

WELFARE AND BEHAVIOR: *Invited Review*

INVITED REVIEW: Design and management of group maternity areas for dairy cows

Katherine C. Creutzinger and Kathryn L. Proudfoot*† 

Veterinary Preventive Medicine, College of Veterinary Medicine, The Ohio State University, 1920 Coffey Road, Columbus 43210

ABSTRACT

Purpose: The purpose of this review is to describe the research to date on the housing and management of dairy cows in group maternity areas.

Sources: We used a review of the peer-reviewed literature to identify articles that included an experimental study using dairy cows kept in groups at calving. Our review also includes studies from the broader literature using cows kept in individual maternity pens, dry cows, lactating cows, and beef cattle.

Synthesis: Housing cows in group maternity areas creates unique challenges compared with housing cows in individual pens. Advantages to calving in group pens include limited pen moves, reduced risk that cows calve in freestalls, and potentially improved labor efficiency. Disadvantages of group maternity areas include the limited ability of cows to express natural behaviors before calving such as seclusion from pen mates, the risk of the calf being nursed by the wrong dam, a lack of space for cows as they prepare to give birth, social instability caused by regrouping, and challenges with pen cleanliness.

Conclusions and Applications: Research to date has focused on creating opportunities for isolation-seeking behavior for dairy cows in group maternity areas. Cows in group pens are motivated to seek isolation at calving, but the ability to do so can be limited by competition. Research is still needed to determine potential negative effects of high stocking density and frequent regrouping in group maternity areas on cow behavior and health.

Key words: isolation, maternal behavior, stocking density

INTRODUCTION

Designing a maternity area for dairy cattle requires knowledge of cows' natural calving behaviors, as well as risk factors for poor health of cows and calves after par-

turition. For the purposes of this review, the “maternity pen” refers to any area where a cow gives birth to her calf. For farms that use a designated maternity area, there are 2 main types: individual and group maternity areas. Individual areas allow one cow giving birth in a separated area, and group areas allow for more than one cow to give birth. There are advantages and disadvantages of both maternity area types (previously reviewed by Proudfoot, 2019); however, this review will focus on research to date on the housing and management of dairy cows in “group maternity areas,” defined for this purpose as any loose-housing area (e.g., bedded pack, dry lot, pasture, and so on) where multiple cows are housed together during labor.

Maternity area design and management is highly variable throughout the world, and recommendations for maternity areas vary by country. For example, in Denmark it is required by law that cows be moved into individual maternity pens for calving (Denmark by Ministry of Environment and Food of Denmark, Danish Veterinary and Food Administration, Law number. 520, Chapter 4, 26/05/2010). The Canadian Dairy Code of Practice recommends that cows be housed in individual or group maternity areas with “adequate space per cow,” although no definition for “adequate space” is provided (NFACC, 2009). Some research in the United States and Canada has gathered data on maternity area types; for example, only 50 to 70% of farms in the United States and Canada report using a dedicated maternity area for cows to give birth (Quebec: Vasseur et al., 2010; USDA, 2016). A survey in the United States (USDA, 2016) found that 58.7% of farms reported using group maternity areas, 48.6% used individual pens, and 22.7% of farms had a calving area listed as “other.” Survey data from Canada found that 25.4% of farms use tiestalls for calving, although the authors strongly discouraged this practice (Villettaz Robichaud et al., 2016).

We reviewed of the peer-reviewed literature using Google Scholar and the following search terms: “dairy cow,” “maternity,” “calving,” and “group.” From the search results, we narrowed the papers down to those published since 1980 and those that included an experimental study using cows kept in groups at calving in a loose-housing system. This search criteria resulted in 15 experimental papers: Edwards (1983); Illmann and Špinková (1993); Lidfors et al. (1994); Pithua et al. (2009); Miedema et al. (2011a,b);

The authors have not stated any conflicts of interest.

*Corresponding author: kproudfoot@upei.ca

†Current address: Department of Health Management, University of Prince Edward Island, Charlottetown, PE, C1A 43P, Canada.

Pithua et al. (2013); Proudfoot et al. (2014b); Black and Krawczel (2016); Rice et al. (2017); Rørvang et al. (2017b); Campler et al. (2018); Jensen and Rørvang (2018); Rørvang et al. (2018a); Jensen et al. (2019). All the dairy animals in the reviewed papers were Holstein-Friesians except in the following: Simmental heifers (dual-purpose dairy and beef; Illmann and Špinka, 1993) and a combination of Swedish-Friesians and Swedish Red and White (Lidfors et al., 1994). Our review includes these manuscripts as well as the broader literature including studies using beef cows, lactating cows, as well as those kept in freestalls during the precalving period, and those kept in individual maternity pens during labor.

We argue that cows kept in group maternity areas face unique challenges that are different from those kept in individual pens during parturition. Advantages of keeping cows in group maternity areas include limited pen moves, reduced risk of calving in freestalls, and potentially improved labor efficiency (i.e., farm employees not having to physically move cows into individual pens). Disadvantages of group maternity areas include (1) a limited ability to express natural behaviors before calving such as seclusion from pen mates, (2) the risk of the calf being nursed by the wrong dam (mis-mothering), (3) high stocking density and a lack of space for cows as they prepare to give birth, (4) social instability caused by regrouping, and (5) ensuring pen cleanliness to prevent the risk of disease later in dams and their calves. The following sections will review these challenges and offer recommendations for how to manage and design group maternity areas to mitigate these challenges.

DRY COW AND MATERNITY HOUSING AND MANAGEMENT

During the dry period, cows are typically housed in bedded packs, dry lots, pasture, freestalls, or tiestalls (USDA, 2016). On some farms, cows are moved into a close-up area approximately 21 d before their expected calving date, whereas others keep cows in the same area for the entire dry period. This close-up or dry cow area may also serve as the group maternity area, as cows are kept in same area until they give birth. In other cases, cows are moved into a group maternity area closer to calving. The stocking densities of these close-up and maternity pens are likely variable; however, there is limited research on stocking densities of these pens.

There are 2 main grouping strategies for group maternity areas: (1) an all-in-all-out approach, where a group of cows are moved into the pen at once and remain together until calving, and (2) a dynamic approach, where new cows enter the maternity area once or multiple times per week (Cook, 2019). All-in-all-out pens may be used less commonly than dynamic pens due to space constraints but may provide some benefit to parturient cows because stable social groups are not disrupted from regrouping (Lobeck-Luchterhand et al., 2014).

A main advantage of group maternity areas is that cows remain in the pen to give birth and do not need to be moved into a separate, individual maternity area. Although individual maternity areas also have advantages, the cow must be moved from the group pen either before or during labor (just in time), which may interfere with the normal progression of labor (Proudfoot et al., 2013). In addition to disrupting the normal progression of labor, it can be difficult to predict the onset of calving (Lange et al., 2017), as farm staff must keep close watch to identify physical and behavioral signs of birth (Proudfoot et al., 2013). The timing of cow movement into the individual pen is an important consideration, as moving cows into individual maternity pens too early may cause unwanted health consequences (Cook and Nordlund, 2004) but waiting to move cows too close to calving increases the risk that cows will give birth in unwanted areas such as the freestall.

Location of the maternity area in the barn is also important. Regardless of housing type, maternity areas are sometimes located in high traffic areas to increase monitoring capabilities of cows during labor. Proper supervision of cows during parturition is important to ensure that cows with dystocia can be properly assisted; however, research with beef cattle suggests that excessive supervision can increase the risk of dystocia (Dufty, 1981). Cows are motivated to avoid disturbances and perceived threats during labor (reviewed by Rørvang et al., 2018b), which can include human activity and noises associated with farm activity.

COW BEHAVIOR BEFORE CALVING

Understanding cows' maternal behavior before calving in natural environments is important to help us better house and manage cows in group maternity areas. For wild ungulates, calf survival is dependent on the formation of the cow-calf bond because the calf is reliant on the cow for nutrition and protection from predators (Leuthold, 1977). Dairy cows are typically separated from their calves soon after birth on commercial farms, although the justification for this early separation has recently been extensively reviewed and criticized (Beaver et al., 2019; Meagher et al., 2019). Despite spending little time with their calves after birth, it has been well documented that dairy cows perform a suite of calving behaviors as calving approaches (reviewed by von Keyserlingk and Weary, 2007; Jensen, 2012).

Isolation-Seeking Before Calving

Separation from conspecifics at parturition is commonly observed in wild ungulates, beef cattle, and dairy cows and is suggested to be driven by the motivation to hide their calf from predators and other cows (see review Rørvang et al., 2018b; Table 1). For example, Lidfors et al. (1994) found that dairy cows increase their distance to herdmates as calving approaches and prefer a calving site

that is dry with soft ground covering and natural overhead protection. Similarly, Edwards (1983) provided heifers and cows with a choice between calving indoors and in 1-ha paddock and found that most animals preferred to calve indoors (74 of 95). However, calving location preference varied with time of day; more cows calved in the paddock at nighttime (17 of 53) compare with daytime (4 of 42). Beef cows on range that lacked coverage from tall grasses and trees separated themselves from herdmates at a distance of 12 to 1,250 m at calving, much longer distances than they would normally separate when not giving birth, and moved further if they were disturbed by other cows during labor (Flörcke and Grandin, 2014). Environmental conditions may play a role in birth site selection for cattle and other ungulates when calving outdoors (Rørvang et al., 2018b). For example, sika deer (Fouda et al., 1990) and pasture-kept bison (Lott and Galland, 1985) give birth away from the herd when vegetative cover is available but give birth within the herd when there are no opportunities to visually isolate from herdmates. Results from these studies suggest that isolation seeking in wild ungulates is a plastic motivation driven by the environmental features.

Cows also seek isolation when housed indoors (Proudfoot et al., 2014a,b). For example, Proudfoot et al. (2014a) housed cows in individual maternity pens (3 × 4.5 m) directly adjacent to a group pen with a plywood barrier covering half of the pen (illustrated in Proudfoot, 2019). Most cows (79%) chose to calve behind the plywood barrier compared with the uncovered half of the pen. The design of the hiding space in individual maternity pens may matter, depending on pen type and the cow's duration of labor (Jensen and Rørvang, 2018; Rørvang et al. 2017a). Rørvang et al. (2017a) found that cows with normal labor duration had no preference for barrier shape in individual maternity pens (tall and narrow, low and wide, and tall and wide). However, cows with a significantly longer than normal duration of labor chose to calve in the secluded areas with the highest amount of coverage. When separating, cows may be trying to avoid human activity and other disturbances that could be perceived as threats or disrupt the progression of labor (Rørvang et al., 2018b). However, these studies used cows kept alone in individual pens during labor; providing opportunities for cows to isolate in group maternity areas may be more challenging.

Table 1. Description of preparturient isolation-seeking behavior in dairy cattle

Maternity area type	Description of maternity area	Number of cows per hide	Percentage of cows seeking isolation
Indoor individual	Open area pen with bedded pack or shelter ¹	1	62% calved in the shelter. 81% calved during the daytime.
Indoor individual	Plywood partially covering the maternity pen ²	1	79% calved in the partially covered area.
Indoor individual	Preference test using 3 levels of seclusion ³	1	No preference for hide type; cows with prolonged labor sought the most seclusion.
Indoor pair	Open area pen with bedded pack or shelter ¹	2	34% calved in the shelter.
Indoor group	Gated and ungated "L" shape hides bordering a group maternity area. Gated hides allowed one cow in a hide at a time. ⁴	1	52% calved in a hide, with a tendency for a preference for ungated hides.
Indoor group	"L" shape hides bordering a group maternity area with wide or narrow openings ⁵	2	10% calved in a hide; no preference for opening width.
Indoor/pasture group	Access to a barn and 1-ha paddock ⁶	NA ⁷	22% calved outside the barn.
Pasture group	20 ha of forest area with dense vegetation and open areas ⁸	NA	64% separated from the herd; >30 m from nearest neighbor.

¹Proudfoot et al. (2014b).

²Proudfoot et al. (2014a).

³Rørvang et al. (2017a).

⁴Rørvang et al. (2018a).

⁵Jensen and Rørvang (2018).

⁶Edwards (1983).

⁷NA = man-made hiding areas were not included as part of the experiment.

⁸Lidfors et al. (1994).

Some research has attempted to create opportunities for cows to isolate from pen mates in group maternity areas (e.g., Proudfoot et al., 2014b; Jensen and Rørvang, 2018; Rørvang et al., 2018a). Hiding spaces created for cows in this group of studies have used similar “L” shaped cubicle hides (providing 3 fully covered walls and 1 partially covered wall that offers access to a group pen) with minor changes. For example, Proudfoot et al. (2014b) found that when pairs of cows were housed in a maternity pen with a shelter, the first cow of the pair to calve avoided the shelter but also increased their distance from their partner as calving approached. In a study with multiple cows in the pen, Jensen and Rørvang (2018) found that only 10% of cows calved in a hide secured to the outside wall of the group pen. Using a similar design, Rørvang et al. (2018a) found that approximately 50% of cows calved in a hide. Although the design of the hides were similar in both studies, the ratio of cow:hide was different; Jensen and Rørvang (2018) used 2:1, whereas Rørvang et al. (2018a) used 1:1. Thus, competition over hides may affect a cow’s use of the space. To ensure cows are able isolate at calving if they are motivated to do so, an effort should be made to limit competition over resources by providing sufficient resources per cow.

Ideally, parturient cows in a group maternity area could choose whether to isolate from pen mates at calving and should not experience disturbances by other cows if they choose to isolate. Rørvang et al. (2018a) provided cows in a group maternity area with access to 2 types of “L” shaped cubicle hides secured to the outside wall of the group pen: a gated pen, where cows were trained to push through a gate to obtain access to the pen (the cow could also leave the pen, but once she entered the pen, the gate locked behind her so no other cows could join her), or an ungated individual pen, where the gates were left open at all times. Approximately half of the cows calved in the individual pens rather than the group area, but cows were more likely to use an individual pen to calve if it was ungated and if they were bold or dominant and were less likely to use an individual pen if there was an alien calf in the pen. These results suggest that some cows will self-isolate when giving birth, but they are less willing to navigate through an obstruction such as a gate. Maternity areas should be designed to accommodate these different preferences.

In addition to seeking seclusion, cows’ calving site selection may be influenced by the presence of odors and pheromones of birth fluids from other cows. For example, Rørvang et al. (2017b) found that 90% of cows calved within one cow length (estimated 2.5 m) of where a previous calving occurred. A follow-up study found that 79% of cows that calved in a group maternity area calved within a 1.25-m radius of their own or an alien cow’s birth fluids (Jensen and Rørvang, 2018). Results from these studies suggest cows are attracted to their own and alien birth fluids before calving, and olfactory cues may be important during calving site selection.

Restlessness During Labor

In addition to isolation seeking, there is ample evidence from cows kept indoors and outdoors that cows become more restless as labor approaches, characterized by more steps and higher transitions from standing to lying during the 24 h before calving compared with previous days (Huzzey et al., 2005; Miedema et al., 2011b; Jensen, 2012; Black and Krawczel, 2016). These transitions and steps may be driven by pain associated with labor, as cows likely experience pain associated with both uterine and abdominal contractions (Mainau and Manteca, 2011) or may also be driven by the comfort and environment provided to them during labor.

The lying surface may influence the cow’s expression of restlessness before calving. For example, Campler et al. (2018) compared the behavior of cows kept in deep-bedded straw packs and those in freestalls during the 4 wk before calving and found that cows in packs had more lying bouts and faster transition times from lying to standing compared with those in freestalls. These authors and others suggest that straw bedding may provide better traction for cows to transition between lying and standing postures compared with harder surfaces (Tucker et al., 2003; Calamari et al., 2009). In a similar study, Campler et al. (2014) found that animals provided access to deep-bedded straw packs had more lying bouts in the 24 h before calving and faster labors compared with those kept in freestalls, despite the fact that both groups were housed in similar individual maternity pens during labor. In agreement with these findings, Black and Krawczel (2016) found that cows kept on pasture had more lying bouts compared with those kept in freestalls. These findings suggest that providing group-housed cows with pasture or deep-bedded packs before and during labor may improve comfort over more restrictive environments such as freestalls.

SOCIAL INTERACTIONS WITH ALIEN COWS AND CALVES AT CALVING

Isolation-seeking behavior in cows and other ungulates is thought to be partially driven by the cow separating from conspecifics to help facilitate the development of the bond with their calf (reviewed by Rørvang et al., 2018b). Some research has explored social behaviors between cows during labor. For example, beef cattle with newborn calves have been found to distance themselves further from pregnant cows than cows that already have a calf, possibly attempting to reduce unwanted attention from these soon-to-be mothers (Finger et al., 2014). Jensen et al. (2019) used the same gated and ungated hides as Rørvang et al. (2018a) and found the cows that calved in the gated hides spent less time interacting with pen mates in the hour following calving (0.5 vs. 28 min/h) compared with those that calved in the group area. Authors concluded that this type of design may help cows avoid disturbance from pen mates during labor.

Group maternity areas may also increase social interactions between cows and alien calves after birth. In a study of cows in a group maternity area, the majority of pregnant cows (14 of 16) spent time licking a newborn alien calf within the first 6 h of its birth (Edwards, 1983). Furthermore, 25% (Illmann and Špinka, 1993) and 33% of calves (Edwards, 1983) were observed suckling alien cows in group maternity areas. Creating a secluded area in the group pen may reduce interactions between cows and alien calves. For example, in the same study where Jensen et al. (2019) provided cows in group maternity areas with gated individual pens after calving, authors also found that calves born in the gated pens experienced less interaction from alien cows compared with those born in the ungated individual pens and the group pen area. Although there is limited research on the effect of the calving environment on cow-calf interactions, there is a growing interest in creating environments where dams can have some contact with their calves after calving (e.g., Johnsen et al., 2016). Research is encouraged to evaluate the effects of secluded environments on both the cow and her calf after birth.

STOCKING DENSITY

To date, research on stocking density has focused primarily on lactating or dry cows kept in freestalls. For example, increased stocking density above 100% is associated with a higher risk of hock injuries and lameness (Barrientos et al., 2013; King et al., 2016) and reduced milk production (3 cows:1 feed bin vs. 3 cows:2 or 3 feed bins, Crossley et al., 2017) in lactating cows. Overstocking has also been shown to decrease lying time (<1 freestall per cow, Fregonesi et al., 2007a) and increase agonistic interactions between lactating cows (0.5 vs. 1.0 m of feeding space per cow, DeVries et al., 2004; >1 cow per freestall and headlock, Krawczel et al., 2012). In dry cows, Huzzey et al. (2012) reported that overstocking (200% stocking: 0.5 lying stalls per cow and 34.5 cm of linear feed bunk space per cow) increased levels of circulating nonesterified fatty acids compared with 100% stocking density (1 lying stall per cow and 68.5 cm of linear feed bunk space per cow). Elevated nonesterified fatty acid levels are an indicator of adipose mobilization and metabolic health, which has been linked to postpartum disease (Ospina et al., 2010). In contrast, a study using close-up Jersey cows housed at 80 versus 100% stocking density did not find any physiological or health differences between treatments (Silva et al., 2014). The results of these studies may differ due to breed or the intensity of the overstocking; for example, cows may be better able to cope with lower stocking densities (e.g., 80–100%) compared with higher densities (e.g., 200%).

Increasing stocking density before calving can also affect social behavior. For example, Proudfoot et al. (2009) found that cows kept in freestalls before calving that were overstocked at electronic feed bins (2:1 cow:feed bins) pre-calving had over twice as many physical displacements from the feed bins compared with those not overstocked

(1:1 cow:feed bins). Similarly, cows housed at 80% stocking density (both lying and feed-bunk space) experienced fewer displacements from the feed bunk and spent more time lying down near parturition compared with those housed at 100% stocking density (Lobeck-Luchterhand et al., 2015).

Stocking density of group maternity areas is highly variable, as it depends on the combination of space allowance, cow movement in and out of the pen, and calving rate (the number of cows calving per given time period). Stocking density should be calculated at both the feed bunk and the usable lying space. Space allowance for these areas is likely fixed on most herds due to space constraints, but calving rate can vary over time (see Cook, 2019, for a detailed review of sizing dry cow pens). Space allowance is likely easier to control in all-in-all-out pens because new cows are not added to the pen as they are in dynamic pens, but space in both pen types may be a challenge.

Based on this research, Cook (2019) recommends building maternity areas to accommodate 120 to 150% of the average calving rate. Although constructing pens in this manner would lead them to be understocked at most times, this method would prevent overstocking of cows during periods of high calving rates. To our knowledge, no research has assessed the effect of high stocking density in group maternity areas. Despite this lack of research, we recommend at least 13 m² of lying space per cow, although >16 m² may better allow the cow to seek seclusion if needed (Proudfoot, 2019; see Figure 1 for an example of different stocking densities used in group calving pens). Research is strongly encouraged to better understand the effects of reduced space allowance on cow and calf behavior and health after calving in group maternity areas.

REGROUPING

Moving cows between social groups (regrouping) is a common management practice in dairy production. Cows are moved between pens based on stage of lactation, dietary needs, and reproductive status. Due to these factors, the majority of pen moves occur during the period around calving, resulting in up to 5 pen moves in a period of under 5 wk (Cook and Nordlund, 2004). Previous research has shown that agonistic interactions increase following regrouping (Brakel and Leis, 1976; Kondo and Hurnik, 1990; von Keyserlingk et al., 2008) as cows establish a new dominance hierarchy when newcomers are added (Hasegawa et al., 1997). Agonistic interactions between lactating cows have been found to return to normal approximately 3 d following regrouping (von Keyserlingk et al., 2008). However, depending on the frequency of regrouping in group maternity areas, cows may be constantly engaging in agonistic interactions with their pen mates.

Research using cows kept in freestalls before calving has found some effects of regrouping on cow health and behavior. For example, Schirmann et al. (2011) found that cows moved into a new pen during the close-up period



Figure 1. Cows in a group maternity area with 9.7 m² per cow (A) and 19.3 m² per cow (B).

had 9% lower DMI and rumination time, as well as higher agonistic interactions, on the day of regrouping compared with previous days. A series of studies documented the effect of dynamic (moving cows into a close-up pen weekly) versus all-in-all-out housing for close-up Jersey cows (Silva et al., 2013a,b; Lobeck-Luchterhand et al., 2014). Lobeck-Luchterhand et al. (2014) found that agonistic behaviors were lower in all-in-all-out pens than in dynamic pens, but there were no differences in physiological or health outcomes between the treatments (Silva et al., 2013a,b). Cook (2019) suggested that controlled studies on regrouping close-up cows may not be able to detect negative effects of regrouping when combined with other stressors such as overstocking. Indeed, in a study of mid-lactation cows in freestalls, Talebi et al. (2014) found when stocking density was decreased at regrouping, the number of displacements at the feed bunk decreased and lying time increased. Also in support of this idea, Proudfoot et al. (2019) found that close-up cows exposed to a combination of stressors (2:1 cow:feed bins as well as unpredictable social and feeding environments) had higher blood concentrations of nonesterified fatty acids and tumor necrosis factor- α and were more likely to be diagnosed with endometritis after calving compared with those in a more predictable environment (1:1 cow:bin without unpredictable social and feeding environments; Proudfoot et al., 2019).

More research is needed to determine the effect of regrouping on the behavior of dairy cows kept in group maternity areas. However, based on research using freestall pens and recommendations by Cook (2019), there may be benefits to reducing the frequency of regrouping events in group maternity areas to no more than once per week.

HYGIENE OF THE GROUP MATERNITY AREA AND RISK OF DISEASE

Immediately after birth is a high-risk period for cows and calves. An estimated 30 to 50% of cows experience metabolic (e.g., ketosis and hypocalcemia) or infectious disease (e.g., metritis and mastitis) after calving (see LeBlanc, 2010, for a review). Additionally, calf health is often compromised in the few days after birth; for example, in the United States, it has been reported that 5.6% of dairy heifer calves die within the first 48 h after birth (USDA, 2016). Ensuring the environment where the calf is born is clean is essential to limit the transmission of disease to both the dam and her calf.

Wet and dirty substrate in maternity areas potentially increases disease risk for cows and calves after calving. Regular cleaning and disinfection of maternity areas can potentially reduce disease incidence for fresh cows and calves. For example, a survey study found farms with maternity areas that were not disinfected after each calving had higher rates of clinical mastitis than farms that sometimes or always cleaned their maternity areas between each calving (Elbers et al., 1998). Donat et al. (2016) found that *Mycobacterium avium* ssp. *paratuberculosis*-positive farms were able to effectively control paratuberculosis with maternity area disinfection. Some research has also found associations between maternity area type (group or individual) and disease incidence in calves (Frank and Kaneene, 1993; Svensson et al., 2003; Pithua et al., 2009). Calves born in individual maternity areas in medium size herds (100–199 cows) had lower risk of diarrhea and calves born in individual maternity areas had lower risk for respiratory disease than calves born in group maternity areas (Frank and Kaneene, 1993; Svensson et al., 2003). However, more recently, a clinical trial found that calves born in group maternity areas were not at higher risk of diarrhea, pneumonia, or morbidity as compared with calves born in individual calving pens (Pithua et al., 2009). The link between maternity area type and calf disease is unclear, but it may be related to frequency of pen cleaning and not maternity area type. Proper pen management may be more important to reducing infectious disease than maternity area type, with an emphasis on cleaning maternity areas regularly.

The rate of cleaning maternity areas across dairy operations is highly variable. For example, Caraviello et al. (2006) found that less than half of herds that used individual maternity pens cleaned after every calving, with the majority of producers cleaning pens after 4 or more

calvings. Group maternity areas may be more difficult to clean after each calving compared with individual pens because they are larger and hold multiple animals at once.

Good maternity area cleanliness promotes cow comfort in addition to reducing disease risk. In mid-lactation, cows will avoid lying on wet substrate when possible and reduce their lying time up to 5 h per day when bedding is wet (Fregonesi et al., 2007b). In the few hours before giving birth, cows increase their lying time (Huzzey et al., 2005) and commonly give birth in a fully recumbent position (Schuenemann et al., 2011); thus, it is very important to keep the maternity area dry to improve cow comfort. To keep the maternity area clean and dry, it is recommended that fresh bedding be added daily and the whole pen be cleaned completely every 3 to 4 wk (Cook and Nordlund, 2004).

APPLICATIONS

The majority of research on group maternity areas has focused on creating opportunities for isolation-seeking behavior for dairy cows to facilitate the expression of natural calving behaviors. Some cows kept on pasture or indoors will seek seclusion from pen mates as calving approaches, but this behavior may be affected by availability of resources for cows to hide. More research is encouraged that provides cows with additional opportunities to seek isolation in group pens, such as fixtures in the pen that allow for more than one cow to hide at a time, creating hiding spaces that allow cows to walk a long distance to separate from pen mates as they would in a more natural setting (e.g., Flörcke and Grandin, 2014), or creating an area that facilitates prolonged contact between the dam and calf.

Despite the emerging research focused on behavior in group maternity areas, there is a clear need for additional research to explore the effects of group maternity areas on the behavior and health of parturient cows and their calves. Research using cows kept in individual pens may be extrapolated to those in group settings; however, there are likely unique stressors that cows face as they undergo labor in a group that requires additional research. For example, effects of problems that may arise from limited space, high stocking densities, regrouping, and other social interactions on the success of a cow's transition period are not well understood. We encourage more work aimed at developing group-housing systems that allow cows to express their natural behavior, while maintaining good hygiene and health for the dam and calf after calving.

ACKNOWLEDGMENTS

A USDA–National Institute of Food and Agriculture–Agriculture and Food Research Initiative Foundation grant (grant no. 2016-67015-24734) from the USDA National Institute of Food and Agriculture funded K. Creutzinger's graduate student stipend. We thank Peter Krawczel at University of Tennessee and Heather Dann at William H.

Miner Agricultural Research Institute for their contributions to the overall ideas presented in this review. The authors of this paper have no financial or personal relationships with other people or organizations that could inappropriately influence or bias the content of this paper.


LITERATURE CITED

- Barrientos, A. K., N. Chapinal, D. M. Weary, E. Galo, and M. A. G. von Keyserlingk. 2013. Herd-level risk factors for hock injuries in freestall-housed dairy cows in the northeastern United States and California. *J. Dairy Sci.* 96:3758–3765. <https://doi.org/10.3168/jds.2012-6389>.
- Beaver, A., R. K. Meagher, M. A. G. von Keyserlingk, and D. M. Weary. 2019. Invited review: A systematic review of the effects of early separation on dairy cow and calf health. *J. Dairy Sci.* 102:5784–5810. <https://doi.org/10.3168/jds.2018-15603>.
- Black, R., and P. Krawczel. 2016. A case study of behaviour and performance of confined or pastured cows during the dry period. *Animals (Basel)* 6:41. <https://doi.org/10.3390/ani6070041>.
- Brakel, W. J., and R. A. Leis. 1976. Impact of social disorganization on behavior, milk yield, and body weight of dairy cows. *J. Dairy Sci.* 59:716–721. [https://doi.org/10.3168/jds.S0022-0302\(76\)84263-4](https://doi.org/10.3168/jds.S0022-0302(76)84263-4).
- Calamari, L., F. Calegari, and L. Stefanini. 2009. Effect of different free stall surfaces on behavioural, productive and metabolic parameters in dairy cows. *Appl. Anim. Behav. Sci.* 120:9–17. <https://doi.org/10.1016/j.applanim.2009.05.013>.
- Campler, M. R., M. B. Jensen, and L. Munksgaard. 2018. The effect of deep straw versus cubicle housing on behaviour during the dry period in Holstein cows. *Appl. Anim. Behav. Sci.* 209:1–7. <https://doi.org/10.1016/j.applanim.2018.10.004>.
- Campler, M. R., L. Munksgaard, M. B. Jensen, D. M. Weary, and M. A. G. von Keyserlingk. 2014. Short communication: Flooring preferences of dairy cows at calving. *J. Dairy Sci.* 97:892–896. <https://doi.org/10.3168/jds.2013-7253>.
- Caraviello, D. Z., K. A. Weigel, P. M. Fricke, M. C. Wiltbank, M. J. Florent, N. B. Cook, K. V. Nordlund, N. R. Zwald, and C. L. Rawson. 2006. Survey of management practices on reproductive performance of dairy cattle on large US commercial farms. *J. Dairy Sci.* 89:4723–4735. [https://doi.org/10.3168/jds.S0022-0302\(06\)72522-X](https://doi.org/10.3168/jds.S0022-0302(06)72522-X).
- Cook, N. B. 2019. Designing facilities for the adult dairy cow during the nonlactation and early lactation period. *Vet. Clin. North Am. Food Anim. Pract.* 35:125–138. <https://doi.org/10.1016/j.cvfa.2018.10.008>.
- Cook, N. B., and K. V. Nordlund. 2004. Behavioural needs of the transition cow and considerations for special needs facility design. *Vet. Clin. North Am. Food Anim. Pract.* 20:495–520. <https://doi.org/10.1016/j.cvfa.2004.06.011>.
- Crossley, R. E., A. Harlander-Matauschek, and T. J. DeVries. 2017. Variability in behavior and production among dairy cows fed under differing levels of competition. *J. Dairy Sci.* 100:3825–3838. <https://doi.org/10.3168/jds.2016-12108>.
- DeVries, T. J., M. A. G. von Keyserlingk, and D. M. Weary. 2004. Effect of feeding space on the inter-cow distance, aggression, and feeding behavior of free-stall housed lactating dairy cows. *J. Dairy Sci.* 87:1432–1438. [https://doi.org/10.3168/jds.S0022-0302\(04\)73293-2](https://doi.org/10.3168/jds.S0022-0302(04)73293-2).
- Donat, K., M. Schmidt, H. Kohler, and C. Sauter-Louis. 2016. Management of the calving pen is a crucial factor for paratuberculosis control in large dairy herds. *J. Dairy Sci.* 99:3744–3752. <https://doi.org/10.3168/jds.2015-10625>.

- Duffy, J. H. 1981. The influence of various degrees of confinement and supervision on the incidence of dystocia and stillbirths in Hereford heifers. *N. Z. Vet. J.* 29:44–48. <https://doi.org/10.1080/00480169.1981.34796>.
- Edwards, S. A. 1983. The behavior of dairy cows and their newborn calves in individual or group housing. *Appl. Anim. Ethol.* 10:191–198. [https://doi.org/10.1016/0304-3762\(83\)90140-2](https://doi.org/10.1016/0304-3762(83)90140-2).
- Elbers, A. R. W., J. D. Miltenburg, D. De Lange, A. P. P. Crauwels, H. W. Barkema, and Y. H. Schukken. 1998. Risk factors for clinical mastitis in a random sample of dairy herds from the southern part of the Netherlands. *J. Dairy Sci.* 81:420–426. [https://doi.org/10.3168/jds.S0022-0302\(98\)75592-4](https://doi.org/10.3168/jds.S0022-0302(98)75592-4).
- Finger, A., K. P. Patison, B. M. Heath, and D. L. Swain. 2014. Changes in the group associations of free-ranging beef cows at calving. *Anim. Prod. Sci.* 54:270–276. <https://doi.org/10.1071/AN12423>.
- Flörcke, C., and T. Grandin. 2014. Separation behavior for parturition of Red Angus beef cows. *Open J. Anim. Sci.* 4:43–50. <https://doi.org/10.4236/ojas.2014.42007>.
- Fouda, M. M., C. J. Nicol, A. J. F. Webster, and M. A. Metwally. 1990. Maternal-infant relations in captive Sika deer (*Cervus nippon*). *Small Rumin. Res.* 3:199–209. [https://doi.org/10.1016/0921-4488\(90\)90038-8](https://doi.org/10.1016/0921-4488(90)90038-8).
- Frank, N. A., and J. B. Kaneene. 1993. Management risk factors associated with calf diarrhea in Michigan dairy herds. *J. Dairy Sci.* 76:1313–1323. [https://doi.org/10.3168/jds.S0022-0302\(93\)77462-7](https://doi.org/10.3168/jds.S0022-0302(93)77462-7).
- Fregonese, J. A., C. B. Tucker, and D. M. Weary. 2007a. Overstocking reduces lying time in dairy cows. *J. Dairy Sci.* 90:3349–3354. <https://doi.org/10.3168/jds.2006-794>.
- Fregonese, J. A., D. M. Veira, and M. A. G. Von Keyserlingk. 2007b. Effects of bedding quality on lying behavior of dairy cows. *J. Dairy Sci.* 90:5468–5472. <https://doi.org/10.3168/jds.2007-0494>.
- Hasegawa, N., A. Nishiwaki, K. Sugawara, and I. Ito. 1997. The effects of social exchange between two groups of lactating primiparous heifers on milk production, dominance order, behavior and adrenocortical response. *Appl. Anim. Behav. Sci.* 51:15–27. [https://doi.org/10.1016/S0168-1591\(96\)01082-9](https://doi.org/10.1016/S0168-1591(96)01082-9).
- Huzzey, J. M., D. V. Nysdam, R. J. Grant, and T. R. Overton. 2012. The effects of overstocking Holstein dairy cattle during the dry period on cortisol secretion and energy metabolism. *J. Dairy Sci.* 95:4421–4433. <https://doi.org/10.3168/jds.2011-5037>.
- Huzzey, J. M., M. A. G. von Keyserlingk, and D. M. Weary. 2005. Changes in feeding, drinking, and standing behavior of dairy cows during the transition period. *J. Dairy Sci.* 88:2454–2461. [https://doi.org/10.3168/jds.S0022-0302\(05\)72923-4](https://doi.org/10.3168/jds.S0022-0302(05)72923-4).
- Illmann, G., and M. Špinková. 1993. Maternal behavior of dairy heifers and suckling of their newborn calves in group housing. *Appl. Anim. Behav. Sci.* 36:91–98. [https://doi.org/10.1016/0168-1591\(93\)90001-6](https://doi.org/10.1016/0168-1591(93)90001-6).
- Jensen, M. B. 2012. Behaviour around the time of calving in dairy cows. *Appl. Anim. Behav. Sci.* 139:195–202. <https://doi.org/10.1016/j.applanim.2012.04.002>.
- Jensen, M. B., M. S. Herskin, and M. V. Rørvang. 2019. Secluded maternity areas for parturient dairy cows offer protection from herd members. *J. Dairy Sci.* 102:5492–5500. <https://doi.org/10.3168/jds.2018-15893>.
- Jensen, M. B., and M. V. Rørvang. 2018. The degree of visual cover and location of birth fluids affect dairy cows' choice of calving site. *J. Dairy Sci.* 101:9483–9492. <https://doi.org/10.3168/jds.2018-14724>.
- Johnsen, J., K. A. Zipp, T. Kälber, A. M. Passillé, U. Knierim, K. Barth, and C. M. Mejdell. 2016. Is rearing calves with the dam a feasible option for dairy farms?—Current and future research. *Appl. Anim. Behav. Sci.* 181:1–11. <https://doi.org/10.1016/j.applanim.2015.11.011>.
- King, M. T. M., E. A. Pajor, S. L. LeBlanc, and T. J. DeVries. 2016. Associations of herd-level housing, management, and lameness prevalence with productivity and cow behavior in herds with automated milking systems. *J. Dairy Sci.* 99:9069–9079. <https://doi.org/10.3168/jds.2016-11329>.
- Kondo, S., and J. F. Hurnik. 1990. Stabilization of social hierarchy in dairy cows. *Appl. Anim. Behav. Sci.* 27:287–297. [https://doi.org/10.1016/0168-1591\(90\)90125-W](https://doi.org/10.1016/0168-1591(90)90125-W).
- Krawczel, P. D., L. B. Klaiber, R. E. Butzler, L. M. Klaiber, H. M. Dann, C. S. Mooney, and R. J. Grant. 2012. Short-term increases in stocking density affect the lying and social behavior, but not the productivity, of lactating Holstein dairy cows. *J. Dairy Sci.* 95:4298–4308. <https://doi.org/10.3168/jds.2011-4687>.
- Lange, K., C. Fischer-Tenhagen, and W. Heuwieser. 2017. Predicting stage 2 of calving in Holstein Friesian heifers. *J. Dairy Sci.* 100:4847–4856. <https://doi.org/10.3168/jds.2016-12024>.
- LeBlanc, S. 2010. Monitoring metabolic health of dairy cattle in the transition period. *J. Reprod. Dev.* 56(Suppl.):S29–S35. <https://doi.org/10.1262/jrd.1056S29>.
- Leuthold, W. 1977. African Ungulates. Springer, Berlin, Germany.
- Lidfors, L. M., D. Moran, J. Jung, P. Jensen, and H. Castren. 1994. Behaviour at calving and choice of calving place in cattle kept in different environments. *Appl. Anim. Behav. Sci.* 42:11–28. [https://doi.org/10.1016/0168-1591\(94\)90003-5](https://doi.org/10.1016/0168-1591(94)90003-5).
- Lobeck-Luchterhand, K. M., P. R. B. Silva, R. C. Chebel, and M. I. Endres. 2014. Effect of prepartum grouping strategy on displacements from the feed bunk and feeding behavior of dairy cows. *J. Dairy Sci.* 97:2800–2807. <https://doi.org/10.3168/jds.2013-7401>.
- Lobeck-Luchterhand, K. M., P. R. B. Silva, R. C. Chebel, and M. I. Endres. 2015. Effect of stocking density on social, feeding, and lying behavior of prepartum dairy animals. *J. Dairy Sci.* 98:240–249. <https://doi.org/10.3168/jds.2014-8492>.
- Lott, D. F., and J. C. Galland. 1985. Parturition in American bison: Precocity and systematic variation in cow isolation. *Z. Tierpsychol.* 69:66–71. <https://doi.org/10.1111/j.1439-0310.1985.tb00757.x>.
- Mainau, E., and X. Manteca. 2011. Pain and discomfort caused by parturition in cows and sows. *Appl. Anim. Behav. Sci.* 135:241–251. <https://doi.org/10.1016/j.applanim.2011.10.020>.
- Meagher, R. K., A. Beaver, D. M. Weary, and M. A. G. von Keyserlingk. 2019. Invited review: A systematic review of the effects of prolonged cow-calf contact on behavior, welfare, and productivity. *J. Dairy Sci.* 102:5765–5783. <https://doi.org/10.3168/jds.2018-16021>.
- Miedema, H. M., M. S. Cockram, C. M. Dwyer, and A. I. Macrae. 2011a. Behavioural predictors of the start of normal and dystocic calving in dairy cows and heifers. *Appl. Anim. Behav. Sci.* 132:14–19. <https://doi.org/10.1016/j.applanim.2011.03.003>.
- Miedema, H. M., M. S. Cockram, C. M. Dwyer, and A. I. Macrae. 2011b. Changes in the behaviour of dairy cows during the 24 h before normal calving compared with behaviour during late pregnancy. *Appl. Anim. Behav. Sci.* 131:8–14. <https://doi.org/10.1016/j.applanim.2011.01.012>.
- NFACC (National Farm Animal Care Council). 2009. Code of practice for the care and handling of dairy cattle. Accessed Nov. 19, 2019. https://www.nfacc.ca/pdfs/codes/dairy_code_of_practice.pdf.
- Ospina, P. A., D. V. Nysdam, T. Stokol, and T. R. Overton. 2010. Evaluation of nonesterified fatty acids and β -hydroxybutyrate in transition dairy cattle in the northeastern United States: Critical thresholds for prediction of clinical diseases. *J. Dairy Sci.* 93:546–554. <https://doi.org/10.3168/jds.2009-2277>.
- Pithua, P., L. A. Espejo, S. M. Godden, and S. J. Wells. 2013. Is an individual calving pen better than a group calving pen for preventing transmission of *Mycobacterium avium* subsp. *paratuberculosis* in

- calves? Results from a field trial. *Res. Vet. Sci.* 95:398–404. <https://doi.org/10.1016/j.rvsc.2013.03.014>.
- Pithua, P., S. J. Wells, S. M. Godden, and E. A. Raizman. 2009. Clinical trial on type of calving pen and the risk of disease in Holstein calves during the first 90 d of life. *Prev. Vet. Med.* 89:8–15. <https://doi.org/10.1016/j.prevetmed.2009.01.001>.
- Proudfoot, K., M. Jensen, P. Heegaard, and M. von Keyserlingk. 2013. Effect of moving dairy cows at different stages of labor on behavior during parturition. *J. Dairy Sci.* 96:1638–1646. <https://doi.org/10.3168/jds.2012-6000>.
- Proudfoot, K. L. 2019. Maternal behavior and design of the maternity pen. *Vet. Clin. North Am. Food Anim. Pract.* 35:111–124. <https://doi.org/10.1016/j.cvfa.2018.10.007>.
- Proudfoot, K. L., M. B. Jensen, D. M. Weary, and M. A. G. von Keyserlingk. 2014a. Dairy cows seek isolation at calving and when ill. *J. Dairy Sci.* 97:2731–2739. <https://doi.org/10.3168/jds.2013-7274>.
- Proudfoot, K. L., D. M. Veira, D. M. Weary, and M. A. G. von Keyserlingk. 2009. Competition at the feed bunk changes the feeding, standing, and social behavior of transition dairy cows. *J. Dairy Sci.* 92:3116–3123. <https://doi.org/10.3168/jds.2008-1718>.
- Proudfoot, K. L., D. M. Weary, S. J. LeBlanc, K. Mamedova, and M. A. G. von Keyserlingk. 2019. Exposure to an unpredictable and competitive social environment affects behavior and health of transition dairy cows. *J. Dairy Sci.* 101:9309–9320. <https://doi.org/10.3168/jds.2017-14115>.
- Proudfoot, K. L., D. M. Weary, and M. A. G. von Keyserlingk. 2014b. Maternal isolation behavior of Holstein dairy cows kept indoors. *J. Anim. Sci.* 92:277–281. <https://doi.org/10.2527/jas.2013-6648>.
- Rice, C., N. Eberhart, and P. Krawczel. 2017. Prepartum lying behavior of Holstein dairy cows housed on pasture through parturition. *Animals (Basel)* 7:32. <https://doi.org/10.3390/ani7040032>.
- Rørvang, M. V., M. S. Herskin, and M. B. Jensen. 2017a. Dairy cows with prolonged calving seek additional isolation. *J. Dairy Sci.* 100:2967–2975. <https://doi.org/10.3168/jds.2016-11989>.
- Rørvang, M. V., M. S. Herskin, and M. B. Jensen. 2018a. The motivation-based calving facility: Social and cognitive factors influence isolation seeking behavior of Holstein dairy cows at calving. *PLoS One* 13:e0191128. <https://doi.org/10.1371/journal.pone.0191128>.
- Rørvang, M. V., B. L. Nielsen, M. S. Herskin, and M. B. Jensen. 2017b. Short communication: Calving site selection of multiparous, group-housed dairy cows is influenced by site of a previous calving. *J. Dairy Sci.* 100:1467–1471. <https://doi.org/10.3168/jds.2016-11681>.
- Rørvang, M. V., B. L. Nielsen, M. S. Herskin, and M. B. Jensen. 2018b. Prepartum maternal behavior of domesticated cattle: A comparison with managed, feral, and wild ungulates. *Front. Vet. Sci.* 5:45. <https://doi.org/10.3389/fvets.2018.00045>.
- Schirmann, K., N. Chapinal, D. M. Weary, W. Heuwieser, and M. A. G. von Keyserlingk. 2011. Short-term effects of regrouping on behavior of prepartum dairy cows. *J. Dairy Sci.* 94:2312–2319. <https://doi.org/10.3168/jds.2010-3639>.
- Schuenemann, G. M., I. Nieto, S. Bas, K. N. Galvão, and J. Workman. 2011. Assessment of calving progress and reference times for obstetric intervention during dystocia in Holstein dairy cows. *J. Dairy Sci.* 94:5494–5501. <https://doi.org/10.3168/jds.2011-4436>.
- Silva, P. R., A. R. Dresch, K. S. Machado, J. G. Moraes, K. Lobeck-Luchterhand, T. K. Nishimura, M. A. Ferreira, M. I. Endres, and R. C. Chebel. 2014. Prepartum stocking density: Effects on metabolic, health, reproductive, and productive responses. *J. Dairy Sci.* 97:5521–5532. <https://doi.org/10.3168/jds.2014-8093>.
- Silva, P. R., J. G. Moraes, L. G. Mendonça, A. A. Scanavez, G. Nakagawa, M. A. Ballou, B. Walcheck, D. Haines, M. I. Endres, and R. C. Chebel. 2013a. Effects of weekly regrouping of prepartum dairy cows on innate immune response and antibody concentration. *J. Dairy Sci.* 96:7649–7657. <https://doi.org/10.3168/jds.2013-6752>.
- Silva, P. R. B., J. G. N. Moraes, L. G. D. Mendonça, A. A. Scanavez, G. Nakagawa, J. Fetrow, M. I. Endres, and R. C. Chebel. 2013b. Effects of weekly regrouping of prepartum dairy cows on metabolic, health, reproductive, and productive parameters. *J. Dairy Sci.* 96:4436–4446. <https://doi.org/10.3168/jds.2012-6464>.
- Svensson, C., K. Lundborg, U. Emanuelson, and S. Olsson. 2003. Morbidity in Swedish dairy calves from birth to 90 days of age and individual calf-level risk factors for infectious diseases. *Prev. Vet. Med.* 58:179–197. [https://doi.org/10.1016/S0167-5877\(03\)00046-1](https://doi.org/10.1016/S0167-5877(03)00046-1).
- Talebi, A., M. A. G. von Keyserlingk, E. Telezhenko, and D. M. Weary. 2014. Reduced stocking density mitigates the negative effects of regrouping in dairy cattle. *J. Dairy Sci.* 97:1358–1363. <https://doi.org/10.3168/jds.2013-6921>.
- Tucker, C. B., D. M. Weary, and D. Fraser. 2003. Effects of three types of free-stall surfaces on preferences and stall usage by dairy cows. *J. Dairy Sci.* 86:521–529. [https://doi.org/10.3168/jds.S0022-0302\(03\)73630-3](https://doi.org/10.3168/jds.S0022-0302(03)73630-3).
- USDA. 2016. Dairy 2014, Dairy Cattle Management Practices in the United States, 2014. USDA–Anim. Plant Health Insp. Serv.–Vet. Serv., Center Epidemiol. Anim. Health, Natl. Anim. Health Monit. Syst., Fort Collins, CO. #692.0216.
- Vasseur, E., F. Borderas, R. I. Cue, D. Lefebvre, D. Pellerin, J. Rushen, K. M. Wade, and A. M. de Passillé. 2010. A survey of dairy calf management practices in Canada that affect animal welfare. *J. Dairy Sci.* 93:1307–1316. <https://doi.org/10.3168/jds.2009-2429>.
- Villetaz Robichaud, M., A. M. de Passillé, D. L. Pearl, S. J. LeBlanc, S. M. Godden, D. Pellerin, E. Vasseur, J. Rushen, and D. B. Haley. 2016. Calving management practices on Canadian dairy farms: Prevalence of practices. *J. Dairy Sci.* 99:2391–2404. <https://doi.org/10.3168/jds.2015-9641>.
- von Keyserlingk, M. A. G., D. Olenick, and D. M. Weary. 2008. Acute behavioral effects of regrouping dairy cows. *J. Dairy Sci.* 91:1011–1016. <https://doi.org/10.3168/jds.2007-0532>.
- von Keyserlingk, M. A. G., and D. M. Weary. 2007. Maternal behavior in cattle. *Horm. Behav.* 52:106–113. <https://doi.org/10.1016/j.yhbeh.2007.03.015>.

ORCIDS

Kathryn L. Proudfoot  <https://orcid.org/0000-0001-5877-2431>