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SHORT COMMUNICATION

The BOS™ as a species-specific method to deliver baits to wild boar in a Mediterranean area

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Abstract The impact of wild boar *Sus scrofa* and feral pigs on ecosystems and human activities is of interest worldwide. Bait-delivered pharmaceuticals such as contraceptives or disease vaccines are increasingly advocated to assist the management of such impacts. We evaluated the Boar-Operated-System (BOS™) to deliver baits to wild boar in a Mediterranean area with a large community of potential nontarget species. In a pre-trial phase (BOS™ open), both wild boar and 12 nontarget species (wildlife and livestock) visited the BOS™ and eight species consumed the baits. In the trial phase, when the BOS™ were closed, only wild boar consumed baits. From pre-trial to trial, the rate of visits by nontarget species to the BOS™ decreased significantly, but that of wild boar did not change. We observed that crested porcupines *Hystrix cristata* prevented the wild boar from using BOS™. We confirmed the effectiveness of BOS™ to deliver baits selectively to wild boar in a Mediterranean area.

Keywords BOS™ · Delivery system · Disease · Feral pigs · Oral vaccine · *Sus scrofa*

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Introduction

Worldwide, wild boar *Sus scrofa* and feral pigs are responsible for disease transmission to livestock and humans and may have substantial ecological and economic impacts (e.g. Massei and Genov 2004; Barrios-Garcia and Ballari 2012, for reviews). To reduce these impacts and to prevent disease transmission, wild/feral pig populations are often managed through lethal control and/or disease vaccination (e.g. Massei et al. 2011; Beltrán-Beck et al. 2012).

In disease control, preventive or reactive vaccination of these species is often recommended as alternative to culling (e.g. Campbell et al. 2006; Beltrán-Beck et al. 2012). Where lethal control is illegal, unfeasible or unacceptable, fertility control through oral delivery of contraceptives is increasingly advocated to manage overabundant pig populations (Killian et al. 2006; Massei et al. 2012). If baits are used to deliver pharmaceuticals, species-specific devices are required to maximize bait uptake by the target species, particularly if baits contain contraceptives (e.g. Long et al. 2010; Massei et al. 2010; Ballesteros et al. 2011; Campbell et al. 2011, 2013; Lapidge et al. 2012).

Three kinds of devices have been designed to deliver baits specifically to wild boar. The Hog-Hopper system has been tested in Australia and in the USA (Lapidge et al. 2012; Campbell et al. 2013), while portable selective feeders for piglets have been tested in Spain (Ballesteros et al. 2011). Both these systems proved to be effective to deliver baits to wild boar or feral swine, but bait uptake by nontarget species was also recorded, at a comparatively low extent (Ballesteros et al. 2011; Lapidge et al. 2012; Campbell et al. 2013; Beltrán-Beck et al. 2014). The BOS™ (Boar-Operated-System) was successfully tested in the UK (Massei et al. 2010) and in the USA (Texas: Long et al. 2010; Campbell et al. 2011) to deliver baits to wild boar and feral pigs. As wild boar coexist with many different species, in different ecological contexts, new tests should be conducted to assess the species-specificity of the BOS™ in areas where different animal assemblies occur. In European Mediterranean areas, the wild boar is considered an important reservoir of diseases such as tuberculosis (e.g. Gortázar et al. 2007; Beltrán-Beck et al. 2012, 2014). Thus, devices that deliver baits containing vaccines specifically to wild boar are required in Mediterranean countries (e.g. Ballesteros et al. 2011). We tested the effectiveness of BOS™ in a protected Mediterranean area, where potential nontarget species include wild ungulates, livestock and other nontarget species typical of a Mediterranean coastal community.

Methods

Study area

The study was carried out in the Maremma Regional Park (MRP, *c.* 10,000 ha, central Italy, 42°39′ N, 11°05′ E). The climate is typically Mediterranean. The main habitat type is Mediterranean sclerophyllic scrubwood, with prevalence of holm oak *Quercus ilex*; other habitats are pinewood (mainly stone pine *Pinus pinea*), abandoned olive groves and pastures, wetland, coastal dune, set-aside grassland and cultivated fields (mainly cereals and sunflower) (see Mencagli and Stefanini 2008).

Potential nontarget species are reported in Table 1. Culling (all year long) and captures (May–October) of wild boar are carried out by park rangers to limit damage to crops and natural vegetation (1990–2013: 516 individuals removed/year, on average).

Data collection and analyses

In April 2013, 12 BOS™ were placed in the pinewood ($n=6$) and scrubwood ($n=6$), in areas with abundant signs of wild boar presence. To minimize the possibility of wild boar visiting more than one BOS™, information on home range size of local wild boar (Massei et al. 1997) was used and the BOS™ were placed at least 800 m from each other. The experiment had three phases: a pre-baiting (PB) phase, carried out to attract all species to the BOS ™, a pre-trial (PT) phase and a trial (T) phase. PB started in May 2013: *circa* 1 kg of wet maize was placed on the base of each BOS™ and left exposed, with the cone lifted in the open position. Maize was also spread on the ground, within 5 m from the BOS™, to attract animals. PT started either as soon as we observed at least one feeding visit by both wild boar and one nontarget species or within 14 days from the first visit of at least one species. During PT, the cone was lifted from the base and left in the "open" position for 7 days. PT was followed by a 14-day T phase, with the cone in the "closed" position. Both during PT and T *circa* 1 kg of wet maize was placed on the base of each BOS™, and no maize was spread on the ground. Infrared motion-activated cameras were placed at *circa* 5 m from each BOS™ (ScoutGuard SG550, $n=8$; Cuddeback TX, $n=4$; one picture/min; one camera/BOS™). Consistency between camera types was checked before starting the experiment.

BOS™ were checked daily to download pictures and replace bait. We defined a visit as an animal observed within

Table 1 Species interacting with BOS™: number of feeding and nonfeeding visits and number of BOS™ visited, in the pre-trial and trial phases. Other potential nontarget species were Eurasian badger *Meles meles*, magpie *Pica pica*

Species	*N* visits				*N* BOS™ visited			
	Pre-trial		Trial		Pre-trial		Trial	
	Feeding	Nonfeeding	Feeding	Nonfeeding	Feeding	Nonfeeding	Feeding	Nonfeeding
Wild boar	120	169	151	380	12	12	9	12
Fallow deer *Dama dama*	9	14	0	28	1	3	0	7
Roe deer *Capreolus capreolus*	0	2	0	0	0	1	0	0
Cattle (feral) *Bos taurus*	3	3	0	1	1	1	0	1
Horse (feral) *Equus caballus*	1	32	0	42	1	1	0	1
Crested porcupine *Hystrix cristata*	38	18	0	56	4	4	0	5
Hare *Lepus europaeus*	0	4	0	1	0	4	0	1
Red fox *Vulpes vulpes*	0	17	0	9	0	4	0	3
Martes foina/Martes martes	0	1	0	0	0	1	0	0
Jay *Garrulus glandarius*	18	33	0	24	6	6	0	4
Hooded crow *Corvus cornix*	13	29	0	7	2	3	0	1
Dove *Streptopelia decaocto/ Streptopelia turtur*	3	12	0	1	2	4	0	1
Common pheasant *Phasianus colchicus*	2	12	0	5	1	2	0	1

1.5 m from the BOS™ (Massei et al. 2010); consecutive pictures taken at >10 min intervals from each other were counted as different visits. We defined a feeding visit as an animal touching the base plate of the BOS™, having bait in the mouth or lifting the cone (Massei et al. 2010). We recorded daily the number of visits (feeding; nonfeeding) to BOS™ by wild boar or by nontarget species and, when possible, sex/age class (for wild boar, according to body morphology and size, coat colour, tusks and gender) of individuals visiting the BOS™. We estimated the bait eaten as 0: no bait eaten, 1: 1–25 % of bait eaten, 2: 26–50 %, 3: 51–75 %, 4: 75–99 % and 5: 100 %.

For both PT and T, we used *G*-tests (Sokal and Rohlf 1995) to compare the number of visits to BOS™ (feeding, nonfeeding; total) between wild boar and nontarget species. We used generalized linear mixed models with Poisson errors (GLMM, Crawley 2007) to compare, between PT and T (i) the number of visit to BOS™/day (feeding, nonfeeding; total) for both wild boar and nontarget species, and (ii) the amount of bait eaten/BOS™/day. BOS™ ID was included in models as a random effect. Analyses were conducted using the R 2.9.2 software (R Development Core Team 2009).

Results and discussion

We recorded 1,255 visits to BOS™ (PT: 6.5 visits/BOS™/day, $n=550$; T: 4.2 visits/BOS™/day, $n=705$). Wild boar visited all the 12 BOS™ while nontarget species ($n=12$) visited 11 BOS™. Wild boar, fallow deer and red fox visited BOS™ throughout the day; cattle, horse, hare, roe deer and birds during the day only; crested porcupines and *Martes* sp. only at night. In PT, wild boar fed on all the BOS™ and nontarget species ($n=8$) fed on 10 BOS™ (Table 1). During T, only wild boar fed on baits (Table 1).

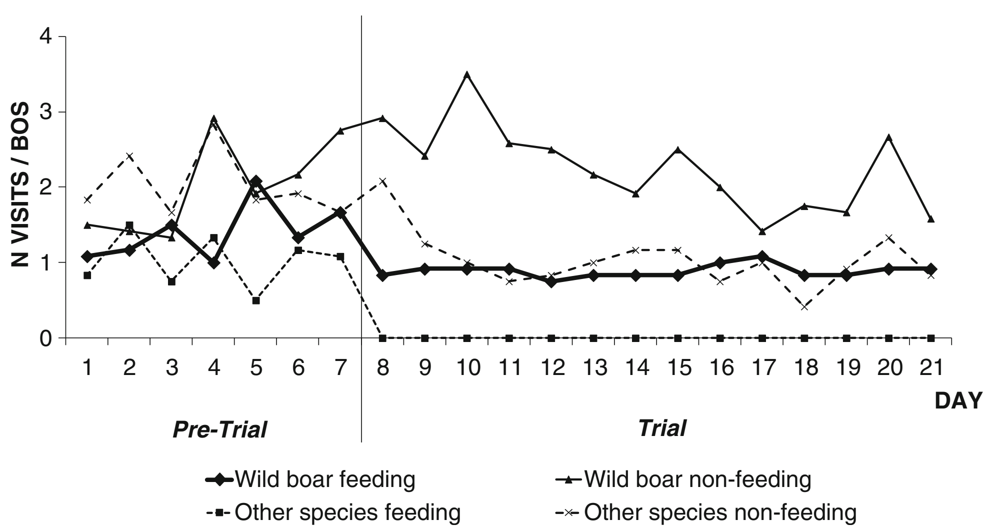
Wild boar visits ($n=820$) comprised 63.9 % of total visits to BOS™ (Table 1). During PT, wild boar and other species visited the BOS™ with similar frequencies (*G*-test $G_{adj}=0.712$; $df=1$; $P=0.399$, total visits; $G_{adj}=2.641$; $df=1$; $P=0.104$, feeding visits). During T, wild boar visited the BOS™ more often than nontarget species (75.3 %; $G_{adj}=97.932$; $df=1$; $P<0.001$; Table 1).

We confirm the effectiveness of BOS™ to deliver baits selectively to wild boar in a Mediterranean area with a different animal community compared to those where BOS™ had been previously tested (Massei et al. 2010; Long et al. 2010; Campbell et al. 2011). While earlier studies reported that livestock never used BOS™ (cattle: Long et al. 2010; Campbell et al. 2011), we recorded feeding visits of cattle and horse, during PT but not during T (Table 1). This suggested that cattle and horses were scarcely attracted by baits or may have been unable to lift the cone to feed from the BOS™.

During T, wild boar did not feed on three out of 12 BOS™. These BOS™ were visited by subadults or by a female with piglets and no attempt to lift the cone was recorded. One of these BOS™ was visited by crested porcupines also (1–5 individuals/night). In the latter case, wild boar ate baits only on the first two PT days; in the following days, porcupines ate baits before the arrival of wild boar. Porcupines tended to visit BOS™ in groups (median group size 2; range 1–5) and were observed trying to lift the cone (i.e. digging under the plate or climbing on the cone) on consecutive nights. Porcupine quills can injure large animals and harass wild boar (Mori et al. 2014). Although porcupine interference could prevent wild boar from using the BOS™, the species occurs only in parts of Italy, northern and Sub-Saharian Africa (Mori et al. 2013), thus the problem is negligible for other countries.

From PT to T, the rate of feeding visits by wild boar to BOS™ decreased, that of nonfeeding visits increased, while the rate of total visits did not vary significantly (Fig. 1;

Fig. 1 Number of visits per BOS™ per day by wild boar and other species, during the pre-trial (BOS™ in "open" position) and the trial (BOS™ in "closed" position) phase



GLMM: $B=-0.457$, SE$=0.123$, $P<0.001$, feeding; $B=-0.217$, SE$=0.104$, $P=0.036$, nonfeeding; $B=-0.040$, SE$=0.079$, $P=0.607$, total). The rate of visits by nontarget species to BOS™ decreased significantly from PT to T (Fig. 1; $B=-0.322$, SE$=0.067$, $P<0.001$, nonfeeding; $B=-1.026$, SE$=0.117$, $P<0.001$, total). The index of quantity of bait eaten/BOS™/day decreased from PT to T (PT: 4.4±1.4, mean±SD; T: 3.2±2.4; $B=-0.322$, SE$=0.067$, $P<0.001$). As in PT the rate of feeding visits by wild boar was comparable to that of nontarget species, whilst in T only wild boar ate baits, the quantity of bait eaten per animal probably increased, as observed by Massei et al. (2010).

Piglets were never observed lifting the cone, but ate baits when a female had lifted a cone. Although we could not identify individual animals, morphological characters, gender and group composition suggested monopolization of BOS™ by adult males and by family groups. Bait monopolization should be further investigated and might be addressed by moving the BOS™ to new locations or by placing the BOS™ in clusters. As the success of wildlife management campaigns based on drugs delivered by baits depends on the proportion of individuals feeding on baits, further studies with marked individuals and/or bait markers should also test spatial and temporal deployment of BOS™ to optimize bait delivery to wild boar or feral pigs.

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