ACTA MYCOLOGICA
Vol. 48 (1): 73–80
2013
DOI: 10.5586/am.2013.009

Effects of wild boar grazing on the yield of summer truffle (Tuscany, Italy)

ELENA SALERNI[1*], LORENZO GARDIN[2], FRANCESCA BAGLIONI[3] and CLAUDIA PERINI[1]

[1] Department of Life Sciences, University of Siena, Via Mattioli 4, I-53100 Siena
[2] Via F.D. Guerrazzi 2/4r, I-50132 Firenze
[3] Regione Toscana - D.G. "Competitività del sistema regionale e sviluppo delle competenze" Area di Coordinamento "Sviluppo rurale" - Settore "Promozione dell'innovazione e sistemi della conoscenza" Via di Novoli 26, I-50127 Firenze, *corresponding author: salerni@unisi.it

Salerni E., Gardin L., Baglioni F., Perini C.: *Effects of wild boar grazing on the yield of summer truffle* (*Tuscany, Italy*). Acta Mycol. 48 (1): 73–80, 2013.

The research presented here seeks to describe the impact of wild boar to a natural truffle ground of *Tuber aestivum* Vittad. on Monte Amiata (Tuscany – Italy). Pedoclimatic analyses indicated that the selected area could be considered suitable for the truffle production. Then classification of the vegetation of a *Quercus cerris* forest was carried out exploring the possibility of the BACI (Before-After-Control-Impact) sampling design. Finally 10 plots were selected, half of which have been fenced. For the first time the impact of wild boar was evaluated by estimating the surface area turned over by its activity. Moreover in each plot the number and weight of summer truffles was performed every 10 days during the fruiting period (June-November 2006-2008). The hypothesis that the presence of *Sus scrofa* has a strong negative influence on truffle harvesting has been amply confirmed by the data presented here, given the large increase of fruiting bodies of the summer truffle collected in the fenced plots. Consequently the destructive behaviour of the wild boar imply not only an ecological but also an economic damage in areas in which non-wood forest products are an important source of income.

Key words: natural truffières, *Quercus cerris*, wild boar, soil turn over, harvesting

INTRODUCTION

The wild boar (*Sus scrofa* L.) is considered as an invasive species introduced in many parts of the world and as an environmental pest not only because carrying parasitic infections but also because of its destructive behaviour moving in herds, digging for foot and wallowing to maintain body's integrity (Lowe et al. 2000); on the other hand the taxon is listed by the IUCN Red List Category & Criteria as least concern (LC)

needing at local level conservation actions against habitat destruction and hunting pressure (Oliver, Leus 2008).

The wild boar occurs throughout the steppe and broadleaved forest regions, worldwide ranging from the Mount Atlas and the extreme south-west of Spain to the Pacific and the islands of Hokkaido, Honshu and Taiwan. To the north, the distribution area stretches beyond the 60° parallel, while to the south it reaches the Indian subcontinent (Olive, Leus 2008). The distribution of wild boar was relatively limited until the end of the Second World War (Boitani et al. 2003), but the populations of this species have increased substantially throughout Europe since the 1960s (Sàez-Royuela, Tellerìa 1986; Apollonio et al. 1988). Albeit at varying intensity, his range continue to increase in France (Boisaubert 1997), Luxemburg (Schley et al. 1998), Spain (Leránoz, Castién 1996; Markina 1998; Rosell 1998) and Italy (Marsan et al. 1990). This expansion in Italy is mainly due to human agency for recreational hunting purposes, to the extent that it is not currently possible to quantify the presence of wild boar in the country (Boitani et al. 2003). As omnivores wild pigs have broad dietary habit with a preference for vegetables and consume different parts of the plants according to the season (Boitani et al. 2003; Giménez-Anaya et al. 2008). Wild boar prefer to graze at dusk and night and those that inhabit woods dig up even hard and rocky ground in search of roots, truffles or bulbs (Fozzer 1981; Herrero et al. 2005).

The wild boar is without doubt the ungulate that has the greatest impact on human socio-economic activities in Italy, being the largest hunt-able mammal in the country. On the other hand, its often artificial commonness and ability to eat almost all types of agricultural crop have led to serious conflict with the classic agricultural sector (Kristiansson 1985; Boitani et al. 2003; Herrero et al. 2006).

Another important source of income are the non-wood forests products and among fungi, bolets and truffles, are the most appreciated. Consequently the management of natural and cultivated grounds of truffle can be seen as an important agriculture alternative, particularly in the Mediterranean region, and is in Italy in continuous expansion and evolution (Bencivenga et al. 2005; Donnini et al. 2013). The consumption of fresh and preserved truffles has increased significantly in recent years, while production in natural truffle grounds has decreased due to intense harvesting, the modification of ecosystems, the abandonment of the countryside (Bencivenga et al. 2005). Various research have been undergone and projects are still in progress in order to describe sustainable action plans for safeguard and increment the fruiting of mycorrhizal fungi, with a particular emphasis on truffles (Donnini et al. 2013). To underline that truffle growers, thanks to personal observations, locally just apply some managements. So for instance they slightly turn-over the soil around productive trees in *Tuber melanosporum* cultivations in order to increase the fruiting bodies collection. Recent research demonstrate through a specific real-time PCR assay that this action significantly increase the quantity of mycelium of *T. magnatum* in natural truffieres (Iotti et al. 2012).

Tuscany is without doubt a region with a strong tradition in truffle producing. This has always and almost exclusively concerned the famous white truffle (*Tuber magnatum* Pico), although operators in the sector have recently shown great interest also in less valued species. The species commonly known as the whitish truffle (*Tuber borchii* Vittad.), the summer truffle (*Tuber aestivum* Vittad.) and the Burgundy

truffle (*Tuber uncinatum* Chatin) are now seen as territorial resources to be promoted or recovered, also from the point of view of their natural production environments (Gardin 2005; Salerni et al. 2006, 2010). Among this truffles *T. aestivum* results with an extreme adaptability to climatic changes especially variations in temperature, by bringing forward or delaying the maturation of fruit bodies (Wedén et al. 2004; Hall et al. 2007). This adaptability is also reflected in its distribution, which in Italy ranges from north to south, including the two main islands (Granetti et al. 2005) and within Europe involves both typically Mediterranean countries (Spain, France, Greece, etc.) and those situated further north, such as Scotland, England and Sweden (Stecchi 1994; Wedén et al. 2004; Granetti et al. 2005).

In this context the work presented here, part of a series of projects evaluating some environmental parameters and the presence of truffles, seeks to evaluate the impact of wild boar on the presence of fruiting body of *Tuber aestivum* in a natural truffle ground of Monte Amiata.

MATERIALS AND METHODS

Study area. The natural truffle ground studied is situated on Monte Amiata, the highest mountain in southern Tuscany, in the municipality of Castell'Azzara (province of Grosseto), at an altitude of approximately 1.000 m (Geographic coordinates: 4°73'42.25''N; 71°25'27''E). From the vegetational survey the most common tree species results *Quercus cerris* L., while the underwood includes shrubs such as *Crataegus monogyna* Jacq., *Euonymus europaeus* L*., Rosa arvensis* Hudson and *Prunus spinosa* L., and common in the herbaceous layer are *Alliaria petiolata* (Bieb.) Cavara & Grande, *Geranium robertianum* L. and *Smyrnium perfoliatum* L. The area is characterized by a submediterranean climate with July and August as hottest months (mean temperature over 24°C) and February usually as coldest one (4.3°C). The most abundant rains are recorded in late autumn (November and December) with an average of 200mm, while June and July are the driest one, with only 10mm of rain. The study area lies on various geological substrates composed of alternating limestones, calcarenites and marly limestones. The soil depth is generally shallow to moderate and texture varies from loam to clay loam. While most of the pedological parameters measured agree with those observed in other Tuscan truffle grounds (Gardin 2005) and in central Italy in general (Granetti et al. 2005), the soil reaction, which according to some authors (Bratek et al. 2001; Tanfulli et al. 2001; Gardin 2005; Granetti et al. 2005; etc.) should be neutral or weakly basic for the production of *T. aestivum*, varies considerably from pH 4.5 to 6.6.

Sampling design. Within this area an experimental design was realized in order to check the possibility of applying the BACI (Before-After-Control-Impact) sampling designs. Specifically, over a period ranging more than one year, we tested whether the area was sufficiently homogeneous to apply a randomized selection of plots to subsequently be fenced off. Following this, 10 plots of 1000 m^2 each were staked out on the ground using coloured posts; half of these plots have been fenced in the 2007 spring, in order to prevent the access of the wild boars.

Data collection. The presence of wild boar was evaluated monthly, from May 2006 till November 2008, by estimating the surface area turned over according to the following scale: **1** (surface area turned over between 1%-25%); **2** (surface area turned over between 26%-50%); **3** (surface area turned over between 51%-75%); **4** (surface area turned over between 76%-100%).

Thanks to the collaboration of truffle hunters and trained dogs fruiting bodies of *T. aestivum* were collected every 10 days in periods of fungal production (June-November 2006-2008) and their frequency and weight was annotated.

Statistical analyses. Significance ($P<0.05$) of differences between open and fenced samples was checked by ANOVA, using Tukey's pairwise comparison. Normality was checked using Shapiro-Wilks test. In addition, for the ANOVA test, the homogeneity of variance was checked using Levene test.

RESULTS AND DISCUSSION

Table 1 shows the quantitative estimate of the impact of wild boar in the 10 plots observed, both prior to and after fencing, which was carried out in May 2007. Before the introduction of fenced areas, the zone was commonly frequented by wild boar.

Table 1
Quantitative estimation of the impact of wild boar before and after fencing off

Date	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10
	O	O	O	F	F	F	O	F	O	F
05-2006	1	1	1	1	2	1	2	1	2	1
06-2006	1	1	1	1	2	1	2	1	3	1
07-2006	4	4	3	2	3	2	3	3	4	2
08-2006	1	1	1				1	1		1
09-2006	1	1	1	1	1	1	1	1	1	1
10-2006	3	2	3	2	3	2	2	2	2	3
11-2006	4	3	4	4	4	3	4	4	4	4
12-2006	4	3	4	4	4	3	4	4	4	4
01-2007	4	3	4	4	4	3	4	4	4	4
02-2007	1	1	1	2	2	2	3	1	3	2
03-2007	1	1	1	1	1	1	2	2	2	2
05-2007	1	1	1	1	2	1	2	1	3	1
06-2007	4	4	3				4		2	
07-2007	4	4	3				4		2	
08-2007	1	2	3				3		1	
09-2007	2	1	3				4		1	
11-2007	4	3	3				4		2	
12-2007	4	3	4				4		2	
01-2008	4	4	4				4		3	
03-2008	1	1	2				2		1	
04-2008	1	1	1				1		1	
05-2008	2	1	3				1		2	
06-2008	3	2	3				2		1	
07-2008	3	2	3				3		2	
08-2008	4	4	3				4		1	
09-2008	1	1	2				1		1	
10-2008	2	1	2				1		1	
11-2008	2	3	1				3		1	

Table 2
Number of fruiting bodies (fb) and weight (w in g) of *Tuber aestivum* recorded in each plot before (2006) and after fencing off (2007-2008)

Year	Plot 1		Plot 2		Plot 3		Plot 4		Plot 5		Plot 6		Plot 7		Plot 8		Plot 9		Plot 10		Total	
	O		O		O		F		F		F		O		F		O		F		fb	w
	fb	w	fb	w	fb	w	fb	w	fb	w	fb	w	fb	w	fb	w	fb	w	fb	w		
2006	5	*114*	8	*225*	11	*167*	4	*30*	11	*149*	8	*225*	3	*18*	3	*141*	2	*21*	5	*117*	60	*1207*
2007	7	*62*	5	*23*	15	*110*	32	*419*	35	*496*	15	*163*	42	*493*	44	*544*	4	*40*	8	*146*	207	*2496*
2008	77	*689*	16	*170*	47	*771*	105	*1354*	109	*1464*	105	*971*	42	*459*	139	*1936*	0	*0*	44	*444*	684	*8258*
Total fb	89		29		73		141		155		128		87		186		6		57		951	
Total w		*865*		*418*		*1048*		*1803*		*2109*		1359		970		*2621*		*61*		*707*		*11961*

In fact, the estimated soil destruction was equivalent to or greater than 75% in all plots with the exception of plot 6 (Tab. 1). During the year of observation the presence changes, being more in July and the autumnal months. This two peach maybe assigned to different activities, the first more due to wallowing in order to refresh the body the second to digging searching food. After fencing the impact of wild bear increased strongly in the open plots, while the fencing resulted to be well done with a complete absence in closed plots. The period of grazing and moving around becomes a little bit longer and in the summer 2008 three months of activity of the wild boar were recorded. To note the nearly constant presence of *Sus scrofa* in plot 7 and simultaneously the decrease in plot 9, maybe the fencing of some plots have changed the route of the herds in movement. Despite the killing permitted by the Provincial Administration, the presence of wild boar in the study area remains relatively high, also in the months in which *T. aestivum* fructifies.

A total of 951 fruiting bodies weighting approximately 12 kg were collected in the ten plots and there was a significant increase in production over the three-year period: while 60 (1207 g) truffles were found in 2006 prior to fencing, there were an important change the years after reaching 207 (2496 g) and 684 (8258 g) in 2007 and 2008 respectively (Tab. 2). The only slight increase in 2007 is partially dependent on the action done to border half of the plots, in fact one year after fencing the truffle recording was higher. To note moreover that nearly 2/3 in number of fruiting bodies and half in biomass was harvested in the fenced plots.

It is quite difficult to find comparable data on the productivity of natural truffle grounds, especially because truffle growers are reluctant to provide such information. However, comparison between the productivity of this truffle ground and that of cultivated or controlled *Tuber melanosporum* (black truffle) grounds reveals that ours is relatively low. The annual production of *Tuber melanosporum* in Italy is estimated to be around 50kg/ha (Bencivenga, Di Massimo 2000), while in Spain it is 15-50 kg/ha (Carbajo 2000) and in France it is over 110 kg/ha (Chevalier, Frochot 1997). The truffle ground in the study area, in contrast, produced only 12 kg/ha.

An ANOVA test was performed to determine whether production (number of truffle and total weight) varied in the plots fenced in comparison to the open ones. The data, compared to the initial situation, show how the absence of wild boar in the fenced areas influences the production (number of truffle and total weight) of *Tuber aestivum* (Tab. 3). A *post hoc* Tukey's test was conducted to determine which averages were different. The result showed that the production of truffle (number and

Table 3
ANOVA of "number of truffle" and total weight; factor: 1 - open and fenced area; 2 - before and after fencing off

Source	SS	d.f.	MS	*F*	*p*-level
a) number of truffle					
1	7334.45	1	7334.45	7.98069	0.012195
2	34528.05	1	34528.05	37.57031	0.000015
12	7182.05	1	7182.05	7.81486	0.012961
Error	14704.40	16	919.02	-	-
b) total weight					
1	1370994	1	1370994	7.50917	0.014521
2	4555485	1	4555485	24.95118	0.000132
12	1251801	1	1251801	6.85633	0.018629
Error	2921215	16	182576	-	-

weight) was significantly higher (p-level < 0.005) in the areas subsequently fenced in comparison to those left open.

CONCLUSIONS

The aim of this experimental project was to evaluate the impact of wild boar on the presence of fruiting bodies of *Tuber aestivum* in natural truffle grounds. Although this type of study requires longer monitoring periods, some conclusions can already be drawn after three years. Even if regular slight soil tillage seems to be favourable to hypogeous fungi (Ławrynowicz et al. 2006) and is used by truffle growers, it was demonstrated that the activities of trampeling in herds, digging and wallowing by the wild boar has a negative influence on the fruiting bodies production. On the other hand in fenced areas, where the grazing of wild boar results prohibited, a large increase was observed. Finally from the point of view of an alternative agriculture, defending some truffle growing zones from the presence of this ungulate means also an economic increase.

Acknowledgments. This project is financed by ARSIA [Regional Agency for Development and Innovation in the Agriculture and Forestry Sector] and realized in collaboration with the Consortia of Municipalities of Monte Amiata. The Authors would like to thank Cesare Papalini (Comunità Montana Amiata Grossetano), Giulio Vicarelli (Castell'Azzara), Giorgio Morganti (Arcidosso), Ugo Santella (Castel del Piano), Prof. Giuseppe Manganelli and Dr. Leonardo Favilli (Department of Environmental Sciences "G. Sarfatti", University of Siena) for their valuable help.

REFERENCE

Apollonio M., Randi E., Toso S. 1988. The systematics of the wild boar (*Sus scrofa* L.) in Italy. Boll. Zool. 3:213-221.

Bencivenga M., Di Massimo G. 2000. Risultati produttivi di tartufaie coltivate di *Tuber melanosporum* Vitt. in Umbria. Micologia Italiana 2: 38-44.

Bencivenga M., Donnini D., Gobbini A. 2005. Stato attuale della tartuficoltura italiana. Atti del Seminario di Spoleto, 21 Febbraio 2004. Grafiche Millefiorini, Norcia, Italia.

Boisaubert B. 1997. Les cervides et le sanglier. Bulletin Mensuel del Office National de la Chasse 225: 22-25.

Boitani L., Lovari S., Vigna Taglianti A. 2003. Mammalia III. Carnivora – Artiodactyla. Fauna d'Italia. Calderoni, Bologna.

Bratek Z., Bagi I., Parádi I., Vikor J. 2001. Differentation among truffle species based on habitat preferences. Actes du V^{ème} Congrès International Science et Culture de la Truffe, Federation Française des trufficultures, pp. 193-195.

Carbajo P. 2000. Plantación de Arotz-Catesa. Proceedings of Jornadas de Truficultura, pp. 26-28.

Chevalier G., Frochot H. 1997. La maîtrise de la culture de la truffe. Rev. Forest. Française 49: 201-213.

Donnini D., Gargano M.L., Perini C., Savino E., Murat C., Di Piazza S., Altobelli E., Salerni E., Rubini A., Rana G.L., Bencivenga M., Venanzoni R., Zambonelli A. 2013. Wild and Cultivated mushrooms as a model of sustainable development. Plant Biosystems 147 (1): 226-236. http://dx.doi.org/10.1080/11263504.2012.754386

Fozzer F. 1981. Cinghiale (*Sus scrofa* L.). (In:) Corpo Forestale dello Stato e delle regioni autonome (ed.). Distribuzione e biologia di 22 specie di mammiferi in Italia. Istituto di Entomologia dell'Università di Pavia, Pavia: 123-127.

Gardin L. 2005. I tartufi minori in Toscana. Gli ambienti di crescita dei tartufi marzuolo e scorzone. Quaderno ARSIA 1/2005, Firenze.

Giménez-Anaya A., Herrero J., Rosell C., Couto S., Garcia Serrano A. 2008. Food habitus of wild boars (*Sus scrofa*) in a mediterranean costal wetland. Wetlands 28 (1): 197-203. http://dx.doi.org/10.1672%2F07-18.1

Granetti B., De Angelis A., Materozzi G. 2005. Umbria terra di tartufi. Gruppo Micologico ternano, Regione Umbria, Terni.

Hall I.R., Brown G.T., Zambonelli A. 2007. Taming the truffle. The History, Lore, and Science of the Ultimate Mushroom. Timber Press, Portland, Oregon.

Herrero J., Irizar I., Laskurain N.A., García-Serrano A., García-Gonzáles R. 2005. Fruit and roots: wild boar foods during the cold season in the south-western Pyrenees. Italian Journal of Zoology 72: 49-52.

Herrero J., García-Serrano A., Couto S., Ortuño V.M., García-Gonzáles R. 2006. Diet of wild boar *Sus scrofa* L. and crop damage in an intensive agroecosystem. European Journal of Wildlife Research 52: 245-250. http://dx.doi.org/10.1007%2Fs10344-006-0045-3

Iotti M., Leonardi M., Oddis M., Salerni E., Baraldi E., Zambonelli A. 2012. Development and validation of a real time PCR assay for detection and quantification of Tuber magnatum in soil. BMC Microbiol. 12: 93. http://dx.doi.org/10.1186/1471-2180-12-93

Kristiansson H. 1985. Crop damage by wild boar in Central Sweden. Proceedings of the XVIIth Congress of the International Union of Game Biologists, pp 605-609.

Ławrynowicz M., Faliński J.B., Bober J. 2006. Interactions among hypogeous fungi and wild boars in the subcontinental pine forest. Biodiv. Res. Conserv. 1-2: 102-106.

Leránoz I., Castién E. 1996. Evolución de la población del jabalí (*Sus scrofa* L., 1758) en Navarra (N península ibérica). Miscellània Zoològica 19: 133-139.

Lowe S., Browne M., Boudjelas S., De Poorter M. 2000. 100 of the world's Worst Invasive Aliena Species. A selection from the Global Invasive Database. The Invasive Species Specialist Group of the Species Survival Commission of the World Conservation Union.

Markina F. 1998. Estudio de las poblaciones de corzo (*Capreolus capreolus*) y jabalí (*Sus scrofa*) y análisis de su explotación cinegètica en el Territorio Histórico de Álava. Dissertation, University of León.

Marsan A., Scheone L., Spanò S. 1990. Il cinghiale in Liguria. Regione Liguria, Recco, Genova.

Oliver W., Leus K. 2008. *Sus scrofa*. (In:) IUCN 2012. IUCN Red List of Threatened Species. Version 2012.2.

Rosell C (1998) Biologia i ecologia del senglar (*Sus scrofa* L. 1758) a dues poblacions del nordest ibèric. Aplicació a la gestió. Dissertation, University of Barcelona.

Sàez-Royuela C., Tellerìa J.L. 1986. The increased population of the wild boar (*Sus scrofa*) in Europe. Mammal Review 16: 97-101.

Salerni E., Landi M., Frignani F., Angiolini C., Perini C., De Dominicis V. 2006. Caratterizzazione climatico-vegetazionale di tre tartufaie naturali della Toscana centro-meridionale. Micologia e Vegetazione Mediterranea 21: 123-140.

Salerni E., Baglioni F., Mazzei T., Perini C. 2010. Rapporto fra la gestione dei soprassuoli forestali e produzione di *Tuber aestivum* Vitt. in una tartufaia naturale del Monte Amiata (Toscana-Italia): primi risultati. (In:) D. Donnini, L. Baciarelli Falini, M. Bencivenga, G. Di Massimo (eds). Atti 3° Congresso Internazionale di Spoleto sul Tartufo. Comunità Montana Monti Martani Serano e Subasio, Spoleto, book & dvd, ISBN 9788890512209: 205-212.

Schley L., Krier M.W., Roper T.J. 1998. Changes in the Wild boar *Sus scrofa* population in Luxembourg during the period 1946 to 1996. Bulletin de la Société des Naturalistes Luxembourgeois 99: 77-85.

Stecchi G. 1994. Tartufo dove, nel suo ambiente ed a tavola. Idea Natura, Milano.

Tanfulli M., Giovanotti E., Donnini D., Baciarelli Falini L. 2001. Analisi della micorrizazione in tartufaie coltivate di *Tuber aestivum* Vittad. e *Tuber borchii* Vittad. impiantate da oltre 12 anni in ambienti pedoclimatici diversi. Actes du V^{ème} Congrès International Science et Culture de la Truffe, Federation Française des trufficultures, pp. 480-484.

Wedén C., Chevallier G., Danell E. 2004. *Tuber aestivum* (syn. *T. uncinatum*) biotopes and their history on Gothland, Sweden. Mycological Research 108 (3): 304-310. http://dx.doi.org/10.1017%2FS0953756204009256