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Tools and Technology Article

The Boar-Operated-System: a Novel Method to Deliver Baits to Wild Pigs

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ABSTRACT Bait-delivered pharmaceuticals, increasingly used to manage populations of wild boar (*Sus scrofa*) and feral pigs, may be ingested by nontarget species. Species-specificity could be achieved through a delivery system. We designed the BOS™ (Boar-Operated-System) as a device to deliver baits to wild pigs. The BOS™ consists of a metal pole onto which a round perforated base is attached. A metal cone with a wide rim slides up and down the pole and fully encloses the base onto which the baits are placed. We conducted a pilot, captive trial and found that captive wild boar fed from the BOS™ either directly, by lifting the cone, or indirectly, by feeding once another animal had lifted the cone. Thus, we tested whether free-living wild boar fed from the BOS™ and whether the BOS™ could prevent bait uptake by nontarget species. We observed that free-living wild boar fed regularly from the BOS™ and that the device successfully prevented bait uptake by nontarget species. The BOS™ should be trialed more extensively to confirm its effectiveness and species-specificity to distribute pharmaceuticals to wild suids. If successful, the BOS™ could be used to deliver vaccines in disease control programs as well as contraceptives to manage overabundant populations of wild suids.

KEY WORDS baits, delivery systems, feral pigs, nontarget species, *Sus scrofa*, wild boar.

Wild boar (*Sus scrofa*) and feral pigs (hereafter collectively referred to as wild pigs) are widespread in 5 continents, and their impact on human interests ranges from damage to crops, to spread of diseases, and to vehicle collisions (e.g., Cushman et al. 2004, Engeman et al. 2004, Fordham et al. 2007). This species may also cause significant reduction in plant and animal abundance and richness (Hone 2002, Massei and Genov 2004, Seward et al. 2004, Fordham et al. 2007).

Methods to manage overabundant populations of wild pigs range from lethal control, such as shooting and poisoning, to disease vaccination and fertility control (Kaden et al. 2000, Geisser and Reyer 2004, Massei et al. 2008, McCann and Garcelon 2008). Worldwide, vaccination programs based on bait-delivered vaccines are increasingly carried out to manage feral pig populations and prevent economic losses resulting from zoonotic diseases transmitted by this species (Fleming et al. 2000, Kaden et al. 2000, Brauer et al. 2006). Baits are also used to deliver contraceptives and toxicants to control numbers of wild pigs (Fleming et al. 2000, Kavanaugh and Linhart 2000, Campbell et al. 2006).

The success of these programs relies on the rate of bait uptake by target species, which in turn depends on a variety of factors such as bait palatability, availability of alternative food resources, baiting strategy, and bait uptake by nontarget species. Studies that evaluated the use of bait-delivered drugs to wild pigs concluded that baits can be very effective at delivering pharmaceuticals, although the percentage of the population ingesting baits may vary greatly between 31% and 89% (Twigg et al. 2005, Cowled et al. 2006, Campbell and Long 2007). In addition, bait uptake by nontarget species can be substantial (Saunders et al. 1990, Fleming et al. 2000, Campbell et al. 2006). Therefore, target specificity must be achieved through bait-delivery systems.

We designed a device, the Boar-Operated-System (BOS™), to deliver baits to wild pigs. Our objectives were to 1) evaluate whether free-living wild boar could learn to feed from the BOS™, and 2) assess whether the BOS™ could prevent bait uptake by nontarget species.

STUDY AREA

We conducted a pilot trial at the Food and Environment Research Agency Animal Unit in York, United Kingdom. We conducted field trials in the Forest of Dean (51°48′N and 2°28′W, Gloucestershire, United Kingdom) between November 2007 and March 2008. The area covered 15,000 ha and was characterized by mixed deciduous and coniferous woodlands. The wild boar have been present for ≥10 years as a result of escapes from local farms.

METHODS

We constructed BOS™ from a metal pole (1.5 m high, 5-cm diam) onto which we attached a round base (Fig. 1). We constructed a metal cone (30 cm high, 60 cm in diam) with a 7-cm-wide rim that slid up and down the pole and fully enclosed a round base plate (50 cm in diam) onto which we placed the baits. The end of the pole is pointed so that the BOS™ can be hammered into the ground. We expected animals to lift the rim of the cone off the base plate with their snouts. The cone can be locked at different heights above the base by metal pins, which fit into the holes along the pole. Similarly, the height of the base plate above the ground can also be adjusted. We placed the base 15–30 cm above ground level. We perforated the round base to allow animals to smell the bait inside the cone. The whole BOS™

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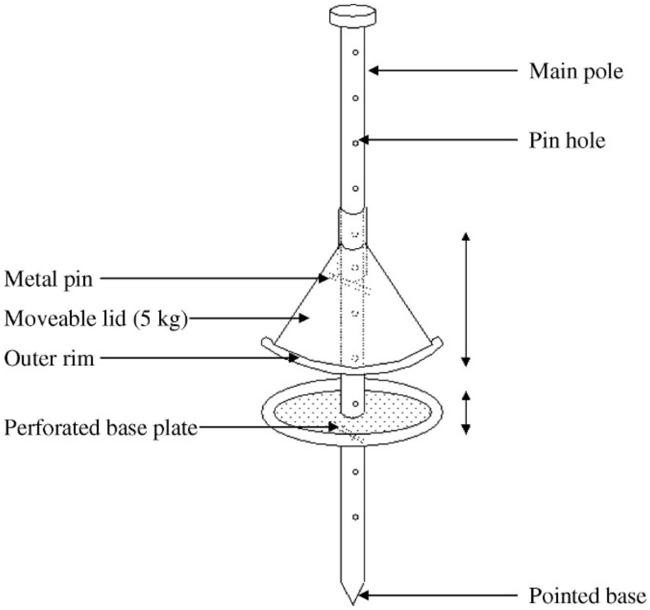

Figure 1. The Boar-Operated-System (BOS™; not to scale), designed as a wild pig–specific feeder to deliver baits containing pharmaceuticals. Baits are placed on the base plate and covered by the cone. Wild pigs must lift the cone to access the baits. We tested the BOS™ between November 2007 and March 2008 in the Forest of Dean (Gloucestershire, United Kingdom).

weighs approximately 17 kg, including the cone, which weighs 5 kg.

The pilot trial indicated that captive boar fed from the BOS™ either directly, by lifting the cone, or indirectly, by feeding once another animal had lifted the cone (G. Massei, Food and Environment Research Agency, unpublished data).

To test the BOS™ on free-living wild boar, we placed the BOS™ in 12 locations where activity signs such as tracks and rooting indicated presence of wild boar. The distance between 2 BOS™ was between 130 m and 5,000 m. Radiotracking data indicated that wild boar had relatively small home ranges (weekly home range of ad F was 35 ha) and that different social groups did not use the same site simultaneously (G. Massei, unpublished data).

We used cylindrical peanut-based baits (8 cm long, 5 cm wide, 125 g; Brandsby Agricultural Trading Association, York, United Kingdom). Each trial consisted of a pretrial period, to habituate and attract animals to the baits, and a trial period during which animals had to lift the cone of the BOS™ to consume the baits. During the pretrial, we placed 5 baits and 300–400 g of loose maize (Brandsby Agricultural Trading Association) inside a BOS™ and replaced this the following day for a minimum of 5 days. If wild boar did not feed from the BOS™, we extended the pretrial up to 8 days. During the trial, we placed only peanut baits ($n = 5$) inside each BOS™ and replaced these every day in the following 5–9 days for a minimum of 5 days.

We used 2 infrared motion-activated cameras (DS-04IR, DS-06IR; Penn's Woods Digital-Scout, Penn's Woods, PA) per BOS™ location to record species visiting each BOS™. We programmed the cameras to take photos every 10 seconds for 24 hours. For each species that visited a BOS™ in a day, we recorded the time of the visit, the number of visits, and the number of times we observed animals feeding from a BOS™. We defined a visit as an animal observed within 1.5 m of the BOS™. If the same animal appeared in consecutive photos, we classed this as one visit. If the animal was part of a group, the visit began when the first animal walked within the 1.5-m range and ended when the last animal left. We defined a feeding visit as an animal touching the base plate of the BOS™, having bait in the mouth, or lifting the cone of the BOS™. We also recorded the number of baits consumed/BOS™/day.

Table 1. Total number of visits (animals observed within 1.5 m from the Boar-Operated-System [BOS™]) and feeding visits (animals feeding or lifting the cone of the BOS™) to the BOS™ ($n = 12$) by all species in the Forest of Dean (Gloucestershire, United Kingdom) between November 2007 and March 2008. During pretrial, we left the BOS™ open so that animals could feed from the food on the base plate; during trial animals had to lift the cone to access the baits.

	All visits		Feeding visits	
Species	Pretrial	Trial	Pretrial	Trial
Badger (*Meles meles*)	52	60	25	0
Bird spp.	103	147	40	0
Wild boar (*Sus scrofa*)	237	208	181	141
Fallow deer (*Dama dama*)	10	5	0	0
Red fox (*Vulpes vulpes*)	2	3	0	0
Wood mouse (*Apodemus sylvaticus*)	55	131	30	0
Sheep (*Ovis aries*)	18	2	12	0
Grey squirrel (*Sciurus carolinensis*)	95	137	81	0
Total	572	693	369	141

Because data were nonnormally distributed, we used nonparametric tests. We averaged the data from the last 3 days of the pretrial period to obtain a baseline of the number of visits and feeding visits/species/day. We used Friedman tests to compare the number of visits and feeding visits by different species during the pretrial and trial periods. We used Mann–Whitney *U* tests to analyze differences in number of baits consumed by wild boar between the pretrial and trial periods. Our study was licensed under a United Kingdom Home Office, in accordance with the Animals (Scientific Procedures) Act 1986, and it was approved by the Food and Environment Research Agency's internal ethical review process.

RESULTS

Throughout the pretrial and trial periods we recorded 1,265 visits including 510 feeding visits to the BOS™ (Table 1). The number of visits to the BOS™ by all species did not differ between pretrial and trial ($\chi^2 = 9.8$; df = 9; $P = 0.37$). The number of feeding visits differed between pretrial and trial ($\chi^2 = 40.2$; df = 9; $P < 0.001$), because only wild boar fed from the BOS™ during the trial period. In the last 5 days of the pretrial, the number of feeding visits differed between species ($\chi^2 = 36.7$; df = 4; $P = 0.00$). When wild boar fed in groups, 2–4 females fed from the same BOS™. Also, we observed one adult male fed from a BOS™ every day, just after we placed the baits, and then fell asleep under the BOS™. One or more single wild boar or groups visited the BOS™ each day. Although we could not identify individuals from the photos, some animals had ear tags or Global Positioning System collars, and we recognized a few individuals from coat color, sex, size, and age.

The mean number of baits removed from the BOS™ during pretrial and trial periods did not differ (Mann–Whitney $U = 14.0$; $Z = -1.15$; $P = 0.30$). Because the wild boar was the only species feeding on baits in the trial period, this suggested that the number of baits consumed by wild boar increased.

DISCUSSION

We demonstrated that the BOS™ is an effective, species-specific system to deliver baits to wild boar. Captive wild boar learned quickly to feed from the BOS™ and agonistic interactions did not prevent animals from feeding from the BOS™. Free-living wild boar also learned quickly to operate the BOS™. Bait consumption did not decrease when we lowered the cone of the BOS™, indicating that lifting the cones did not prevent the wild boar from obtaining baits. The mean number of baits removed from the BOS™ did not differ between pretrial and trial periods, suggesting that wild boar (which was the only species feeding from the BOS™ during the trial period) consumed more baits. We recognized only a few individuals, so we could not determine whether the unchanged rate of removal was due to more animals eating baits or more baits eaten/animal.

The presence of groups of wild boar feeding simultaneously from a BOS™ indicated that, at least within a group, agonistic interactions would not prevent several animals from consuming baits from the same BOS™. Conversely, our preliminary observations suggested potential BOS™ monopolization by adult males.

We demonstrated that the BOS™ is very effective in excluding nontarget species, although the number of visits to BOS™ by nontarget species did not decrease during the trial period. This might be due to bait spillage, high turnover of nontarget species, or relatively short duration of the trial period. Modifying the formulation to make the bait less crumbly could prevent bait spillage. Alternatively, the risk of nontarget species could be minimized by inserting the drug in a capsule placed in the core of the bait. Baits containing the active ingredient in core capsules or sachets are already used in classical swine fever vaccination campaigns for wild boar (Kaden et al. 2000) and in oral rabies vaccination of carnivores (Jojola et al. 2007). In addition, more species-specific baits, such as those developed for feral pigs in Australia could be used (Cowled et al. 2006). The turnover of both target and nontarget species could be assessed by marking individuals with ear-tags, collars, or fur dyes. By increasing the duration of the trial period and by marking animals, it should be possible to test whether the number of visits to BOS™ by nontarget species decreases.

Several species-specific bait-delivery systems have been designed for wildlife applications. Some of these systems, such as the bait hopper developed to deliver baits to grey squirrels (*Sciurus carolinensis*), rely on physical exclusion so that only animals of a particular strength can access the baits (Mayle et al. 2007). Automated bait-delivery systems operate through a mechanism triggered by image-recognition or body-size detection (body wt or body length or a combination of wt and length; Isaac et al. 2004, King et al. 2007). Other systems exploit the feeding behavior of the target species. For instance the Coyote Lure Operative Device is based on a bait-delivered toxicant contained in a stick-mounted plastic vial that coyotes chew to ingest the bait (Berentsen et al. 2006). To our knowledge, no other wild pig–specific feeder has been experimentally tested, although several authors have tried to improve target specificity by improving the palatability of baits aimed at wild pigs (e.g., Cowled et al. 2006, Campbell and Long 2007). In addition, Ballesteros et al. (2009) designed selective piglet feeders to improve age-related bait specificity in wild boar. These feeders prevent adult wild boar from accessing the baits but allow bait uptake by piglets and smaller nontarget species.

An ideal species-specific bait-delivery system should 1) make baits available to the target species only; 2) allow group-living animals to feed simultaneously; 3) be easy to assemble, move, and deploy; 4) be relatively inexpensive; and 5) be capable of operating under extreme weather conditions. The latter 2 requirements suggest that sophisticated systems such as image-recognition devices would be more appropriate for use in controlled environments rather than in field conditions, because they might be prohibitively expensive for large-scale applications. The BOS™ satisfied all the above requirements except cost, which is currently around US$500 per BOS™. However, we anticipate this cost would decrease by 30–50% if production was scaled up.

Worldwide, the use of bait-delivered pharmaceuticals is increasing to manage problems caused by wild pigs to human interests (Kaden et al. 2000, Twigg et al. 2005, Campbell et al. 2006). These conflicts can also be managed through culling or eradication of wild pigs, particularly in areas where the species is nonnative. However, eradication can be very expensive (reviewed in McCann and Garcelon 2008) and culling in some instances can lead to social perturbation and potential increase of diseases due to increased movements of animals (e.g., Maillard and Fournier 1995, Woodroffe et al. 2005, Keuling et al. 2008).

The BOS™ could play a significant role in baiting campaigns aimed at delivering contraceptives, vaccines, or other pharmaceuticals to wild pigs. Because the success of these campaigns depends on the proportion of the target population that ingests baits, bait markers such as iophenoxic acid could be employed to monitor bait uptake by wild pigs (Cowled et al. 2006, Massei et al. 2009).

MANAGEMENT IMPLICATIONS

The BOS™ could be employed to develop effective baiting strategies for wild pigs, particularly when non–species-specific pharmaceuticals are delivered in baits. Future studies should establish whether monopolization could be prevented by either placing BOS™ in clusters or by frequently moving the BOS™ to new sites to maximize the number of animals consuming baits. In addition the BOS™ could also be used as baiting stations to attract wild pigs and to estimate, through remote photography, minimum local densities, sex and age-class ratio, timing of births, and activity patterns. If animals could be individually identified, the BOS™ could also be employed to monitor movements between baiting stations and across different habitats, to quantify the proportion of animals that feed on baits in consecutive weeks, and the frequency of their visits to the site. To maximize bait uptake by a large proportion of a population, future studies should determine the optimal density of BOS™ to be used in an area, the distribution of BOS™ (uniform or clustered) at each site, the frequency with which BOS™ need to be relocated, and the timing of their deployment.

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