Behavioral aspects of electronic bull separation and mate allocation in multiple-sire mating paddocks

C. Lee,*2 K. C. Prayaga,† A. D. Fisher,* and J. M. Henshall*

*Commonwealth Scientific and Industrial Research Organisation (CSIRO) Food Futures Flagship and CSIRO Livestock Industries, F. D. McMaster Laboratory, Armidale, New South Wales 2350, Australia; and †CSIRO Food Futures Flagship and CSIRO Livestock Industries, J. M. Rendel Laboratory, Rockhampton, Queensland 4701, Australia

ABSTRACT: Controlling spatial positioning of cattle through use of electronic collars could provide new ways to farm under extensive conditions. This study examined the potential for bulls to be controlled during mating using mild electric shocks delivered through radio-controlled collars. Eighteen Belmont Red bulls were fitted with collars containing the Global Positioning System and that were able to emit a mild electric shock (500 mW) at the top of the neck behind the poll. Eighteen Belmont Red cows were fitted with Global Positioning System collars only. The experiment was replicated 3 times in 3 paddocks. Each paddock contained 2 bulls and 1 cow in induced estrus. On d 1, the bulls were either assigned to the cow or not assigned to the cow, and on d 2, the assignments were reversed, and bulls received the other treatment using a new cow. Treatments were applied for 2 h on each day. The nonassigned bull received a mild electric shock on approach to either the cow or a bull, whereas the assigned bull received a mild electric shock on approach to the other bull only. The electric shock was applied when the bulls were within approximately 10 m and moving toward the nonallowed animal. The electric shock was terminated when the animal responded by stopping movement toward the nonallowed animal. In the first 10 min, nonassigned bulls spent less time within 5 m of the cow (P = 0.03) than assigned bulls. Assigned bulls spent more time close to the cow during the entire 120 min on d 1 than on d 2 (P = 0.014). On d 1, the assigned bulls moved more toward the cow and the nonassigned bull than they did on d 2 (P = 0.02). Assigned bulls displayed more sexual behaviors than nonassigned bulls (P = 0.004). Nonassigned bulls were sometimes observed not to approach the cow despite a change in its location. This suggests that the bull associated the electric shock with the cow and not with the location in which it received the electric shock. Instances were observed in which the cow pursued the nonassigned bull, in which case the bull did not receive an electric shock, and this may reflect the preference of the cow. This study demonstrated that bulls can be separated and prevented from approaching a cow in estrus using a mild electric shock. However, mate allocation was not completely successful due to the potential for cow preference for certain bulls.

Key words: bull behavior, conditioning, electric shock, electronic collar, multiple-sire mating

©2008 American Society of Animal Science. All rights reserved.

doi:10.2527/jas.2007-0647

INTRODUCTION

The scale of extensive beef production in many areas of the world, including Northern Australia, limits the ability to subdivide paddocks due to cost and difficulty of erecting fencing. Multiple-sire mating is commonly practiced during the breeding season. Problems associated with multiple-sire mating exist due to the social relationships between bulls, which include fighting, injuries, and the resulting losses of bulls from the herd at the end of a breeding season (Kilgour and Campin, 1973; Fordyce et al., 2002). Additionally, the social structure, in which dominant bulls have greater access to females, results in uneven representation of bulls in the resulting progeny (Holroyd et al., 2002; Mooring et al., 2006). The ability to control the allocation of cows to bulls in multiple-sire mating paddocks would facilitate genetic improvement programs in extensive beef herds and result in significant gains to producers.

One possible method to achieve control over bulls during mating to reduce fighting and enable mate allo-
cation is by using mild electric shock cues. Studies have shown that location of cattle can be controlled using virtual fencing, in which animals learn to avoid a location in response to a nonaversive conditioning stimulus (visual, audio cues) and an aversive but nonnoxious response stimulus (mild electric shock) (Tiedeman et al., 1999; Lee et al., 2007). Bull separation and mate allocation are cases of virtual fencing, which use other animals (bull or cow) as the conditioning stimulus (and hence may be a combination of visual, acoustic, and odor stimuli) in association with the response stimulus (mild electric shock) to maintain spatial separation of animals.

The objective of this study was to achieve spatial separation of bulls and mate allocation. The hypothesis was that bulls would learn to associate their action of approaching another animal (conditioned stimulus) with a mild electric shock (response stimulus), thus maintaining separation from a nonallowed animal.

**MATERIALS AND METHODS**

**Ethical Approval of Animal Experimentation**

The protocol and conduct of the study were approved by the Institutional Animal Ethics Committee, under the Queensland Animal Care and Protection Act 2001.

**Animals**

Belmont Red bulls (n = 18, 727 ± 229 kg of BW, 3.4 ± 1.2 yr of age) and Belmont Red cows (n = 36, 453 ± 66 kg of BW, 3.9 ± 1.9 yr of age) were used for the experiment. At selection, the bulls were separated into 2 groups for a period of at least 4 wk before the beginning of the experiment.

**Electronic Collars**

Electronic dog collars (Dogmaster Trainers, Currumbin, Australia) were used to deliver mild electrical stimuli to the bulls and were controlled by an operator through a remote device. The electric shock intensity was set to 1,000 V and 500 mW. In a pilot study, this intensity of electric shock was found to change the movement of the cattle toward a feed trough, with cattle turning away from their direction of movement, stopping, or backing up. All animals were fitted with dummy collars for 1 wk before the experiment commenced to familiarize them with the collars. On each day of the experiment, dummy collars were removed, and the bulls had electronic collars secured around the neck, with the electrodes placed in contact with the skin at the top of the neck behind the poll. A separate collar containing a Global Positioning System (GPS) unit was attached both to the cows and to the bulls. The GPS unit was contained within a Fleck device (Sikka et al., 2004), which contained a memory card for logging data. Each bull was identified with a number on both flanks using a stock marker (Heiniger, Bibra Lake, Australia).

**Hormonal Treatment of the Cows**

A total of 36 cows were given hormonal treatment, such that at least 3 cows in estrus were available for the 6 d of the experiment. Cows were selected based on the detection of a corpus luteum or an ovarian follicle greater than 10 mm in diameter through ultrasound scan examination of the reproductive tract. Synchronization of estrus was achieved by a 2-mL i.m. injection of 1.5 mg/mL of norgestomet and 2.5 mg/mL of estradiol valerate and an ear implant containing 3 mg of norgestomet (Intervet, Castle Hill, Australia) on d 0. This was followed by a 2-mL i.m. injection of prostaglandin (500 mg of cloprostenol; Schering-Plough, Baulkham Hills, Australia) on d 9. On d 10, the implants were removed to induce estrus on d 11 or 12. These hormonal treatments were staggered for 3 sets of 12 animals in such a way that the cows came into estrus for each experimental replicate.

**Treatment Design**

The experiment was conducted at Belmont Research Station (GPS coordinates: longitude 150.3897125, latitude −23.213914) near Rockhampton, Queensland, Australia during April and May 2005. The experimental unit was a pair of bulls in a paddock for 2 consecutive days. This was replicated over 3 paddocks (approximately 100 × 125 m) and 3 wk so that 18 bulls were used in total. As such, the design was a randomized block design with bulls allocated to treatment, paddock, and week at random, but subject to the constraint of pairing bulls of similar size from each preexperiment group to be assigned on d 1 and the other to be assigned on d 2. Cows were allocated to paddock and a week at random but were allocated to day on the basis of estrous status. Each day, a new cow in estrus was introduced into the paddock, followed by the assigned bull, then by the nonassigned bull. The nonassigned bull received a mild electric shock on approach to either the cow or the assigned bull, and the assigned bull received a mild electric shock on approach to the nonassigned bull only (Figure 1). The nonassigned bull did not receive a mild electric shock if approached by the cow. The experimental design is shown in Table 1.

A person, standing on an elevated viewing platform located approximately 2 m outside of the paddock boundary, operated a hand-held manual device to remotely administer a mild electric shock. The electric shock was applied based on the person’s visual estimation of an animal being at approximately 10 m from a nonallowed animal. The electric shock was applied as described by Lee et al. (2007); application of the electric shock was consistent with the behavior of the animal of moving toward the nonallowed animal and ceased immediately when an animal stopped moving toward the other animal (Lee, 2006). This system allowed the animal to learn the association between its behavior of moving toward another animal and the electric shock.
Application of the electric shock was terminated when the animal responded in any of the following ways: 1) stopped movement toward the other animal, 2) turned away or backed up, or 3) ran forward. Each single application of the electric shock was for a maximum duration of 3 s.

Sexual behaviors of the bulls and the number of shocks received were recorded by a second person for the 2-h experimental period. Behaviors recorded were as follows: sniffing of the genital area of the female, flehmen (flaring of the nostrils of the bull and retraction, or curling, of the upper lip), and mounting (movement of the bull toward the cow with both front feet off the ground, resulting in physical contact).

At the end of the 2-h period, the bulls and the cow were moved to the holding yards. Collars were removed from the cows, and they were returned to their herd. Electronic collars were removed from the bulls, whereas the GPS collars remained on overnight, and the bulls were returned to the experimental paddock.

### Table 1. Experimental design

<table>
<thead>
<tr>
<th>Day</th>
<th>Animal</th>
<th>Paddock 1</th>
<th>Paddock 2</th>
<th>Paddock 3</th>
<th>Paddock 1</th>
<th>Paddock 2</th>
<th>Paddock 3</th>
<th>Paddock 1</th>
<th>Paddock 2</th>
<th>Paddock 3</th>
<th>Paddock 1</th>
<th>Paddock 2</th>
<th>Paddock 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bull</td>
<td>1, 2, 3</td>
<td>2, 3, 4</td>
<td>5, 6</td>
<td>7, 8</td>
<td>9, 10</td>
<td>11, 12</td>
<td>13, 14</td>
<td>15, 16</td>
<td>17, 18</td>
<td>19, 20</td>
<td>21, 22</td>
<td>23, 24</td>
</tr>
<tr>
<td></td>
<td>Cow</td>
<td>1, 2</td>
<td>2</td>
<td>3</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>13</td>
<td>14, 16</td>
<td>15, 17</td>
<td>18</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Bull</td>
<td>1, 2, 3</td>
<td>2, 3, 4</td>
<td>5, 6</td>
<td>7, 8</td>
<td>9, 10</td>
<td>11, 12</td>
<td>13, 14, 16</td>
<td>15, 16</td>
<td>17, 18</td>
<td>19, 20</td>
<td>21, 22</td>
<td>23, 24</td>
</tr>
<tr>
<td></td>
<td>Cow</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>16, 17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
</tr>
</tbody>
</table>

1The experiment was conducted at 3 time periods (weeks) and also in 3 paddocks within each week with different sets of bulls and cows, as shown. Bull numbers and cow numbers are shown in the table to better appreciate the allocation of bulls across days and replications.
2Loss of Global Positioning System data.
3Assigned bulls.

### Statistical Analysis

**GPS Analysis.** The GPS devices logged the location for each animal each second. There were several technical problems associated with the data from the Fleck devices, including faulty batteries and damaged memory cards. Although there were only 11 device failures (of 54 deployments), a full crossover study requires the success of all 6 devices in a week × paddock block, and this only occurred in 3 blocks from a possible 9. Ignoring crossover effects, there were 10 successful day × paddock blocks from a possible 18. Whether the GPS failed was not known until after the experiment, so electrical stimuli were still applied. The empty cells affect the conclusions that can be drawn from the data, and although for 10 replicates there was both a cow record and 2 bull records, preliminary analyses suggested the presence of a week × treatment interaction, which may have been due to the lack of balance caused by the missing data. Accordingly, only the records from wk 2 were used in the final analyses. Although a smaller data set, the 12 records for wk 2 were balanced across treatment, day, and paddock. The GPS data were extracted for each animal. The distance between cows and bulls was calculated for the resulting 12 cow-bull combinations, beginning when the animals entered the paddock and continuing until the end of the treatment period, for a total of approximately 2 h.

**GPS Distance Analysis.** The distance measurements comprised repeated records on cow-bull combinations, and the summary statistic of interest was the proportion of time the distance was less than 5 m during the first 10 min and during the entire 120 min. The distance of 5 m was chosen, because it allowed for any inaccuracy in determining the exclusion zone, which was nominally 10 m, and therefore was approximately the proportion of time in which a bull was in the exclusion zone around the cow.

Linear models were fitted using the statistical software package R (The R Development Core Team, Version 1.6.2, Free Software Foundation Inc., Boston, MA). The dependent variables were proportion of time less than 5 m from the cow during the first 10 min and proportion of time less than 5 m from the cow during the entire 120 min. Factors in the model were treatment...
Of the number of sexual events were tested. Of primary interest were the main effect of treatment and the crossover effect (i.e., the day × treatment interaction).

GPS Movement Analysis. The GPS distance data indicated how far apart the pairs of animals were but did not provide information on which animals were responsible for causing the key distance variables measured. This was determined by GPS-derived animal movement data. Movement of one animal relative to another was summarized as follows:

1. The GPS locations at 0.1-s intervals were interpolated between the recorded samples (which were at 1-s intervals) for all animals. The reason for this is that when 2 animals were close together and moving quickly, the distance traveled per second could exceed the distance between the animals, producing misleading estimates of the relative movements of the animals.
2. For each time point, the velocity vector of animal A was projected onto the vector leading from animal A to animal B and the magnitude of the projection obtained.
3. The sign of the magnitude of the projection was changed if animal A was moving away from animal B.
4. The mean of the resulting values multiplied by 10 (to account for the interpolation) was calculated as an estimate of the average velocity of animal A moving toward animal B, (in m/s).
5. This velocity was divided by the total distance moved by animal A, and the resulting variable, projection, was analyzed.

The contrasts of interest for projection were as follows: cow to assigned bull vs. cow to nonassigned bull, assigned bull to cow vs. nonassigned bull to cow, and assigned bull to nonassigned bull vs. nonassigned bull to assigned bull. For these contrasts, projections estimated from both the first 10 min and the entire 120 min were fitted as dependent variables in a linear model containing the factors treatment (assigned or nonassigned), day (1 or 2), and paddock, using the statistical software package R. Treatment referred to the treatment of animal A (i.e., the animal doing the moving) when animal B was a bull, whereas treatment related to the treatment of animal B when animal A was a cow.

Behavior. The variable analyzed was the counts of sexual events, which was the sum of the individual behavioral categories. Sexual events were analyzed for all records and with only assigned bulls to examine the effect of day without any day × treatment interactions. A linear model was fitted to log-transformed counts of sexual events, using the R statistical software. The effects of day, week, paddock, and treatment on the log of the number of sexual events were tested.

RESULTS

GPS Distance

A summary of the proportion of time bulls spent within 5 m of the cow is shown in Table 2. During the first 10 min, assigned bulls spent more time close to the cow than nonassigned bulls (P = 0.03). During the entire 120 min, there was a significant day × treatment interaction (P = 0.014), with assigned bulls on d 1 spending more time close to the cow than on d 2. The SE for the assigned bull treatment was greater than that for the nonassigned bull treatment. This was caused by a bimodal distribution for assigned bulls; of the 6 assigned bulls, 4 spent most of the time close to the cow, whereas 2 spent almost no time close to the cow.

GPS Movement

The relative movement of animals (projection) is shown in Table 3. There was a significant carryover effect (treatment × day interaction) for movement of bulls toward the cow during the entire 120 min. The assigned bull on d 1 moved more toward both the cow and the nonassigned bull than the assigned bull on d 2 (P = 0.02). Overall, the assigned bull on d 2 displayed less movement toward other animals than the assigned bull on d 1. There was a day effect for movement of the bulls toward the cow during the first 10 min, with greater movement on d 1 than d 2 (P = 0.03). During the entire 120 min, the cow moved more toward the unassigned bull on d 1 than on d 2 (P = 0.01).

Behavior

Counts of sexual behavior by bulls are shown in Table 4. The effect of treatment was highly significant and differed between weeks (P = 0.004). There was no significant treatment × day interaction, with counts of sexual events not differing between treatments on d 1 and 2 (P = 0.10). Assigned bulls differed in the number of sexual events displayed between weeks (P = 0.004).

Assigned bulls received an average of 2 shocks on d 1 and 1 shock on d 2. Nonassigned bulls received an average of 6 shocks on d 1 and 7 shocks on d 2. Figure 2 plots observational data from 2 paddocks on cow movement and electrical stimuli received by the nonassigned bull. Nonassigned bulls received more frequent stimuli when they first entered the paddock. In plot A, the bull received 5 stimuli within the first 30 min but only one in the last 30 min. In plot B, the bull received only 2 stimuli within the first 45 min and none thereafter. The cow moved freely around the paddock for the majority of the 2 h without the nonassigned bull attempting to approach it.

DISCUSSION

The study showed that bulls can be successfully controlled and prevented from approaching a cow in estrus...
using electrical stimuli. Nonassigned bulls spent less time ($P < 0.05$) close to the cow than assigned bulls. Despite the strong drive to contact and mate with a cow in estrus, the mild electric shock was effective at preventing such action.

In this study, we applied the electric shock manually, based on the distance between animals and their behavior of moving toward another animal. The electric shock ceased immediately when the animal responded in a desired way, which was to stop moving forward, turn, or back up. This method enables the animal to learn the association between the conditioning stimulus (moving toward another animal) and the response stimulus (electric shock). To facilitate animals learning the association between the conditioning and response stimulus, the position and behavior of the animal must be considered when applying and releasing the electric shock. It appears that the bulls received more frequent electrical stimuli when they first entered the paddock and over time they learned not to approach the cow. The observation that even when the cow changed location the bull did not approach the cow suggests that a bull may associate the cow with the electric shock and not the location in which it received the shock. This suggests that the other animal may be an effective conditioning stimulus. Despite the fact that bulls are known to push through electric fences to reach cows in estrus, we were able to prevent mating using electronic collars. One possible explanation is that the conditioning stimulus, in this case the cow, is a stronger and more persistent conditioning stimulus than the visual electric fence, which, once the bull goes through it, delivers no further conditioning or aversive stimuli.

The finding of a carryover effect of the treatment on day 1 on the movement of bulls on day 2 shows that the bulls behaved differently after the treatment. The assigned bull on day 2 appeared more hesitant to approach the other animals in the paddock, showing less overall movement toward the cow and nonassigned bull and spending less time close to the cow than the assigned bull on day 1. It appears the assigned bull on day 2 learned to overcome this initial reluctance to approach the cow, because the number of sexual behaviors displayed by the assigned bull between day 1 and 2 did not differ. The low number of mounts may have been an artifact resulting from the hormonal induction of estrus such that the assigned bulls interacted sexually with the cows as evidenced by the counts of vulval sniffing and

---

**Table 2.** Proportion of time the bull was less than 5 m from the cow ($\pm$SEM) during the first 10 min and during the entire 120 min$^{1,2}$

<table>
<thead>
<tr>
<th>Item</th>
<th>Day</th>
<th>Assigned</th>
<th>Nonassigned</th>
<th>Treatment</th>
<th>Day</th>
<th>Treatment $\times$ day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of time less than 5 m from the cow, first 10 min</td>
<td>1</td>
<td>0.82 ± 0.18</td>
<td>0.02 ± 0.02</td>
<td>0.03</td>
<td>0.17</td>
<td>NS$^3$</td>
</tr>
<tr>
<td>5 m from the cow, first 10 min</td>
<td>2</td>
<td>0.26 ± 0.26</td>
<td>0.09 ± 0.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proportion of time less than 5 m from the cow, entire 120 min</td>
<td>1</td>
<td>0.72 ± 0.12</td>
<td>0.01 ± 0.01</td>
<td>0.002</td>
<td>0.03</td>
<td>0.014</td>
</tr>
<tr>
<td>5 m from the cow, entire 120 min</td>
<td>2</td>
<td>0.19 ± 0.13</td>
<td>0.05 ± 0.03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 and 2</td>
<td>0.45 ± 0.14</td>
<td>0.03 ± 0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^1$The nonassigned bull received a mild electric shock on approach to either the cow or the assigned bull, and the assigned bull received a mild electric shock on approach to the nonassigned bull only. The nonassigned bull did not receive a mild electric shock if approached by the cow.

$^2$The results are derived from Global Positioning System (GPS) data for wk 2 only due to GPS device failure.

$^3$NS = $P > 0.05$.

---

**Table 3.** Movements of animals relative to each other ($\pm$SEM) during the first 10 min (projection 10 min) and the entire 120 min (projection 120 min)$^{1,2}$

<table>
<thead>
<tr>
<th>Item</th>
<th>Day 1</th>
<th>Assigned bulls</th>
<th>Nonassigned bulls</th>
<th>Day 2</th>
<th>Assigned bulls</th>
<th>Nonassigned bulls</th>
<th>Treatment</th>
<th>Day</th>
<th>Treatment $\times$ day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projection 10 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cow to bull</td>
<td>0.00 ± 0.09</td>
<td>0.21 ± 0.13</td>
<td>0.13 ± 0.11</td>
<td>0.02 ± 0.05</td>
<td>0.01</td>
<td>0.02</td>
<td>NS$^3$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bull to cow</td>
<td>0.25 ± 0.08</td>
<td>0.22 ± 0.12</td>
<td>−0.05 ± 0.11</td>
<td>0.07 ± 0.06</td>
<td>NS</td>
<td>0.03</td>
<td>NS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bull to bull</td>
<td>−0.03 ± 0.06</td>
<td>0.27 ± 0.09</td>
<td>0.13 ± 0.05</td>
<td>0.13 ± 0.05</td>
<td>NS</td>
<td>NS</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Projection 120 min                         |       |                |                   |       |                |                   |           |     |                        |
| Cow to bull                                | −0.16 ± 0.09 | 0.12 ± 0.08 | 0.00 ± 0.03 | −0.02 ± 0.04 | 0.03 | NS | 0.01 |
| Bull to cow                                | 0.24 ± 0.09 | −0.08 ± 0.04 | 0.00 ± 0.04 | 0.06 ± 0.07 | NS | NS | 0.02 |
| Bull to bull                               | 0.20 ± 0.05 | −0.14 ± 0.03 | −0.02 ± 0.05 | 0.07 ± 0.07 | 0.05 | NS | 0.003 |

$^1$The nonassigned bull received a mild electric shock on approach to either the cow or the assigned bull, and the assigned bull received a mild electric shock on approach to the nonassigned bull only. The nonassigned bull did not receive a mild electric shock if approached by the cow.

$^2$The results are derived from Global Positioning System data.

$^3$NS = $P > 0.05$. 
flehmen but did not display a high number of mounts, which suggested that cows were not in standing estrus but were sexually attractive to the assigned bulls. Other sources of variation in sexual behavior could have been dominance relationships or individual differences in libido.

Controlling the bull and preventing access to the cow was possible; however, mate allocation was more problematic, because the operators observed some instances in which the cow followed the nonassigned bull, which may reflect cow preference for a certain bull. This is supported by research showing that cows in estrus prefer the more dominant bull (Blockey, 1979). The female appears to play a role in determining which bull to mate with; therefore, automated mate allocation through controlling only access of the bull to the cow will not be totally successful. Allocation of bulls to cows could be made possible if the cow were also controlled and received stimuli on approaching the nonassigned bull. However, cost factors may restrict this in practice. Provided the frequency of cow preference events is low, the effect on breeding program design would be minimal.

Table 4. Total counts of sexual behaviors displayed by the bulls

<table>
<thead>
<tr>
<th>Sexual behaviors</th>
<th>Day 1&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Day 2&lt;sup&gt;2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Assigned bulls</td>
<td>Nonassigned bulls</td>
</tr>
<tr>
<td>Sniffing vulva</td>
<td>66</td>
<td>2</td>
</tr>
<tr>
<td>Flehmen</td>
<td>43</td>
<td>2</td>
</tr>
<tr>
<td>Mounting</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

<sup>1</sup>The nonassigned bull received a mild electric shock on approach to either the cow or the assigned bull, and the assigned bull received a mild electric shock on approach to the nonassigned bull only. The nonassigned bull did not receive a mild electric shock if approached by the cow.

<sup>2</sup>Bulls received mild electric shocks to maintain separation when approaching within approximately 10 m of a nonallowed animal; only the approaching bull received a mild electric shock.

<sup>3</sup>Row values within a day differ for the total counts of sexual behaviors ($P < 0.001$).

<sup>4</sup>Total counts are for 120 min daily for all bulls.

Figure 2. The distance (m) moved by 2 cows between the time points in which successive electric shocks were received by the nonassigned bull.
using multi-sire mating. Using another animal as a conditioning stimulus appears to be effective; however, further studies are needed to confirm this observation. Cows appear to play a significant role in mate selection and therefore would also need to be prevented from pursuing nonallowed bulls if mate allocation were to be totally successful. Further research is needed to quantify welfare outcomes of the use of electrical stimuli for control of mate allocation and bull separation together with its effect on libido and reproduction in bulls.

LITERATURE CITED