# WILD UNGULATES AND FORESTS IN EUROPE: INSIGHTS FROM LONG TERM STUDIES IN CENTRAL ITALY

**Andrea Cutini[1], Francesco Chianucci[1], Marco Apollonio[2]**

[1]Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Centro di Ricerca per la Selvicoltura, Arezzo, Italy; andrea.cutini@entecra.it
[2]Dipartimento di scienze della natura e del territorio, Università degli studi di Sassari, Sassari, Italy

The relationship between wild ungulates and forest has been increasingly investigated in Europe in the last few decades, a consequence of the impressive increase in wild ungulates density occurred in the continent. The issue is of great interest not only under a scientific but also under an economical and social perspective. Starting from a European perspective we examined in detail what happened in Italy where in the last two decades ungulates, and in particular deer species and wild boar, increased many fold. Consequently a considerable impact was experienced not only in conifer forest stands within protected areas but in coppice woods too. This situation needs answers not only from the forest managers but also from the scientific community heading to new and more integrated management schemes between forestry and wildlife management. At the same time any change is at risk as it is often strongly opposed by the two sides as consequence of the existing conflicts. On the basis of long term studies in the Apennines on the relationships between forest and ungulates (and predators) manly concerning ungulate population dynamics, forestry management of broadleaf woods and their interactions, we suggest possible future scenarios on the evolution of these ecosystems and make suggestions on an integrated approach in their management in order to necessary change the present approach and to give proper solutions to a new environmental challenge.

*Keywords*: silviculture, coppice, impact, forest management, wildlife management.
*Parole chiave*: selvicoltura, cedui, impatto, gestione forestale, gestione faunistica.

http://dx.doi.org/10.4129/2cis-ac-wil

## 1. Introduction

The relationships between wild ungulates and forest ecosystems have been investigated from the end of WWII, i.e. from the start of the impressive increase in wild ungulates density in the continent, where now this group has reached unrecorded densities in the last two centuries (Jorritsma *et al*., 1999; Reimoser *et al*., 1999; Sipe and Bazzaz, 2001; Partl *et al*., 2002; Horsley *et al*., 2003).
The issue has been more and more interesting in Italy and in other European countries, where the social changes occurred in rural and mountainous areas have supported a progressive abandonment of agricultural activities and a marked forest expansion (Bätzing *et al*., 1996; Hötch *et al*., 2005). These environmental changes favoured the expansion and the reintroduction of wild ungulates, which in many cases were regarded as rare species until the 1970s.
At present time there are 20 ungulate species in Europe (Fig. 1), with an estimated total number of 18 M and a total biomass of 770.000 tons around (Apollonio *et al*., 2010). Among ungulates roe deer (*Capreolus capreolus* L.), wild boar (*Sus scrofa* L.) and red deer (*Cervus elaphus* L.) represent the most important species, which account for the 88% of total number of ungulates heads and the 81% of total biomass. As a consequence, these species have major impacts on agricultural and forest crops.
Overall, ungulates contributed significantly to biodiversity and represented an important cultural, aesthetic social asset (hunting tradition included) with important economic revenues. For example, game meat production as alone was estimated over 121.000 tons in EU-27, corresponding to a total value of above 394 M euro (UNECE-FAO, 2011). The number of heads culled each year is 5.2 M, which feed an increasing important collateral economic segment like the hunting tourism. Conversely, increasing criticisms due to ungulates expansion are connected to damages to agricultural crops and forests, with a forest area damaged by wildlife and grazing grew from 1 M ha in 1990 up to 2.4 M ha in 2005; at the same time the percentage of forest area with damage by wildlife and grazing grew from 1.1% up to 1.9% (UNECE-FAO, 2011). In addition, vehicle collisions with ungulates represent another relevant criticism, considering the average number of car accident in Europe (on average 750.000 each year (Langbein *et al.,* 2011). With respect to damage compensation marked differences exist at European level: two countries (Finland and Slovenia) provide compensation for agriculture and forest damage and vehicle collisions; two countries for agriculture and forestry (Hungary, Slovakia); two

countries for agriculture only (France and Switzerland) and two countries for forestry only (Austria and Sweden). Eleven out of 23 monitored countries (Italy too) haven't existing national schemes of countrywide monitoring systems for recording impacts or monetary damages by wild ungulates (Reimoser and Putman, 2011).

The relationships between ungulates and forests are problematic due to the distance from natural equilibrium of both components, in many cases originated or emphasised by human activities. Latham (1999) pointed out several cases of ungulate density found to be much higher than expected under natural or non-human-influenced conditions. Accordingly, the damage caused by deer browsing was more and more frequently recorded and forest owners began to complain about the negative impact of ungulates on forest vegetation. Moreover, high deer density determined a decrease in habitat suitability in the long term (Tremblay *et al*., 2005) and indirectly threatened the sustainability of deer population size too because of the growing lack of resources (Caughley, 1970; Forsyth and Caley, 2006). In this context silvicultural practices were found to be unlikely to restore natural regeneration as long as the presence of a deer population at high density was reported (Beguin *et al*., 2009).

Deer browsing was shown to affect the individual tree survival and it still represents an economic problem: considerable damage in tree recruitment was reported, among others, for *Abies alba* (Motta, 1995) and *Abies balsamea* (Beguin *et al*., 2009). The impact of browsing varies to a substantial degree according to deer density (Reimoser, 1986; Gill, 1992), environmental factors such as the climate, and cultural factors such as the silvicultural techniques which are meant to design the spatial and temporal distribution of resources (Motta, 1995; Putman, 1996; Morellet and Guibert, 1999; Mysterud and Ostbye, 1999; Reimoser and Ellenberg, 1999; Morellet *et al*., 2007; Jarni *et al*., 2004).

Overall, estimating browsing damage is a very complex issue (Canham *et al*., 1993; Reimoser *et al*., 1999), one more frequently explored in relation to conifer species (Welch *et al*., 1991; Gill, 1992; Heuze *et al*., 2005), and poorly investigated in relation to broadleaved species and agamic regeneration in coppice woods (Eiberle, 1980; Putman 1994; Drexhage and Colin, 2003; Espleta *et al*., 2006).

At another level, wild boar is an ungulate species which turned out to be one of the most problematic among ungulates in Europe. Wild boar population densities have been growing notably during the past few decades (Saez-Royuela and Telleria, 1986) due to the abandonment of rural areas, restocking, lack of predators, and supplementary feeding (Saez-Royuela and Telleria, 1986). Wild boar can reach high densities, on account of its high adaptability, and can be considered a typical *r*-strategy species, with high ecological plasticity and a very high reproductive capacity, due to its relatively short gestation period and its high mean litter size (Saez-Royuela and Telleria, 1986). It shows intense responses to food pulses (Jedrzejewska *et al*., 1997; Bieber and Ruf, 2005) such as mast seeding (acorns, chestnuts and beech nuts), which also represent the species' main source of food from September to late spring. Its increase has caused substantial damage to agricultural crops and the invasion of urban environments in many countries (Geisser and Reyer, 2004).

## 2. Long term studies in Central Italy

The trends observed at European level were similar in Italy, where the increase of total surface of forested areas was two millions of hectares in the last two decades (INFC, 2007). Silvicultural systems and practices, shaped according to natural processes and oriented towards a cautious approach in forest exploitation, became more and more common; conversely, increasing criticism involved clear-cutting systems, especially on large areas. In addition, since the 1980s the total surface of protected forested areas in Italy noticeably increased, also on account of the establishment of a consistent number of national as well as regional parks, and of protected areas. Accordingly, as a result of the increase of the total forested area, the changes in forest management, and the greater importance attached to protected areas, the productivity and structural complexity of forest ecosystems in Italy consistently improved in a relatively short time. As a consequence an important expansion of ungulates was observed (Fig. 2). This trend involved mainly roe deer, red deer and wild boar (Fig. 3) (Apollonio, 2004). As a consequence, damage to agricultural crops or forest stands became more and more frequent and the need for forest adjustment and hunting management plans dramatically increased, also on account of the changes in the status and structure of herbivore populations and their rapid changes.

Since the end of '90 of last century and within the framework of the national research programme within the framework of the national research project "The implementation of game management in rural and mountainous areas", supported by funding from the Ministery of Agriculture and Forest Policy, we conducted researches on the relationships between forest management and ungulates in Central Italy, by means of a multidisciplinary approach (forest ecologist, foresters, zoologist, forest and game planner) and in strict collaboration with the forest and game managers (Regione Toscana, Provincia di Arezzo, Unione dei comuni montani del Casentino).

Due to their importance among ungulates, researches focused on roe deer and wild boar, their population dynamics and the relationship with structure and management of deciduous forests under traditional coppice system or in transition o high forest. More in details the aim was to assess to the effects of roe deer population on the agamic regeneration of Turkey oak (*Quercus cerris*) and chestnut (*Castanea sativa*), two of the most important broadleaved species in Italy, for their environmental as well as economic value, in connection to coppice exploitation. The study was established in Alpe di Catenaia (43°48'N, 11°49'E), a mountainous area in the province of Arezzo, which

well represents the typical forested areas of northern and central Apennines (Cutini *et al*., 2007). The ungulate community within the study area consisted of roe deer and wild boar, with an estimated density of 23.0 (± 0.8) and 11.6 (± 2.0) respectively (Chianucci *et al*., 2015; Cutini *et al*., 2013). Red deer appeared in 2007 and its presence was occasional. The impact was estimated through an eleven-year period following the coppicing, in order to analyse the evolution of the degree of browsing through time and to compare the recovering capacity of the two broadleaved species considered. Data were collected from permanent monitoring plots established in three 1-ha stands do-minated by chestnut and Turkey oak, which were coppiced in 2002.

Two sampling plots sized 200 $m^2$ were established within each stand, one of which was fenced (protected, P), while the other was left accessible to browsing (non-protected, NP). Within each plot, the ratio of browsed sprouts over the total number of sprouts was recorded in the early four years after coppicing to calculate a browsing index; later, diameter at breast height and total height of sprouts were measured. Differences in browsing index and growing stock (basal area and volume) between P and NP by repeated inventories were analysed (Cutini *et al*., 2011). Roe deer impact on the agamic regeneration differed between chestnut and Turkey oak. In fact, one year after coppicing only 30% of chestnut stools in open areas were seriously damaged, while in Turkey oak every single stool was heavily browsed (Cutini *et al*., 2011). Three years after the coppicing, 50% of Turkey oak stools still suffered from heavy roe deer browsing, while chestnut coppices showed almost no damage (Fig. 4). Repeated inventories in 2008 and 2013 demonstrated that the effects of early browsing on Turkey oak produced prolonged impacts through time (Chianucci *et al*., 2015). Although the trend decreased, the average reduction in volume observed eleven years after coppicing was still over 40% and heavily retarded shoot growth (Fig. 5).

In order to evaluate the effect of deer density on vegetative regeneration of Turkey oak coppice stands in a broader context, the severity of roe deer browsing on new sprouts after coppicing was observed along a gradient of ungulate density. In that case the study area involved all the Province of Arezzo (Tuscany, Italy). Three sub-districts were selected representing a gradient of roe deer population densities in hilly and mountain areas of Central Italy: low, medium and high density scenario with a roe deer density of 13.9±0.9, 22.6±0.5 and 38.3±2.6 h $km^{-2}$, respectively (Chianucci *et al*., 2015). The observed mean roe deer densities were comparable to that indicated by the Italian National Institute for Environmental Protection and Research (ISPRA) as low (i.e., between 10 and 15 individuals per $km^2$), medium (i.e., between 20 and 25 individuals per $km^2$) and high (i.e, more than 25 individuals per $km^2$) roe deer densities in Apennines and Mediterranean environments. Within each study area, a number of oak coppice stands aged 0-2 years with minimum size of 2500 $m^2$ were individuated. Within these plots, we randomly sampled 744 stools. For each stool, we recorded the number of sprouts, top height of sprouts, and number of recently browsed sprouts to calculate the browsing index (Chianucci *et al*., 2015).

The incidence of roe deer browsing was high in all the three different scenarios. The percentage of browsed sprouts ranged from 65% to 79%. Browsing was significantly higher in the higher density scenario, compared with the others. By contrast, medium and higher density scenarios did not exhibit significant differences (Chianucci *et al*., 2015).

The relationship between annual seed production in deciduous forests and wild boar population densities, estimated by means of drive censuses and hunting bag records, were analysed in Alpe di Catenaia research area. More in details, we analysed the annual seed mass production in stands in conversion to high forest (aged over 50-60 years) of Turkey oak, beech (*Fagus sylvatica*) and chestnut, chosen due to their wide distribution and significant trophic value for wild boar. We analysed data on masting behaviour, mass production and plasticity of seed production collected yearly from 1991 to 2010 by means of litter traps, so as to quantify the effect of long term seed production on wild boar density and on hunting bag records, in relation with yearly variation of the three deciduous species, considered both separately and combined together, in order to develop strategies for an integrated management (Cutini *et al*., 2013).

The three species showed marked differences as regards mast seeding. Seed mass (dry weight) production was relatively low in beech with an average of 0.080 ±0.022 Mg $ha^{-1}$ $year^{-1}$. Conversely, average seed production was significantly higher in Turkey oak and chestnut with 0.757±0.184 and 0.758 ± 0.093 Mg $ha^{-1}$ $year^{-1}$ respectively. In the twenty years observation period a strong correlation between seed annual production and wild boar population dynamics was observed (Cutini *et al*., 2013).

More in details the total number of culled animals was positively affected by annual seed production of Turkey oak and chestnut (Fig. 6).

## 3. Concluding remarks

The long term studies established in central Italy since the late ‘90 of last century issued interesting results about the relationships between broadleaves forests and wild boar and roe deer population dynamics and, consequently, defined some guidelines for better managing both components.

With respect to deer browsing, roe deer had a different effect on the agamic regeneration and growth of Turkey oak and chestnut sprouts. Few years after coppicing chestnut did not show any browsing-related damage, while in Turkey oak biomass, volume and height of the sprouts in fenced plots significantly differed from those in non-fenced plots. The impact is relevant after eleven years after coppicing, i.e., after sprouts height get over the browsing height. In other words, results showed that the effects of early browsing

on Turkey oak sprouts after coppicing were not ephemeral but produced prolonged impacts through time, with a noticeably reduction in volume observed still eleven years after coppicing, with relevant ecological as well as economic consequences.

The observed browsing pressure was remarkable even at lowest deer density, in which about two third of the sprouts were browsed. The browsing impact showed a density-dependency because significantly higher impacts were observed at medium and high roe deer density, compared with the low density scenario. Based on the observed impacts and trends a reduction of -25% in volume at the end of the coppice rotation period is foreseeable. Accordingly, a prolongation in the minimum rotation period in Turkey oak coppice to achieve a profitable harvesting, under the observed medium roe deer density, can be expected. Overall, results indicated the browsing impacts are sustained in a range of roe deer density regarded as "normal" (ISPRA, 2013) and regularly occurring in Apennines. Accordingly, a serious revision of these guidelines and thresholds which takes into account, from the different point of view of all the stakeholders, the wide range of factors (site conditions, landscape mosaic, availability and quality of alternative food resources, ungulate sympatry) and namely forest stand stability and resilience, is needed.

Overall, both early and long-term results, indicated the impacts are just severe at European, regional and country level (UNECE-FAO, 2011), and it badly needs answers not only from the forest managers but also from the scientific community heading to new and more integrated management schemes between forestry and wildlife management.

We strongly believe this is a necessary change in the present approach in order to give proper solutions to a new environmental challenge, even though the larger and larger ungulate damages to agricultural and forest crops makes the time of refunding over, due to the not enough money available at European and country level for compensations.

On the other hand, elaborating more and more detailed and complex systems and models, both in forestry and zoology, without moving from a sector/discipline-branch based approach to a multi-disciplinary one, make them an academicism.

According to the performed analysis, chestnut and Turkey oak seed production was shown to positively affect the wild boar piglets 'density, i.e. the part of the population that is driving its dynamics (Bibier and Ruf, 2005), whereas beech had no influence on it. Several studies have reported a relationship between mast occurrence and average body weight in wild boar (Groot Bruinderink and Hazebroek, 1995) as well as between mast and reproductive cycle of females (Groot Bruinderink *et al*., 1994), since in mast years gestation may begin at any time during the hunting season (Servanty *et al*., 2007). It is important to observe that the concurrent presence of three species, with special reference to Turkey oak and chestnut, guarantees a steady provision of food for wild boar, as one of the two major mast-producing tree can compensate the lack of production of the other. In this respect, the presence of chestnut is especially relevant as its current European distribution matches closely that of the largest wild boar population and is presumably responsible for their abundance (Conedera *et al*., 2004; Apollonio *et al*., 2010). Therefore, wild boar can be considered a species with a strong dependency on mast to satisfy energetic requirements in winter (Groot Bruinderink and Hazebroek, 1995).

Consequently, an integrated approach in properly manage deciduous forests and wild boar populations is required. Management plans that maintain coppice or, on the contrary, increase deciduous high forest areas by means of their coppice conversion to high forest may limit or enhance food resources for wild boar populations respectively, and, as a consequence, their impact on human activities.

In this context, management strategies for wild boar can be improved by a continuous monitoring of seed production of the most significant forest species (i.e., oak, chestnut) and adopting an adaptive approach when planning proper hunting bags. The increase of hunting pressure on piglets after a full mast of chestnut and/or oak (Bieber and Ruf, 2005) may be an option to be experienced to control wild boar population growth and limits its impact on human activities.

In order to accomplish the purpose of an integrated forest - fauna management, besides the deep changes above mentioned, there is a need for rapid and objective indicators to monitor the impact of ungulates on gamic and agamic regeneration (mast frequency, browsing index…).

The definition of common schemes and indexes of monitoring the impact of ungulates on forest and agricultural crops can be useful tools.

We also advocate the need to collect information on ungulates impact over large areas because effects on forests cannot be generalized to the spatial and temporal scales that are relevant to management.

Integrating information on ungulates impact in e.g., regional and national forest inventory alongside with the definition of rigorous and systematic long-term monitoring programs to measure the interaction forest-ungulates can be a decisive step towards the definition of appropriate protection measures in landscape and large scale planning.

Finally, the adoption of similar management approach and of a set of indicator useful in the monitoring of forest – fauna relationships may be the base for the definition of common schemes at European or country level for compensating damages to agricultural crops, forestry and vehicles collisions, whereas the present situation show marked differences among the European countries.

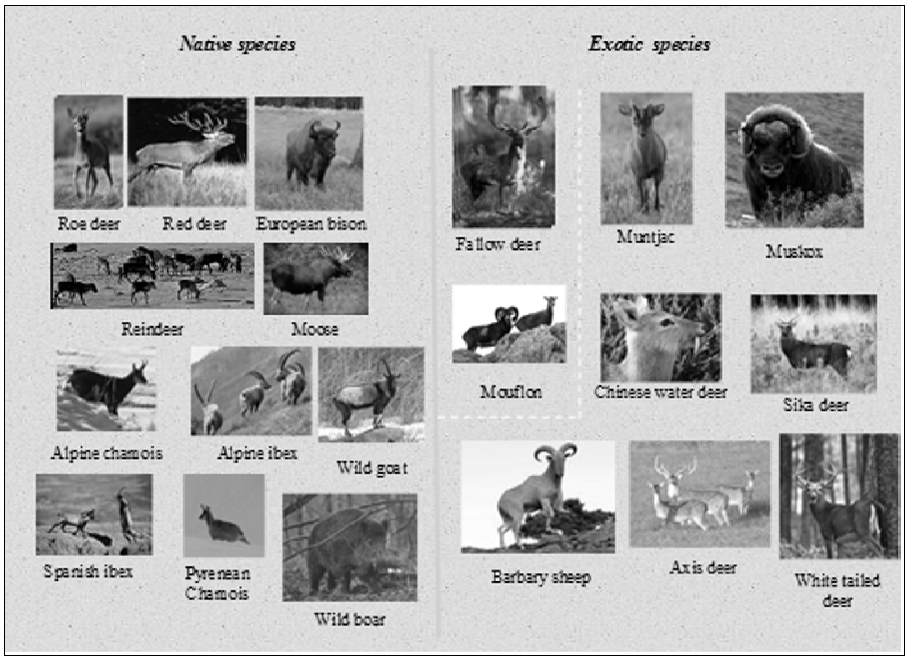


Figure 1. Native and non native ungulate species in Europe.

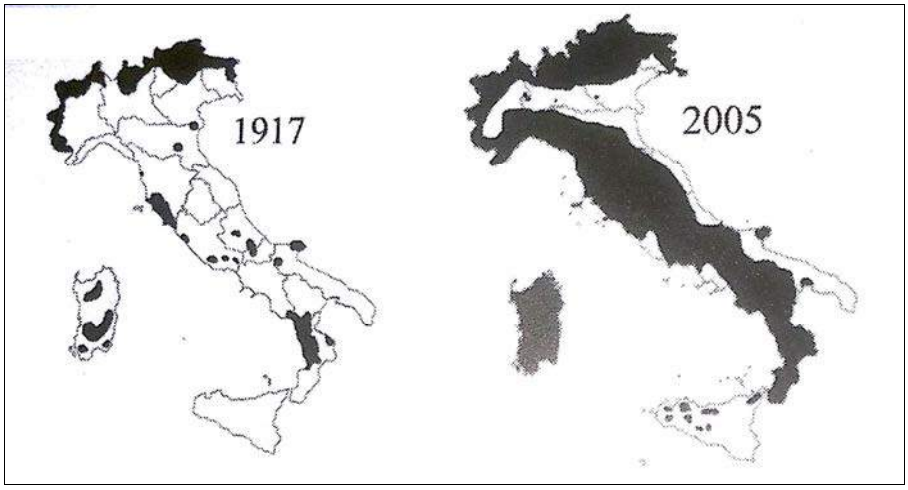


Figure 2. Ungulates distribution in Italy.

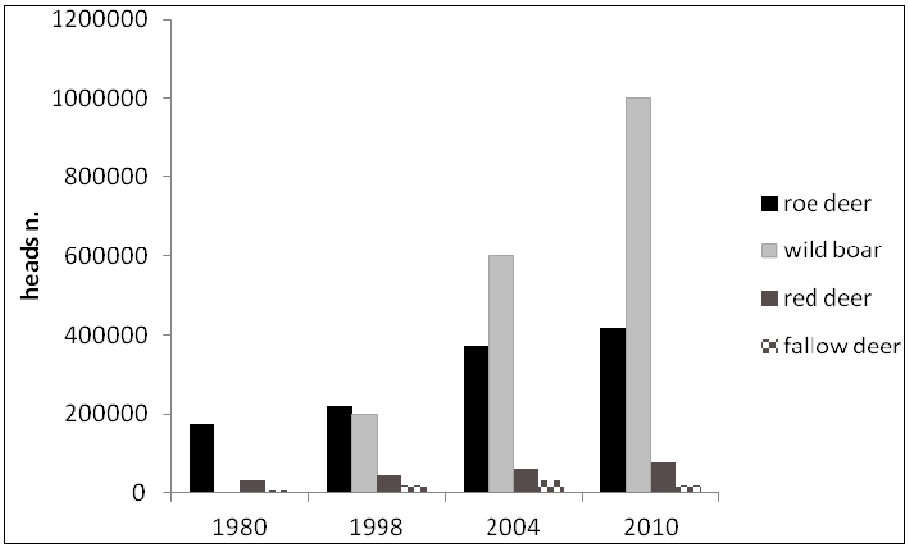


Figure 3. The increase of ungulates in Italy (from ISPRA 2011, mod.).

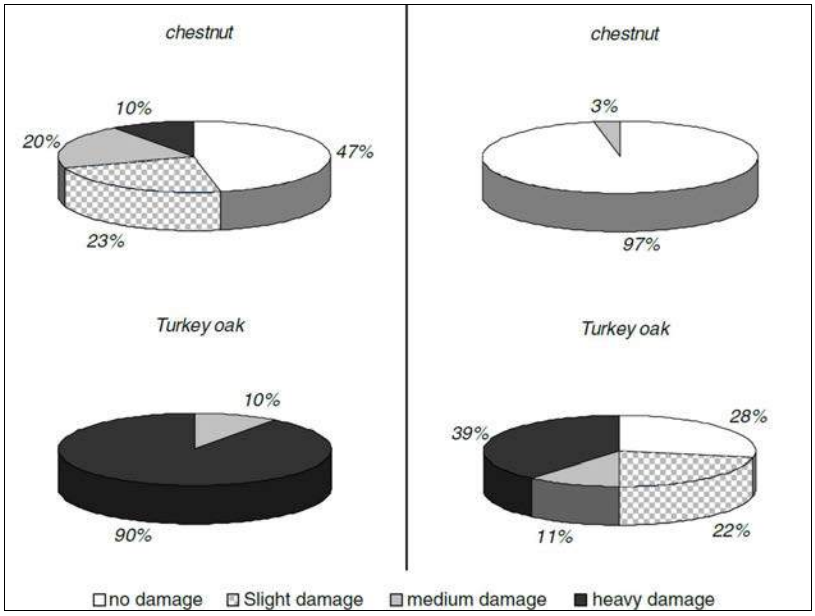


Figure 4. Impact of roe deer browsing on chestnut and Turkey oak stools one (A) and three (B) year after coppicing.

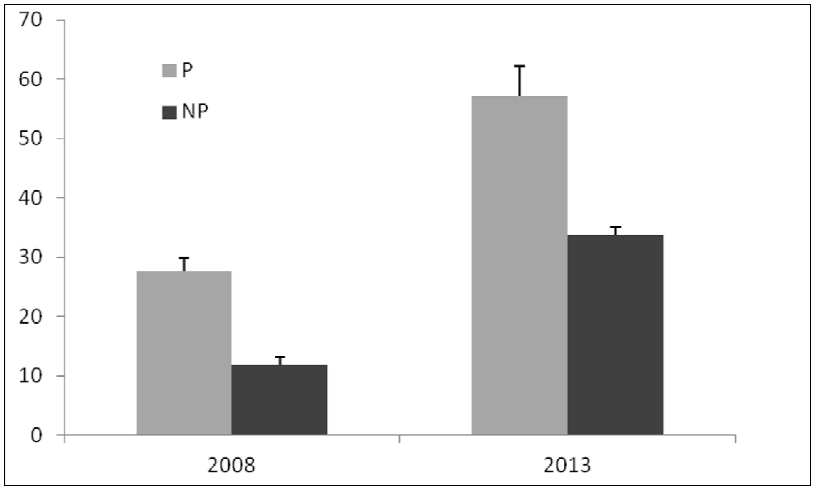


Figure 5. Impact of roe deer browsing on Turkey oak coppice stocking (P protected, NP non protected).

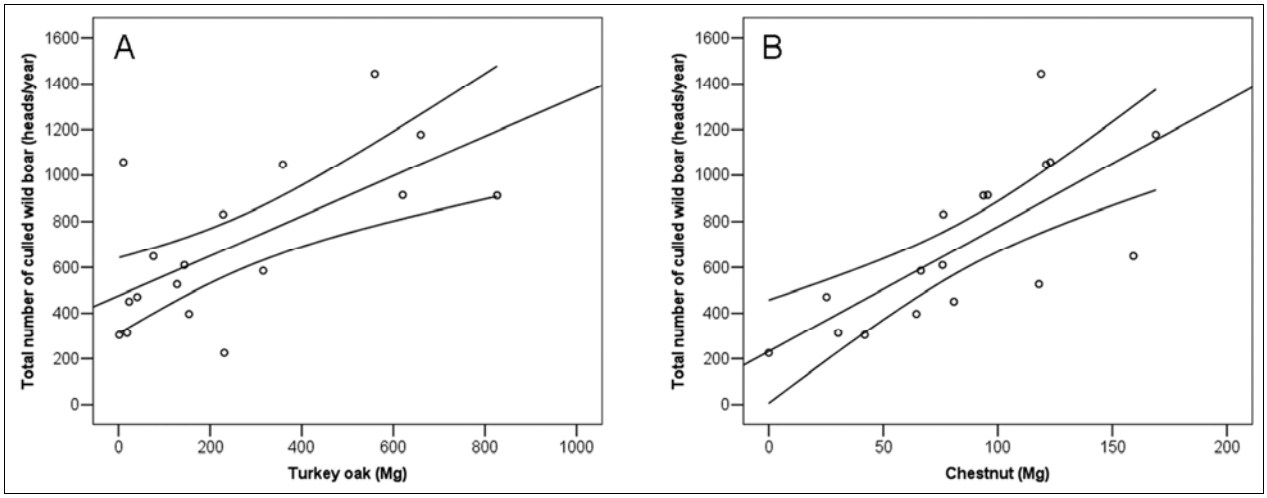


Figure 6. Turkey oak (A) and chestnut (B) annual seed production (dry weight) and wild boar population dynamics.

## RIASSUNTO

**Rapporti fra ungulati selvatici e foreste in Europa: riflessioni e indicazioni di ricerche decennali condotte in Italia centrale**

Il rapporto fra ungulati selvatici e formazioni forestali è stato oggetto di una crescente attenzione in Europa a partire dal secondo dopoguerra. Il tema è di interesse non solo scientifico, ma anche economico e sociale. Partendo da un'analisi a livello europeo si analizza poi con maggiore dettaglio la situazione italiana, interessata nell'ultimo ventennio da una forte espansione degli ungulati selvatici, in particolare dei cervidi e del cinghiale. Se ciò ha da un lato contribuito ad accrescere la complessità dei nostri ecosistemi forestali, favorendo anche il reinserimento e l'espansione di predatori quali il lupo, nonché la valorizzazione anche sotto il profilo economico del patrimonio faunistico, dall'altro sono emerse con forza nuove problematiche conseguenti all'aumento degli impatti sulla vegetazione e le attività agricole e forestali. Mentre fino agli anni '90 l'impatto degli ungulati sulle foreste era limitato alle fustaie - in particolare di conifere e nell'ambito di aree protette - nell'ultimo decennio il problema si è manifestato anche nelle aree a ceduo, ampiamente diffuse nel nostro paese e in gran parte di proprietà privata. Sulla base di ricerche multidisciplinari condotte per oltre dieci anni in ambiente appenninico sulle relazioni tra differenti forme di gestione di boschi di latifoglie da un lato e dinamiche delle popolazioni di capriolo e cinghiale e relativi impatti sugli ecosistemi forestali dall'altro, vengono svolte considerazioni sulla possibile evoluzione degli ecosistemi forestali e sulla necessità di un approccio integrato nella gestione delle risorse forestali e faunistiche, passaggio ineliminabile per dare risposte adeguate ad un problema che presenta criticità crescenti.

## BIBLIOGRAPHY

Apollonio M., 2004 – *Gli ungulati in Italia: status, gestione e ricerca scientifica*. Hystrix - Italian Journal of Mammalogy, 15: (1): 21-34.

Apollonio M., Andersen R., Putman R., 2010 – *European ungulates and their management in the 21th century*. Cambridge University Press, Cambridge.

Bätzing W., Perlik M., Dekleva M., 1996 – *Urbanization and depopulation in the Alps*. Mountain Research and Development, 4: 335-350. http://dx.doi.org/10.2307/3673985

Beguin J., Pothier D., Prévost M., 2009 – *Can the impact of deer browsing on tree regeneration be mitigated by shelterwood cutting and strip clear-cutting*? Forest Ecology and Management, 257: 38-45. http://dx.doi.org/10.1016/j.foreco.2008.08.013

Bieber C., Ruf T., 2005 – *Population dynamics in wild boar* Sus scrofa: *ecology, elasticity of growth rate and implications for the management of pulsedresource consumers*. Journal of Applied Ecology, 42: 1203-1213. http://dx.doi.org/10.1111/j.1365–2664.2005.01094.x

Canham C.D., McAninch J.B., Wood D.M., 1993 – *Effects of the frequency, timing, and intensity of simulated browsing on growth and mortality of tree seedlings*. Canadian Journal of Forest Research, 24: 817-825. http://dx.doi.org/10.1139/x94-107

Caughley G., 1970 – *Eruption of ungulate populations, with emphasis on Himalayan Thar in New Zealand*. Ecology, 51: 53-72. http://dx.doi.org/10.2307/1933599

Chianucci F., Mattioli L., Amorini E., Giannini T., Marcon A., Chirichella R., Apollonio M., Cutini A., 2015 – *Early and long-term impacts of browsing by roe deer in oak coppiced woods along a gradient of population density.* Annals of Silvicultural Research, 39: 32-33

Conedera M., Krebs P., Tinner W., Pradella M., Torriani D., 2004 – *The cultivation of* Castanea sativa *(Mill.) in Europe, from its origin to its diffusion on a continental scale.* Vegetation history and archaeobotany, 13: 161-179. http://dx.doi.org/10.1007/s00334–004–0038–7

Cutini A., Bartolucci S., Amorini E., 2007 – *Gestione dei boschi cedui di caducifoglie e relazioni con gli ungulati selvatici*. In: La valorizzazione agro-forestale e faunistico dei territori collinari e montani. Lucifero M., Genghini M. Ist. Naz. Fauna Selv., Min. Pol. Agr. Alim. E For., St.e.r.n.a. Ed. Grafiche 3B, Toscanella di Dozza (BO). pp. 287-304.

Cutini A., Bongi P., Chianucci F., Pagon N., Grignolio S., Amorini E., Apollonio M., 2011 – *Roe deer* (Capreolus capreolus L.) *browsing effects and use of chestnut and Turkey oak coppiced areas*. Annals of Forest Science, 68: 667-674. http://dx.doi.org/10.1007/s13595–011–0072–4

Cutini A., Chianucci F., Chirichella R., Donaggio E., Mattioli L., Apollonio M., 2013 – *Mast seeding in deciduous forests of the northern Apennines (Italy) and its influence on wild boar population dynamics.* Annals of Forest Sciences, 70: 493-502. http://dx.doi.org/10.1007/s13595–013–0282–z

Drexhage M., Colin F., 2003 – *Effects of browsing on shoots and roots of naturally regenerated sessile oak seedlings*. Annals of Forest Sciences, 60, 173-178. http://dx.doi.org/10.1051/forest:2003010

Eiberle K., 1980 – *Methodische möglichkeiten zum verständnis der waldbaulich tragbaren verbissbelastung*. Schweiz. Z. Forstwes., 131: 311-326.

Espleta J.M., Habrouk A., Retana J., 2006 – *Response to natural and simulated browsing of two Mediterranean oaks with contrasting leaf habit after a wildfire*. Annals of Forest Sciences, 63: 441-447. http://dx.doi.org/10.1051/forest:2006024

Forsyth D.M., Caley P., 2006 – *Testing the irruptive paradigm of large-herbivore dynamics*. Ecology, 87: 297-303. http://dx.doi.org/10.1890/05–0709

Geisser H. and Reyer H.U., 2004 – *Efficacy of hunting, feeding, and fencing to reduce crop damage by wild boars*. Journal of Wildlife Management, 68: 939-946. http://dx.doi.org/10.2193/0022-541X(2004)068[0939:EOHFAF]2.0.CO;2

Gill R.M.A., 1992 – *A review of damage by mammals in north temperate forests: 1 Deer*. Forestry, 65 (2): 145-169. http://dx.doi.org/10.1093/forestry/65.2.145

Groot Bruinderink G.W.T.A., Hazebroek E., 1995 – *Modelling carrying capacity for wild boar* Sus scrofa scrofa *in a forest/heathland ecosystem*. Wildlife Biology, 1: 81-87.

Groot Bruinderink G.W.T.A., Hazebroek E., van der Voot H., 1994 – *Diet and condition of wild boar,* Sus scrofa scrofa*, without supplementary feeding*. Journal of Zoology, 233: 631-648. http://dx.doi.org/10.1111/j.1469–998.1994.tb05370.x

Heuze P., Schnitzler A., Klein F., 2005 – *Is browsing the major factor of silver fir decline in the Vosges Mountains of France?* Forest Ecology and Management, 217: 219-228. http://dx.doi.org/10.1016/j.foreco.2005.06.003

Höcht F., Lehringer S., Werner K., 2005 – *"Wilderness": what it means when it becomes a reality - a case of study from the southwestern Alps*. Landscape and Urban Planning, 70: 85-95. http://dx.doi.org/10.1016/j.landurbplan.2003.10.006.

Horsley S.B., Stout S.L., De Calesta D.S., 2003 – *White-tailed deer impact on the vegetation dyamics of northern hardwood forest*. Ecological Applications, 13 (1): 98-118. http://dx.doi.org/10.1890/1051-0761(2003)013[0098:WTDIOT]2.0.CO;2

INFC, 2007 – *Le stime di superficie 2005 – Prima parte.* In: «Inventario Nazionale delle Foreste e dei Serbatoi di Carbonio», Tabacchi G., De Natale F., Di Cosmo L., Gagliano C., Gasparini P., Genchi L., Scrinzi G., Tosi V. MiPAF - Corpo Forestale dello Stato - Ispettorato Generale, CRA-ISAFA, Trento.

ISPRA, 2013 – *Linee guida per la gestione degli ungulati*. Manuali e Linee Guida, 91/2013: 221 pp.

Jarni K., Robič D., Bončina A., 2004 – *Analysis of the influence of ungulates on the regeneration of Dinaric fir–beech forests in the research site Trnovec in the Kočevje forest management region*. Zbornik gozdarstva in lesarstva, 74: 141-164.

Jedrzejewska B., Jedrzejewski W., Bunevich A.N., Milkowski L., Krasinski A., 1997 – *Factors shaping population densities and increased rates of ungulates in Bialowieza Primeval Forest (Poland and Belarus) in the 19th and 20th centuries*. Acta Theriologica, 42: 399-451. http://dx.doi.org/10.4098/AT.arch.97-39

Jorritsma I.T.M., van Hees A.F.M., Mohren G.M.J., 1999 – *Forest development in relation to ungulate grazing: a modelling approach*. Forest Ecology and Management, 120: 23-34. http://dx.doi.org/10.1016/S0378–1127(98)00540-4

Kay S., 1993 – *Factors affecting severity of deer browsing damage within coppiced woodlands in the south of England*. Biological Conservation, 63: 217-222. http://dx.doi.org/10.1016/0006-3207(93)90715-D

Langbein J., Puman R., Pokorny B., 2011 – *Traffic collisions involving deer and other ungulates in Europe and available measures for mitigation*. In: Ungulate management in Europe, problems and practices. Putman R., Apollonio M., Andersen R. Eds. Cambridge University Press, Cambridge, pp. 215-260.

Latham J., 1999 – *Interspecific interactions of ungulates in European forests: an overview*. Forest Ecology and Management, 120: 13-21. http://dx.doi.org/10.1016/S0378–1127(98)00539–8.

Morellet N., Guibert B., 1999 – *Spatial heterogeneity of winter forest resources used by deer*. Forest Ecology and Management, 123: 11-20. http://dx.doi.org/10.1016/S0378–1127(99)00007–9.

Morellet N., Gaillard J.M., Hewison A.J.M., Ballon P., Boscardin Y., Duncan P., Klein F., Maillard D., 2007 – *Indicators of ecological change: new tools for managing populations of large herbivores*. Journal of Applied Ecology, 44: 634-643. http://dx.doi.org/10.1111/j.1365–2664.2007.01307.x

Motta R., 1995 – *Rinnovazione naturale delle foreste di montagna ed impatto degli ungulati selvatici nelle Alpi Occidentali italiane*. Monti e Boschi, 5: 15-23.

Mysterud A., Østbye E., 1999 – *Cover as a habitat element for temperate ungulate: effects on habitat selection and demography*. Wildlife Society Bulletin, 27 (2): 385-394.

Partl E., Szinovatz V., Reimoser F., Schweiger-Adler J., 2002 – *Forest restoration and browsing impact by roe deer*. Forest Ecology and Management, 159: 87-100. http://dx.doi.org/10.1016/S0378–127(01)00712–5

Putman R.J., 1996 – *Ungulates in temperate forest ecosystem: perspectives and recommendations for future research*. Forest Ecology and Management, 88: 205-214. http://dx.doi.org/10.1016/S0378–1127 (96)03878–9

Putman R.J., 1994 – *Deer damage in coppice woodlands: an analysis of factors affecting the severity of damage and options for management*. Quarterly Journal of Forestry, 88: 45-54.

Reimoser F., 1986 – *Wecheslewirkungen zwischen Waldstruktur, Rehwildverteilung und Rehwild-bejagbarkeit in Abhängigkeit von der waldbaulichen Betriebsform*. VWGÖ-Dissertation, n. 28. University of Agricultural Sciences, Vienna.

Reimoser F., Ellenberg H., 1999 – *Forest management system as a component of ungulate-game pest management with special reference to roe deer and edge effects*. In: Advances in Vertebrate Pest Management. Cowan P.D. and Feare C.J. Eds. Filander Verlag, Fürth, pp. 219-238.

Reimoser F., Armstrong H., Suchant R., 1999 – *Measuring forest damage of ungulates: what should be considered*. Forest Ecology and Management, 120: 47-58. http://dx.doi.org/10.1016/S0378–1127(98)00542–8

Reimoser F. and Putman R., 2011 – *Impacts of wild ungulates on vegetation: costs and benefits*. In: Ungulate management in Europe, problems and practices. Putman R., Apollonio M., Andersen R. Eds. Cambridge University Press, Cambridge, pp. 144-192.

Saez-Royuela C., Telleria J.L., 1986 – *The increased population of the wild boar (*Sus scrofa *L.) in Europe*. Mammal Review, 16: 97-101. http://dx.doi.org/10.1111/j.1365-2907.1986.tb00027.x

Servanty S., Gaillard J.M., Allainéb D., Brandta S., Baubeta E., 2007 – *Litter size and fetal sex ratio adjustment in a highly polytocous species, the wild boar*. Behavioral Ecology, 18: 427-432. http://dx.doi.org/10.1093/beheco/arl099

Sipe T.W., Bazzaz F.A., 2001 – *Shoot damage effects on regeneration of maples (Acer) across an understory-gap microenviromental gradient*. Journal of Ecology, 89: 761-773. http://dx.doi.org/10.1046/j.0022–0477.2001.00587.x

Tremblay J.P., Thibault I., Dussault C., Huot J., Coté S.D., 2005 – *Long-term decline in white-tailed deer browse supply: can lichens and litterfall act as alternate food sources that preclude density-dependent feedbacks?* Canadian Journal of Zoology, 83: 1087-1096. http://dx.doi.org/10.1139/z05–090

UNECE-FAO, 2011 – *State of Europe's Forests 2011. Status and Trends in Sustainable Forest Management in Europe*. 337 pp.

Welch D., Staines B.W., Scott D., French D.D., Catt D.C., 1991 – *Leader browsing by red and roe deer on young Sitka spruce trees in western Scotland. Damage rates and the influence of habitat factors*. Forestry, 64: 61-82. http://dx.doi.org/10.1093/forestry/64.1.61