

Editorial Manager(tm) for Rangelands  
Manuscript Draft

Manuscript Number: RANGELANDS-D-09-00001R1

Title: Evaluation of Feral Swine-Specific Feeder Systems

Short Title: Feral Swine Feeders

Article Type: Research Article

Keywords: bait, hog, pharmaceutical, pig, Sus scrofa, Texas, wild boar

Corresponding Author: Dr. Tyler A. Campbell, Ph.D.

Corresponding Author's Institution: USDA-APHIS-Wildlife Services

First Author: David B Long, M.S.

Order of Authors: David B Long, M.S.; Tyler A. Campbell, Ph.D.; Giovanna Massei

Abstract: Feral swine have been introduced across many rangeland ecosystems of the United States. Our objective was to evaluate candidate non-target exclusion feeder systems for feral swine as a means to deliver baits containing pharmaceuticals. The percent decrease in bait removal following the activation of the boar operated systems (BOS) was 48% for feral swine and 100% for all other species. The percent decrease in bait removal following the activation of the non-target exclusion device was 19, 28, 100, and 100% for raccoons, feral swine, white-tailed deer, and collared peccaries, respectively.

## Evaluation of Feral Swine-Specific Feeder Systems

By David B. Long, Tyler A. Campbell, and Giovanna Massei

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*Authors are Wildlife Biologist (Long) and Research Wildlife Biologist (Campbell), USDA, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, Texas A&M University-Kingsville, 700 University Boulevard, MSC 218, Kingsville, TX 77363, USA, tyler.a.campbel@aphis.usda.gov; and Senior Ecologist, Food Environment and Research Agency, Sand Hutton, York YO41 1LZ, UK (Massei).*

Feral swine (*Sus scrofa*) have been introduced across many portions of the globe, including rangeland ecosystems of the United States. Feral swine populations are expanding because of their adaptability, high reproductive potential, and because they are (accidentally and intentionally) released by humans. Today, feral swine are the most abundant exotic ungulate in the United States.<sup>1</sup>

Rangeland ecosystems are impacted by feral swine primarily through soil disturbance caused by rooting activities. Within these systems, natural disturbances (e.g., burrowing, grazing by native animals, and periodic fire) generally increase or maintain species diversity.<sup>2</sup> However, rooting by feral swine often occurs at intensities and frequencies that do not mimic natural disturbances and may have negative impacts, such as disseminating exotic plant species and reducing native plant species diversity.<sup>3</sup>

Feral swine damage to livestock enterprises within rangeland ecosystems is direct (e.g., predation) and indirect (e.g., destruction of fencing and disease transmission) and both cause substantial economic losses.<sup>4</sup> In Australia, predation on lambs is often widespread and is

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4 influenced by feral swine density.<sup>5,6</sup> Feral swine predation on livestock is also a problem in the  
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6 United States in localized regions.<sup>7</sup> Furthermore, Seward et al. (2004) recommend close  
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8 monitoring of livestock and confining pre-parturition animals prior to calving and lambing to  
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10 minimize risks of predation by feral swine.<sup>4</sup>  
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14 Tools available to control feral swine damage have not been universally successful.<sup>8</sup>  
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16 New methods, such as fertility control agents, vaccines, or toxicants, are needed and will require  
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18 an oral delivery system for effective administration to feral swine populations.<sup>1</sup> Prior  
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20 investigations of baits intended for pharmaceutical delivery to feral swine in the United States  
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22 has found that the concept is feasible,<sup>9</sup> but that there are challenges in developing a species-  
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24 specific baits for feral swine.<sup>10,11</sup> These studies have led to the creation of relatively inexpensive  
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26 prototypes of non-target exclusion feeder systems (NEFS) for feral swine. None of these feeder  
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28 systems have been evaluated in the United States.  
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33 Our overall objective was to evaluate candidate NEFS for feral swine as a means to  
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35 deliver baits containing pharmaceuticals. Our specific objective was to compare feral swine and  
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37 non-target animal consumption events at three different feeder systems in a rangeland ecosystem  
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39 of southern Texas. Given the successes of the Boar-Operated-System (BOS) feeder in the  
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41 United Kingdom,<sup>12</sup> we hypothesized that this unit would be specific to feral swine in southern  
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## 50 **Methods**

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53 Our study occurred on the Rob and Bessie Welder Wildlife Foundation (WWF) (28°06'N,  
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55 97°22'W) in San Patricio County, Texas, USA. The WWF is approximately 3,100 ha and  
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57 receives an average of 79 cm of rainfall annually. The WWF is bordered to the north by the  
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4 Aransas River, the west by United States Highway 77, and the south and east by private  
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6 rangeland. Overstory vegetation consists of huisache (*Acacia farnesiana*), honey mesquite  
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8 (*Prosopis glandulosa*), live oak (*Quercus virginiana*), cedar elm (*Ulmus crassifolia*), net-leaved  
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10 hackberry (*Celtis reticulata*), anaqua (*Ehretia anacua*) and muscadine (*Vitis rotundifolia*). Non-  
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12 target species of interest on the WWF are raccoons (*Procyon lotor*), white-tailed deer  
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14 (*Odocoileus virginianus*), and collared peccaries (*Pecari tajacu*).  
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19 We used three NEFS prototypes during this study. The first prototype consisted of a  
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21 model developed by the Food Environment and Research Agency in the United Kingdom,  
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23 known as the BOS (Fig. 1).<sup>12</sup> The second prototype, or non-target exclusion device (NED),  
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25 consisted of a wooden feeder system with spring-loaded push-up lid (Fig. 2). The third  
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27 prototype, or bucket, consisted of a plastic feeder system with a spring-loaded push-up lid (Fig.  
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29 3). We baited feeder systems with 200 g whole kernel corn and six polymer fishmeal baits (Bait-  
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31 Tek Inc, Orange, TX). We used fishmeal baits that were 2.87 cm and were open-ended and  
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33 hollow for insertion of a pharmaceutical agent. We used fishmeal bait to increase attractiveness  
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35 to omnivorous non-target animals. We presented fishmeal baits to captive feral swine to ensure  
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37 their consumption prior to their use in our trial.<sup>13</sup>  
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43 The BOS feeder was fabricated from metal and rested on a lubricated mast that was  
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45 hammered into the ground. The base plate where we placed bait was positioned 30 cm from the  
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47 ground and was fixed to the mast. The conical lid of the BOS feeder was larger than the base  
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49 plate and sat firmly on the base plate when closed (Fig. 1). We constructed the NED feeder from  
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51 treated pine 2½" x 4" finished lumber. We built the NED feeder to an initial lift height of 13 cm  
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53 (Fig. 2). We constructed the bucket feeder system with a treated pine 2½" x 4" finished lumber top  
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55 attached to a 22.7 L bucket filled with 27.2 kg of 5000 psi concrete. We positioned the lid such  
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4 that half could be lifted for bait access. On the bucket feeder, we set the wooden extension that  
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6 allows for feeder system usage to 35 cm above the ground (Fig. 3). All three types of feeder  
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8 systems required a lifting motion for bait access. The NED and bucket feeders were constructed  
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10 to keep the bait at the front of the system. We measured the weight needed to lift the lid for bait  
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12 access with a spring scale (Model 80020, PESOLA AG, Baar, Switzerland). The lift weight was  
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14 5–7 kg for the BOS, 3–4 kg for the NED, and 0.5–1 kg for the bucket feeders. We anchored the  
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16 NED and bucket feeders to vegetation or fence posts to keep feral swine from turning systems  
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18 over, whereas the BOS feeder did not need additional anchoring after we hammered them into  
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20 the ground (~60 cm).  
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26 We collected proof-of-concept digital image data on the NED and bucket feeders to  
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28 determine performance in a captive setting prior to our field trial. Based on these data, and  
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30 information from limited field deployments of the bucket feeder, we did not include this system  
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32 in our trial due to heavy non-target use when systems were activated (i.e., lids were closed).  
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36 We used 10 BOS feeders and 10 NED feeders during our trial. We selected 10 sites  $\geq 1$   
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38 km apart in areas of high feral swine activity. At each of the 10 sites we placed one BOS feeder  
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40 and one NED feeder 30 m apart. We monitored each feeder system for 4 wks (during  
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42 November–December 2008) using camera traps (Silent Image Professional and Rapidfire  
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44 Editions, Reconyx, Holmen, WI, USA). We operated camera systems ( $n = 20$ ) at their highest  
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46 sensitivity setting and programmed cameras to maintain a 0.5 s delay. We set up camera systems  
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48 3–5 m from feeder systems and used vegetation or artificial structures (e.g., fence posts) as  
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50 supports. During the first 14 d of the trial we tied all feeder system lids slightly open (i.e., 10  
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52 cm) to allow most animals access to bait. During the second 14 d of the trial we untied and  
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54 activated feeder system lids (i.e., lids were closed).  
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4 We revisited feeder systems daily from 0800–1200 hours to check baits and cameras,  
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6 recording the presence or absence of bait and bait condition. Additionally, at this time we  
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8 downloaded digital images that were stored. If bait was removed from the feeder system, then  
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10 we replaced the bait, ensuring that six fishmeal baits and 200 g of corn were available at the  
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12 beginning of each 24-hour period. If fishmeal baits were not removed after seven nights, then  
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14 we replaced baits.  
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19 We quantified feeder system usage as visitation and bait removal (i.e., consumption  
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21 events) by species through digital image analyses. We defined visitation as the total number of  
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23 individuals within 1 m of baits prior to and including bait removal. When possible, we used  
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25 unique physical characteristics (e.g., body size, pelage color, antler pattern) to identify  
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27 individuals. To reduce inflated visitation estimates, we did not count individuals that made  
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29 repeated visits within a 30 minute period. We considered such events to be one visit. We  
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31 recorded digital image data into one of three bait removal categories: definitely removed by  
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33 species (images in which the bait is in the mouth of an animal or a series of images 5 minutes or  
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35 less apart in which only the species of record was observed and the bait was removed); possibly  
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37 removed by species; and removed by unknown species. If all bait was removed from a feeder  
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39 system within a 24-h period, we did not continue to count usage within that period. We report  
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41 consumption events and performed statistical analyses on the percent change in consumption  
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43 pre- and post-feeder system activation by feeder type and species. For these models, we used  
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45 paired *t*-tests (PROC UNIVARIATE, SAS Institute, Inc).  
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## Results

We recorded more than 400,000 digital images during November–December 2008. We found removal rates for BOS and NED feeder systems were 96 and 95% during the pre-activation period and 45 and 90% while feeder systems were activated, respectively. Both the corn and fishmeal baits were consumed by feral swine and raccoons, the primary non-target species observed during our trial. Overall (both feeder systems combined), we found bait removal rates of 54% by raccoons, 33% by feral swine, 10% by white-tailed deer, and 4% by collared peccaries. For BOS feeders during pre-activation, the mean bait removal rates were 36% by raccoons, 34% by feral swine, 21% by white-tailed deer, and 10% by collared peccaries. Once BOS feeders were activated, 100% of the baits were removed by feral swine. For NED feeders during pre-activation, the mean bait removal rates were 64% by raccoons, 22% by feral swine, 2% by white-tailed deer, and 1% by collared peccaries. Once NED feeders were activated, removal rates were 70% by raccoons, 20% by feral swine, 0% by white-tailed deer, and 10% by collared peccaries. The bucket feeder system was used by all species immediately upon activation and was omitted from further experimentation.

Following activation of BOS feeders, bait removal decreased 48% for feral swine and 100% for all other species (Fig. 4). Following activation of the NED feeders, bait removal decreased 19, 28, 100, and 100% for raccoons, feral swine, white-tailed deer, and collared peccaries, respectively. Comparing feeder system performance by species we found no differences in feral swine usage between types following activation ( $t_7 = -1.231$ ,  $P = 0.258$ ). Raccoons used the NED feeder more than the BOS feeder following activation ( $t_9 = -4.75$ ,  $P = 0.001$ ). Other wildlife that visited the BOS and NED feeders in low numbers were southern plains woodrat (*Neotoma micropus*), eastern cotton-tail (*Sylvilagus floridanus*), nine-banded

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4 armadillo (*Dasypus novemcinctus*), coyote (*Canis latrans*), striped skunk (*Mephitis mephitis*),  
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6 gray fox (*Urocyon cinereoargenteus*), bobcat (*Lynx rufus*), and various avian species. We found  
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8 no interest in either feeder system by cattle, which were present throughout the trial.  
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## 11 12 13 14 **Discussion**

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16 Researchers within rangeland ecosystems of Pakistan have used simple feeder systems similar to  
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18 our NED feeders to deliver the toxicant coumatetralyl to feral swine with success.<sup>14</sup>  
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21 Additionally, an inexpensive feral piglet-specific feeder system has been evaluated in rangeland  
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23 ecosystems of south-central Spain to increase bait uptake.<sup>15</sup> Our simple and inexpensive bucket  
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25 and NED feeders did not perform as well as these systems. We believe that this discrepancy is  
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27 due to the presence of raccoons, a persistent and resourceful omnivorous non-target species that  
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29 occurs throughout the United States. Similarly, raccoons have proven to be a formidable non-  
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31 target species in other studies testing feral swine-specific delivery systems in rangelands of  
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33 southern Texas.<sup>11</sup> However, the performance of the BOS feeder in our trial was excellent and  
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35 consistent with our hypothesis that bait removal with this system would be specific to feral  
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37 swine.  
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43 All three feeder systems used in our trial exploited the rooting behavior of feral swine.  
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45 Additionally, we observed variation in feral swine foraging at feeder systems. When feral swine  
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47 used the BOS feeder they tended to pick up the lid, consume a small amount of bait, and drop the  
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49 lid again. However, when feral swine used the NED feeder, they tended to pick up the lid, let the  
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51 lid rest on their back, and consume all the bait in one feeding bout. These observations account  
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53 for the lower number of consumption events at the NED feeders and greater removal rate by feral  
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4 swine compared to BOS feeders. We observed that raccoons typically consumed bait for a brief  
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6 moment, and then quickly vacated the NED. This strategy may be related to predator avoidance.  
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9 Differences between feeders may explain the differences in our observations while  
10 systems were activated. The BOS feeder was accessible from 360° whereas the NED feeder  
11 was accessible from only the front 90° (Figs. 1 and 2). We observed that this confused feral  
12 swine and that they would often leave the NED feeder site or try to flip over or push the system  
13 to obtain bait. We recommend that lids of NED feeders be modified to extend an overhang edge  
14 to facilitate lid lifting around three sides of the lid rather than only at the front of the system.  
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16 Another difference in feeders was the lid height when the feeder was activated. The BOS feeder  
17 was adjustable and set at 30 cm, whereas the NED feeder was permanently set at 13 cm. The  
18 lower lid height of the NED feeder possibly restricted access by larger swine and facilitated  
19 access by smaller non-target species. An additional factor that influenced access to the feeders  
20 was the weight of the lid. The BOS feeder required animals to lift 12–15 kg, whereas the NED  
21 feeder required animals to lift 3–4 kg. We believe that lift effort was the most important factor  
22 allowing non-target species access to NED feeders and restricting access to BOS feeders. For  
23 example, because the weight of an adult raccoon in southern Texas ranges from 5–11 kg, these  
24 animals would have to lift up to twice their body weight to gain access to the BOS feeder. We  
25 recommend that lids of NED feeders be modified by adding weight to the lid, thereby increasing  
26 the amount of effort required to lift the lid.  
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50 One potential downside to the BOS feeder is cost. Each BOS feeder cost approximately  
51 \$400 to fabricate, whereas the NED feeder and bucket feeder cost approximately \$50 and  
52 \$20/system, respectively. A BOS feeder could be constructed by a metal fabricator for relatively  
53 little cost, but to duplicate the BOS feeder design without any materials or knowledge of  
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4 metalwork would be challenging. Metal used in the BOS feeders is typically sold in large, rather  
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6 than small, pieces and skilled welders cost from \$40–\$60/hour, with each system taking  
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8 approximately 5–10 hours to construct. Large orders involving tens of BOS feeders would be  
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10 less expensive than small or individual orders. Because the BOS feeders are constructed from  
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12 metal they have a long life expectancy and are virtually unbreakable, which is good considering  
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14 the destructive habits of feral swine. Consequently, there is potential for initial costs to be  
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16 recouped over time with continuous use, perhaps in a cooperative arrangement among  
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18 landowners.  
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24 Past research has suggested using diel activity patterns as a means to create a more  
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26 species-specific delivery system for omnivores. This concept has not proven useful for feral  
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28 swine because these animals are primarily nocturnal with crepuscular peaks, similar to most non-  
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30 target species occurring in this region. Consequently, applying baits to feeder systems only  
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32 during periods of peak feral swine activity in hopes of only delivering baits to feral swine is not a  
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34 plausible strategy.  
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## 40 41 **Implications**

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43 In five years of performing trials on feral swine-specific delivery systems, the BOS feeder marks  
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45 the first system we have identified to meet our needs. Consequently, we recommend further  
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47 trials with the BOS feeders within rangeland and other ecosystems of the United States. Of  
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49 particular interest are ecosystems that contain sympatric feral swine and black bears (*Ursus*  
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51 *americanus*). Furthermore, future trials should be related to optimum BOS feeder density and  
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53 positioning, time until feral swine discovery and use, and feral-swine use at the population level.  
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57 Additionally, given the inexpensive and simple characteristics of the NED feeder, we  
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4 recommend further evaluations of this system employing the abovementioned modifications.  
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6 Lastly, a bait that is highly attractive to feral swine and is capable of housing and delivering  
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8 pharmaceuticals needs further development.  
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## 10 11 12 13 14 **Acknowledgments**

15  
16 We thank T. Blankenship and the Welder Wildlife Foundation for allowing property access. We  
17  
18 thank K. Kubala and D. Sanders for assistance with feeder system construction and J. Rattan, S.  
19  
20 Rabe, J. Delgado-Acevedo, and P. Rabe for field assistance. Financial support was provided by  
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22 USDA, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife  
23  
24 Research Center. Mention of commercial products herein is for identification purposes and does  
25  
26 not constitute endorsement or censure by the USDA. All experimental procedures were  
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28 approved by the Institutional Animal Care and Use Committee at the National Wildlife Research  
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30 Center (Permit No. QA-1595).  
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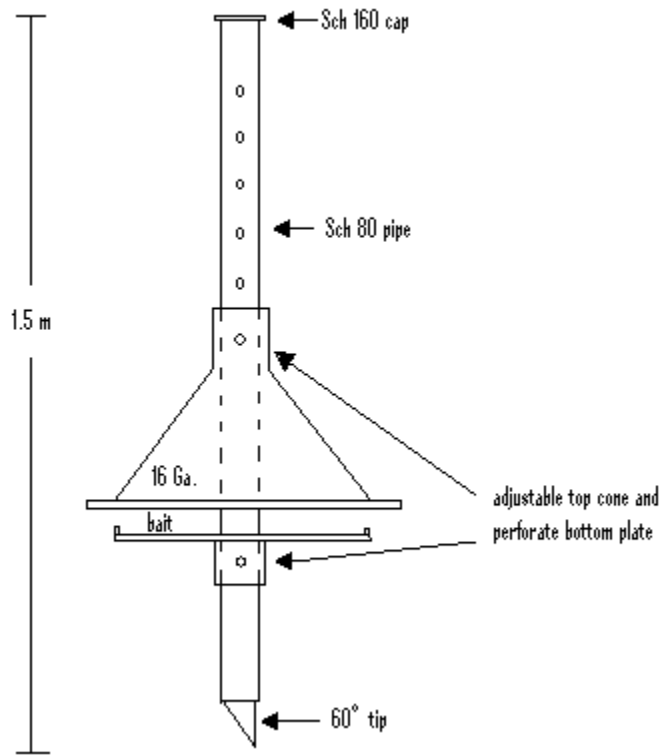
**Figure 1.** Diagram of the boar operated system (BOS) feeder prototype used during November–December 2008 in San Patricio County, Texas.

**Figure 2.** Diagram of the non-target exclusion device (NED) feeder prototype used during November–December 2008 in San Patricio County, Texas.

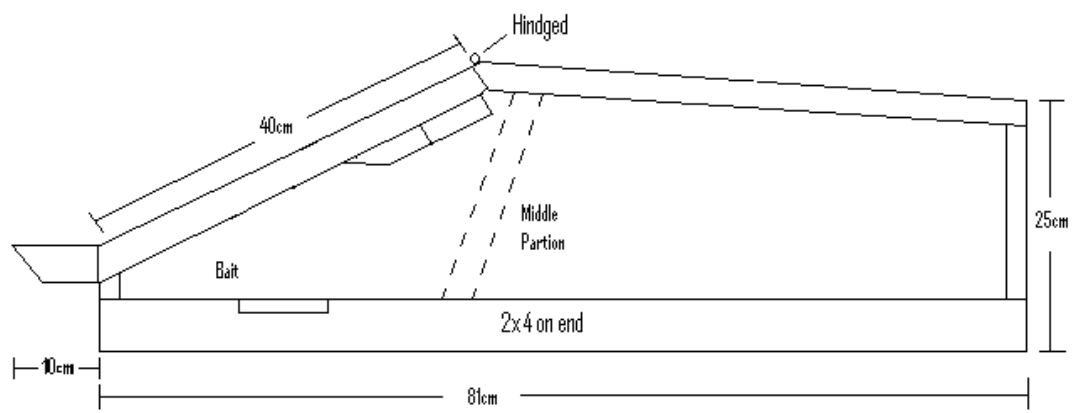
**Figure 3.** Diagram of the bucket feeder prototype used during November 2008 (during a proof of concept period) in San Patricio County, Texas.

**Figure 4.** Total consumption events by day for feral swine (top) and raccoons (bottom) for the BOS and NED feeder systems. Both feeder systems were activated on day 15, during November–December 2008 in San Patricio County, Texas.

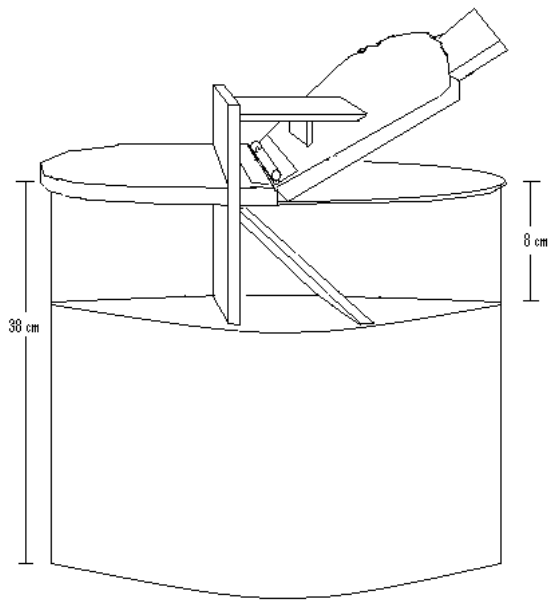
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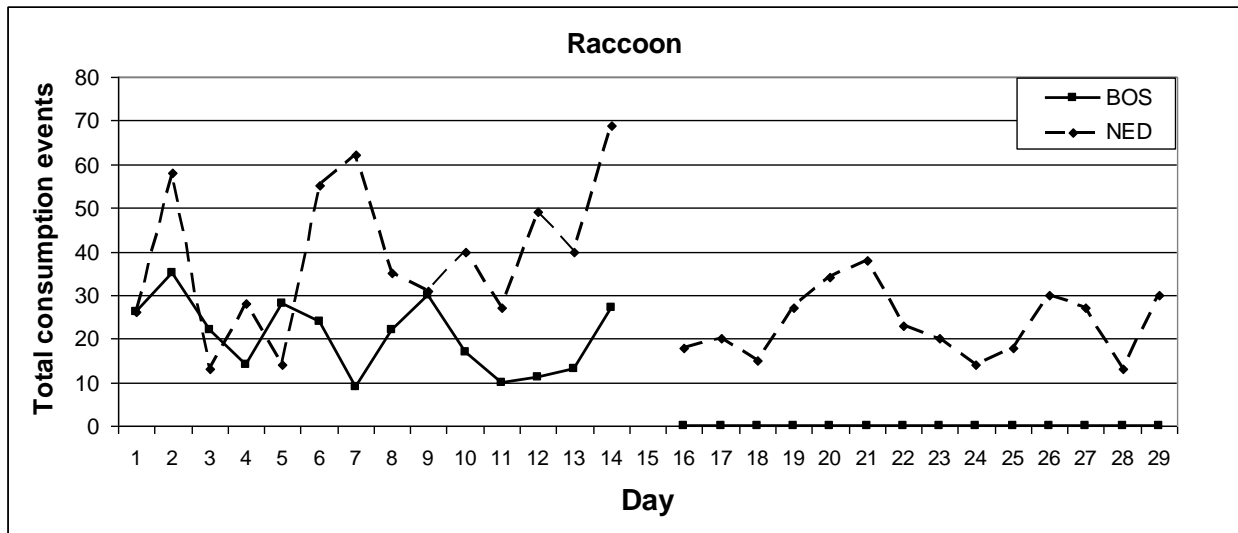
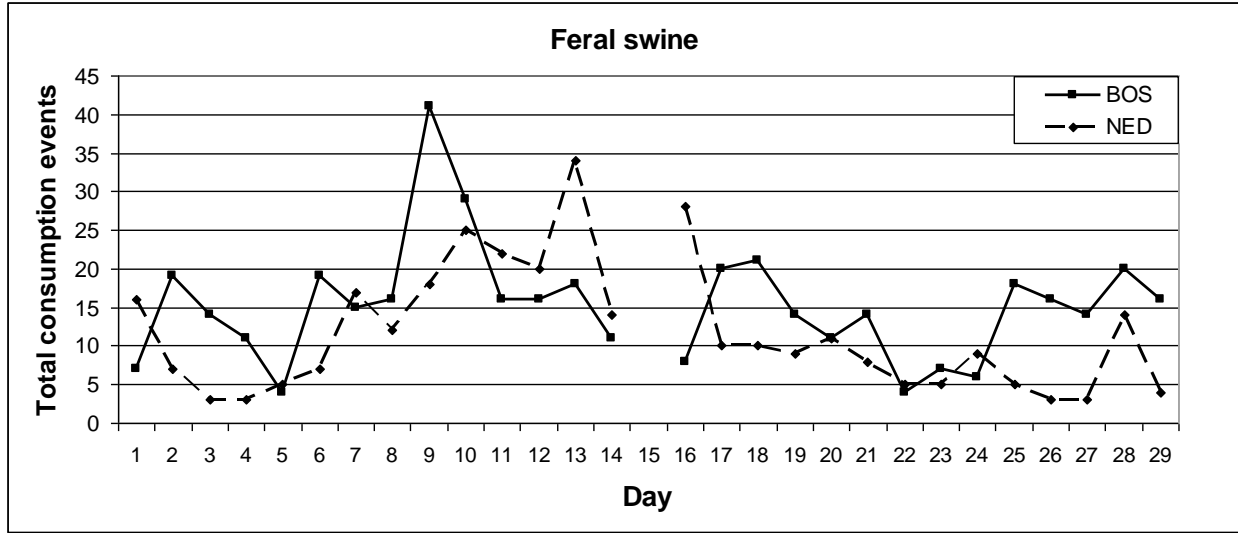


Figure - Picture1



Figure - Picture2



Figure - Picture3

