Etología, 3:219-234 (1993)

The space-time continuum, and its relevance to farm animals

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ABSTRACT. *The space-time continuum, and its relevance to farm animals*.- Space for farm animals has been viewed in a simplistic manner as an area of floor space per animal, and it has been assumed that a linear increase in floor space per animal will translate into a linear improvement in animal welfare. Arbitrary space guidelines have been established based on economic and political pressures. This paper reviews the complexities of space use by farm animals from a biological perspective, taking into account the impact of barriers to dispersal, consequences of restricted space on fitness, availability of resources, motivation to gain access to different locations, the impact of time budgets on use of space for exploration and locomotory play, the influence of anti-predator behaviour on use of space, and sharing of space. It is concluded that farm animal welfare will be better served by attention to methods of reducing mortality and morbidity up to the point of slaughter than by setting floor space guidelines using simplistic formulas based on body size and housing type.

KEY WORDS. Animal welfare, Use of space, Time budgets, Animal housing, Exploration, Anti-predator behaviour

Introduction

The term "space-time continuum" may evoke thoughts on the vastness of outer space. However, I wish to consider a different aspect of space, that relating to the limited space which we, as human predators, provide our domesticated prey species. The vision of farm animals being kept in small spaces which greatly restrict movement or in close proximity in large groups has generated public concern for farm animal well-being. This concern has prompted the development of national legislation (eg. Her Majesty's Stationary Office, 1987) or voluntary codes of practice (eg. Agriculture Canada, 1989) stipulating space allowances for farm animals.

Space standards usually represent a compromise at some arbitrary point between the demands of animal producers for stocking levels which maintain economic competitiveness and the demands of animal welfarists for space in which animals can express a full behavioural repertoire. There are inconsistencies between countries in the adoption of legislation on space allocations and in the standards set in those countries where legislation does exist. Thus, we can find a whole array of different recommended space allowances for the same species kept under similar conditions, all in the guise of promoting animal welfare.

It is not clear that legislation on space allocations is effective in promoting farm animal welfare. In some cases, space recommendations may merely serve to support the *status quo*. Where legislation demands more generous space allocations, economic pressures can result in loss of market share and the importation of cheaper products from countries with less stringent regulations. For example, Denmark changed from being an egg exporting country to an egg importing country (Appleby et al., 1992) after the introduction in 1988 of a minimum floor area allocation of 0.06 m^2 per animal for caged laying hens (domestic fowl, *Gallus gallus domesticus*, selected for egg production). If legislation is to improve farm animal welfare, it is essential to consider the full economic and ethical impact of changes to existing space allocations, including the impact on international trade.

Legislation banning confinement of animals in small cages or stalls can replace one set of welfare problems associated with restricted movement with a new set of welfare problems associated with housing of animals in alternative housing systems in larger groups. Problems may include reduced access to resources, increased disturbance of resting animals by active group members and increased risk of exposure to cannibalistic individuals, pathogens and parasites. In the absence of an objective method for quantifying animal well-being (eg. how to weigh suffering from pain against suffering from hunger, how to balance a major risk to future well-being against a minor risk to current well-being, etc.), difficulties exist in comparing the degree of welfare of animals in different housing systems. Appropriate legislation on farm animal welfare is also difficult in the absence of an ethical framework for deciding how much suffering is acceptable in terms of the severity and duration of suffering by individuals, and the number of animals involved. Furthermore, legislation for specific space allocations implies that there is a fixed amount of space above which welfare is good and below which welfare is poor. Use of a cut-off point for determining animal welfare implies a level of scientific rigour which does not exist (Mendl, 1991; Rushen & de Passillé, 1992). It is suggested that, rather than legislating for increased space or banning certain methods of confinement, a more effective strategy for improving farm animal welfare will be to concentrate on reducing the incidence of life-threatening conditions such as injuries, diseases, malnutrition, dehydration and heat or cold stress. It is assumed that these conditions are associated with acute or prolonged unpleasant emotional states (ie. suffering - Dawkins, 1980).

This paper reviews different approaches to the determination of appropriate space allocations for farm animals and points out some of the difficulties associated with such efforts. Space is considered from a biological perspective, taking into account barriers to dispersal, enclosure size, shape and structure, and the availability of resources within time and space. Emphasis is placed on assessing how animals use different parts of their environment at different times rather than attempting to define a single, rigid space allocation per animal. Methods for stimulating activity are examined as a means of ensuring that animals maintained in confined conditions have sufficient physical fitness to withstand future changes in environment. Enabling animals to access alternative spaces for limited periods of time is suggested as one way of promoting fitness through stimulation of exploration and play.

Use of space by intensively farmed *versus* free-living animals

One approach to the assessment of space requirements involves observing use of space by domestic farm animals or their wild relatives under natural or semi-natural conditions. Intensive farming of domestic species involves confinement of animals at high densities with no opportunity for dispersal and in groups differing in size and composition from those found in natural environments. Under intensive husbandry, adult dairy cows (*Bos taurus*) and calves may be maintained indoors continuously on tethers or in stalls which restrict movement to about two steps forward and backward and which limit physical contact with conspecifics to that with the neighbour on either side. Clearly, the movement and social behaviour of these cattle is greatly restricted by comparison with that of free-ranging cows with calves, such as those in the Chillingham herd which roam over the entire 134-ha park (Hall, 1989). Similarly, domestic pigs (*Sus scrofa*) in the 2.3-ha Edinburgh Pig Park used more space in their daily movements between foraging and nest sites and were able to interact with a wider variety of individuals of different ages and gender (Newberry & Wood-Gush, 1986; Stolba & Wood-Gush, 1989) than is possible when pigs are confined indoors within stalls, farrowing crates or small pens. Stolba (1981) used information gained from observations of use of space and spatial relationships between group members in the Pig Park to design "enriched pens" for pigs.

Depending on the habitat and time of year, free-living domestic fowl, and red junglefowl (*Gallus gallus*) from which domestic fowl are thought to be derived (Crawford, 1990), may be found in flocks comprised of 5-15 individuals including a dominant adult male, two or more hens and one or more subordinate males (Johnson, 1963; McBride et al., 1969; Nishida et al., 1992). The location and size of the home range is influenced by the presence of roosting sites, food and water (Collias & Collias, 1967). If these resources are readily available, individuals show strong site attachment and range no more than about 70 m away from the flock roost site (Collias et al., 1966). Hens separate from the group to raise their broods alone, although a yearling male may assist in feeding of the chicks (Stokes, 1971). Wood-Gush et al. (1978) reported home range sizes of 0.09-2 ha for individual hens with broods in a population of domestic fowl released on an island off the coast of Scotland.

Broiler chickens (domestic fowl selected for meat production) are typically reared from hatch to 6 weeks of age on the floor in large sheds in flocks of 10,000 or more chickens (eg. 10,000 chickens in a 12 X 57 m shed). By comparison with free-ranging fowl, movements of these chickens are probably not greatly restricted by the size of their enclosure. At least some broiler chickens move over most of the floor area at some time or another despite high stocking densities and large group sizes, although movement may be limited by the physical presence of chickens blocking the path of movement (Newberry & Hall, 1988; 1990). On the other hand, adult laying hens in flocks of 6,000 or more are typically divided into sub-groups of 3-7 hens, each confined within a small wire cage providing about 0.14-0.42 m^2 of floor space (varying with group size and between countries) for a period of one year or more. The movement of these hens is extremely restricted by comparison with free-living hens. Nevertheless, comparisons of use of space in intensive and more natural conditions can only be suggestive of problems with lack of space in intensive housing, since use of space under natural conditions is greatly influenced by local ecological conditions, and farm animal species show tremendous capacity to adapt to different environments.

Barriers to dispersal

Some wildlife ethologists may be inclined to dismiss farm animals as being unworthy of study when kept under unnaturally restricted spatial conditions and subjected to artificial selection pressures. Therefore, it is worth noting that farm animals continue to exhibit behaviour patterns shaped by natural selection during their evolutionary history. Domestic fowl, for example, perform anti-predator responses such as tonic immobility (Arduino & Gould, 1984) and context-specific alarm calling (Gyger et al., 1986) even though these responses have no obvious adaptive value in an intensive farming environment. Domestication has changed the intensity and completeness of certain behaviour patterns (Wood-Gush, 1983) but the behavioural repertoire is based on millions of years of natural selection and the behaviour exhibited follows the same underlying rules as that of wild animals (Price, 1984).

Farm animals show many adaptations typical of wild animals living on islands in which dispersal is prevented by physical barriers created by water courses, mountains, roadways or other inhospitable environments, and predation pressure is reduced. Features of island dwellers include increased size, a more sedentary nature, loss of migratory behaviour, reduced wariness and adaptation to relatively high population density (MacArthur & Wilson, 1967). Under intensive farming conditions, individuals or groups are physically separated from one another and dispersal is prevented by walls or restraining devices. The islands thus created can be extremely small relative to the animals' body size and usually contain very rich food patches, with low travelling times required between patches and with the food requiring very little handling time. These conditions allow for a relaxation of time budget constraints due to a reduction in time required for foraging. They also allow for a reduction in physical activity since less effort is required to locate and utilize essential resources. Thus, farm animals will usually have more energy available for investment in growth and reproduction than wild animals. Nevertheless, extreme spatial restriction may be beyond the adaptive capacity of some individuals, with negative consequences for animal welfare.

Consequences of restriction of movement

The confinement of individuals or small groups of animals in stalls, cages and small pens which restrict movement and prevent the performance of rapid locomotion can have adverse effects on physical condition, resulting in increased susceptibility to injuries and other health problems. In a Swedish study, dairy cows kept continuously on tethers were more susceptible to parturient paresis, clinical ketosis, bloat, mastitis, non-infectious leg and claw disorders and hock lesions than cows given the opportunity to walk 0.4 - 3 km daily (depending on time of year). They also spent more time preparing to lie down, and had more interruptions when lying down, than exercised cows (Gustafson, 1993). Sows are housed in farrowing crates in order to prevent crushing of piglets when the sow lies down. However, lack of exercise in farrowing crates may contribute to piglet mortality if the sows are physically unable to lower themselves gently to the floor when lying down or to stand up quickly if they lie on a piglet.

Cages do not provide sufficient space for wing flapping and flying by laying hens (Bognor et al., 1979; Dawkins & Hardie, 1989; Nicol, 1987). Lack of exercise contributes to bone fragility in caged hens (Meyer & Sunde, 1974; Knowles & Broom, 1990; Nørgaard-Nielsen, 1990). Although bone fragility may not cause suffering for hens while living in cages, problems occur when the hens are handled, especially when removed from cages and transported to the slaughter house. During this period, the hens are at high risk of sustaining bone fractures. Gregory & Wilkins (1989) reported that 29% of caged hens had freshly broken bones following transport to the slaughter house. Thus, consideration of space requirements for farm animals should not be made solely on the basis of space to maintain welfare in the short term but should consider the impact on future welfare, especially when animals are to be subjected to handling and transportation to a new environment. Of course, if increased space is provided and vigorous activity is stimulated, it is important to design the space in such a way as to prevent injuries resulting from collisions or crash landings. Reports of a high incidence of broken bones among laying hens in some aviaries are of concern in this respect (Gregory et al., 1991).

Recommendations on space have been based on formulas for body weight (Edwards et al., 1988) or body surface area (Hurnik & Lewis, 1991), with more space being allocated to older animals due to their larger body size. Although this method is realistic if the sole intent is to house as many individuals within a pen as is physically possible, it does not take into account changes in activity profiles during ontogeny. In free-range pigs, peak levels of playful running occur between 2 and 6 weeks of age, prior to commencement of natural weaning (Newberry & Wood-Gush, 1988; Newberry et al., 1988). Running play is energetically costly, implying that this behaviour has adaptive value and is actively maintained by natural selection (Miller & Byers, 1991). In view of the potential benefits of physical exercise on current and future fitness (Fagen, 1981), it is argued that young animals should be provided with sufficient unobstructed space to allow for locomotory play. The possibility that older, more sedate animals may require less space relative to their body size should be investigated. Farmers are often reluctant to provide extra space to stimulate activity because of increased energy use by the animals resulting in higher feed costs. However, there may be alternative benefits to exercise stimulated by space, including a reduction in the fat content of animal products, improved survival until the point of slaughter and a reduction in injuries resulting in carcass losses.

Space guidelines, productivity and welfare

Productivity (ie. growth rate or reproductive output) has been a major factor used in decisions regarding space allocations for farm animals, based on an underlying assumption that welfare is compromised when animals are producing at less than maximum rates and that a linear increase in floor space per animal will translate into a linear improvement in animal welfare. However, under confined conditions, the relationship between space and productivity is not linear but curvilinear. Rapid improvements in productivity occur with increasing space at low space allowances and more gradual improvements occur at higher space allowances up to a maximum (Kornegay & Notter, 1984; Adams & Craig, 1985; Shanaway, 1988). There has been little systematic investigation of productivity at even higher space allocations but productivity could decline if, for example, further increases in floor space were associated with increased energy expenditure on travel between food, water and resting sites, increased energy expenditure on agonistic behaviour associated with the emergence of resource defence, or reluctance to cross large empty spaces to obtain food.

Small improvements in productivity with increasing space at intermediate space allowances are unlikely to compensate for the additional cost of building, maintaining and operating the extra barn space and associated equipment. Furthermore, increasing the space allowance per animal also results in higher feed, or heating, costs in areas with a cool climate due to the reduced metabolic heat production in the barn. Therefore, maximum profits generally occur at space allocations below those which maximize productivity, creating an economic pressure to crowd animals. For example, increased egg production can occur with increased floor space over the range of 0.030-0.065 m^2/hen (Hughes, 1983a) but profits can be maximized at less than 0.04 m^2/hen when margins (egg prices relative to feed costs) are high (Adams & Craig, 1985; Roush, 1986). Space guidelines usually fall at some arbitrary point between maximizing profits and maximizing productivity. Thus, a European Community Directive (Commission of the European Communities, 1988) stipulates a minimum space allocation of 0.045 m^2/hen for caged laying hens. Yet, hen welfare could be improved beyond that possible in a conventional cage with sufficient space for maximum production (eg. 0.065 m^2/hen) if the cages provided space for unrestricted movement and access to foraging, nesting, dust bathing and perching sites (Appleby, 1993).

Relationships between space, productivity and animal welfare are complex. Welfare may be compromised due to poor design of housing space (eg. slippery flooring, poorly positioned bars which trap body parts, cold draughts) regardless of floor area. Productivity may be good despite reduced welfare associated with restricted movement. Gustafson (1993) reported that dairy cows had poorer health when tethered indoors continuously than when given access to an outdoor exercise area but were able to produce the same amount of milk. Providing more space does not automatically result in greater well-being. For example, an increase in floor space per animal without modifications to the heating and ventilation system can create problems with condensation and wet litter, which may result in suffering from cold stress and ammonia-induced eye, respiratory tract and skin lesions.

Productivity may vary according to environmental temperature, feeding regimens and other environmental factors but these differences may be within the adaptive capacity of the animals and cause no significant level of suffering. On the other hand, high productivity may promote the development of metabolic diseases which compromise welfare such as leg bone deformities and ascites in poultry, which are associated with rapid early growth (Classen et al., 1991; Blair et al., 1993). Confined farm animals may have poor welfare and still achieve a high level of reproductive success by comparison with wild animals since they can produce many offspring without having to invest as much energy in their care (eg. eggs removed from hens and hatched in artificial incubators, piglets weaned from the sow at a young age and fed separately). Thus, providing sufficient space to maximize productivity may not be sufficient to safeguard well-being.

Availability of resources in space and time

Space-related limitations on productivity may be associated with reduced welfare due to reduced access to resources. For example, caged hens with insufficient space to obtain ready access to the feed trough eat less food, produce fewer eggs, and can have a higher mortality rate (Hughes, 1983b). Reduced access to feed may provoke increased risk-taking, raising the probability of injury from accidents and attacks by conspecifics, and inanition may compromise the thermoregulatory and immune systems. If cage size is increased so that all hens in the cage can feed at the same time, feed intake increases. However, a similar increase in feed intake can be obtained by changing the cage orientation so that the food trough is located along a long wall of a rectangular cage rather than a short wall, thereby allowing all hens to stand side by side to eat at the feed trough (Hughes, 1983b).

Sufficient space for syncronized access to resources will be important if all group members are motivated to access the same resource at the same times of day (eg. feeding at the start and end of the photoperiod). Low ranking animals may have to wait for access to feed if access is limited, as is the case of dairy cows in large groups with limited feeding stations (Wierenga, 1991). Waiting may reduce productivity and welfare if animals are exposed to danger while waiting, forced to feed at less optimum times and have less time for resting. Galindo & Broom (1993) reported that submissive cows spent more time standing in slurry, and that standing time was positively correlated with the occurrence of foot lesions. Therefore, in considering the impact of space on productivity and welfare, it is important to look at the mechanism by which productivity is being limited (eg. due to restricted access to an essential resource). In some cases, a change in the orientation, shape, height, structure or interior design of an enclosure, or increasing the number of feeding sites or frequency of feed renewal, may be more effective in improving productivity and welfare than increasing the size of the enclosure.

Enclosure size and shape

Space guidelines are generally presented as a two-dimensional area of floor space per animal, space which is generally provided in a rectangular form. When maintained in individual enclosures, the total floor space available is the same as the floor space per animal. However, when farm animals are kept in groups rather than individually, they are potentially able to move throughout the entire enclosure, thereby sharing the available space with other group members. In this case, actual use of space within the enclosure may be limited by factors such as territoriality (McBride & Foenander, 1962), ability to obtain access to resources during scramble competitions, locomotory ability and the physical space occupied by other group members. Therefore, consideration of the effects of enclosure size and shape on survival and health seems more meaningful from a biological perspective than concentrating simply on floor area per animal.

Schouten (1991) reported on the importance of providing young pigs with a sufficiently large enclosure during rearing to enable threatening behaviour. He noted that, in small pens, fights often started without warning and biting was more frequent than in large pens. Zhou & Stricklin (1992) used computer simulations to demonstrate an interaction between pen shape and group size, independent of floor area per animal. To minimize encounters between animals during random movements around a pen, triangular pens had an advantage for housing three animals, and square pens for housing four animals. Lou & Hurnik (1993) reported that use of oval rather than rectangular farrowing crates for sows resulted in fewer piglet crushings. Although space guidelines usually specify more space per animal for individually- than group-housed animals, many variables can affect actual patterns of space use by different individuals. Thus, a simple set of guidelines on floor area per animal is unlikely to secure the well-being of all individuals. In addition, greater attention to the vertical housing space is warranted, both in terms of physical use of the space by animals and the impact of animal density and patterns of space use on the atmospheric environment (dust, gases, temperature and humidity).

Consumer demand theory and working for space

A popular approach for identifying appropriate environments for farm animals on welfare grounds has been to determine how much work an animal is prepared to do to obtain different environmental resources. This method is based on consumer demand theory (Dawkins, 1983; 1990). Inelastic commodities (essentials) are those which the animal will continue to demand as the price (amount of effort required, or time required relative to time available) is increased whereas elastic commodities (luxuries) are those for which the animal is not willing to pay a high price to obtain. Dawkins (1983) reasoned that commodities for which the animal is willing to pay a high price must be considered essential by the animal and should therefore be provided to ensure the animal's welfare.

This approach has been used to assess the importance of space to laying hens (Mills et al., 1987; Lagadic & Faure, 1988). Hens were kept in groups of four in a cage with one moveable wall. By pecking on a key, the hens could cause the wall to move out to expand the cage. The wall would move back to its original position if the hens stopped pecking at the key but, by continuing to peck at the key, the hens could obtain access to increasing increments of cage space. The results showed that the hens spent most time in cage sizes providing 0.04-0.0625 m^2 of floor space/hen and were willing to peck for the maximum possible space (0.1525 m^2/hen) on only a small proportion of days. Furthermore, some hens avoided cage sizes providing about 0.1-0.1075 m^2/hen, pointing to a non-linear relationship between space and well-being. Interestingly, Al-Rawi & Craig (1975) had previously reported a curvilinear relationship between cage floor area/hen and frequency of agonistic pecks and threats, with a higher frequency occuring at 0.0824 m^2/hen than at 0.0412 or 0.2884 m^2/hen. Mills et al. (1987) concluded that hens are not particularly motivated to work for increased cage sizes. A similar experiment indicated elasticity in the willingness of rabbits (*Oryctolagus cuniculus*) to work for increased space (Kienle & Bessei, 1993).

These results could lead to the conclusion that extra space is a luxury rather than an essential commodity. Nevertheless, caution is urged in interpreting the results of this type of experiment. Results could be very sensitive to the methodology. Entirely different results could be obtained if the space was increased in three dimensions rather than one dimension, providing sufficient space for running, wing flapping, flying and other space-demanding behaviours. Birds may be inhibited from flying in a narrow space because of a perceived risk of crashing even if the space is theoretically large enough for flying by a skilled bird under ideal conditions (Guilford, 1988). Factors such as adequate footing for rapid locomotion, location of resources such as food, water, nest sites and perches, temperature within the test room, location (or absence) of other individuals within the test room, group size, social dynamics within the test group (Mench & Stricklin, 1990), propensity of the test subjects to perform stereotypies rather than explore their environment (Cooper & Nicol, 1991), time of day, age, previous experience, genetic strain, type of work required (eg. key pecking, pushing through a door, etc), and choice of reward schedule could all influence the results of such an experiment.

Escape from a perceived danger (eg. a predator) is a major motivating factor for movement through space. Escape responses occur very rapidly and the requirement for additional space is immediate. Therefore, a test requiring animals to make numerous key pecks for small increments in space is not appropriate for measuring this type of space requirement. Also, although individuals may work for extra space relatively infrequently, the extra space could be important for their well-being on those occasions when they do work for the extra space.

When interpreting results from experiments requiring animals to work for additional space, it is important to consider the implications of an elastic response to space. Consumer demand theory creates an artificial dichotomy between "essential" and "luxury" commodities whereas, in reality, the value of different commodities will vary over time and on different time scales. Locomotory play may be a luxury if food is short and an animal has to spend a large proportion of its time foraging to survive (Müller-Schwarze et al., 1982). However, when food is plentiful, as it is for many farm animals, the animals may be motivated to perform space-demanding locomotory play.

Time budgets

McFarland (1989) has discussed the implications of providing rich food sources which allow animals to meet their total daily food requirements in a very short period (eg. half an hour/day). Under natural conditions, animals are usually obliged to spend a considerable proportion of their waking day searching for and handling food. Dawkins (1989) observed that free-ranging red junglefowl spent a large proportion of their active (non-roosting) time engaged in foraging behaviour (ground pecking observed in 61% of all minutes of observation, and ground scratching observed in 34% of observation minutes) although concentrated feed was provided three times per day. Stolba & Wood-Gush (1989) also reported a high level of foraging behaviour in pigs in a semi-natural enclosure, with grazing occurring in 31% of the observation scans and rooting in 21% of scans. By contrast, intensively reared broiler chickens with access to an *ad libitum* food supply spent only about 6% of the day feeding (Newberry et al., 1988), and 2% ground pecking and scratching (Newberry et al., 1987). Broiler chicken breeding stock on a restricted food supply ate their entire daily food allocation in 4-16 minutes (Kostal et al., 1992).

The consequence of reduced time expenditure on feeding is an increase in time available for other activities. An increase in resting behaviour is expected in intensively reared farm animals with adequate food supplies since resting conserves energy, aids digestion and may reduce the risk of encountering aggressive conspecifics. However, space-demanding behaviours such as locomotory play and exploration which would normally be limited by time constraints may also become more important, suggesting that provision of sufficient space for the performance of these behaviours would be beneficial.

Exploration

Space requirements of farm animals have been assessed by placing animals in a test environment with compartments of different sizes, with the relative amount of time spent in the different compartments being used as an indicator of preference (eg. Phillips et al., 1992). Animals usually show non-exclusivity in use of the different compartments, and may use differently sized compartments for different functions. Nicol (1986) found that when hens entered a tall space, they performed a disproportionately high level of neck stretching and wing flapping whereas when entering a low space, they performed components of nesting behaviour. Animals may spend most of their time in the largest space but make frequent short visits to the smaller spaces, suggestive of a "monitoring" function (Nicol, 1986). Monitoring is a form of exploratory behaviour in which the animal seaches for novelty in the form of changed rather than totally new conditions (Nicol, 1986). Opportunities to enter different areas at different times may counteract boredom and loss of behavioural flexibility (Wemelsfelder, 1991) in farm animals with relaxed time constraints on behaviour. Therefore, care should be taken in interpreting the results of tests of preference for different sizes of enclosure.

Evidence for the importance of opportunities for exploration is provided by an experiment of Wood-Gush & Vestergaard (1991) in which weaned piglets were given the opportunity of entering two pens adjacent to their home pen for a short period each day. One pen contained hidden novel objects and the other pen contained no novel objects. An observer waved the Danish flag beside the pen containing the novel objects to give the piglets a clue as to their location. The piglets exhibited a strong preference for the pen containing the novel objects but also made frequent short visits to the empty pen.

In an experiment involving broiler chickens (Newberry, 1992), the chickens were given the opportunity to enter an extra space adjacent to their home pen for 3 h daily. In different treatments, the extra space contained (1) essential resources (food, water and heat), (2) supplementary resources (peat moss dust bath, straw bale, wooden platform) not present in the home pen, (3) novel objects not present in the home pen, or (4) no additional resources (empty). Chickens spent the most time in the extra space when it contained alternate sources of the essential resources even though these resources were readily available in the home pen. They spent intermediate amounts of time in the extra area when it contained the supplementary resources or novel objects, and least time in the "empty" space. In all treatments, chickens quickly learned to enter the extra area, running in groups through the gate as soon as it was opened, and subsequently made frequent visits back and forth between the home pen and the extra space. The length of time spent in the extra space depended on the nature of the resources found in the extra space.

These experiments demonstrate that use of space depends upon the resources found in the space. Farm animals appear to be motivated to explore novel objects and to make visits to accessible areas even when these areas provide no alternative resources to those present in the home area. The results illustrate the importance of flexibility in considering appropriate space allocations for farm animals rather than concentrating on a constant floor area per animal. The quality of space is at least as important as the quantity of space in determining how space is used over time. Nevertheless, even brief periods of access to alternative locations may satisfy a motivation to monitor different sites for the potential appearance of new resources. Since farm animal species have been subjected to natural selection in unpredictable environments during their evolutionary history, lack of access to a variety of potential foraging sites may be perceived as life-threatening to farm animals even though they are now maintained in a highly predictable farm environment.

Anti-predator behaviour, group size and habitat structure

It has been noted above that providing additional barn space is expensive. Costs of construction, equipment and maintenance increase with increasing barn size. One way of providing additional space to farm animals would be to make greater use of cheaper outdoor space. This would be especially relevant to areas with a warm, dry climate and low predation risk (eg. south of Spain). Yet, providing access to outdoor space is of little value unless animals feel safe to use it. Lack of suitable cover may explain the observation of Keeling et al. (1988) that only 15-22% of hens in a "free-range" husbandry system were outdoors at any one time and that some birds were never seen outdoors. They reported a positive correlation between the number of hens outdoors and mean distance of the flock from the poultry house. Estevez et al. (1992, 1993) observed greater use of an outdoor area by broiler chickens with increasing group size. Grigor (1993) demonstrated the importance of cover to enhance emergence of laying hens onto outdoor free-range areas. Metcalf (1990) reported that available space for intensively-reared fish was increased by providing overhead cover. The fish then used the whole tank rather than clustering around the sides and structural features such as drain holes.

Since the red junglefowl is subject to limited visibility in its jungle environment, necessitating a short reaction time to danger, it is perhaps not surprising that domestic fowl respond to sudden noises or movements with alarm (Gyger et al., 1987; Evans et al., 1993b) and head for cover in the absence of real predators (Evans et al., 1993a). They may perceive danger in indoor housing where they are protected from predators other than humans. Newberry & Hall (1990) observed greater use by broiler chickens of space close to walls than in the centre of their pen and Newberry et al. (1986) reported greater avoidance of an area close to a human observer by chickens in pens with brighter lighting. Incorporating cover in the design of intensive housing for farm animals originating from forest dwelling species may be of benefit in enhancing utilization of expensive indoor barn space, reducing energy expenditure and injuries associated with escape responses, and promoting a sense of security. Since risks of predation and parasitism affect group size and spacing between individuals in spacious, outdoor environments (Hamilton, 1971; Schmidtmann & Valla, 1982; Lima & Dill, 1990; Mooring & Hart, 1992), a better understanding of the impact of these factors on intensively housed farm animals is also warranted.

Space sharing and efficient use of space

In cooler climates where some protection from the elements is needed, it may be possible to stimulate exercise and learning about the environment by providing animals with access to additional indoor barn space for a short time each day. Since animals spend most of their time near essential resources and do not use all of the available space simultaneously, the same extra space could be made available to different groups at different times of day (ie. space sharing). This method would maximize the efficient use of expensive barn space. Use of alternative space would be promoted through provision of wide gateways and non-slip flooring, enabling groups of individuals to move rapidly back and forth between the home area and the peripheral space. Morris & Hurnik (1990) have provided access to alternative space in the design of a housing system for dry sows. Access to a set of expensive automatic feeders is rotated among different groups of sows. The system is controlled by automated gates which open to allow a group of sows to move down one alley to the feeders and return to their pen via another alley.

In addition to providing access to alternative spaces to stimulate exploration and play, greater attention could be paid to the interior design of animal enclosures. Walls and interior structures (eg. perches) could be designed which enhance the animals' sense of security, and supplementary resources such as dust baths and nest boxes could be provided. Although these features may appear expensive initially, there could be unexpected benefits. For example, Newberry and Blair (1993) found that provision of low perches in broiler chicken pens resulted in chickens which were easier to handle when picked up. Provision of a peat moss dust bath to broiler chickens resulted in a substantial reduction in mortality (Newberry, 1993).

Another approach to the efficient use of space could be the provision of resources within a fixed space at different times rather than providing a larger enclosure, or access to alternative spaces. For example, Luescher et al. (1982) enriched the cage environment of laying hens by providing an automatic perch which emerged from the cage floor for the night and retracted into the floor during the daytime. In addition, more efficient use of barn space could be made by greater use of vertical space within the barn. Fraser et al. (1986) observed that pigs kept in two-tiered pens had improved opportunities for thermoregulation, avoidance of aggressors and dunging away from the resting site.

Conclusions

Space for farm animals has been viewed in a simplistic manner as an area of floor space per animal. However, a linear increase in floor space per animal does not translate into a linear improvement in animal welfare. Arbitrary space guidelines have been established based on a compromise between economic pressure to crowd farm animals and pressure placed on politicians by animal activists for increased space for farm animals. Space guidelines do not adequately take into consideration how animals use space over time. Greater attention is needed to interactions between group size, enclosure size and shape, habitat structure, and availability of resources. Future well-being could be enhanced by providing space for rapid locomotion without risk of collisions with other animals or structures within the enclosure, and with non-slip floors and landing platforms which minimize the risk of falling or crash landings. Space cannot be considered in isolation from time, since animals are mobile and use more space than that taken up by their body. It is concluded that farm animal welfare would be better served by attention to methods of reducing threats to survival up until the time of slaughter than by setting floor space guidelines based on simplistic formulas of body size and housing type.

Resumen

El continuo espacio-tiempo y su aplicabilidad a animales de granja.

El espacio para los animales de granja se ha visto de forma simplista como un área de espacio de suelo por animal y se ha asumido que un incremento lineal en el espacio de suelo por animal se traducirá en una mejora lineal del bienestar animal. Se han establecido guías arbitrarias sobre el espacio basadas en presiones económicas y políticas. Este trabajo revisa las complejidades del uso del espacio por los animales de granja desde una perspectiva biológica, teniendo en cuenta el impacto de las barreras para la dispersión, las consecuencias de la restricción espacial sobre la eficacia, la disponibilidad de recursos, la motivación para conseguir acceso a posiciones diferentes, el impacto del presupuesto de tiempo sobre el uso del espacio para la explotación y el juego locomotor, la influencia del comportamiento antidepredador sobre el uso del espacio, y la división del espacio. Se concluye, que el bienestar del animal de granja se conseguira mejor prestando atención a métodos que reduzcan la mortalidad y la insalubridad hasta el momento del sacrificio, que por el establecimiento de normas de espacio de suelo que usan fórmulas simplistas basadas en el tamaño corporal y tipo de alojamiento.

Acknowledgements

I would like to express my deep appreciation to the organizing committee of the International Ethological Conference for inviting me to present this paper, and to Inma Estevez, University of Córdoba, for valuable discussion during preparation of this paper.

References

Adams, A.W. & Craig, J.V., 1985. Effect of crowding and cage shape on productivity and profitability of caged layers: a survey. *Poultry Sci.*, 64:238-242.

Agriculture Canada, 1989. *Recommended Code of Practice for the Care and Handling of Poultry from Hatchery to Processing Plant,* Ottawa: Agriculture Canada, Publication 1757/E.

Al-Rawi, B. & Craig, J.V., 1975. Agonistic behavior of caged chickens related to group size and area per bird. *Appl. Anim. Ethol.*, 2:69-80.

Appleby, M.C., 1993. Should cages for laying hens be banned or modified? *Animal Welfare,* 2:67-80.

Appleby, M.C., Hughes, B.O. & Elson, H.A., 1992. *Poultry Production Systems, Behaviour, Management and Welfare,* Wallingford: C.A.B. International.

Arduino, P.J. & Gould, J.L., 1984. Is tonic immobility adaptive? *Anim. Behav.*, 32:921-923.

Blair, R., Newberry, R.C. & Gardiner, E.E., 1993. Effects of lighting pattern and dietary tryptophan supplementation on growth and mortality in broilers. *Poultry Sci.*, 72:495-502.

Bognor, H., Peschke, W., Seda, V. & Popp, K., 1979. Studie zum Flachenbedarf von Legehennen in Kafigen bei Bestimmten Aktivitaten. *Berliner und Muchener Tieraerztliche Wochenscrhift,* 92:340-343.

Classen, H.L., Riddell, C. & Robinson, F.E., 1991. Effects of increasing photoperiod length on performance and health of broilers. *Br. Poult. Sci.*, 32:21-29.

Collias, N.E. & Collias, E.C., 1967. A field study of the Red Jungle Fowl in north-central India. *Condor*, 69:360-386.

Collias, N.E., Collias, E.C., Hunsaker, D. & Minning, L., 1966. Locality fixation, mobility, and social organization within an unconfined population of Red Jungle Fowl. *Anim. Behav.*, 14:550-559.

Commission of the European Communities, 1988. Council Directive 88/1166/EEC: amendment to 86/113/EEC on Welfare of Battery Hens. *Official Journal of the European Communities*, March 19, 1988, L74, p83.

Cooper, J.J. & Nicol, C.J., 1991. Stereotypic behaviour affects environmental preference in bank voles, *Clethrionomys glareolus*. *Anim. Behav.*, 41:971-977.

Crawford, R.D., 1990. Origin and history of poultry species. In: *Poultry Breeding and Genetics*: 1-41 (R.D. Crawford, Ed.). Amsterdam: Elsevier.

Dawkins, M.S., 1980. *Animal Suffering - the Science of Animal Welfare*, London: Chapman & Hall.

Dawkins, M.S., 1983. Battery hens name their price: consumer demand theory and the measurement of ethological "needs". *Anim. Behav.*, 31:1195-1205.

Dawkins, M.S., 1989. Time budgets in Red Junglefowl as a baseline for the assessment of welfare in domestic fowl. *Appl. Anim. Behav. Sci.*, 24:77-80.

Dawkins, M.S., 1990. From and animal's point of view: motivation, fitness, and animal welfare. *Behav. Brain Sci.*, 13:1-61.

Dawkins, M.S. & Hardie, S., 1989. Space needs of laying hens. *Br. Poult. Sci.*, 30:413-416.

Edwards, S.A. , Armsby, A.W. & Spechter, H.H., 1988. Effects of floor area allowance on performance of growing pigs kept on fully slatted floors. *Anim. Prod.*, 46:453-459.

Estevez, I., Newberry, R.C. & Arias de Reyna, L., 1992. The effect of semi-external rearing on growth and use of space by broiler chickens. *J. Anim. Sci.*, 70 (Suppl. 1): 172.

Estevez, I., Recuerda, P. & Arias de Reyna, L., 1993. An alternative hypothesis to the hierarchical social system in the domestic fowl. *Abstracts of XXIII Int. Ethol. Conf., 1993, Torremolinos, Spain*: 69.

Evans, C.S., Evans, L. & Marler, P., 1993a. On the meaning of alarm calls: functional reference in an avian vocal system. *Anim. Behav.*, 46:23-38.

Evans, C.S., Macedonia, J.M. & Marler, P., 1993b. Effects of apparent size and speed on the response of chickens, *Gallus gallus*, to computer-generated simulations of aerial predators. *Anim. Behav.*, 46:1-11.

Fagen, R., 1981. *Animal Play Behavior*, New York: Oxford University Press.

Fraser, D., Phillips, P.A. & Thompson, B.K., 1986. A test of a free-access two-level pen for fattening pigs. *Anim. Prod.*, 42:269-274.

Galindo, F, & Broom, D.M., 1993. The occurrence of lameness in relation to individual behavioural responses in dairy cows. In: *Proc. Int. Cong. Appl. Ethol., Berlin, 1993*: 318-320 (M. Nichelmann, H.K. Wierenga & S. Braun, Eds.). Darmstadt: Kuratorium für Technik und Bauwesen in der Landwirtschaft.

Gregory, N.G. & Wilkins, L.J., 1989. Broken bones in domestic fowl: handling and processing damage in end-of-lay battery hens. *Br. Poult. Sci.*, 30:555-562.

Gregory, N.G., Wilkins, L.J., Kestin, S.C., Belyavin, C.G. & Alvey, D.M., 1991. Effect of husbandry system on broken bones and bone strength in hens. *Vet. Rec.*, 128:397-399.

Grigor, P.N., 1993. Use of space by laying hens: social and environmental implications for free-range systems. *Unpublished Ph.D. Thesis*, Edinburgh: University of Edinburgh.

Guilford, T., 1988. Assessed risk of crashing: a new currency in bird decision-making. In: *Program & Abstracts - 2nd International Conference on Behavioural Ecology*: 60. Vancouver: Behavioral Ecology Research Group, Simon Fraser University.

Gustafson, G., 1993. Effect of regular exercise on the production, health and locomotion of tied dairy cows. In: *Proc. VII World Conference on Animal Production, 1993, Edmonton, Canada, Vol. 3*: 263-264. Edmonton: University of Alberta.

Gyger, M., Karakashian, S.J. & Marler, P., 1986. Avian alarm calling: is there an audience effect? *Anim. Behav.*, 34:1570-1572.

Gyger, M., Marler, P. & Pickert, R., 1987. Semantics of an avian alarm call system: the male domestic fowl, *Gallus domesticus. Behaviour*, 102:15-40.

Hall, S.J.G., 1989. Chillingham cattle: social and maintenance behaviour in an ungulate that breeds all year round. *Anim. Behav.*, 38:215-225.

Hamilton, W.D., 1971. Geometry for the selfish herd. *J. Theor. Biol.*, 31:295-311.

Her Majesty's Stationary Office, 1987. *Animals, Prevention of Cruelty, The Welfare of Battery Hens Regulations 1987*, London: Her Majesty's Stationary Office.

Hughes, B.O., 1983a. Space requirements in poultry. In: *Farm Animal Housing and Welfare*: 121-128 (S.H. Baxter, M.R. Baxter & J.A.D. MacCormack, Eds.). Aberdeen: C.E.C. Seminar.

Hughes, B.O., 1983b. Conventional and shallow cages: a summary of research from welfare and production aspects. *World's Poult. Sci. J.*, 39:218-228.

Hurnik, J.F. & Lewis, N.J., 1991. Use of body surface area to set minimum space allowances for confined pigs and cattle. *Can. J. Anim. Sci.*, 71:577-580.

Johnson, R.A., 1963. Habitat preference and behaviour of breeding jungle fowl in central western Thailand. *Wilson Bull.*, 75:270-272.

Keeling, L.J., Hughes, B.O. & Dun, P., 1988. Performance of free-range laying hens in a polythene house and their behaviour on range. *Farm Bldg. Prog.*, 94:21-28.

Kienle, H. & Bessei, W., 1993. Floor space preferences in growing rabbits as determined by operant conditioning techniques. In: *Proc. Int. Cong. Appl. Ethol., Berlin, 1993*: 520-523 (M. Nichelmann, H.K. Wierenga & S. Braun, Eds.). Darmstadt: Kuratorium für Technik und Bauwesen in der Landwirtschaft.

Knowles, T.G. & Broom, D.M., 1990. Limb bone strength and movement in laying hens from different housing systems. *Vet. Rec.*, 126:354-356.

Kornegay, E.T. & Notter, D.R., 1984. Effects of floor space and number of pigs per pen on performance. *Pig News Infor.*, 5:23-33.

Kostal, L., Savory, C.J. & Hughes, B.O., 1992. Diurnal and individual variation in behaviour of restricted-fed broiler breeders. *Appl. Anim. Behav. Sci.*, 32:361-374.

Lagadic, H. & Faure, J.M., 1988. Conditionnement operant et utilisation de l'espace chez la poule pondeuse en cage. *Behav. Proc.*, 16:43-56.

Lima, S.L. & Dill, L.M., 1990. Behavioral decisions made under the risk of predation: a review and prospectus. *Can. J. Zool.*, 68:619-640.

Lou, Z. & Hurnik, J.F., 1993. The development of alternative farrowing crate for sows. In: *Program & Abstracts, Int. Cong. Appl. Ethol., Berlin, 1993*: 125. Darmstadt: Kuratorium für Technik und Bauwesen in der Landwirtschaft.

Luescher, U.A., Hurnik, J.F. & Pos, J., 1982. New cage design for laying hens. *Poultry Sci.*, 61:606-607.

MacArthur, R.H. & Wilson, E.O., 1967. *The Theory of Island Biogeography*, Princeton: Princeton University Press.

McBride, G. & Foenander, F., 1962. Territorial behaviour in the domestic fowl. *Nature, Lond.*, 194:102.

McBride, G., Parer, I.P. & Foendander, F., 1969. The social organization and behaviour of the feral domestic fowl. *Anim. Behav. Monogr.*, 2:127-181.

McFarland, D., 1989. *Problems of Animal Behaviour*, Harlow, U.K.: Longman Scientific and Technical.

Mench, J.A. & Stricklin, W.R., 1990. Consumer demand theory and behavior: all chickens are not equal. *Behav. Brain Sci.*, 13:28.

Mendl, M., 1991. Some problems with the concept of a cut-off point for determining when an animal's welfare is at risk. *Appl. Anim. Behav. Sci.*, 31:139-146.

Metcalf, N.B., 1990. Aquaculture. In: *Managing the Behaviour of Animals*: 125-154 (P. Monaghan & D.G.M. Wood-Gush, Eds.). London: Chapman & Hall.

Meyer, W.A. & Sunde, M.L., 1974. Bone breakage as affected by type of housing or an exercise machine. *Poultry Sci.*, 53:878-885.

Miller, M.N. & Byers, J.A., 1991. Energetic cost of locomotor play in pronghorn fawns. *Anim. Behav.*, 41:1007-1013.

Mills, A.D., Lagadic, H. & Faure, J.M., 1987. Problèmes de distances inter individuelles chez la poule. *Organisation sociale chez les vertébrés, Toulouse, 1985*: 181-190. Paris: INRA (Les Colloques de l'INRA, 38).

Morris, J.R. & Hurnik, J.F., 1990. An alternative housing system for breeding gestating sows. *Can. J. Anim. Sci.*, 70:957-961.

Mooring, M.S. & Hart, B.L., 1992. Animal grouping for protection from parasites: selfish herd and encounter-dilution effects. *Behaviour*, 123:173-193.

Müller-Schwarze, D., Stagge, B. & Müller-Schwarze, C., 1982. Play behavior: persistence, decrease, and energetic compensation during food shortage in deer fawns. *Science*, 215:85-87.

Newberry, R.C., 1992. Motivational factors influencing use of space by chickens. *J. Anim. Sci.*, 70 (Suppl. 1):174.

Newberry, R.C., 1993. Does dust bathing increase broiler productivity? In: *Proc. Int. Cong. Appl. Ethol., Berlin, 1993*: 527-528 (M. Nichelmann, H.K. Wierenga & S. Braun, Eds.). Darmstadt: Kuratorium für Technik und Bauwesen in der Landwirtschaft.

Newberry, R.C. and Blair, R., 1993. Perches ease handling of broiler chickens. In: *Proc. 4th Europ. Symp. Poult. Welfare*: 270-271 (C.J. Savory & B.O. Hughes, Eds.). Potters Bar: Universities Federation for Animal Welfare.

Newberry, R.C. & Hall, J.W., 1988. Space utilization by broiler chickens in floor pens. In: *Proc. Int. Cong. Appl. Ethol. Farm Animals, Skara, 1988*, 305-309 (J. Unshelm, G. Van Putten, K. Zeeb & I. Ekesbo, Eds.). Darmstadt: Kuratorium für Technik und Bauwesen in der Landwirtschaft.

Newberry, R.C. & Hall, J.W., 1990. Use of pen space by broiler chickens: effects of age and pen size. *Appl. Anim. Behav. Sci.*, 25:125-136.

Newberry, R.C. & Wood-Gush, D.G.M., 1986. Social relationships of piglets in a semi-natural environment. *Anim. Behav.*, 34:1311-1318.

Newberry, R.C. & Wood-Gush, D.G.M., 1988. Development of some behaviour patterns in piglets under semi-natural conditions. *Anim. Prod.*, 46:103-109.

Newberry, R.C., Gardiner, E.E. & Hunt, J.R., 1987. Behavior of chickens prior to sudden death syndrome. *Poultry Sci.*, 66:1446-1450.

Newberry, R.C., Hunt, J.R. & Gardiner, E.E., 1986. Light intensity effects on performance, activity, leg disorders, and sudden death syndrome of roaster chickens. *Poultry Sci.*, 65:2232-2238.

Newberry, R.C., Hunt, J.R. & Gardiner, E.E., 1988. Influence of light intensity on behavior and performance of broiler chickens. *Poultry Sci.*, 67:1020-1025.

Newberry, R.C., Wood-Gush, D.G.M. & Hall, J.W., 1988. Playful behaviour of piglets. *Behav. Proc.*, 17:205-216.

Nicol, C.J., 1986. Non-exclusive spatial preference in the laying hen. *Appl. Anim. Behav. Sci.*, 15:337-350.

Nicol, C.J., 1987. Behavioural responses of laying hens following a period of spatial restriction. *Anim. Behav.*, 35:1709-1719.

Nishida, T., Hayashi, Y., Shotake, T., Maeda, Y., Yamamoto, Y., Kurosawa, Y., Douge, K. & Hongo, A., 1992. Morphological identification and ecology of the Red Jungle Fowl in Nepal. *Anim. Sci. Technol. (Jpn.)*, 63:256-269.

Nørgaard-Nielsen, G., 1990. Bone strength of laying hens kept in an alternative system, compared with hens in cages and on deep litter. *Br. Poult. Sci.*, 31:81-89.

Phillips, P.A., Fraser, D. & Thompson, B.K., 1992. Sow preference for farrowing-crate width. *Can. J. Anim. Sci.*, 72:745-750.

Price, E.O., 1984. Behavioural aspects of animal domestication. *Quart. Rev. Biol.*, 59:1-32.

Roush, W.B., 1986. A decision analysis approach to the determination of population density in laying cages. *World's Poult. Sci. J.*, 42:26-31.

Rushen, J. & de Passillé, A.M.B., 1992. The scientific assessment of the impact of housing on animal welfare: a critical review. *Can. J. Anim. Sci.*, 72:721-743.

Schmidtmann, E.T. & Valla, M.E., 1982. Face-fly pest intensity, fly avoidance behavior (bunching) and grazing time in Holstein heifers. *Appl. Anim. Ethol.*, 8:429-438.

Schouten, W.G.P., 1991. Effects of rearing on subsequent performance in pigs. *Pig News and Information*, 12(2):245-247.

Shanawany, M.M., 1988. Broiler performance under high stocking densities. *Br. Poult. Sci.*, 29:43-52.

Stokes, A.W., 1971. Parental and courtship feeding in Red Jungle Fowl. *Auk*, 88:21-29.

Stolba, A., 1981. A family system in enriched pens as a novel method of pig housing. In: *Alternatives to Intensive Husbandry Systems*: 52-67. Potters Bar: Universities Federation for Animal Welfare.

Stolba, A. & Wood-Gush, D.G.M., 1989. The behaviour of pigs in a semi-natural environment. *Anim. Prod.*, 48:419-425.

Wemelsfelder, F., 1991. Animal boredom: do animals miss being alert and active? In: *Applied Animal Behaviour: Past, Present and Future*: 120-123. (M.C. Appleby, R.I. Horrell, J.C. Petherwick & S.M. Rutter, Eds.). Potters Bar: Universities Federation for Animal Welfare.

Wierenga, H.K., 1991. Adaptation of cubicle-housed dairy cows to their housing and management. In: *Applied Animal Behaviour: Past, Present and Future*: 65-68. (M.C. Appleby, R.I. Horrell, J.C. Petherwick & S.M. Rutter, Eds.). Potters Bar: Universities Federation for Animal Welfare.

Wood-Gush, D.G.M., 1983. *Elements of Ethology*. London: Chapman and Hall Ltd.

Wood-Gush, D.G.M. & Vestergaard, K., 1991. The seeking of novelty and its relation to play. *Anim. Behav.*, 42:599-606.

Wood-Gush, D.G.M., Duncan, I.J.H. & Savory, C.J., 1978. Observations on the social behaviour of domestic fowl in the wild. *Biol. Behav.*, 3:193-205.

Zhou, J.Z. & Stricklin, W.R., 1992. The influence of pen shape and group size on crowding when density is constant. *J. Anim. Sci.*, 70 (Suppl. 1):174.

(Recibido: enero 1994)