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Effect of water depth on pool choice and bathing behaviour in commercial Pekin ducks.

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ABSTRACT

Pekin ducks (*Anas platyrhynchos domestica*) are raised for meat, often in indoor intensive systems. Research into the welfare of intensively reared ducks makes clear the importance of access to bathing water. Most researchers agree that bathing behaviours such as preening are important; however, the welfare implications of swimming are not so clear. A choice test was therefore designed to compare three depths of water: 10 cm, where ducks could stand but not swim; 20 cm, where ducks could stand and swim; and 30 cm, where ducks could swim but not stand. Ducks were housed in groups of four and each group had access to a shallow pool (10 cm), a deeper pool (either 20 or 30 cm) and two turkey bell drinkers which were added just as sources of clean drinking water. Observations were made between 29 and 48 days post-hatch. No difference was found between the usage of 10 and 20 cm deep pools, but ducks chose to use the 10 cm pools more than the 30 cm pools. This is a useful indication of duck preferences for water depth, but not a definitive measure because observations of bathing behaviour suggested that pools of different depths were used in different ways (30 cm pools were more suitable for swimming, but more dabbling was performed in the 10 cm pools than in deeper pools) and because not all groups of ducks made the same choices. Age had very little effect on bathing behaviour. Water cleanliness was also considered in the analysis: when the water was dirty, ducks spent less time inside the pools, spent less time sitting during bathing bouts and drank more from the bell drinkers. These results indicate that water depth and cleanliness have an impact on duck bathing behaviour.

Keywords: domestic duck, preference, water provision, water depth, swimming, bathing, choice test.

1. INTRODUCTION

Domestic ducks (*Anas platyrhynchos domestica*), especially the Pekin breed, are raised for meat production in many parts of the world. Their importance as a source of animal protein has increased in recent decades, one reason being their adaptability to a wide range of environmental conditions (Solomon et al., 2006). Pekin ducks are reared in production systems ranging from traditional farms, where ducks are confined around a pond or riverbank, to commercial intensive systems; but the tendency, mainly due to water pollution concerns, is towards indoor intensive systems (Lee et al., 1992).

In general, indoor intensive systems offer advantages such as controlled conditions and lower environmental impact, but they may also have disadvantages for the animals' welfare, the main concern being the lack of access to bathing water. Several studies have shown that easily accessible open water (in the form of troughs, baths or even showers) seems to be beneficial for the welfare, including the health, of the birds and that it encourages the display of natural bathing behaviours (Heyn et al., 2006; Jones & Dawkins, 2010b; O'Driscoll & Broom, 2011a; Waitt et al., 2009). These bathing behaviours include wet preening, head dipping, wing rubbing and different types of shaking movements (McKinney, 1965) and most researchers agree that these behaviours are important in the bathing sequence and in maintaining good plumage conditions and good health (O'Driscoll & Broom, 2011a). For example, Jones & Dawkins (2010a) reported preening as the most frequent behaviour in commercial ducks (more than 17% of total time) after "alert" and "small body movements". Waitt et al. (2009) reported wet preening as the behavioural state of longest duration during bathing bouts at troughs, followed by “drink/dabble”, while drink/dabble occupied the most time when observations were made at pools. Although frequency of behaviour does not necessarily imply relevance to welfare, an increase in preening behaviour has been widely used as proof of improved welfare in ducks with access to open water (Knierim et al., 2004; O’Driscoll & Broom, 2010; Ruis et al., 2003), mainly because it has been shown to improve health through the maintenance of eye health and feather hygiene (Jones & Dawkins, 2010a; O’Driscoll & Broom, 2011; Waitt et al., 2009).

Swimming behaviour has not been studied to such an extent as other bathing activities and its importance for duck welfare is less clear. Some researchers claim that swimming water might not be necessary for ducks to take proper care of their bodies (van Krimpen & Ruis, 2010) and that bell drinkers or narrow troughs could be sufficient to maximize bird hygiene and to satisfy most of their needs to show certain behaviours, while also minimizing water contamination, water usage, and bedding moisture (O’Driscoll & Broom, 2011a). On the other hand, Appleby et al. (1994) stated that ducks are strongly water-oriented and require access to water for swimming and bathing in order to fulfill their biological needs. Limited scientific evidence is available to support these views, but if swimming is an important bathing behaviour then open water should be provided in a pool deep enough to allow it.

One way to assess the relevance that a resource, or behaviour, has for an animal is to test its preference or motivation for it. Understanding motivation is important to interpret how the inability to perform some behaviours affects animal welfare (Fraser, 2008). Previous studies have investigated the preference of ducks for different types of open water (O’Driscoll & Broom, 2011a; Reiter, 2003), some of them including options such as pools of different depths (Knierim et al., 2004; Jones et al., 2009). However, these studies were not designed in a way that allowed clear conclusions about preference for depth of water, because they compared water resources that differed substantially in various physical dimensions, not only in their depth.

Consequently, the identification of pool depth preference is an important step in determining optimum water provision for commercial ducks. The current study was designed to investigate the preferences of farmed ducks among open water sources varying in depth and to analyse the differences in bathing behaviour when using the different pools. Specifically, a choice test was designed to study pools of three different depths: 10 cm (standing in the water was possible, but not swimming); 20 cm (standing and swimming were both possible); and 30 cm (swimming was possible, but not standing). In order to ensure that the water resources were commercially realistic, it was necessary to incorporate access ramps and steps into the design of the deeper (20 and 30 cm depth) pools that were not present in the shallow pools. Thus, the treatments differed in some respects other than water depth. The objective of the present experiment was to conduct and applied study of the preference between realistic water resources that differed primarily in their depth, as opposed to a more basic investigation of preference for water depth *per se.*

2. MATERIALS AND METHODS

2.1. Animals and treatments

Sixty-four ducklings (Cherry Valley Pekin type) were commercially brooded and reared until 21 days old, when they were introduced in groups of four to the test pens. Eight groups of ducks were studied during each of two replications in the spring and summer of 2010 (1st replication: May-June; 2nd replication: July-August) with a total of 16 groups. Ducklings were brooded commercially in one barn that was constructed on a concrete floor and had forced ventilation. They had access to a gas heater until 12 days post-hatch, and were managed on straw litter that was topped up daily. From day 1 post-hatch they were restricted to a section of the barn where they had access to chicken bell drinkers (diameter: 23 cm; height: 12 cm; drinker width: 4.5 cm; water depth to lip: 4 cm) and hopper feeders (89 cm × 145 cm). At 14 days, the ducklings were provided with access to the entire barn where the same hopper feeders were present and the drinking water was instead provided in troughs (length: 150 cm; height: 14 cm; width: 15 cm; water depth to lip: 8 cm) to comply with the RSPCA welfare standards for ducks (RSPCA, 2011). At 21 days, the ducklings were moved to the test barn.

The test barn was divided into 8 pens, 4 on each side of the building with a servicing corridor in the middle. Each test pen consisted of a straw-bedded area on a solid concrete floor (3.2 m × 6.0 m = 19.2 m^2), a raised drained area with a perforated plastic floor (1.2 m × 6.0 m = 7.2 m^2) and a grooved concrete ramp (0.6 m × 6.0 m = 3.6 m^2) between the two areas (Figure 1). The total floor area per pen was 28.8 m^2. Four ducks were allocated to each pen and they were marked with coloured sprays for individual identification. Each group had access to two different open water sources (pools). There were two treatments, in each of which a different pair of water sources was available: (1) choice between a shallow pool (SH, 10 cm depth) and a deep pool (DE, 30 cm depth); (2) choice between a SH pool and an intermediate pool (IN, 20 cm depth). Each group received only one treatment.

All pools were large enough for all four birds to use them simultaneously (total area: 1.1 m^2) and they had the same dimensions (1.00 x 1.10 m) with the exception of depth. Pools were located in the raised drained area of the pens. This area was divided in half by a solid partition and each half contained a pool, as well as a turkey bell drinker to ensure a constant supply of clean drinking water. Pools were individually connected to the main water supply and were self-filling, with the water level controlled by a ballcock. Because of their depth, DE and IN pools had wooden ramps followed by wooden decks to facilitate access. These ramps always had the same angle (20°) but were of different lengths (30cm for IN pools and 50cm for DE pools). DE and IN pools also had an inside step to facilitate entry and exit. These steps ensured that the height of the pool edge was the same for all pool types (SH, IN and DE), with the ducks being required to step over a 15 cm barrier to enter or leave the pools in all cases.

All partitions, between pens and between pools inside the same pen, consisted of opaque boarding that prevented direct access between pool areas and also prohibited visual and physical contact between animals in different pool areas or pens. Birds were fed a standard commercial duck feed appropriate for their age. The bedding was topped up as needed and pools were emptied, cleaned and refilled once a week. There was artificial light inside the test barn, with 30 min of total darkness per day from 23:30 to 24:00h, as normally occurred under commercial conditions. Some natural light was available through windows that were left partially open at all times.

2.2. Data collection and analysis

2.2.1. Environmental measures

Ambient air temperature, relative humidity (RH) and pool water temperature were recorded using Gemini Tinytag Extra Data Loggers, TGX-3580 (Gemini Data Loggers (UK) Ltd., Chichester, UK) between day 21 and 49 of each cycle. One data logger was suspended at a height of 180 cm at a central point of the barn to record ambient temperature and RH. To record water temperature, 12 data loggers were submerged in the pools, 4 loggers per type of pool per replication, and secured at the bottom of the pools to protect them from being moved by the ducks. Data were recorded at 5 min intervals. A descriptive analysis of these data was performed, reporting average temperature and RH values during the period of study and comparing the daily water temperature fluctuations that occurred in pools of different depths.

2.2.2. Behaviour measures

Animals were recorded using a CCTV system (WebCCTV NVR, from Quadrox) and CCTV cameras (Sony CXD3142R, with 2.45mm board lens, model BL2.45) during a 3-week period between 29 and 48 days of age. The previous week (day 21 to 28) was considered as a habituation period. Birds were re-marked weekly with coloured sprays and the pools were emptied, cleaned and refilled on days 28, 35, 42 and 49. Twenty-four hour video recordings were watched on 2 days per week: days 29 and 34 (week 5), days 36 and 41 (week 6) and days 43 and 48 (week 7). To analyse the effects of age, the two recording days on each week were combined (scores were calculated for each day and then averaged to get a combined data point per week). To evaluate the effects of water cleanliness, the combined "clean" days, 1 day after cleaning (days 29, 36 and 43), were compared with the combined "dirty" days, 6 days after cleaning (days 34, 41 and 48). To analyse the effects of water depth, all 6 days were combined.

2.2.2.1. Preference analysis

Behaviour was continuously observed and time budgets were calculated using The Observer XT 9.0 (Noldus Information Technology, Wageningen, The Netherlands). Pens were divided into seven areas: SH pool; SH poolside; SH drinker area; treatment pool (DE or IN); treatment poolside; treatment drinker area; and straw-bedded area. Poolside areas included the wooden deck and the wooden ramp in the case of IN/DE pools, or the equivalent virtual space in the case of SH pools, plus the part of the concrete ramp that was adjacent to the pool, wooden deck and wooden ramp (total area: 2.50 m^2). Drinker areas included the bell drinker plus the perforated plastic floor area around it and the remainder of the concrete ramp (total area: 1.80 m^2).

Twenty-four hour video recordings were watched for their entire duration and time budgets were calculated as the % of time spent in each pen area. Levels of area usage were obtained for each of the individually marked birds and then mean values were calculated per pen. Area usage measures were not adjusted to account for differences between the dimensions of different pen areas, since the only comparisons made were between areas of the same size.

Relative pool usage was measured in three ways: as the amount of time spent inside the SH pool, expressed as a proportion of the total time spent inside both pools; as the amount of time spent in and around the SH pool (pool + poolside) as a proportion of the total time spent in and around any pool; and as the total amount of time spent in "water-related" areas linked to the SH pool (pool + poolside + drinker area) as a proportion of the total time spent in water-related areas associated with both pools. These measures were used to describe the ducks' choices between the pool types, from which their preferences could be inferred. The frequency of visits to the pools (number of visits per 24 h period) and the average duration of the visits (in seconds) were also measured.

Pool usage data were analysed using PASWStatistics18 software, examining the effects of treatment (3 levels), age (3 levels), cleanliness (2 levels), replicate (2 levels) and pool temperature. The pen was considered the experimental unit. Hence, the data used to evaluate preference consisted of measures of the relative usage of the two alternative pools within each pen. Prior to analysis, all data were checked for normality by examination of histograms and normal distribution plots. Kolmogorov-Smirnov and Levene's tests were also performed to assess normality and homogeneity of variance. As these tests were significant in most cases, and transformations failed to render the data consistent with the assumptions of parametric analysis, non-parametric tests were used.

To evaluate preference for water depth, one-sample Wilcoxon signed-ranks tests were employed to assess differences between measures of the relative usage of the SH pool (% time spent in the SH pool; % time spent in the SH pool + SH poolside; and % time spent in the SH water-related areas) and a constant reference level of 50%. Two-sample Wilcoxon signed-ranks tests were used to test the effect of water cleanliness, Friedman's ANOVA by ranks to determine the effect of age, and Mann-Whitney tests to account for the possible effects of pen and replication. A similar approach was taken to assess the effects of these variables on the number of visits, and the average visit duration, to the pools.

Since temperature might influence pool choice, the correlation between mean SH pool temperature and relative pool usage (the % time spent in the SH pool) was calculated using Kendall rank correlation coefficients. An additional analysis to determine whether pool temperature influenced absolute, as opposed to relative, pool usage was also carried out. For this analysis, the amount of time spent in each pool type (SH, IN and DE), expressed as a proportion of the total time spent anywhere in the pen was calculated. Kendall rank correlation coefficients were again used.

2.2.2.2. Bathing bout analysis

Using the same 24 h videos recorded for the preference analysis, bathing bouts were identified using The Observer XT 9.0. 1657 complete individual bathing bouts were recorded in total and these were further investigated to describe bathing behaviour. An ethogram was created to score the birds' behaviour (see Table 1). A bathing bout started when the first duck involved in the bout entered any of the water-related areas (pool, poolside or drinker area). A duck involved in the bout was defined as any duck bathing in one of the pools before the end of the bout; if a duck was present but never entered the pool it was not included in the bathing analysis. A bathing bout finished when the last duck involved in the bout left the water-related areas, or remained sitting inactive showing no water-related behaviour for more than 5 min. The behaviour of all ducks involved in a bathing bout was scored and time budgets were calculated as the % of total time in all cases except for the behaviours "shake", "stretch" and "flap wings" that were considered events and were included as the number of occurrences per bout. The results were averaged for all ducks involved in a joint bout. A descriptive analysis of the ducks' bathing behaviour was performed, including measures of the time spent bathing and the frequency and duration of bouts.

A statistical analysis was also carried out to assess the effect of water depth on bathing behaviour. The objective was to ascertain whether ducks used the different pool types in different ways. This is an important aspect of any preference testing study, partly to understand the reasons for any preferences found, but also to check that a meaningful preference can be inferred from the animals' choices (Kirkden & Pajor, 2006). The design of the experiment was not ideal for a comparison of the behaviours performed in the different water resources: it would have been better to have obtained this information from a separate experiment in which groups of ducks received only one type of resource. With two water resources available, activities carried out in one might have affected the behaviours performed in the other. However, for the purpose of checking for substantial differences between the pool types that might be responsible for observed choices, it was judged that the existing data were adequate. In order to minimise this potential confound, only those groups of ducks that showed a strong choice of one pool type (defined as spending more than 90% of total pool time in the preferred type of pool) were included in the analysis. It was reasoned that because these groups spent almost all of their time in one of the water resources, usage of the other resource should have a relatively small effect on the behaviours observed. To evaluate the effect of water depth on bathing behaviour, SH pools were compared with deeper pools, not distinguishing between IN and DE. This was a between-groups analysis, since a particular group could express a strong choice either for the SH pool or for the deeper alternative, but not for both. Twenty-six bathing bouts were suitable for analysis, 2 per pen on different days, except in 4 pens where just one bout was recorded. Results from the 2 bouts per pen were averaged, giving a final sample size of N=8 for SH bouts and N=7 for IN and DE bouts. Because the data were not consistent with the assumptions of parametric analysis, Mann-Whitney tests were employed to assess the effect of water depth (2 levels, SH and IN/DE) on bathing behaviour.

Additional statistical analyses were carried out to assess the effects of age and water cleanliness on bathing behaviour. In this case, the analyses focused on use of the SH pools, since all groups had access to these, and only groups that showed a strong choice of this pool type were included.

The effect of age was of interest because some producers claim that ducklings under 5 or 6 weeks of age do not need open water, on the grounds that bathing behaviour is not yet fully developed. Thirty-six bathing bouts were analysed, 12 per week and 6 from each recording day. The effects of age (3 levels; N=8 for each week) on bathing behaviour were assessed using Mann-Whitney tests and the effects of cleanliness (2 levels; N=10 for "clean" and N=9 for "dirty") using Kruskal-Wallis tests.

3. RESULTS

3.1. Environmental measures

Ambient temperatures were within the optimal range for ducks, whose thermoneutral zone is considered to be between 7 and 23°C (Cherry & Morris, 2008). Air temperature ranged between 7 and 20°C, and RH between 58 and 89%. Average values were 15.3 ± 3.7°C (mean ± s. d.) for ambient air temperature; 71.9 ± 6.8% for RH; and 14.1 ± 3.6°C for pool temperature. Daily temperature fluctuations differed among different types of pools. Shallow pools were the warmest on warm days (Figure 2a shows an example of 4 warm days during the 2^{nd} replication) and the coldest on cold days (Figure 2b shows an example of 4 cold days during the 1^{st} replication).

Water temperature in the SH pool was not correlated with relative usage of this pool, calculated as time spent in the SH pool as a % of total time inside both pools (Kendalls' Tau: τ = -.032, $P > 0.05$). When the amount of time spent in the pools was calculated as a % of total time spent anywhere in the pen, no significant correlation with water temperature was found for DE or IN pools; but the water temperature inside SH pools was significantly correlated with the time spent inside them (Kendall's Tau: τ = -.174, $P = 0.013$), with ducks spending less time inside the SH pools at higher temperatures (see Figure 3). This is consistent with the observation made above that SH pools became warmer than IN or DE pools during warm weather.

3.2. Preference analysis

Ducks used the SH pools more than the DE pools, with the % of time spent at the SH pools being significantly different from 50% (results are shown in Table 2), but relative usage of the SH and IN pools did not differ from 50%.

Age had a significant effect on the relative usage of pools in the SH vs. DE treatment (see Table 2), with the proportion of time spent using the SH pools increasing with age. Water cleanliness, pen and replication were also tested as possible influences on the ducks' choice behaviour, but no significant effects were found.

Water depth had a significant effect on the number of visits to the pools, with SH pools receiving more visits than DE pools (P=0.005; see Table 3). Water cleanliness had a significant effect on the duration of the visits to the SH pools (see Table 4), with visits being longer when the water was clean (P=0.009); but the number of visits was not affected by water cleanliness. Age significantly affected the number of visits to the SH pools (P=0.015), with ducks visiting these pools most often during week 7 (see Table 5).

3.3. Bathing bout analysis

A descriptive analysis of the ducks' bathing behaviour showed that ducks spent 8.9 ± 6.6% of their time inside the pools, which amounted to an average of 2.1 hours per day inside water. When time spent in all water-related areas was calculated (pools, poolsides and drinker areas) the percentage was 36 ± 18%, which corresponded to 8.5 hours a day. Bathing bouts were selected from these time budget data. 587 complete group bathing bouts were present in total, which amounted to 6.8 bathing bouts per day and pen. The mean duration of a bathing bout was 28 ± 24 minutes, and a mean of 2.8 ± 1.2 birds were involved in each bout. 64% of these bathing bouts occurred in SH pools, while 36% occurred in the other pools (16% in DE pools and 20% in IN pools). Bathing bouts occurred at a constant frequency during the course of the day with no specific peaks of activity.

Table 6 shows that water depth had no effect on the % of bathing time spent inside or outside the pool, but it did have a significant effect on the % of time ducks spent standing or sitting/floating during the bathing bouts (P=0.015), with SH pools encouraging more standing behaviour and IN/DE ones more sitting/floating behaviour. Ducks spent significantly more time moving (walking or swimming) when the bathing bout occurred at an IN/DE pool than at a SH one (P=0.004), and they also stayed inactive significantly more (P=0.049). Ducks bathing in the SH pools spent significantly more time dabbling than those bathing in the IN/DE ones (P=0.028).

The effects of age and water cleanliness were assessed for SH pools only. Age had no effect on any of the bathing behaviours analysed except for the % of time spent standing (P=0.009) and sitting (P=0.001), with ducks spending more time sitting in week 5 than in week 7 (see Table 6).

Water cleanliness affected several aspects of the ducks' bathing behaviour. They spent a higher percentage of their bathing bouts inside the pool when the water was clean (P=0.009) and conversely they spent significantly more time outside the pools on days when the water was dirty. Water cleanliness also affected the percentage of time ducks spent standing or sitting during the bathing bouts, with ducks spending significantly more time standing and less time sitting when pools were dirtier (P=0.023). Finally, there was a significant effect of water cleanliness on drinking behaviour with ducks drinking more often from the drinkers during the dirty days (P=0.01).

4. DISCUSSION

No evidence of preference for deep swimming water could be found in the present study. On the contrary, the results suggest a preference for shallow water. However, the findings of this preference test must be treated with caution because the measures of relative time spent in the pools depend on the types of behaviours carried out in these different resources. The results of the bathing bout analysis suggest that shallow and deep pools may have been suited to the performance of different activities. By design, the water resources differed in their suitability for the performance of floating and swimming. If the pools had differed only in this respect, then the greater usage of the SH pool compared to the DE pool would have implied an aversion to floating or swimming. However, the analysis of bathing behaviour revealed that the pool types also differed in another respect, since ducks spent more time dabbling in the SH pool than in deeper pools. It is possible that this was because the SH pools were better suited to this behaviour (see below). Hence, the resources may have differed in two behavioural dimensions, with the DE pools favouring one type of behaviour and the SH pools another. Because of this, the reason for the observed choice of the SH pool over the DE pool is unclear. It is possible that the ducks were simply averse to floating and swimming, or overwhelmingly motivated to dabble, and that the greater usage of the SH pool reflected a straightforward preference for this pool. However, it may be that the ducks were motivated to use each pool type for a different reason. In this case, the relative amount of time spent using each might reflect the different amounts of time required to satisfy different motivations (i.e. ducks might require less time to satisfy a motivation to swim than to satisfy a motivation to dabble) rather than reflecting the relative strength of these motivations (Kirkden & Pajor, 2006). Hence, the current results are suggestive of duck preferences but do not provide definitive evidence for a preference for shallow water over deep.

In order to investigate this question further, it would be necessary to contrive experiments that ascertained more directly: (1) the differential suitability of these water resources for swimming versus dabbling; and (2) the relative importance of being able to perform these two behaviours. The first of these objectives could be achieved by measuring the substitutability of shallow and deep water resources using a method such as the one described by Warburton & Mason (2006), in which one resource is made unavailable and the effect of this upon the level and type of usage of the other is assessed. This would ascertain whether ducks require a shallow pool for dabbling and a deep pool for swimming; or whether in the absence of one resource, the other will permit the behaviour in question to be performed to a significant extent. Meeting the second objective would require a much lengthier and more complex experiment and would probably only be justified if the pool types proved to be poor substitutes. It would involve comparing the strength of motivation for access to a shallow pool versus a deep pool using the highest price paid or consumer surplus (Kirkden & Pajor, 2006).

With respect to the basic finding that ducks chose to use SH pools more than DE pools, there are also two important methodological caveats that must be considered. The first is that the ducks' previous experience might have influenced their relatively high usage of the SH pools. They had prior experience of shallow water, due to the provision of troughs on week 3, but not of intermediate or deep water and this may have increased their preference for the previously known option. This aspect of experimental design was necessary for several practical reasons. In the first place, it was not possible to make deep or intermediate pools available at an earlier age, since deep water can be dangerous for ducklings under 21 days of age due to physical difficulties with entering and exiting the resource that can result in drowning. An alternative approach might have been to provide ducks with bell drinkers instead of shallow troughs prior to day 21, since bell drinkers would not have resembled any of the experimental water resources. However, this was not possible because troughs were required to meet production standards (RSPCA, 2011). In order to investigate the influence of previous experience on pool usage, a further study using bell drinkers before the introduction of open water would need to be conducted.

The second caveat concerning the finding that ducks used SH pools more than DE pools is that although the current analysis showed this to be the case on average, it was not true of all groups; and in some cases, relative pool usage varied from one week to the next within a given group. Caution is required when extrapolating from the findings of a preference test to commercial recommendations (Nicol et al., 2009) since the “average preference” may not be the best measure of what many individual ducks, or sub-groups of ducks, want in a commercial barn. Moreover, the majority of the groups exhibited a very high level of usage of one pool relative to the other, perhaps as a result of social relationships within the group. For example, social status might have affected choice behaviour (Desforges & Wood-Gush, 1975a), since the choices observed could have been those of certain members of the group that control the behaviour of others (Broom, 1981). Once again, the choices that were observed may not have reflected the preferences of all individuals. To further investigate this, more detailed investigations have been carried out of the social behaviour within groups, including leadership and group cohesion analyses (Liste et al., manuscript in preparation). Despite this problem, it is generally recognized that testing social species such as ducks in groups is preferable to testing them alone, since social isolation can cause stress and has been shown to influence measures of motivation (Sherwin, 2003). Moreover, it is commercially realistic to test ducks in groups because farmed Pekin ducks are kept in flocks, although commercial flocks are much larger than our experimental groups and the social dynamics that occur within these flocks may be more complex (Mench & Keeling, 2001).

The fact that ducks in this study were observed to perform a wide range of bathing behaviours, including swimming, dabbling and preening, suggests that they were motivated to do so and it is worth considering the likely reasons for this and the implications for the provision of open water sources. As stated by the Council of Europe (1999), farmed ducks make use of water for foraging, feeding, drinking, exploration, locomotion and preening, even without prior experience (Heyn et al., 2006), just like their wild ancestors. Wild mallards use deep water (such as rivers or ponds) for several reasons including protection from predators, foraging, transportation and mating. However, they also spend much of their time at the water's edge performing social behaviours, feeding, resting and parts of the bathing sequence, such as shaking movements, wing and leg stretches, bill dipping, dabbling and oiling (McKinney, 1965). The fact that these behaviours are performed in shallow water suggests that being able to stand in the open water source might be helpful to carry them out. In the current study, the higher level of dabbling in the shallow pools might have been due to a preference for performing this behaviour while standing, or it might have been linked to visibility and distance to the bottom of the pool.

Dabbling can partly be considered as foraging behaviour, and ducks perform a high proportion of foraging behaviours in water (Rodenburg et al., 2005). Water-based enrichment has been found to increase the foraging behaviour of Muscovy ducklings (Riber & Mench, 2008). Cooper et al. (2002) found that ducks performed more water-directed activities, such as dabbling and head dipping, at bell drinkers and troughs than at nipple drinkers, and used the nipple drinkers just for drinking and some wet-preening. It is difficult to assess the importance of dabbling as part of the bathing sequence, but in the current study this behaviour took a similar proportion of time as preening and drinking during the bathing bouts. In contrast, Jones & Dawkins (2010a) reported a higher proportion of time spent preening (more than 17% of total time) than drinking (almost 7%) or dabbling (less than 2%).

Water temperature did not affect the ducks' pool choices within the range of temperatures occurring in the study. However, shallow pools showed the most variable temperature while intermediate and deep pools were able to maintain a fairly constant temperature despite environmental changes. High water temperatures were correlated with lower absolute amounts of time spent in the shallow pools (as a proportion of time spent anywhere in the pen), which indicates some degree of aversion to warm bathing water when environmental conditions are also warm. Ducks use bathing water for thermoregulatory purposes and they can suffer from heat stress if this is lacking, especially in hot climates (Abd El-latif, 2003). Previous research with farmed Pekin ducks has reported panting behaviours at temperatures as low as 15°C, measured as a weekly average, and this was linked with increased levels of wet preening (Jones & Dawkins, 2010a). This suggests that providing open water resources that are able to keep a stable low temperature might increase the welfare of farmed ducks, especially in cases of high ambient temperatures. Shallow pools are probably less suitable for this function than deeper pools.

Age barely affected bathing behaviour, with the exception of standing and sitting postures. There seems to be a direct correlation between postures and age, as previous studies (Jones & Dawkins, 2010a; O'Driscoll & Broom, 2011b) have also found that younger ducklings spend a higher proportion of their time sitting and resting than older ones, while older ducks spend more time standing while alert or preening. The fact that age had no effect on specific bathing behaviours in the present study suggests that bathing behaviour is fully developed from at least 29 days of age and that ducks can make the most of the pools from an early time in their lives. The only limit on the time of introduction of the pools has to do with access, since all ducks must be able to enter and leave the open water in a safe way. When offering shallow open water from an early age, in the form of a gutter, neither Bulheller et al. (2004) nor Knierim et al. (2004) found any evidence of chilling or drowning in Muscovy ducklings. But when testing deeper options, such as 50 cm deep pools, Erisir et al. (2009) reported problems during the first three weeks of age, although they did not describe the pool design in enough detail to ascertain the ease of access.

Pools became very dirty at some points during the trial, with green algae starting to grow in some corners. This did not stop ducks from bathing in them and choice was not affected by water cleanliness. However, ducks were able to distinguish between clean and dirty water since they spent a greater percentage of their bathing bouts outside the pools, and spent less time sitting in the water when it was dirty. Moreover, ducks drank significantly more from the bell drinkers when the pool water was dirty. This clearly indicates that ducks prefer to drink clean water. There is no research conducted into the drinking preferences of ducks, but in a study performed by Houldcroft et al. (2008) on the drinking preferences of broilers it was found that chickens chose mains water, which was clean, over puddle water that was dirty and possibly contaminated. The issue of drinking water quality is addressed in UK legislation (DEFRA 2007), stating that “birds should have fresh water at all times” and that “stale or contaminated water should not be allowed to accumulate and should be replaced immediately”. Another important aspect to consider is that poor water quality negatively affects the water-repellant properties of a bird’s plumage (Van Rhijn, 1977). Provision of an open water source alone does not satisfy the requirement that ducks should be provided with fresh and clean drinking water. Therefore, drinkers, i.e. water sources that do not allow body access and can keep a better water quality, should always be provided in conjunction with open water.

When researching sustainable systems to provide farmed ducks with open water, some have suggested providing limited access to the resource, mainly in order to save water. Heyn et al. (2006) offered different resources (nipple drinkers, bell drinkers, showers, troughs and modified round drinkers) with a range of access levels (from continuous access to just 2 hours a day) and found that very restricted access reduced water consumption and that the ducks adapted by increasing their use per unit time when restrictions were in place. However, the current study suggests that a long period of access would be beneficial, since ducks were found to spend a large proportion of their time engaged in water-related activities: 9% of their time was spent inside water, and 36% performing water-related activities. Slightly lower levels were reported by Jones et al. (2009) who found that ducks spent 2.6 - 3.5% of their time “bathing” (considering the behaviour as just wet-preening) and less than 1% of their time swimming. When time spent resting by the resource and drink-dabbling from the edge of the resource were included, the time went up to a 22%. This disparity of results could be due to different definitions of the terms used in the ethogram and different observation schedules. On the basis of these results, Jones and colleagues suggested that it might not be necessary to provide constant access to bathing water through the day. However, the ducks in the present study were active, and bathing, all day long. This could have been affected by the artificial lighting regime (with a minimum of 2 lux in the bathing area during 23 hours a day, although Jones et al. did not describe their lighting regime), but it is well known that many species of ducks are active in twilight and at night, as well as during daylight (Reiter, 1997); and even in farmed ducks the most common time for laying eggs has been documented to be around midnight (Lee et al., 1992). Also, bathing bouts at the pools were observed to be complex activities that required a long time to be properly performed. On average, the ducks in the current study spent more than 28 minutes per bathing bout (although this is referring to “group” bouts, with more than 2 ducks involved on average). A similar study carried out by Waitt et al. (2009) reported a much lower average bout length of 3 minutes at pools. This large disparity could again be due to differing definitions of “bathing bouts” or to the fact that they investigated individual bouts.

A sustainable and economical system for providing open water should be developed that meets the behavioural requirements of the ducks and prevents any increased risk for bird health and the environment. It has already been suggested that the provision of shallow bathing water with regular or continuous water exchange could be a practical solution (Knierim et al., 2004). However, more research on the possible effects of poor water hygiene on duck and consumer health is necessary before a final conclusion can be drawn. Also, following recommendations by Waitt et al. (2009) and Jones and Dawkins (2010b), further work is needed into the social aspects of bathing behaviour especially in connection with environmental conditions (such as warm weather), as this will help to answer practical questions such as the percentage of ducks in a flock that would use the resource at any given time and to calculate the necessary density of water sources per duck.

5. CONCLUSION

Commercial Pekin ducks chose to spend more time using a shallow pool in which they could stand than a deep pool that permitted swimming. This is a useful indication of duck preferences for water depth, but not a definitive measure because observations of bathing behaviour suggested that pools of different depths were used in different ways and because not all groups of ducks made the same choice. Deep pools were better suited to floating and swimming, while shallow pools were used more for dabbling. The age of the ducks did not have a great impact on the birds' behaviour. Water conditions such as temperature and dirtiness influenced the amount of time spent in the shallow pools. A welfare-friendly and sustainable open water source for farmed ducks could be offered in the form of a pool but more research is needed to assess its impact on a commercial scale. It is predicted that maintaining an acceptable water quality in these receptacles at commercial densities might prove challenging and more work is needed to solve this issue.

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Figure 1. Diagram of test pen for four ducks showing a shallow pool on the left and an intermediate pool on the right.

Figure 2a. Temperature inside the pools (shallow: SH, intermediate: IN and deep: DE) and ambient air temperature (ENVIRONMENT) during 4 days of warm weather.

Figure 2b. Temperature inside the pools (shallow: SH, intermediate: IN and deep: DE) and ambient air temperature (ENVIRONMENT) during 4 days of cold weather.

Figure 3. Correlation between water temperature in the shallow pools and % of time spent in shallow pools (as a % of total time spent anywhere in the pen).

Table 1. Ethogram for ducks in test pens with pools.

Behavioural states	**Definitions**	
LOCATION		
In water-related area	Inside SH pool	Duck located inside shallow pool
	Inside IN/DE pool	Duck located inside intermediate / deep pool
	Outside pool	Duck located in any other water-related area of the pen (poolsides or drinker areas)
In non-water related area		Duck located in the straw area
POSTURE		
Standing	Duck standing	
Sitting	Duck sitting on floor, inside shallow pool or on intermediate / deep pool steps	
Floating	Duck floating on deep area of intermediate / deep pool	
BEHAVIOUR		
Moving	Locomotion: duck moves more than two steps (or equivalent distance when swimming) in the same direction.	
Inactive	Standing or sitting stationary. Duck could be alert (including alert head movements) or resting.	
Preening	Nibbling at or stroking feathers to maintain plumage condition	
Head/body dip	Dipping head and/or body into pool water with vigorous upward/downward movements	
Head/body/tail shake (event)	Rapid shaking movements of head, body or tail from side to side	
Neck/wings/legs stretch (event)	Stretching movements involving extended neck, wings or legs	

Flap wings (event)	Beating the air with the wings, with the function of drying the feathers
Drinking from pool	Ingesting water by means of downward and upward head movements at pool
Drinking from drinker	Ingesting water by means of downward and upward head movements at bell drinker
Dabble	Rapid beak-dipping movements either at the pool water surface or deeper (including head immersions), with a foraging function
Explore/peck	Nibbling and pecking at solid objects (exploratory function)

Table 2. Effects of water depth, duck age and water cleanliness on pool choice (proportion of time spent in one pool, or pool area, compared with another). Data are shown as medians with inter-quartile ranges (IQRs).

Area evaluated[1]:		**Shallow vs. Intermediate**			**Shallow vs. Deep**		
		Pool	**Pool+ poolside**	**Water-related**	**Pool**	**Pool+ poolside**	**Water-related**
Water depth[2]		31 (96)	45 (98)	65 (96)	100 (79)***	100 (69)***	100 (56)***
Age[3]	Week 5	23 (100)	48 (100)	50 (100)	77 (92)^{a}	94 (91)^{a}	93 (91)^{a}
	Week 6	44 (73)	43 (60)	73 (67)	100 (86)^{ab}	100 (75)^{a}	100 (62)^{ab}
	Week 7	25 (74)	51 (82)	66 (82)	100 (50)^{b}	100 (19)^{b}	100 (14)^{b}
Water cleanliness	Clean	34 (83)	57 (96)	68 (85)	100 (83)	100 (86)	100 (66)
	Dirty	26 (100)	42 (97)	43 (96)	100 (80)	100 (67)	100 (37)

[1] "Pool": time spent in the shallow pool as a % of total time spent in both pools; "Pool+poolside": time spent in the shallow pool and the poolside area as a % of total time spent in both pools and poolside areas; "Water-related": time spent in all water-related areas around the shallow pool as % of total time spent in the water-related areas around both pools

[2] ***: P<0.001 when comparing shallow pools usage (% time spent in the shallow pool, or % time in the shallow pool + poolside area, or % time in all water-related areas around the shallow pool) with 50%

[3] Values with different superscripts (a, b) differ significantly between weeks at P<0.05

Table 3. Effect of water depth on number of visits, per 24 h period, and length of those visits, in seconds, to the pools. Data are shown as medians with inter-quartile ranges (IQRs).

	Shallow vs. Intermediate		**Shallow vs. Deep**	
	Shallow	**Intermediate**	**Shallow**	**Deep**
Visits	9 (24)	11 (20)	20 (14)[a]	0 (17)[b]
Length (s)	258 (500)	616 (1042)	402 (515)	0 (1144)

a, b: Values with different superscripts are significantly different ($P<0.01$).

Table 4. Effect of water cleanliness on number of visits (per 24 h period) and length of those visits to the pools. Data are shown as medians with inter-quartile ranges (IQRs).

	Shallow pools		**Intermediate / Deep pools**	
	Clean	**Dirty**	**Clean**	**Dirty**
Visits	16 (17)	16 (21)	10 (21)	8 (17)
Length (s)	401 (710)[a]	281 (416)[b]	278 (1114)	285 (1051)

a, b: Values with different superscripts are significantly different (P<0.01).

Table 5. Effect of age on number of visits (average per 24h period) and length of those visits to the pools. Data are shown as medians with inter-quartile ranges (IQRs).

	Shallow pools			Intermediate / Deep pools		
	Week 5	Week 6	Week 7	Week 5	Week 6	Week 7
Visits	14 (18)[a]	16 (17)[a]	23 (31)[b]	9 (22)	6 (15)	10 (17)
Length (s)	379 (807)	293 (646)	360 (436)	482 (1287)	295 (795)	212 (883)

a, b: Values with different superscripts are significantly different ($P<0.05$).

Table 6. Effect of water depth, duck age and water cleanliness on bathing behaviour. Behaviours are expressed as % of time spent performing them during the bathing bout, through medians with inter-quartile ranges (IQRs).

	Effect of depth		**Effect of age (SH[3] pools only)**			**Effect of water cleanliness (SH[3] pools only)**	
	SH	**IN / DE[3]**	**Week 5**	**Week 6**	**Week 7**	**Clean**	**Dirty**
Outside pool	41 (40)	25 (25)	30 (43)	51 (54)	35 (49)	20 (36)[c]	54 (34)[d]
Inside pool	59 (40)	75 (25)	70 (43)	49 (54)	65 (49)	80 (36)[c]	46 (34)[d]
Standing	76 (31)[a]	36 (30)[b]	64 (50)[c]	82 (38)[cd]	97 (12)[d]	65 (64)[a]	93 (17)[b]
Sitting (+ Floating)[2]	24 (31)[a]	64 (30)[b]	36 (50)[c]	18 (38)[cd]	3.4 (12)[d]	35 (64)[a]	6.7 (17)[b]
Moving	6.8 (1.9)[c]	14 (5.0)[d]	8.9 (3.2)	8.1 (4.6)	9.4 (4.2)	9.3 (4.0)	8.7 (2.9)
Inactive	11 (10)[a]	31 (15)[b]	9.7 (19)	8.1 (21)	10.8 (8.3)	9.8 (21)	11 (12)
Preening	21 (21)	9.1 (10)	8.1 (18)	25 (34)	15 (22)	14 (24)	18 (23)
Dip (head/body)	3.0 (3.7)	3.3 (2.6)	2.5 (2.9)	3.7 (4.7)	3.5 (4.3)	3.3 (5.6)	3.1 (2.6)
Shake[1]	13 (4.8)	11 (4.3)	11 (6.8)	9.6 (6.7)	10 (8.2)	8.4 (6.9)	11 (8.7)
Stretch[1]	0.38 (0.72)	0.38 (0.67)	0.13 (0.50)	0.25 (0.63)	0.00 (0.50)	0.00 (0.50)	0.29 (0.56)
Flap wings[1]	2.1 (1.8)	2.8 (1.8)	2.5 (3.3)	1.9 (2.7)	2.1 (1.1)	2.0 (3.5)	2.3 (1.4)
Drink from pool	14 (8.8)	12 (5.7)	17 (16)	12 (11)	15 (11)	17 (8.6)	11 (8.5)
Drink from drinker	2.7 (11)	2.3 (5.8)	4.5 (8.4)	4.2 (9.4)	1.1 (4.4)	0.86 (4.2)[a]	7.7 (7.7)[b]
Dabble	17 (13)[a]	9.2 (8.6)[b]	14 (14)	16 (4.3)	18 (26)	16 (12)	16 (18)
Explore/peck	7.7 (12)	9.9 (5.2)	3.2 (6.0)	8.4 (8.7)	13 (11)	8.4 (11)	7.7 (13)

a, b, c, d: Different superscripts in the same row indicate significant differences between treatments (a-b, $P<0.05$; c-d, $P<0.01$)

[1] These are events and are expressed as average number of occurrences per bathing bout.

[2] Sitting and Floating were combined for the analysis of water depth, because intermediate / deep pools were included in the analysis. Floating was not considered in the analysis of the effects of age or water cleanliness because only shallow pools were included.

[3]SH: shallow pools; IN / DE: intermediate and deep pools, combined.

Figure 1. Diagram of test pen for four ducks showing a shallow pool on the left and an intermediate pool on the right.

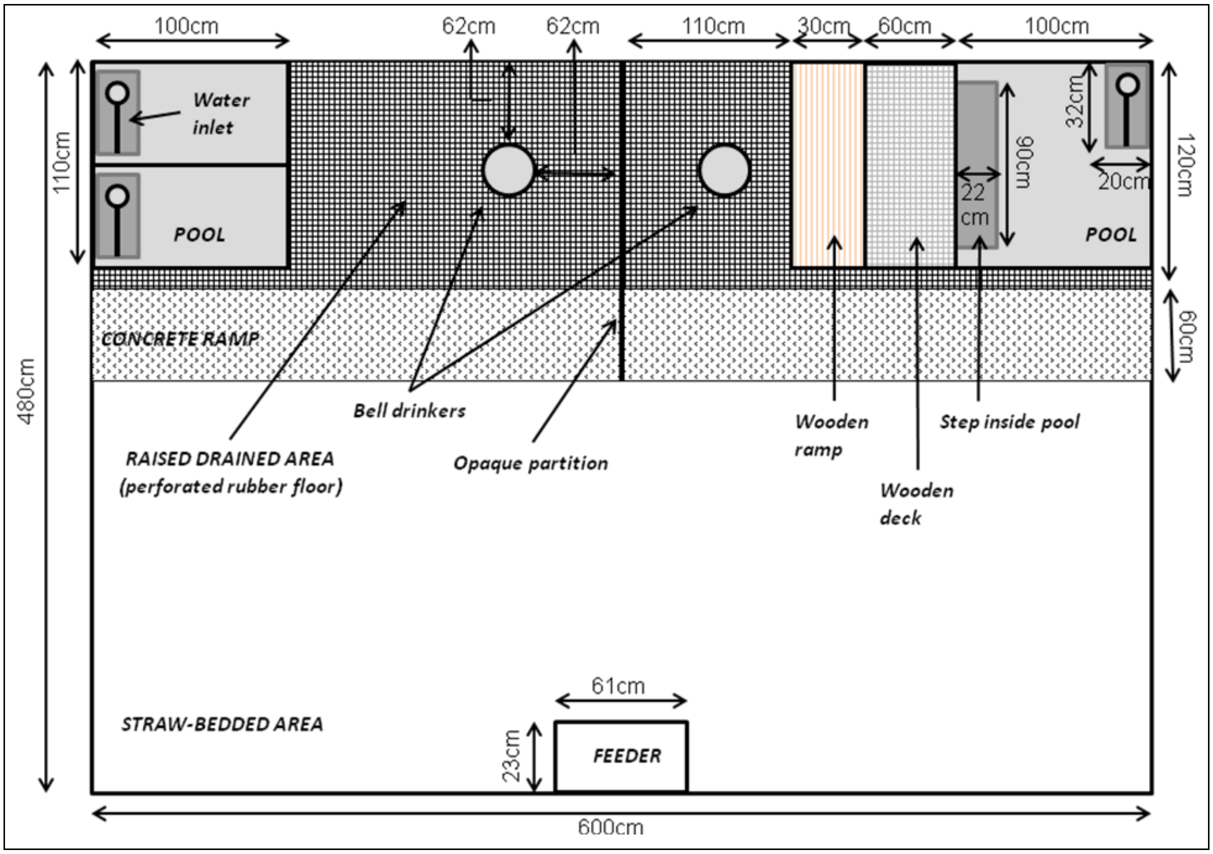

Figure 2a. Temperature inside the pools (shallow: SH, intermediate: IN and deep: DE) and ambient air temperature (ENVIRONMENT) during 4 days of warm weather.

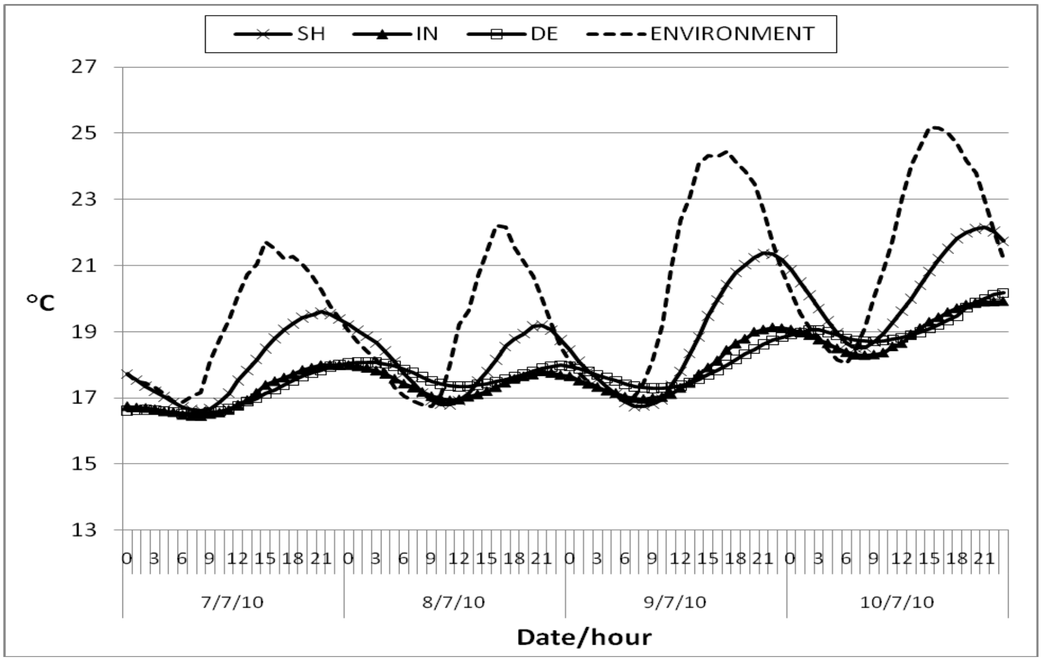

Figure 2b. Temperature inside the pools (shallow: SH, intermediate: IN and deep: DE) and ambient air temperature (ENVIRONMENT) during 4 days of cold weather.

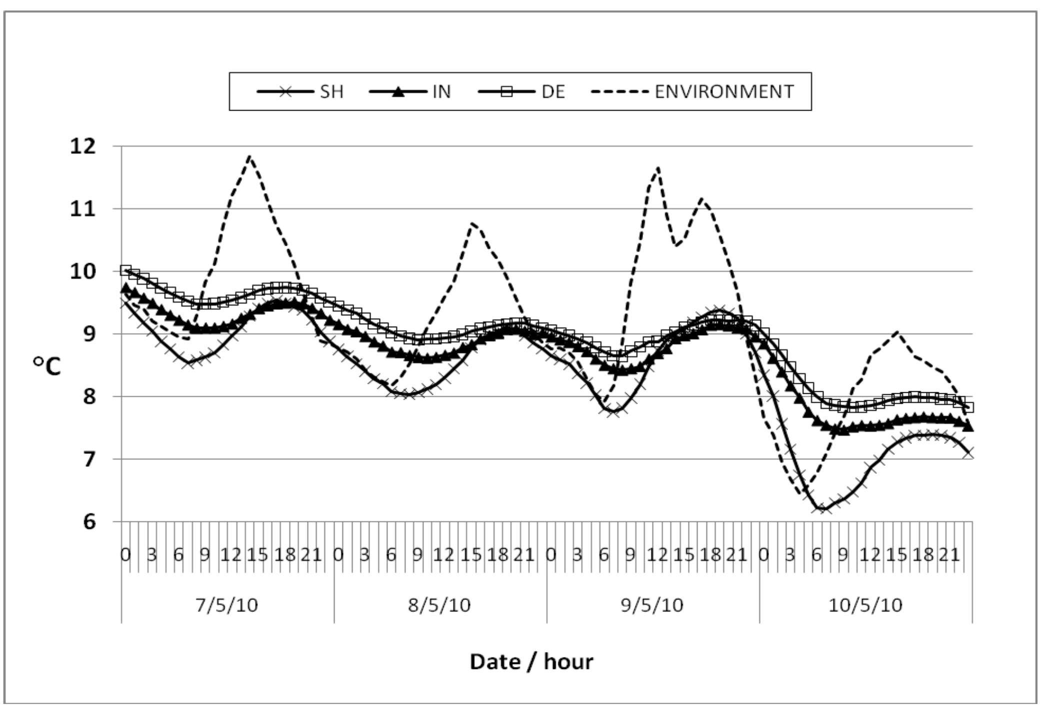

Figure 3. Correlation between water temperature in the shallow pools and % of time spent in shallow pools (as a % of total time spent anywhere in the pen).