods were in reducing field damage by wild boars. Based on data from 44 hunting territories in the Canton Thurgau, Switzerland, we related damage frequency to harvest success, supplemental feeding, and fencing effort by means of 2 multiple regression analyses. The analysis of mean damage frequency among territories (averaged over 3 years) and changes in damage frequency within territories from 1994 to 1996 showed that only hunting reduced damage by wild boars. Because our results question the effectiveness of wild boar management practices and wild boar populations and damage are increasing throughout Europe, we suggest that control efforts and funds be reconsidered. Because only hunting seems to clearly reduce wild boar damage, we suggest more emphasis be put on the development and introduction of new harvest models among local hunting teams.

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The wild boar is the fifth largest ungulate species in Europe and ranges over the entire continent (McDonald 2001). Since about 1980, populations have increased, and the species has naturally colonized new areas or has been accidentally reintroduced through individuals escaping from farms (Goulding 2003). In some regions, the number of harvested animals multiplied within only a few years (Saez-Royuela and Telleria 1986, Fruzinski 1995, Vassant 1997, Hahn and Eisfeld 1998). Because boar activity extends into farmland, the spread and increase in population size intensifies conflicts with human activities. Swine fever virus may be transferred from wild boars to domestic pigs, resulting in economic losses (Hennig 1998). Furthermore, wild boars cause considerable damage to crop fields (particularly maize and wheat), which they visit for feeding, raising piglets, or use as shelter during the day. In many European countries, compensations for crop damages cost hundreds of thousands of U.S. dollars every year (Mazzoni della Stella et al. 1995, Vassant 1997).

Three methods dominate among the attempts to reduce wild boar damage (Briedermann 1990). First, intensive harvest occurs throughout the year. Second, hunters regularly offer supplemental food in the forest to bait wild boars for harvest or to keep the animals near these feeding places and out of the farmland. Third, farmers install electrical fences to stop wild boars from entering fields. All 3 methods are highly recommended damage prevention measures in many scientific and popular articles (Breton 1994, Mazzoni della Stella et al. 1995, Vassant 1997) and thus are officially supported by many European wildlife management services. Although the methods may work locally (Andrzejewski and Jezierski 1978, Meynhardt 1991, Vassant 1994), they do not help to solve the problems in general because damage and numbers of harvested wild boars are increasing in many European countries, including Germany (Hahn and Eisfeld 1998), France (Vassant 1997) and Switzerland (yearly published harvest statistics of the Swiss Agency for the Environment, Forests and Landscape [www.umwelt-schweiz.ch/buwal/eng]).

This situation also is true for the Canton Thurgau, a region in northeastern Switzerland. Until the end of the 1980s, the Thurgau did not support wild boars. However, following the spread of the species over Switzerland, the population started to grow in the early 1990s causing increasing problems in agriculture (Geisser 1998, Geisser and Bürgin 1998). Although the government pays compensations for wild boar damages, 3 measures were taken to counteract the development. (1) Hunters increased harvest pressure on

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wild boars and established more feeding places to bait the animals. Wild boar harvest, mostly from elevated stands or towers, is practiced throughout the year. Hunters are organized in local hunting teams, where each team has its own hunting territory that is leased for 8 years (i.e., the "Reviersystem"). In addition, drive hunts (called battues), in which game is startled by beaters and dogs, are conducted between October and December, but these are performed to hunt mainly roe deer (*Capreolus capreolus*) and red fox (*Vulpes vulpes*). (2) In addition, hunters offer supplemental food (e.g., maize, fruits, potatoes, industrial food pellets) at feeding stations. Supplemental feeding is practiced to bait wild boars for easier shooting or to keep them in the forest and prevent them from going into the farmland. (3) To protect fields from wild boar damage, farmers put electrical fences around vulnerable fields from spring to harvest in late summer. Farmers are reimbursed by the government for this effort. A fence usually has 2 wires, the first 20–40 cm and the second 50–70 cm above the ground. We investigated whether harvest, supplemental feeding, and electrical fences were able to reduce field damages by wild boars in the Canton Thurgau.

STUDY AREA

The Canton Thurgau (86,000 ha) ranges in elevation from 400 to 1,000 m. The topography is gently undulated and the southern areas are prealpine. The climate is continental with an average annual precipitation of 900–1,300 mm, and average temperatures range from –0.9 °C in January to 18.3 °C in July. Forests cover 21% of the study area and mostly are used for the lumber industry. The forest structure is patchy with an average patch size of 233 ha (±104). Agricultural (i.e., crop) land covers 55% of the area and consists mainly of pasture (59%), wheat (11%), and maize (10%). Natural predators of wild boar are absent.

METHODS

We analyzed the efficacy of hunting, feeding, and fencing for reducing boar damage by comparing mean damage frequency from 1994 to 1996 and change in damage over these 3 years for 44 hunting territories that supported wild boars. We collected data on 7 parameters: (1) damage frequency—number of wild boar damage events per 100 ha of crop land, (2) battues—number of drive hunts per 100 ha of forest, (3) hunters—number of hunters per 100 ha of forest, (4) total bag—number of animals harvested per hunter, (5) boar bag—number of boars harvested per hunter, (6) feeding stations—number of supplemental feeding stations per 100 ha of forest, and (7) fence costs—annual reimbursement for fencing per 100 ha of crop land.

We obtained data for damage and fencing from annual statistics kept by the government. The government of the Canton Thurgau has compensated farmers for wild boar damage since 1974. Every damage incident reported to the fish and wildlife service is assessed by a government agent, and information on time of damage, damage size, type of damage, and type of damaged crop are collected in a database. For our analysis, we used damage frequency, which we defined as the number of damage incidents per 100 ha of crop land occurring within each hunting territory during the study period.

Farmers also are reimbursed for the cost of an electrical fence. The reimbursement is based on a standard sum per hectare, independent of crop type, location, and topography. Hence, annual reimbursement for fencing provides a representative measure for the surface of fenced fields and the effort put into that method of damage prevention.

Data for the number of feeding stations and the number of yearly battues were obtained from a survey of hunters. We obtained data for the number of hunters, the yearly total bag, and the wild boar bag in each hunting area from harvest statistics of the fish and wildlife service. Forest and farmland sizes were obtained from governmental statistics.

Because the variables that represent various measures of hunting intensity (e.g., battues, hunters, bags) were likely to be correlated, we performed a principal component analysis (PCA) to reduce them to a smaller number of independent factors (Sokal and Rohlf 1995). Following the recommendations of Aspey and Blankenship (1977) and Bauer (1986), only factors with eigenvalues ≥1 were extracted (i.e., Kaiser criterion). For interpretation of the varimax-rotated factors, only loadings ≥|0.45| were considered to be meaningful. Using stepwise multiple regression analyses with a P-threshold = 0.10, we then related the factors to (1) the mean damage frequency per territory over 3 years (1994–996) and (2) the change in damage frequency within territories from 1994 to 1996. For both the 3-year mean and the 3-year change analyses, independent data that were available on an annual basis (e.g., fences, bags) were averaged over the study. For the other variables (battues, hunters, feeding sta-

Table 1. Ln (mean damage frequency) per territory (Model A) and damage change within territories (Model B) over 3 years in relation to hunting activity, harvest success, ln(no. feeding stations), ln([number of feeding stations]^2), fence costs, and (fence costs)^2 in Canton Thurgau, Switzerland, 1994–1996. The table shows the variables remaining in the models after stepwise elimination of nonsignificant variables. Model A: R^2 = 0.746, $F_{4,39}$ = 12.226, P < 0.001; Model B: R^2 = 0.371, $F_{3,40}$ = 7..654, P < 0.001.

	Coefficient	SE	df	*F*	*P*
Model A					
Hunting activity	–1.208	0.354	1	11.666	0.002
ln(Feeding stations)	0.542	0.325	1	2.780	0.103
Fence costs	0.193	0.060	1	10.206	0.003
(Fence costs)^2	–0.002	0.001	1	4.519	0.040
Model B					
Hunting success	–0.295	0.106	1	7.681	0.009
Fence costs	0.074	0.017	1	18.121	<0.001
(Fence costs)^2	–0.001	0.000	1	18.586	<0.001

tions), we have only 1 value for the 3-year period, but we assumed these were representative because hunting territories are leased for 8 years and owners usually do not change their management practices.

Prior to the regression analyses, the variables mean damage frequency, boar bag, and feeding stations were ln(x + 0.1) transformed to achieve better approximation of a normal distribution; all other variables and the PCA scores of the factor hunting effort entered the models untransformed. Statistical analyses were done with SYSTAT 8.0 for Windows.

RESULTS

Relationship between Hunting Variables

The PCA reduced the 4 harvest variables to 2 independent factors. The first factor, explaining 45% of the variance, represents the number of battues and hunters per 100 ha of forest and hence was termed "hunting activity." The second factor, explaining 30% of the variance, represents the total and wild boar bag and hence was named "harvest success." For the subsequent analyses, the original 4 harvest variables were replaced by the scores of their respective factors.

Comparison of 3-year Mean Damage among Territories

The stepwise multiple regression analysis showed no influence of harvest success on the 3-year mean damage in a hunting territory. However, damage frequency tended to decrease significantly with hunting activity (Table 1a; Fig. 1a). In contrast, damage frequency tended to linearly increase, rather than decrease, with the number of feeding stations (Fig. 1b) and increased significantly with both the linear and the quadratic term of fencing (Table 1). This results in a curve function (Fig. 1c). Overall, the 4 variables in the final model explained 74.6% of the variance in damage.

Change in Damage from 1994 to 1996 within Territories

Results from the analysis of damage changes within territories closely resembled those from the analysis of mean damage frequency (Table 1), but the final model explained only about half as much variation (37.1%) as the model for 3-year mean damages. Changes in damage frequency from 1994 to 1996 decreased with harvest success (Fig. 1d; i.e., average number of animals harvested per hunter and year) whereas mere hunting activity had no effect. The damage change was unrelated to feeding stations (Fig.1e) but significantly related to the linear and the quadratic term of fencing (Table 1). The resulting polynomial function (Fig. 1f) suggests an initially positive relationship between damage and fencing (as in the analysis of 3-year means), followed by a peak, and then a decline when fencing effort is further increased. This apparent decrease in damage is due to only 1 hunting territory with exceptionally intensive fencing. When this outlier (indicated by an arrow in Fig. 1f) is removed from stepwise multiple regression analyses, the polynomial relationship in the analysis of 3-year damage means (Fig. 1c) does not change; whereas in the analysis of damage changes, only the positive linear term remains in the final model (straight line in Fig. 1f). Thus, the positive relationship between damage and fencing is very robust and holds over the whole range of the usual fencing effort.

A closer look at the damage details helps to explain this unexpected positive fence–damage relationship. More than 90% of all electrical fences were used to protect maize, wheat, and pasture that cover 80% of the agricultural fields. Between 1993 and 1996, the costs to protect these fields with fences almost quadrupled from US$7,294 to 28,546 (Table 2); although, during the same period, compensation rates for fencing were raised only by approximately 25% per ha. Hence, the considerable increase in protection costs within only 3 years mainly reflects a marked increase in the number and surface of fenced fields, rather than a change in compensation pol-

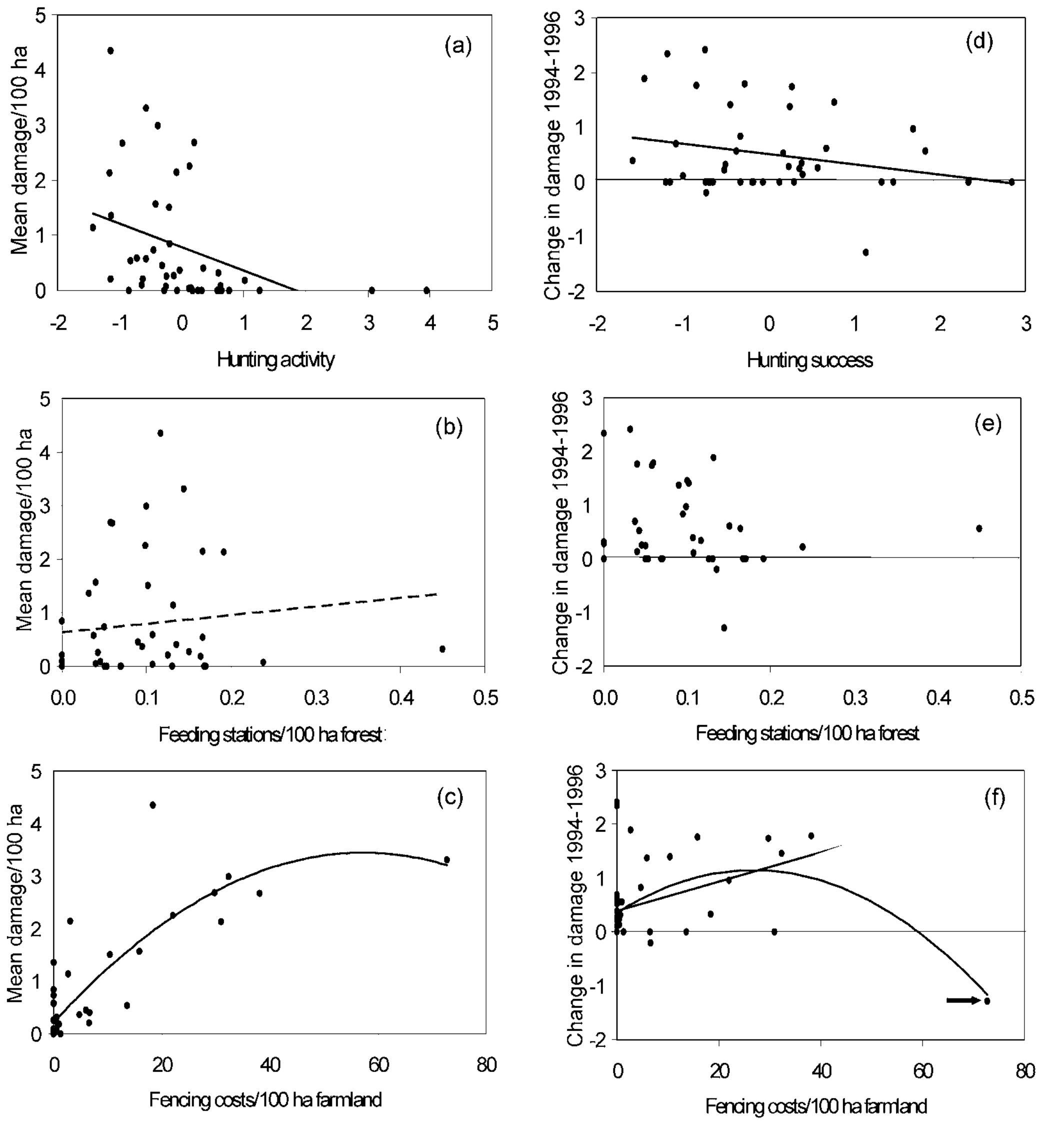

Fig. 1. Three-year mean number of wild boar damages per 100 ha agricultural land in 44 hunting territories (a–c) and changes in damage from 1994 to 1996 within each territory (d–f) in relation to harvest (a,d), number of feeding stations per 100 ha forest (b,e), and average annual fencing costs per 100 ha farmland (c, f) in Canton Thurgau, Switzerland. Significant relationships are shown by solid lines, tendencies by broken lines. In (f), the polynomial function is based on the whole dataset, the linear function describes the relationship after exclusion of an outlier (marked by an arrow). In (d)–(f), values above the thin horizontal lines indicate an increase, those below the lines a decrease in damage from 1994 to 1996.

icy. Although more fields were protected with electrical fences, the overall extent of damage increased by 27% (from 255 to 324) during the same period. However, the change differed among the types of cultivated areas. While the proportion of damages decreased from 23.5 to 12.7% for wheat and from 16.9 to 8.0% for "others," it generally remained stable for maize (23.5 to 21.3%) and increased in grassland from 51.8 to 58.0%. Hence, the major effect of fencing seems to be a shift, rather than a reduction of damage.

DISCUSSION

Of the 3 management practices used to reduce wild boar damages in crop land, only hunting had the desired effect. Supplemental feeding and fencing were inefficient. This result emerges from both the comparison of 3-year mean dam-

Table 2. Compensation costs in U.S. dollars for electrical fences and numbers and percentages (in parentheses) of damages from 1993 to 1996 for grassland, maize, wheat, and other crops (e.g., vegetables, wineyards) in Canton Thurgau, Switzerland. Costs in US$ were calculated by assuming an exchange rate of 1 US$ = 1.4 CHF (Switzerland Francs).

		Damages in				
Year	Costs (US$)	Grassland	Maize fields	Wheat fields	Others	Total
1993	7,294	132 (51.8)	60 (23.5)	60 (23.5)	43 (16.9)	255
1994	10,101	68 (46.0)	43 (29.1)	20 (13.5)	17 (11.5)	148
1995	17,529	174 (65.2)	61 (22.8)	22 (8.3)	10 (3.7)	267
1996	28,546	188 (58.0)	69 (21.3)	41 (12.7)	26 (8.0)	324

age numbers among territories and changes in damage frequency over 3 years within territories. The consistency between the 2 analyses is reassuring because the mean damage pattern—reflecting the outcome of long-term differences among territories—supports the pattern of damage change over time which, in itself, may not have been too conclusive. This is because a period of 3 years is hardly sufficient to reliably document the long-term consequences of management practices on the wild boar populations and on the resulting changes in damage. In addition, the model based on 3-year means explained twice as much variance in damage frequency as the model testing for changes from 1994 to 1996.

Hunting

Previous studies have shown that hunting can significantly reduce population density (Sweitzer et al. 2000) and damage frequency (Mazzoni della Stella et al. 1995). Our results confirm these findings and provide additional insights into the mechanisms. While the mean number of damages per territory decreased with increasing hunting activity (Fig. 1a), damage within territories over years decreased only with increasing harvest pressure (Fig. 1d). This suggests that the mere presence of large numbers of hunters and battues may deter wild boars and drive them to another area with fewer disturbances. Within a particular territory, however, damage seems to be only reduced when animals are harvested. But the effect of culling seems to be relatively small, as indicated by the shallow slope of the regression (Fig. 1d). This is not surprising regarding the high reproductive potential of wild boars. With maximal litter sizes ≥10 piglets / female, the species has been compared with small mammals (Jezierski 1977). To our knowledge, the wild boar has the highest reproductive output among all ungulate species worldwide. In a population, up to 90% of all female wild boars can reproduce (Massei et al. 1996). Therefore, selectively harvesting females could effectively reduce population size (Briedermann 1990). But sex determination of young wild boars in the field is not very reliable. Hence, selective harvest of females is difficult, and compared to hunting effort, the number of harvested female boars may be too low to significantly reduce the reproductive output of the population. Marsan et al. (1995) describe a similar situation for a wild boar population in Italy.

Supplemental Feeding

Although moderately effective, wild boar harvest is time-consuming. Thus, to optimize harvest effort and / or to directly reduce damage, hunters maintain feeding stations in the forest. While some studies provide evidence for the success of supplemental feeding in reducing field damages (Andrzejewski and Jezierski 1978, Meynhardt 1991, Vassant 1994), others showed no positive effect (Hahn and Eisfeld 1998). Our study does not support supplemental feeding as a means to reduce crop damage. Within territories, the increase or decrease in damage frequency during our study was not related to the density of feeding stations (Fig. 1e). The comparison of 3-year means showed a tendency for more damages to occur in hunting areas with more supplemental feeding (Fig. 1b). Of course, the causal relationship could be reversed, meaning that a high density of feeding stations reflects hunters' answer to more damage. However, some indications are that supplemental feeding has indeed increased the problems. With 1.05 feeding stations / 100 ha of forest and an average distance between a feeding place and the next crop field or pasture of 300 m (Geisser 2000), density of feeding stations in the Thurgau is >50% higher and distance to farmland about 60% lower than the values recommended in the scientific and the popular hunting literature (0.67 / 100 ha and 500–1,000 m, respectively; Bahr 1996, Berger and Gauville 1994). Such intensive feeding might increase damage in 2 ways. First, due to the high density of feeding stations, wild boars may be attracted to forests they would not (or not as frequently) visit if no food were provided. Second, due to the short distance to agricultural land, boars may visit and damage crops more (rather than less) often than in the absence of supplemental food. This does not mean that supplementary feeding has no positive effect (Andrzejewski and Jezierski 1978, Jullien et al. 1991, Vassant 1994), but our results stress that the density and location of feeding stations must be carefully planned and coordinated.

Moreover, the effectiveness of feeding stations can vary with time. Stomach contents of 430 wild boars from Germany contained an average of 37% maize from feeding stations (Hahn and Eisfeld 1998). During September and October, however, when maize and wheat are ready to harvest and thus especially vulnerable to damage, wild boars in our study area hardly visited the feeding stations, no matter what food was offered (Geisser 2000). Thus, at the time when supplemental feeding should have helped the most, it had no effect. Finally, even when feeding stations decrease the pressure of boars on crops, they may increase the damage to farmland in the future because abundant food supply can enhance population growth through improved survival and reproductive output (Groot Bruinderink et al. 1994). This trade-off between short-term benefits and long-term costs of feeding is illustrated by the studies of Andrzejewski and Jezierski (1978) and Jullien et al. (1991). Although these authors were able to diminish damages through supplemental feeding, wild boar numbers in their study areas tripled in 7 years and quadrupled in 4 years, respectively.

Electrical Fences

Electrical fencing has been recommended as the most successful method of damage prevention (Vassant and Boisaubert 1984, Baettig 1988, Bouldoire 1990, Breton 1994, Vassant 1994). Our results, however, provide no evidence of a decrease in damage frequency with increasing fencing effort. On the contrary, we found a highly significant positive relationship for the spatial (Fig. 1c) and the temporal comparisons (Fig. 1f). The most plausible explanation for the positive fencing–damage relationship is that more fences reflect farmers' responses to more damage. In other words, with respect to fencing, the wild boars affect human activities rather than the humans being able to control the animals. This statement may sound bold in light of the earlier cited studies that supported the effectiveness of fences in reducing damage. But 2 reasons explain why the claim of several of these studies is not well supported. First, some authors did not consider that a change in damage might result from a change in wild boar numbers (Vassant and Boisaubert 1984) or a change in the potential for damage (e.g., a shift in the relative areas of the threatened crops). In our study area, the 27% increase in total damage from 1993 to 1996 (Table 2) was paralleled by a similar increase of 21% (107 to 130) in the number of harvested wild boars, which is a good measure for population density (Geisser 2000). On the other hand, during the same period, the relative frequency of damage numbers in maize hardly changed (23.5 to 21.3%; Table 2), although the area of maize cultivation decreased markedly by 27% (3,000 to 2,200 ha). This means that, relative to the available maize area, the damage in this crop increased. Hence, without considering changes in wild boar numbers, damagable areas, harvest pressure, or other factors, attributing a decline in damage to fencing is premature.

Second, several studies finding the desired negative effect of fencing on damage are restricted to small areas or only to fenced crops like maize, wheat, or potatoes (Baettig 1988, Breton 1994, Vassant 1994). Fences can protect limited areas to a certain extent. However, these studies did not investigate how fencing affected the damage in adjacent areas or in less protected cultures like pasture. Our study, which covered a larger area and included fenced and unfenced farmland, suggests that fences do not effectively decrease the total damage; fences only cause wild boars to shift their damaging activity to less protected regions in the area or to other cultures (e.g., grassland; Table 2). In this respect, the effect of fences resembles the deterring effect of harvest activity.

MANAGEMENT IMPLICATIONS

Given that fencing seems to track rather than control damage (Figs 1c,f) and that increased funding for fencing from 1993 to 1996 failed to reduce damage from wild boars (Table 2), we do not support the usefulness of this management method. The high costs for buying and maintaining electrical fences may be justified for fields of high economic value or high risk of being damaged. However, our results do not justify fencing as a method of damage prevention, nor do they support the effectiveness of supplemental feeding. Only hunting caused limited damage reduction.

Admittedly, our findings are restricted to the situation in the Canton Thurgau. In other places, a combination of the 3 management methods has helped to reduce the problems with wild boars. Yet, our results and the increasing wild boar populations and damage numbers throughout Europe call for a serious reconsideration of the present-day prevention measures and the funds allocated to them. Because only hunting seems to clearly reduce wild boar damage, we suggest more emphasis be put on the development and introduction of new harvest models among local hunting teams. Such reconsiderations and potential alternative solutions are important for (1) successfully reducing crop damage; (2) regulating the impact of wild boars on plant diversity, vegetation community, and regeneration patterns in natural habitats (Welander 2000, Hone 2002, Kuiters and Slim 2002); (3) decisions whether to reintroduce wild boars (Leaper et al. 1999); and (4) the attitude of local people toward the establishment of reserves and parks housing feral pigs and other animals that pose threats to people's subsistence (Rao et al. 2002).

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