USE OF OUTDOOR RANGES BY LAYING HENS IN DIFFERENT SIZED FLOCKS

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Abstract

In studies assessing outdoor range use of laying hens, the number of hens seen on outdoor ranges is inversely correlated to flock size. The aim of this study was to assess individual ranging behavior on a covered (veranda) and an uncovered outdoor run (free-range) in laying hen flocks varying in size. Five to ten percent of hens (aged 9 to 15 months) within 4 small (2-2500 hens), 4 medium (5-6000), and 4 large (≥ 9000) commercial flocks were fitted with RadioFrequencyIDentification (RFID) tags. Antennas were placed at both sides of all popholes between the house and the veranda and the veranda and the free-range. Ranging behavior was directly monitored for approximately three weeks in combination with hourly photographs of the free-range for the distribution of hens and six hour long video recordings on two parts of the free-range during two days. Between 79 and 99% of the tagged hens were registered on the veranda at least once and between 47 and 90% were registered on the free-range at least once. There was no association between the percentage of hens registered outside the house (veranda or free-range) and flock size. However, individual hens in small and medium sized flocks visited the areas outside the house more frequently and spent more time there than hens from large flocks. Foraging behavior on the free-range was shown more frequently and for a longer duration by hens from small and medium sized flocks than by hens from large flocks. This difference in ranging behavior could account for the negative relationship between flock size and the number of hens seen outside at one point of time. In conclusion, our work describes individual birds` use of areas outside the house within large scale commercial egg production.

Keywords: Laying hen; Flock size; Free-range; RFID

1. Introduction

Animal friendly production systems are gaining popularity in Europe and elsewhere (Magdelaine and Mirabito, 2001). Especially in poultry, animal welfare concerns are being raised by the public regarding intensive husbandry practices, particularly in regard to high density systems with thousands of animals (Kunzmann, 2011). Perceived natural production and animal welfare are central concepts mentioned by consumers regarding quality of food (Brunsjø, 2002 in Grunert, 2005). Laying hens ranging outside fit into these perceived concepts. For instance British consumers consider free-range eggs more animal-friendly than cage eggs (Bennett and Blaney, 2003).

However, most laying hens are kept in large flocks and only a small percentage can be seen outside the house at any one time (e.g. Bubier and Bradshaw, 1998). Generally, flock size inversely correlates to the number of hens observed outside (Bubier and Bradshaw, 1998; Bestman and Wagenaar, 2003; Gilani et al., in press; Hegelund et al., 2005; Kijlstra et al., 2007; Whay et al., 2007), although other factors, e.g., stocking density and rearing conditions with or without access to outside areas can affect this behavior, were not controlled for and represent confounds (except in Gilani et al., in press). It is also not clear whether the same birds consistently venture onto the range, or whether different birds use the range at different times. Recent findings by Richards et al (2011) indicated that the majority of the flock ventured into the pophole at some point during the laying cycle, though they were unable to confirm if birds continued onto the range or the associated duration. Other influences on the percentage of a flock observed outside include genetics (Icken et al., 2008), weather (Gilani et al., in press; Hegelund et al., 2005) (Richards et. al., 2011), experience through exposure to an outside area during rearing (Grigor et al., 1995a;

but see Gilani et al, in press) or age (Bestman and Wagenaar, 2003; Icken et al., 2008), cockerel presence and ratio, cover (Bestman and Wagenaar, 2003; Gilani et al., in press; Hegelund et al., 2005), light intensity in the house and pop hole availability (Gilani et al., in press), diversity of structures (Zeltner and Hirt, 2008), vegetation (Nicol et al., 2003), and the presence of keel bone fractures (Richards et al., 2012). Different reasons for the unexpected low range usage may include: fear (of predation, novelty) (Grigor et al., 1995b), presence of unfamiliar birds (Grigor et al., 1995c), missing feeding times in the hen house (Bubier and Bradshaw, 1998), or unattractive habitat (e.g. due to destruction by the hens) (Bubier and Bradshaw, 1998). Higher stress can also be associated with a higher use of the outdoor area (Mahboub et al., 2004).

Range size is typically proportional to flock size but often most hens are seen in a small area immediately surrounding the house (Hirt et al., 2000; Zeltner and Hirt, 2003; Elbe et al., 2005). The concentration of grazing may lead to a problematic accumulation of nitrogen due to faeces (Aarnink et al., 2006) and destruction of grass cover. Given the lack of accurate information regarding individual hens` usage of the range and the implications for flock management, we sought to provide this information using a radio frequency identification (RFID) system that could accurately track the passage of hens` entry and exit onto the range. The aim of this study was to assess individual ranging behavior within system containing a covered (veranda) and an uncovered outdoor run (free-range) in laying hen flocks varying in size. Verandas provide many potential welfare benefits of outdoor runs. Verandas also provide their own benefits including: space for extensive locomotion, foraging, dust-bathing, lower density in the house and the veranda, and reduced exposure to UV light while protecting birds from adverse weather, predation, and infection from wild birds. In pursuit of

this aim we monitored the frequency and duration of visits to the outdoor areas, the behavior of birds on the range, as well as the distance from the house. We also assessed these variables to determine the effect of flock size (independent of stocking density).

2. Materials and Methods

2.1. Flocks

Characteristics of the investigated flocks are shown in Table 1. The particular flock sizes chosen were based on Swiss legislation which limits number of laying hens that a farmer is allowed to keep to a maximum of 18,000 (Verordnung 916.344, 26.11.03), http://www.admin.ch/opc/de/classified-compilation/20030950/index.html#a2, accessed 5-31-13). Thus, commercial flocks numbering from 2,000 to 18,000 hens were chosen for investigation. As most laying hens in Switzerland are white hybrids and no large flocks with brown hybrids were available, all flocks (n = 8) in the small (2,000 to 2,460 hens) and large (9,000 to 18,000 hens) categories were white. Half (two) of the medium sized flocks consisted of brown hybrids. All hens were between 9 and 14 months of age. During rearing after the 42nd day of age flocks had access to a veranda but not to a free-range. They were given access to a free-range from the 24th week of age onwards. The flocks were housed in single and multitier systems with access to separate outdoor ranges (Fig 1). All houses had an adjacent covered outdoor run (hereafter called 'veranda[2]') with a concrete floor with litter. Verandas were positioned on one long side of the house except on farm 2. At the opposite long side of the veranda, hens had access to an open outdoor range consisting of grassland and, on some farms, trees, shrubs, or artificial shelters (e.g. elevated nets) (hereafter called 'free-range[2]'). For all flocks, an area approximately ten meters adjacent to the veranda was without vegetation but covered with gravel stones of various sizes except on Farm 3 where shredded bark was provided..

[2] Terms used by EFSA (www.efsa.europa.eu)

Flocks were considered to be statistically independent because they lived in different buildings with different ranges although three were located on one farm and two belonged to the same farm in two instances. Flock sizes were balanced in regard to the seasons and years; stocking density was constant across all flocks (according to Swiss legislation). Spring was defined as mid-March until the end of June and fall as the period between the end of August and the end of November. Due to equipment limitations, the use of the veranda of one flock (farm 8) was measured after assessment of the range during January; use of the veranda of the flocks (farm 6) was not assessed. Three flocks (farm 4, 6) had been reared on the same farm; the others had been bought from rearing farms.

2.2 Housing

With the exception of farm 2, all houses were equipped with aviaries that consisted of several tiers where feed, water, and perches were provided. Space on the litter and at the feeders, number of drinkers, and perch length per bird were maintained in compliance of Swiss legislation. The outdoor areas veranda and free-range as well as the total space of pop-holes and the management of using these areas conformed to Swiss regulations for subsidies and were controlled by officials regularly. Faeces were removed by mechanically driven belts approximately once a week. Farm 2 had a floor housing system with perches, raised areas with litter, and a manure pit. In all houses, group laying nests were attached to the walls of the hen houses or on a tier of the aviary rack. Access points between the house and the veranda and the veranda and the free-range (termed popholes) varied in size and numbers with flock size. Access to the veranda began between 5:30 and 10:00 h and concluded between 16 to 18:00 h depending on individual farm protocol. Access to the free-range via

the popholes was provided from between 8 and 12:00 h to 16 to 18:00 h also depending on individual farm protocol. No housing parameters or management procedures were altered during data acquisition to obtain an accurate representation of bird movements within the flock.

2.3 RFID equipment

Antennas of the *Gantner Pigeon System* (http://www.benzing.cc/, accessed on Feb. 21, 2013) were placed on either side of each pophole linking the house/veranda and veranda/free-range at least three weeks before data were collected to allow birds to acclimate to the presence of the antennas. The width of the popholes ranged from 1.2 to 4.6 m. Depending to the size of the pophole, up to 12 antennas, six on each side of the pophole, were put side-by-side to cover the entire width (Gebhardt-Henrich et al., 2011). The RFID system operated by registering and recording the time and date that individual tags (ø 4.0 / 34.0 mm Hitag S 2,048 bits, 125 kHz, attached to leg bands worn by the birds and described in detail below) came within 15 cm vertical distance of an antenna. The inclusion of antennas on either side of the pophole represents an added level of assurance as transition between two areas required registration of two events – both entrance into the pophole in one area (e.g. inside the house) followed by exit from the pophole into a second area (e.g. to the veranda). Collected data, including the unique tag identification number, timestamp (with a precision of 0.1 s), and the antenna number, were written to a connected computer. The system allowed for multiple tags (and the associated hen) to be registered by the same antenna at the same time. The direction of movement was referred from the sequence of antennas. More details of the RFID system and its reliability are provided in Gebhardt-Henrich et al. (2011).

184 **2.4 Procedures**

185 Hens were acclimated to the presence of the equipment (e.g.,
186 antennas and cables) at least three weeks before data collection. At night
187 when hens were perching in the dark house, RFID tags were attached to
188 10% of the hens of the first three flocks (summer 2008 - to spring 2009)
189 and later to 5% of the flock via a stratified selection process to insure
190 representative covering of all locations in the hen house (i.e., aviary, litter,
191 slats, nestbox). A blue head lamp was used and all hens remained at their
192 position during tagging. Each building was divided into different sections
193 and the same number of tags were used in each section. Tags, previously
194 placed inside a wing band, were mounted to one leg of the hen with an
195 adjustable RFID leg band, both commercially available (IDs, Roxan,
196 Scotland). At depopulation, most tags were recovered (Table 1). Tags that
197 were not recovered were excluded from analyses. Ten flocks were
198 monitored at least 21 days during which access to the outdoor ranges was
199 provided, though in some cases inclement weather caused the producer to
200 deny free-range access and reduced the number of days assessments
201 could be made of free-range usage. Two flocks were monitored for 18
202 (farm 3, 6000 hens) and 19 days (farm 2).

203 On two days without rain during the recording period, the entire free-
204 range was photographed every hour between 10:00 and 16:00 h. Weather
205 conditions (e.g. sunshine, temperatures, wind exposure etc.) could not be
206 standardized and varied across farm. Resulting images were used to count
207 the number of hens in the different parts of the free-range relative to
208 vegetation, shelters, and distance from the house. In one flock (Farm 4)
209 crowding prevented reliable counting and on this farm no photographs were
210 taken. During the same period that photographs were taken, video
211 recordings were made of two areas next to the veranda (one area covered

with pebbles and a second with grass) to provide a behavioral assessment of each flock within these areas. Recordings were coded with Observer 5.0 software (Noldus Information Technology, Wageningen, The Netherlands) using behaviors defined in an established ethogram (Table 2). At the top of each hour, a focus hen was chosen which was closest to the center of the screen and observed for 5 min. If the hen left the screen before the 5 min observations could be completed, another hen was chosen for observation from the center of the screen and observed as long as she was visible or until the 5 min were over. These observations were repeated to obtain 5 min of observation time for each area at every hour that access to the free-range was provided.

2.5 Analyses

The reliability of registration by the RFID equipment largely depended on the velocity of the hens as they passed through the popholes with 1.5 m/s representing a threshold above which greater velocities reduced reliability (Gebhardt-Henrich et al., 2011). When calculating durations of stay, two missed registrations of a tag as it passed over an antenna would distort the measured duration considerably. Therefore, only durations on days when the individual hen had 100% matching registrations, i.e. each passage to the free-range required a passage back to the veranda etc., were included in the final data set. When discrepancies in the dataset where identified, e.g. daily time records for individual hens where time spent on the veranda and/or free-range did not equal the time outside the house, these records were deleted. Durations of stays on the veranda or free-range shorter than 0.5 min. were excluded. Median duration on the veranda and the free-range were calculated for each hen, day, and each farm separately.

Data were checked for normality with the Kolmogorov-Smirnov test and the daily duration on the veranda and the free-range were logarithmically transformed as was duration of sitting, standing, and the ratio of foraging to walking.

Data were analyzed using SAS® 9.1.3 and 9.2. Full models including all interactions were computed first. Non-significant interactions ($p>0.2$) were pooled. Individual Spearman`s correlations were calculated between daily duration on the free-range with number of days on the free-range and between daily duration on the free-range with the time of day they went out then averaged per farm. To test for the presence of bimodality, the coefficient of bimodality was calculated as (skewness^2 + 1) / kurtosis where a value greater than 0.555 indicates bimodality (Freeman and Dale, 2013), (calculated by Proc MODECLUS in SAS® http://support.sas.com/documentation/onlinedoc/stat/121/modeclus.pdf, accessed on 6-3-2013). For the analyses, 0.555 was deducted from each calculated coefficient and determined whether equal to 0 by a sign test in Proc UNIVARIATE (SAS®). The test statistic *M* was calculated as M = (number of values greater than 0 - number of values smaller than 0). To account for the bimodal distribution of use of the outdoor ranges the frequency of ranging was analysed as a bimodal variable (at least or less than 2/3 of the days) with Proc GENMOD (SAS®) using farm as a subject factor. A generalized linear model with maximum likelihood estimation was used and the p-values based on their chi-square distributions. The estimated parameters of the generalized linear model GEE are given in the text. Further details about the specific analyses are given with the results.The experiment was approved by the Office of Agriculture of the Canton Bern for all Swiss cantons (19/07).

3. Results

3.1. Registration on veranda and free-range

During the investigation 90.4% ± 2.2 (mean ± standard error) of the marked laying hens per flock were registered on the veranda and 70.5% ± 3.4 were registered on the free-range at least once (Table 1). There was no association of flock size on the percentage of tagged hens on the veranda (r^2 = 0.14, N = 10, NS) or on the free-range (r^2 = 0.08, N = 12, NS). However, individual hens used the veranda and the free-range differently and many of them did not enter the veranda or the free-range every day (Table 3). Using the hens registered in the outdoor areas at least once as a subset of the overall dataset, the number of days when the veranda or free-range was used had bimodal distributions (Fig. 2 a, b) and confirmed by the coefficients of bimodality being larger than 0.555 (number of days on the veranda: M = 5, P = 0.002, N = 10, number of days on the free-range: M = 6, P = 0.0005, N = 12).

Individuals as well as farms differed in the daily duration on the free-range (mixed model, farm: $F_{9,23000}$ = 697.26, P < 0.0001, individual nested in farm: $F_{1735,23000}$ = 9.77, P < 0.0001). When attendance of the free-range is categorized into spending ¼, ½, ¾, and more than ¾ of the days there, hens going to the free-range more often also spent more time there (repeated analysis with farm as the subject factor, $F_{3,32}$ = 500.69, P < 0.0001). This means that hens which spent a greater daily amount of time in the outdoor areas were more likely to spend more days in those areas, as well. The proportion of hens in the categories using the free-range at least or less than 2/3 of the days was influenced by flock size: Flock size was negatively associated with the percent of days spent on the free-range (χ^2_2 = 7.85, P = 0.02, small flocks = 0, medium flocks = -1.23, large flocks = -1.68, modeling the category ‘spending more than 2/3 of all days on the

294 free-range') and the duration (χ^2_2 = 8.15, P = 0.02, small = 0, medium = -
295 295.3, large = -319.3, for the variable total time on the free-range[min.]).
296 Similarly, the number of hens in a flock was negatively correlated with the
297 percentage of days that were spent on the veranda (r_s = -0.66, P = 0.04, N
298 = 10). The duration spent on the veranda was significantly different among
299 flock sizes ($F_{2,5}$ = 13.13, P = 0.01, least square means, log transformed:
300 small = 4.22±0.077 (4 flocks), medium = 3.80±0.077 (4 flocks), large =
301 3.65±0.09 (2 flocks)) while the contrasts between large vs. medium and
302 small flocks as well as small vs. medium and large flocks were significant
303 ($F_{1,5}$ = 11.56, P = 0.02; $F_{1,5}$ = 25.65, P = 0.004). The sooner after the
304 opening of the popholes the hens went out on the free-range compared
305 with other hens on the same farm, the greater the total duration on the free-
306 range was (r_s = - 0.55 ± 0.03, P < 0.0001, N = 12 flocks).
307
308 **3.2. Areas of the free-range**
309 The percentage of hens seen on the area with gravel adjacent to the
310 veranda vs. the percentage of hens on the grass varied among flocks but
311 was not correlated with flock sizes (r_s = -0.28, P = 0.40, N = 11). The mean
312 percentage of hens on the free-range that were underneath artificial
313 structures was 6.8 % (minimum, maximum: 0.2, 69%); underneath
314 vegetation like bushes or trees 22.4% (minimum, maximum: 3.9, 57.7%);
315 and on open grass 41.8% (minimum, maximum: 31.8 and 60.7%).
316
317 **3.3. Behavior on the free-range**
318 Hens spent more time moving (walking and foraging) on grass than on
319 gravel ($F_{1,9}$ = 13.01, P = 0.006) though was unrelated to flock size ($F_{2,9}$ =
320 1.64, P = 0.25). However, the ratio of foraging to walking differed both for
321 the location (i.e., grass or gravel) and flock size (location: $F_{1,9}$ = 49.51, P <

0.0001, size: $F_{2,9} = 12.43$, P = 0.003, interaction between location and flock size: $F_{2,9} = 2.4$, P = 0.15, Fig. 3) with hens generally foraging more on grass than on gravel. Large flocks displayed less foraging behavior than medium and small flocks (contrast: $F_{1,9} = 11.63$, P = 0.008), a relationship maintained when brown hybrids are excluded (contrast: $F_{1,7} = 10.03$, P = 0.016). Hens stood longer on gravel than on grass ($F_{1,9} = 12.95$, P = 0.006) and their sitting duration varied with flock size ($F_{2,7} = 5.05$, P = 0.044).

4. Discussion

To the authors' knowledge, this is the first study monitoring continuous ranging behavior of individual hens in large scale commercial flocks where no aspect of their housing (e.g. size and number of popholes) was altered. Previous related work included small experimental groups of 50 birds (Mahboub et al., 2004) and a flock of 12,000 that was divided into groups of 1,500 birds (Richards et al., 2011). In this latter study however, registration in the pophole rather than time on range was recorded, thus the methodology did not allow quantification of actual time on range or if the hen actually exited the house. Hens in studies by Icken et al. (2008, 2011) had a veranda though no free-range. In this regard, this is the first study to test the influence of flock size on the number of hens on a veranda and free-range and the duration of their stay in those areas.

4.1 Flock size and numbers of ranging hens

Although there was no significant influence of flock size on the percentage of hens that were registered at least once on the veranda and/or the free-range during three weeks, flock size was associated with the behavior of the hens in the outdoor areas. Unexpectedly, many hens that were registered on the veranda or the free-range during the investigation did not go there every day. The average number of hens seen outside at any one time is similar to that seen in other studies (Fig. 4, Supplementary data) which showed an inverse relationship between flock size and hens outside. Taken together, these results suggest that while the percentage of the flock on the range at any point in time varies and is relatively low, the percentage of the flock that actually uses the range at some point is much higher, a finding which raises several important issues. Firstly, the ability to range might be important to a large percentage of the flock and not just a subset

of hens. Given the varied systems that are currently being developed for laying hen production as replacements for battery cages, our results suggest consideration should be given to ranging ability given the widespread usage. Particularly given that hens in semi-natural conditions spend most of their time foraging (Savory et al., 1978), our results suggest that this is a behavior which is maintained in current genetic stock despite intense breeding. Secondly, assuming that ranging is a critical behavior which some hens have a strong motivation to perform, research is needed to assess the variable use of the range with varying flock size, changes in individual bird behavior, and consequences to animal welfare.

Our methodology also indicated a bimodal distribution of hen: those using the free-range every day for a long time and those using the free-range sporadically for short periods of time. It is unclear whether these differences present unique personality types, e.g. as shown in great tits between fast and slow explorers and individuals dispersing and philopatric birds (Dingemanse et al., 2003), or some other mechanism. The percentage of days when hens used the free-range was associated with flock size so environmental effects on this trait are likely although a genetic component might also be present (Drent et al., 2003; Van Oers et al., 2004). Substantial individual variation in the length of stay on the veranda was also found by Icken et al. (2008) and in the frequency of pophole use by Richards et al. (2011). In the latter study 80% of the hens frequently used the popholes but length of stay on free-range was not measured.

Long and frequent stays on the free-range are sometimes taken as indicators for good welfare (Swiss Animal Protection, pers. comm.) though scientific evidence for this is lacking. Since we did not assess welfare-related parameters we cannot interpret our results in this respect, though our methodology and results offer an interesting means to interpret

assumptions regarding welfare and range use. Knierim (2006) states that access to free-range offers opportunities both to increase and decrease welfare. On the one hand access to a free-range provides enrichment for the hens improving welfare, while predation, diseases, or an imbalanced diet might decrease welfare. Other studies have shown that use of an outdoor range reduces feather pecking which is thought to be redirected foraging behavior (Green et al., 2000; Bestman and Wagenaar, 2003; Nicol et al., 2003; Mahboub et al., 2004; Whay et al., 2007) and thus improves welfare. Given our methodology and results, we should interpret these findings at the individual level to ensure theoretical benefits are actually realized throughout the flock rather than an unknown and likely variable subset of animals.

4.2 Flock size and behavior of hens on free-range

Foraging (moving with head held low) was observed more on grass than on gravel and more in small and medium sized flocks than in large flocks, for reasons that are not clear. Hens in semi-natural conditions spend most of their time awake foraging (Savory et al., 1978). Those hens were released on an island and they were not fed by people. Hens in larger flocks might have foraged more inside the house where they were not observed. The interior of hen houses of larger flocks might have been more attractive than the houses of smaller flocks due to environmental (e.g. improved temperature regulation with more birds, more absolute space), social (e.g., greater feelings of security), or nutritional (e.g., increased number of feeders) factors, though appropriately designed studies would need to test these possibilities.

It is important to note that flock sizes were not manipulated so that causality cannot be concluded. Care was taken to balance flock sizes with

414 environmental conditions (seasons and years). However, farms differed in
415 many aspects and this likely plays a role in the large variation in range use
416 and behavior. Weather conditions like cloud cover which is known to
417 influence ranging behavior could not be standardized. Some flocks were
418 located on the same farm and thus were not entirely independent. Due to
419 the small sample size of twelve flocks, parameters like hybrid,
420 management, size of popholes, and structure of the free-range could not be
421 analyzed. Instead of standardization, a realistic variation in these
422 parameters was selected to provide representative results that could be
423 applied to commercial conditions. In this sense the flock with the fewest
424 hens registered on the free-range (47%) and the flock with one of the
425 highest registrations (90%) belonged to flocks of 6,000 hens. The free-
426 range that was only visited by 47% of the tagged hens consisted of grass
427 only. Outdoor areas without structures and shelters are known to attract
428 fewer hens (Bestman and Wagenaar, 2003; Zeltner and Hirt, 2003; Zeltner
429 and Hirt, 2004; Hegelund et al., 2005; Zeltner and Hirt, 2008). Likewise, the
430 distribution of hens with regard to the distance to the house which was not
431 associated with flock size might have been influenced by the structure and
432 vegetation of the free-range (Zeltner and Hirt, 2003). Brown hybrids range
433 more than white hybrids (Mahboub et al., 2004) and this was reflected in
434 this study where the duration outside was highest in the medium sized
435 flocks that contained two brown flocks. These influences, namely hybrid
436 and range characteristics, seemed more important than flock size to predict
437 how many hens were entering the outdoor areas. However, these results
438 cannot be readily extrapolated to small groups of hens or much larger
439 flocks that are common outside Switzerland.
440 In even small flocks an uneven distribution of hens crowding near
441 the house was detected similar to the findings of Elbe et al (2005). They

442 measured a high concentration of the amount of nitrogen in the soil of up to
443 2086 kg N / ha close to the house. Similar figures are probably true for our
444 flocks and could be a problem for the environment.
445
446 **4.4 Conclusion**
447 Although a majority of hens visited the veranda and at least half of the
448 tagged birds accessed the free-range, relatively few hens used those areas
449 extensively every day. Usage of the outdoor ranges had a bimodal
450 distribution where a subpopulation of hens appeared to use the range with
451 different patterns, i.e. many days at a long duration or infrequently of short
452 duration. The proportion of hens using the outdoor ranges frequently was
453 greater in small and medium sized flocks. The reason of the association
454 between time on the free-range and flock size and the implications for the
455 welfare of the hens in small and large flocks between 2,000 and 18,000
456 hens remain unclear and should be studied further.

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List of Figures

Fig. 1. Drawing of a laying hen house with the different outdoor ranges veranda and free-range. Antennas were placed on both sides of the popholes between the house and the veranda and between the veranda and free-range. A part of the free-range closest to the veranda was without vegetation, mostly consisting of gravel.

Fig. 2. Bimodal distributions of the percentage of days that hens entered the veranda (a) and the free-range (b). Data of all farms are pooled. The height of the bars denotes the percentage of hens in the flock that falls into the following categories: using the veranda (a) or free-range (b) up to 10 % of the monitored days (bar at the most left), between 10 and 20% of the days (next bar to the right) etc.

Fig. 3. Boxplots (showing the median (50th percentile) line inside box, the third quartile (75th percentile) upper edge of box, the first quartile (25th percentile) lower edge of box, and the minimum and the maximum (endpoints of lower and upper whiskers) of the ration between foraging and walking movements for hens on the gravel and vegetation portions of the free-range in differently sized flocks. Significant differences are marked with different letters.

Fig. 4. Relationship between flock size and number of birds seen outside at one instance. The references and actual numbers are shown in Appendix 1.The outside areas are classified as veranda when they were covered or free-range when they were uncovered. The data of the present study are included but distinguished by separate symbols.

Table 1. Attributes of the investigated flocks and the number of tags which were recovered during depopulation (% recovered), how many tagged hens were registered at the antennas inside of the house (% house), at the antennas at the outer side of the popholes between house and veranda or the antennas at the inner side of the popholes between veranda and free-range (% veranda), and at the antennas on the free-range (% free-range). LSL are white and LB are brown hens. The number and the width [m] of the popholes between house and veranda and veranda and free-range are given. On farm 5 the size of the popholes between veranda and free-range were variable and ranged between 1.2 (1 pophole) and 4.6 m (4 popholes).

# hens	Hybrid[1]	Season	Farm	House - veranda	Veranda – free-range	% recovered	% house	% veranda	% free-range
2,000	HN White	Spring 09	1	4 (1.15)	3 (1.5)	84	99	98	90
2,000	LSL	Fall 09	2	2 (3)	1 (5)	68	87	82	72
2,000	HN White	Spring 10	3	5 (1.2)	2 (1.2)	72	97	90	63
2,460	HN White	Fall 08	1	5 (1.2)	3 (1.5)	77	97	90	66
5,000	LB	Fall 08	4	8 (1.2)	8 (1.5)	72	97	96	85
5,600	HN Brown	Spring 10	1	13 (1.3)	11 (1.5)	88	100	99	90
6,000	HN White	Fall 09	3	9 (1.2)	3 (4.6)	91	98	96	47
6,000	LSL	Spring 09	5	8 (1.2)	5 (var.)	82	98	91	78
9,000	LSL	Fall 10	6	-	13 (3)	68.2	-	-	70
9,000	LSL	Fall 10	6	-	13 (3)	82	-	-	70
12,000	LSL	Spring 08	7	15 (1.5)	10 (2)	22	83	79	56
18,000	LSL	Fall 09	8	21 (1.2)	15 (2.25)	85	88	83	59

[1] Hybrids: LSL = Lohmann Selected Leghorn, LB= Lohmann Brown (www.ltz.de) HN White = H&N Nick Chick, HN Brown = H&N Brown Nick (www.hn-int.com)

Tables

Table 2. Ethogram of behaviors scored from collected video recordings. Each flock was videotaped at two locations on the free-range on two non-rainy days between 10 and 16 hrs. One location was close to the veranda without vegetation and the other location was on the grass further away from the veranda.

Behavior	Definition
Sit	Stationary, legs are not visible
Stand	Stationary, at least one leg is visible and stretched, no pecking
Walk	Locomoting with head above the body
Forage	Locomoting with head below the body, or standing and pecking

Table 3. Summary statistics of the ranging behavior in the twelve flocks. Summary statistics were only computed when a particular hen had no mismatching records for a day (see text). Means with standard errors are provided for the number of hens as indicated. This number includes only those hens in the flock that were registered on the veranda and the free-range and whose tags were recovered at depopulation.Durations are given in min. % veranda is the percentage of days that hens visited the veranda and % free-range is the percentage of days that hens visited the free-range.

# hens	Veranda	Free-range	% veranda	% free-range	N hens
2,000	98.27 ± 7.05	31.00 ± 4.12	85.15 ± 1.80	54.13 ± 2.73	196
2,000	67.09 ± 11.25	14.67 ± 2.52	86.49 ± 2.73	54.67 ± 4.84	76
2,000	107.42 ± 11.17	54.88 ± 9.90	91.38 ± 2.48	78.24 ± 3.99	96
2,460	61.13 ± 5.57	18.18 ± 3.07	70.76 ± 2.34	53.54 ± 3.06	222
5,000	127.90 ± 8.08	102.13 ± 55.31	90.76 ± 1.02	85.17 ± 0.91	347
5,600	113.25 ± 10.59	36.89 ± 3.75	70.22 ± 1.60	57.42 ± 1.54	291
6,000	77.00 ± 9.95	45.45 ± 4.90	73.97 ± 1.96	70.62 ± 2.79	276
6,000	91.59 ± 5.13	52.19 ± 4.28	80.71 ± 1.84	68.35 ± 2.42	269
9,000	-	36.24 ± 4.49	-	39.92 ± 1.94	313
9,000	-	73.74 ± 8.49	-	53.43 ± 2.19	324
12,000	60.42 ± 5.05	9.77 ± 5.25	77.54 ± 2.89	52.24 ± 4.26	99
18,000	59.76 ± 3.24	37.68 ± 2.82	26.73 ± 1.30	52.81 ± 1.61	560

Figure

Fig. 1

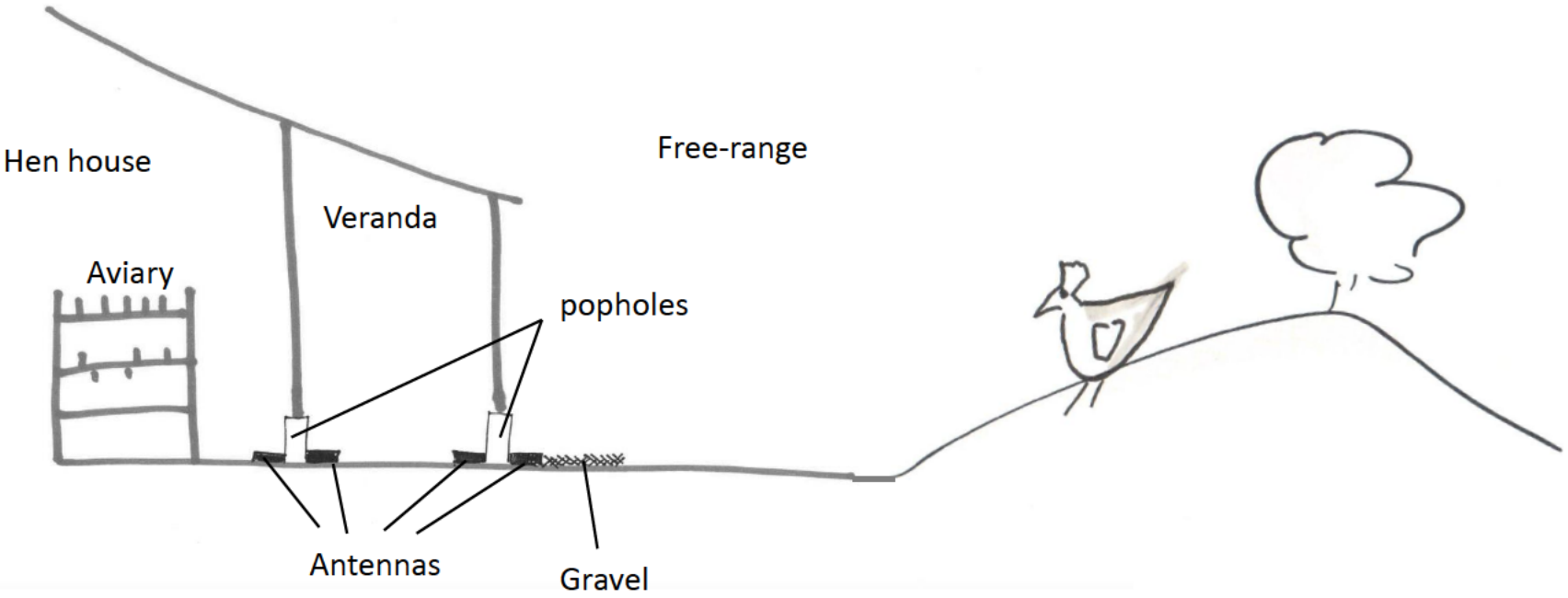

Hen house
Free-range
Veranda
Aviary
popholes
Antennas
Gravel

Fig. 2 a)

b)

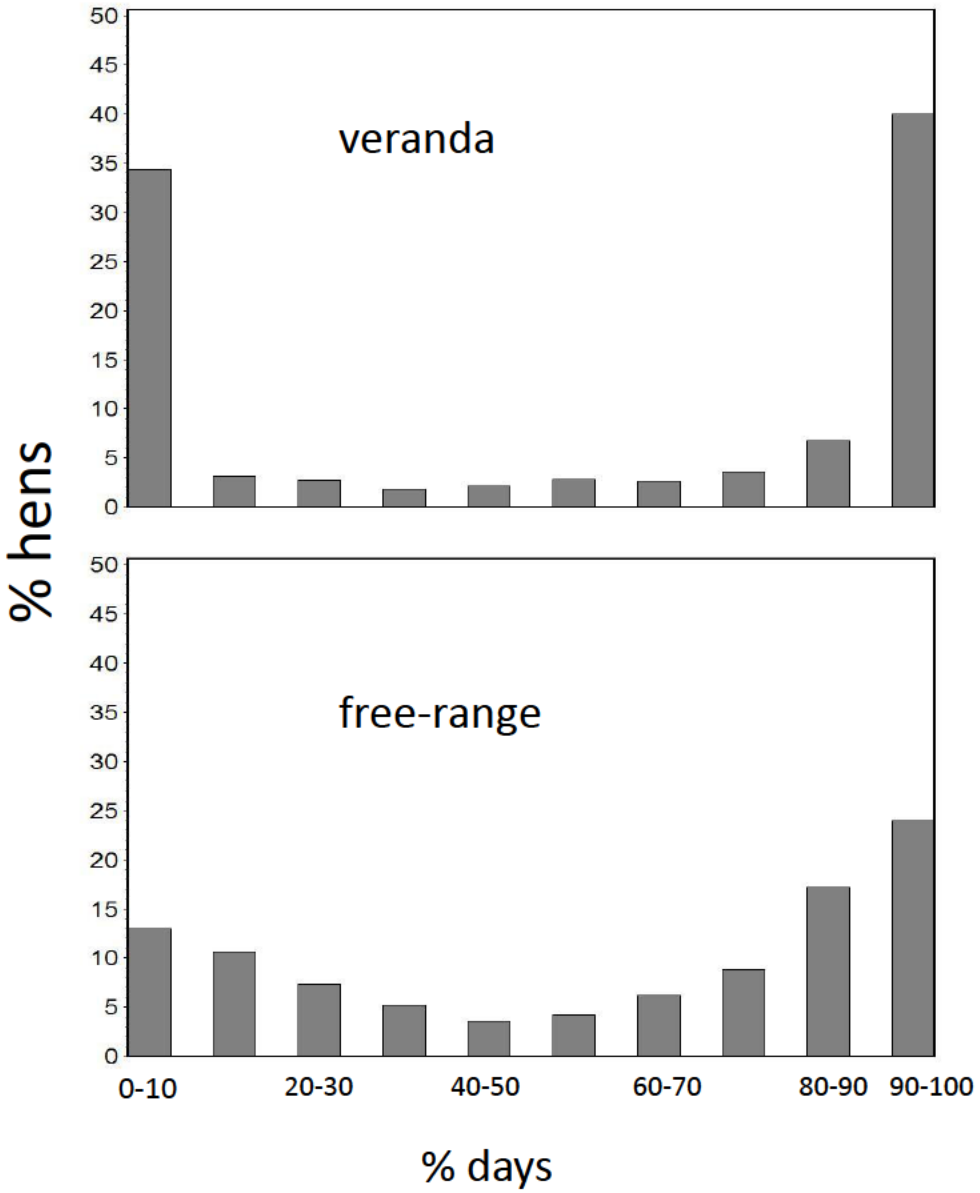
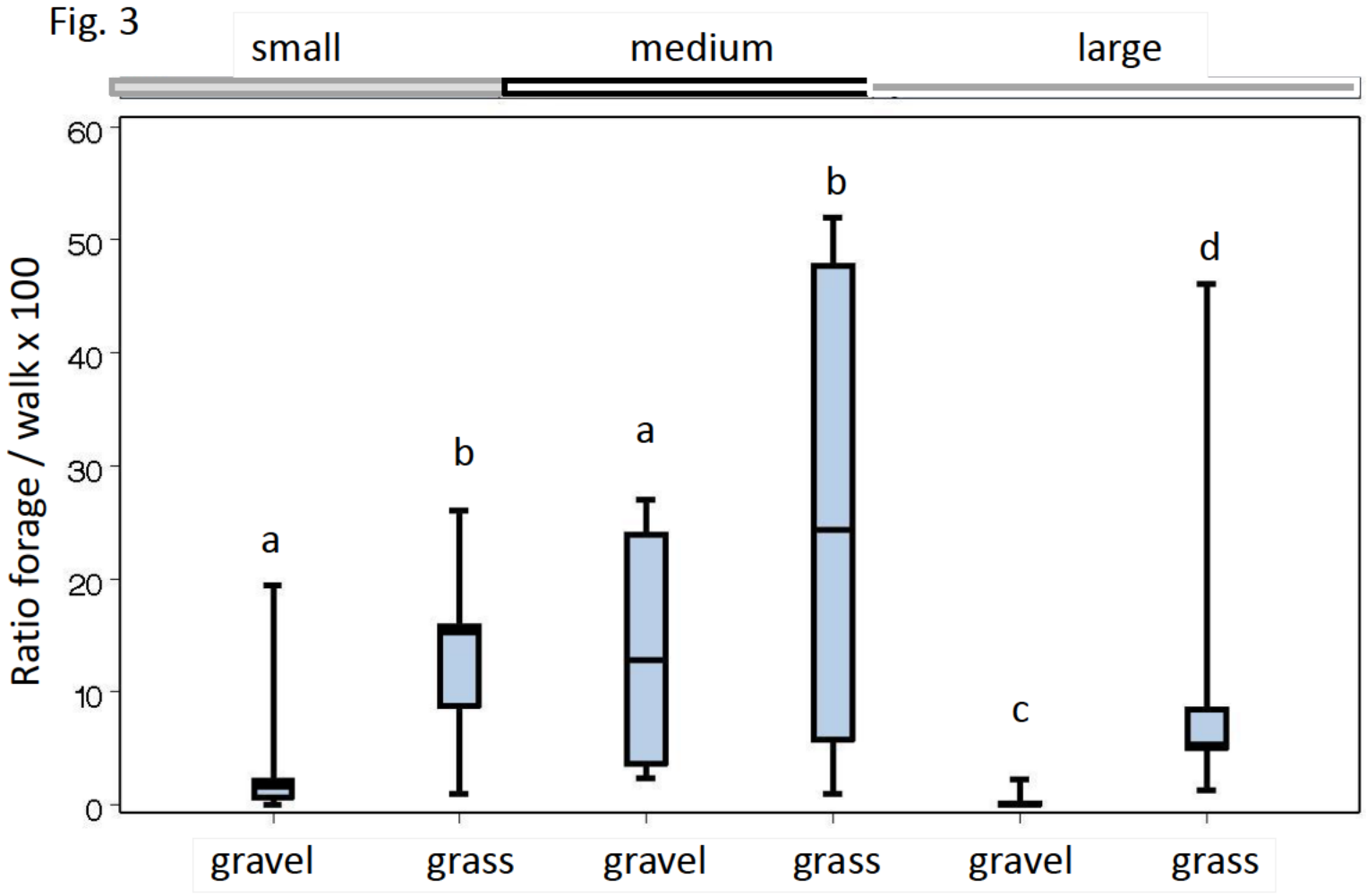

veranda
free-range
% hens
0
5
10
15
20
25
30
35
40
45
50
0-10
20-30
40-50
60-70
80-90
90-100
% days

Fig. 3


small
medium
large
Ratio forage / walk x 100
60
50
40
30
20
10
0
a
b
a
b
c
d
gravel
grass
gravel
grass
gravel
grass

Figure

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