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Use of space in the domestic fowl: separating the effects of enclosure size, group size and density

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An understanding of how confined animals move within the space available to them is essential in the design of effective captive environments that maximize animal welfare. In addition to the obvious effect of enclosure size, other factors such as the number of individuals in the group and their density per unit of area are likely to affect movement patterns. Yet determining the specific contribution of each (enclosure size, group size and density) is a challenge because confounding between two or more of these factors is experimentally difficult to avoid. The aim of our study was to isolate their unique effects by using multiple contrasts with an efficient experimental design that included combinations of groups of 10, 20 and 30 domestic fowl (*Gallus gallus domesticus*) housed in 1.5, 3.0 and 4.5 m^2 enclosures. This treatment structure enabled us to make comparisons across increasing enclosure size at both constant group size and constant density. In this study we show that enclosure size and density are the primary factors affecting patterns of movement and use of space for groups of domestic fowl. Animals in larger enclosures maintained larger nearest-neighbour distances, travelled greater distances and had bigger home ranges as measured by minimum convex polygons. These results suggest that larger enclosures encourage more exploratory movement in groups of domestic fowl. However, the positive effects of large enclosures may be limited by the effects of density. In this study, we found that group size had few effects.

Keywords: density; domestic fowl; enclosure size; *Gallus gallus domesticus*; group size; movement; space use

The evolutionary benefits of living in groups are well understood (for review see Krause & Ruxton 2002). By living in a group individuals benefit from reduced predation risk (Hamilton 1971), enhanced foraging opportunities (Clark & Mangel 1986) or increased positive social interactions. Although we commonly consider the behavioural dynamics of entire groups (Estevez et al. 2002), it is the decisions of each individual that ultimately shape the collective behaviour of the social group (Gueron et al. 1996). Individuals can opt to be closer to their groupmates to reduce predation risk, or maintain greater distances to minimize competition for resources (Leone & Estevez 2008b). Members can choose to remain in the group or abandon it. Animal movement and use of space are therefore integral components of social grouping and one of the main mechanisms that can bring a group together or tear it apart.

The movements of individuals within a group may be based on both density-independent and density-dependent decisions (Gueron et al. 1996), because animals respond to internal motivation states as well as a wide range of environmental factors. Even in a homogeneous group small differences in environmental, nutritional, or emotional and motivational states may influence an individual's behavioural decisions that will ultimately shape the overall structure and cohesion of the group. Arnold & Maller (1985) described spacing patterns as being determined by 'social' and 'individual' distances among group members. These two factors act as attractive and repulsive forces shaping group spacing and specifically

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interindividual distances among animals (Warburton & Lazarus 1991). Keeling & Duncan (1991) showed that domestic fowl (*Gallus gallus domesticus*) adjusted their interindividual distances according to their activity, with the smallest distances observed while resting and the largest during foraging. Variation in interindividual distances according to activity was also shown by Michelena et al. (2008) in groups of merino sheep (*Ovis aries*). Similar to domestic fowl, the closest proximity was observed during resting periods. Even variation in social segregation can be explained by small differences in the speed of movement (Michelena et al. 2004). These examples show the clear link between animal movement and social dynamics.

Understanding how wild animals use space has been recognized as a key element in population biology (see Wu et al. 2000). For captive species, understanding the connexion between movement and social behaviour may be even more critical. In confinement, animals are constrained by the space and conditions provided for them; they cannot disperse or abandon the group when conditions become adverse, as they are restrained within the limits of the enclosure. Inadequate physical and social features of the captive environment can be a source of discomfort and stress that can lead to serious physiological, behavioural and welfare problems (Estevez et al. 1997, 2007; Würbel 2001; Morgan & Tromborg 2007). Enclosure size is a feature of critical importance for captive animals, because they are willing to work actively to gain access to additional space (Faure 1991, 1994; Sherwin 2004, 2007). In addition to enclosure size, animal movement in captive environments may be limited by specific features such as environmental complexity.

The physical features of the captive environment, specifically the complexity of the environment (Estevez, in press) and the amount of perimeter space available (Christman & Leone 2007), can have a major influence on movement and interindividual distances (Stricklin et al. 1979; Jeanson et al. 2003; Jensen et al. 2003; Leone et al. 2007). The impact of the structural characteristics may be especially relevant in small enclosures or when maintaining high animal densities, as interactions among animals become more intricate (Estevez et al. 1997, 2002; Febrer et al. 2006). One of the most distinct features of space use in captive animals is their strong attraction to enclosure walls, as can be seen in the domestic fowl (Cornetto & Estevez 2001). This attraction is such that even when domestic fowl are maintained at high densities individuals will aggregate near the wall, while the centre of the enclosure remains unoccupied. However, when wall-like structures are provided, the use of central areas improves dramatically, resulting in a more homogeneous spatial distribution with subsequent benefits for the health, welfare, and performance of the animals (Cornetto et al. 2002). Interindividual distances among chickens as well as their home ranges are also affected by environmental complexity, with larger distances and home ranges observed in complex environments (Leone et al. 2007; Leone & Estevez 2008a).

Although previous research has been conducted on the impacts of enclosure size, group size and density in poultry and other species (for example Alanärä 1996; Sørensen et al. 2005; Estevez et al. 2007; Morgan & Tromborg 2007), these studies all involved some degree of confounding between factors. For example, group size has to be manipulated when testing for density effects in enclosures of equal size, leading to confounding between density and group size. Thus the reduction in locomotion associated with high densities (Estevez et al. 1997) may be a consequence of the decline in 'free' enclosure space, which is reduced as animal density increases (Newberry & Hall 1990) in enclosures of constant size, rather than the increased social conflict and social restriction as a result of large group sizes as suggested by some authors (McBride & Foenander 1962).

In these studies it is difficult to isolate the precise contributions of enclosure size, group size and density to changes in behaviour and movement patterns. Yet a clear understanding of the effects of each factor is critical to improve the quality of the environment for captive animals. This is particularly relevant in production systems in which space is a precious commodity, and potential legislative actions are being considered concerning suitable space allowances/densities that would ensure the welfare and health of broiler chickens (European Commission 2005). It is obvious that recommendations on minimum space requirements cannot be based on the simplistic view of mere units of space per animal. Features such as the structural characteristics of the environment or social aspects of the group (such as group size or density) must also be considered to establish meaningful recommendations.

In this study we use broiler chickens as our species model. Broilers, as with other genetic lines of domestic fowl, are descended from the red jungle fowl (*Gallus gallus*; Siegel et al. 1992; Fumihito et al. 1994); both the ancestor and the domestic species are characterized as being highly social with a clear dominance hierarchy when in small groups (Schjelderup-Ebbe 1922). Broilers can reach a body weight of around 2–3 kg in about 6 weeks and are often housed at high densities upwards of 15 birds/m^2 (Estevez 2007). Because of their efficient growth rate broiler chickens are the most commonly raised domestic species around the world, with 8.9 thousand million chickens raised annually in the United States alone (National Agricultural Statistics Service 2007). The results of this study are likely to have direct implications for their management, as enclosure size, group size and density are commonly manipulated in production systems. We hypothesized that each characteristic of the environment, enclosure size, group size and density, has a unique impact on movement and space use in the domestic fowl and we used a unique experimental design to separate the confounded effects of each factor.

METHODS

Facilities and Experimental Animals

This project was conducted at the University of Maryland's Applied Poultry Research Facility in Upper Marlboro, Maryland, U.S.A., from September through November 2005. We