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Preferences of growing ducklings and turkey poults for illuminance

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Abstract

The illuminance and spectral power distribution in 19 duckling and 16 turkey poult houses in the UK were sampled. Illuminance was highly variable within duckling houses and to a lesser extent in housing for turkey poults. In a free choice experiment, the preferences of commercial ducklings and turkey poults for four incandescent illuminances (<1, 6, 20 and 200 lx; Osram, 60 W, Pearl) were tested at 2 and 6 weeks of age. Four replicate flocks of 12 birds were given continuous access to four compartments illuminated with each illuminance for six days. The illuminances were changed daily between the compartments. After two days of conditioning, the birds' location and behaviour was recorded at 10 min intervals over 22 h. Nine and 12 defined behavioural categories were recorded for the ducklings and poults respectively. Ducklings spent significantly more time occupying the three brightest light environments both at 2 and 6 weeks of age, and the least time in the dimmest. Illuminance had a significant effect on the partition of behaviours amongst the light environments. At 2 weeks of age, locomotion and environmentally directed pecking occurred most often in 6, 20 and 200 lx, whereas at 6 weeks, preening and feeding also occurred more often in these light environments. At 6 weeks of age, resting, standing and drinking occurred significantly more often in 6 lx than in the dimmest environment. Turkeys spent most time in the brightest environment at 2 weeks of age, but in 20 and 200 lx at 6 weeks. This change in overall preference was reflected in the partition of different behaviours between the light environments. At 2 weeks of age, all behaviours were observed to occur most often in 200 lx. At 6 weeks, resting and perching were observed least often in <1 lx, whereas all other activities were observed more in the two brightest light environments. These results show that ducklings and turkey poults have significant but differing preferences for illuminance, and imply that some spatial or temporal variation in the ambient illuminance of housing would be consistent with their preferences.

Keywords: *animal welfare, behaviour, ducklings, environmental preference, lighting, turkey poults*

Introduction

Light plays a pivotal role in poultry production and is arguably the most important stimulus that birds receive from the physical environment (Perry & Lewis 1993). Most poultry in the UK are housed in environmentally controlled buildings where the light environment is provided artificially. In such houses, the design of lighting systems is largely determined by production parameters, ease of maintenance and human vision, with little regard given to the visual abilities of the birds. Whilst we now have a good understanding of the effects of lighting, especially illuminance and photoperiod, on reproduction and production, relatively little is known about the visual abilities of poultry or their involvement in key behaviours such as social interactions and feeding.

The effects of lighting on the behaviour and welfare of poultry are mediated mainly by vision. Lighting of an inappropriate colour balance or of very low illuminance may not allow the birds to use their full range of visual abilities and this may have consequences for the behaviour and welfare of these birds. Prescott and Wathes (1999a) surveyed light environments in laying hen and broiler houses in the UK, and Grimes and Siopes (1999) in turkey breeder housing in the USA. However, no studies describe in detail the light environments typically used in the commercial housing of ducklings and turkey poults.

The manipulation of illuminance has profound effects on the physiology and behaviour of poultry (Manser 1996). There is a significant positive relationship between illuminance, general activity and energy expenditure (Proudfoot & Sefton 1978; Boshouwers & Nicaise 1987). Light control is therefore an important management tool for producers, and the practice of rearing birds in low illuminances such as 1–10 lx can have advantages for growth and food conversion rates (Appleby *et al* 1992). Turkeys frequently engage in injurious pecking (Sherwin 1998), and low illuminances can also prevent or control this undesirable behaviour (Hester *et al* 1987).

However, the use of low illuminances has also been implicated in the aetiology of significant welfare problems. First, very dim environments can make it difficult for farm personnel to inspect birds and to recognise injuries and signs of disease (Appleby *et al* 1992). Second, commercially employed illuminances and colour balances may impose a degree of visual sensory deprivation, inhibiting foraging, exploration and social behaviours. Third, low illuminances increase lameness, perhaps through decreasing activity levels (Hester *et al* 1987), and may affect the development of vision, causing complete or partial blindness (Siopes *et al* 1984). Fourth, fearfulness is greater in laying hens housed in 17–22 lx, compared to those reared in brighter illuminances of 55–80 lx (Hughes & Black 1974). Finally, the use of very low illuminances may be perceived by the public as unpleasant for the birds.

To address these welfare issues, the Farm Animal Welfare Council (FAWC), the Royal Society for the Prevention of Cruelty to Animals (RSPCA), major supermarket retailers, and the (then) Ministry for Agriculture, Fisheries and Food (MAFF) (now the Department for Environment, Food and Rural Affairs, DEFRA) have published guidelines on the provision of lighting for a number of poultry species, including ducks and turkeys. The RSPCA welfare standards recommend a minimum illuminance of 20 lx, more than 6 h continuous darkness, and the provision of a dawn/dusk period both for turkeys and for ducks (RSPCA 1999a,b). The FAWC (1995) recommends illuminances greater than 5 lx, and an 8 h continuous dark period for turkeys, whilst commenting that light levels should be adopted that are as bright as practicable but may be reduced if pecking damage occurs. The MAFF (1987a,b) recommend simply that lighting should enable birds to be inspected and that provision should be made for a period of darkness. While the need to optimise the light environment in poultry houses is recognised, many producers and farm managers are concerned that increasing illuminance to the recommended levels will result in increased injurious pecking, particularly for turkeys. Therefore, more information is required on which to base these recommendations, and the above organisations and others (Manser 1996) have called for further research into the preferences and motivation of poultry for illuminance, and the levels required for different activities.

Preferences for different light environments have been shown in domestic fowl (Savory & Duncan 1982/83; Appleby *et al* 1984; Alsam & Wathes 1991; Widowski *et al* 1992; Davis *et al* 1999) and in turkeys (Sherwin 1998). However, there is a lack of studies detailing such preferences in domestic ducks. In general, information concerning the effects of light on this species' productivity, vision, behaviour and welfare is scarce. As a consequence, applications from research on other poultry species are often applied, although this may be inappropriate given the different ecology of fowl, ducks and turkeys.

The aims of the current investigations were, firstly, to survey the light environments used in commercial duckling and turkey poult houses and, secondly, to determine the preferences of growing ducklings and turkey poults for illuminance, and to establish whether such preferences are influenced by age (2 versus 6 weeks).

Methods

Study 1: A survey of the light environment in duckling and turkey poult houses

A two-part survey was undertaken to quantify the characteristics of the light environments of eight major duckling and turkey poult producers in the UK (19 and 16 houses respectively). A questionnaire was completed by the farm managers, and measurements were made of the lighting environments within the houses surveyed. Visits were made in order to collect data from a number of houses on different farm sites representing various types of housing, lighting system and management practices. Houses with similar layouts and lighting sources, but containing birds of differing ages between 1–49 days old, were also included in the survey since lighting conditions are often changed during the production cycle.

The questionnaire addressed issues of lighting practices and management, and was completed by the farm manager/personnel for each house surveyed to ascertain the type and duration of lighting and the methods of measuring illuminance used by producers. The questionnaire also invited managers to estimate the level of illuminance within their houses and to comment on how satisfied they were with their lighting practices.

Illuminance was measured in lx using a calibrated light meter (Model 545, Testo Ltd, Alton, UK). Since the light fittings were regularly spaced within the houses, measurements were made from transects of the building directly under and between rows of luminaires. Illuminance was recorded at 20 cm above floor level at nine points along each transect. The sensor of the light meter was angled in the direction of maximum illuminance, as described by Prescott and Wathes (1999a). Measurements of the spectral power distributions (spectral composition of light output) of two representative luminaires within each house were made using a portable spectroradiometer (Model ST2000, Ocean Optics Inc, Dunedin, Florida, USA).

Study 2: The preferences of ducklings and turkey poults for illuminance

Subjects and rearing

Sixty female ducklings (Cherry Valley SM2I strain, Cherry Valley Farms Ltd, Market Rasen, Lincolnshire, UK) and 60 female turkey poults (BUT Big 6 strain, British United Turkeys Ltd, Chester, UK) were obtained at one day of age, in two batches of 30, one week apart. The birds were reared in groups of 30 until they were 2 weeks old, and were then separated into two flocks of 15 birds (ie Batch 1 into Flocks 1 & 2 and Batch 2 into Flocks 3 & 4). Flocks from each batch were housed in separate pens in the same room. Each pen had an area of approximately 5 m^2, wood-shavings litter, a feeder and drinker. During rearing, the temperature was maintained at 30°C for the first three days, and was then

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reduced by 1°C per day until 19°C at 14 days. The ducklings' drinker was suspended over the centre of a 1 m^2 metal tray. Spilt water from the drinker was caught in this tray and emptied twice daily to maintain litter quality in the rest of the pen, and also to make some water available with which the birds could preen. The turkey poults were provided with perches (1.8 m long and 0.2 m high) and other environmental enrichment, including suspended compact discs, empty feed bags cut into strips, Pecka-Blocks™ (Breckland International Ltd, Norfolk, UK) and cabbages, to minimise injurious pecking. The birds were fed conventional starter crumbs, starter pellets, and grower and finisher rations appropriate for their species and age. Ducklings were fed chick crumbs (W Jordan & Sons, Biggleswade, UK) for the first three weeks and then grower pellets (Fenland Range, Clark & Butcher Ltd, Ely, UK). The turkey poults were fed turkey starter crumbs for the first two weeks, turkey starter pellets until 4 weeks old, and then turkey grower pellets for the remaining three weeks of the experiment (BOCM Pauls Ltd, Ipswich, UK). All birds were regularly inspected five times per day throughout the rearing period.

The lighting system during rearing consisted of 16 incandescent 60 W bulbs (Osram, Pearl) and a series of dimmer switches and timers in each rearing room. Each 24 h period was divided into four 6 h blocks of four illuminances, <1, 6, 20 and 200 lx, presented according to a randomised schedule. These were the same four illuminances that were later used during the preference experiment. Illuminance both here and for the preference experiment was measured by angling the sensor of a calibrated light meter (Macam Photometer Model L103, Macam Photometrics Ltd, Livingston, UK) in the direction of maximum radiance, as defined by Prescott and Wathes (1999a). Illuminance was measured 20 cm above the litter at 17 points within each pen and did not vary by more than ± 10% of the mean. Measurements of the spectral power distributions of the incandescent luminaires used at each of the four illuminance settings were made using a portable spectroradiometer (Model ST2000, Ocean Optics Inc, Dunedin, Florida, USA), and the emissions were found to be similar regardless of the level of dimming.

Preference test chamber

A preference chamber, described by Jones *et al* (1996) and Davis *et al* (1999), was used to test the illuminance preferences of the ducklings and turkey poults. The chamber consisted of eight identical compartments arranged in an annulus. Adjacent compartments were accessed via an opening in the connecting walls between the compartments. For this experiment, the chamber was divided into two sets of four compartments, allowing two flocks (each from the same batch) to be tested simultaneously. Individual compartments were trapezoidal in shape, with a floor area of 1.6 m^2, and the internal surfaces were painted white. Each compartment was provided with a feeder containing 5 kg of food, a drinker and wood-shavings litter as in the rearing pens. The turkey poults were also provided with perches, strips of plastic feed bags and a Pecka-Block™ in each compartment to help minimise injurious pecking during testing.

The same four illuminances of <1, 6, 20, and 200 lx used during the rearing of the birds were used in the experiment. These illuminances were chosen to provide the birds with a choice between: virtual darkness (<1 lx); an illuminance often used in commercial housing (6 lx); the minimum illuminance recommended by the RSPCA welfare standards for these species (20 lx) (RSPCA 1999a,b); and a higher illuminance (200 lx). The latter is the logarithm ($\log_{10}$) of 20 lx, and was chosen because the growth response is apparently proportional to the logarithm of illuminance (Morris 1967). Light was provided by 40 incandescent 60 W bulbs (Osram, Pearl) in reflectors; five being placed above the transparent roof of each compartment, and was controlled by dimmer switches. This method of dimming the incandescent luminaires, rather than by neutral density filters for example, was used because it is the way that such light sources are dimmed in commercial practice. As stated above, measurements of the spectral power distributions of the luminaires used in the home pen and the preference chamber were found to be similar regardless of the level of dimming. Thick black paper covered the roof between the lamps of each compartment to exclude extraneous light. The luminaires were carefully positioned so that the illuminance within each compartment did not vary by more than ± 10% of the mean, as calculated from 16 measurements taken 20 cm above the litter prior to each testing period.

Experimental design and protocol

Two flocks from the same batch were tested concurrently; each flock containing 12 birds chosen at random from the 15 reared. Each flock was randomly assigned to a set of four compartments for six days. The first two days were used to condition the birds to the chamber and the remaining four days, for testing. During conditioning, the four illuminances were presented randomly, but during testing the light treatment varied according to a quasi-Latin square design, changing every 24 h so that each compartment provided each illuminance once over the four days of the experiment. At the beginning of the conditioning period, three birds from each flock were placed in each of the four compartments with all doorways closed. At 1100 h the connecting doors were lifted to allow birds to move freely between the four compartments. No dark period was provided since one environment was always non-illuminated (<1 lx).

During testing, the birds' behaviour was recorded over 22 h using time-lapse video recording from cameras positioned above each compartment; a bank of infra-red (non-visible) LEDs allowed the camera to image the inside of the non-illuminated compartment. During the remaining two hours (0900–1100 h), the feeders were refilled, birds were inspected, any necessary cleaning was carried out and the illuminances were reallocated among the compartments. The birds were then given 30 mins to settle before the time-lapse video recording resumed. Throughout testing in the chamber, the birds were inspected four times a day by lifting a corner of the black paper covering the clear perspex

Table 1 Ethogram used to categorise the behaviour of ducklings.

Behaviour	Definition
Standing	Bird standing inactive
Resting	Bird sleeping or recumbent
Stretching	Bird stretching a single leg or wing; a wing-and-leg-stretch; or both wings stretched together, vertically
Preening	Preening of feathers with bill, with or without the use of water; using the bill to throw water over the head and body; scratching head with foot; foot pecking and cleaning; body, head and wing shaking
Moving	Bird walking or running
Feeding	Head lowered at feeder
Drinking	Head lowered at drinker
Environment-directed pecking	Any floor, wall, litter or door-related pecking
Other	Any other behaviour not covered by above categories

Table 2 Ethogram used to categorise the behaviour of turkey poults.

Behaviour	Definition
Standing	Bird standing inactive on floor
Resting	Bird sleeping or recumbent
Perching	Bird standing, sleeping or sitting on perch
Preening	Preening of feathers with beak; scratching head with foot; foot-pecking and cleaning; body, head and tail-shaking; wing-flapping and shaking; dustbathing
Preen-perch	Above preening behaviours carried out by bird on the perch
Moving	Bird walking or running on ground or perch
Feeding	Head lowered at feeder
Drinking	Head lowered at drinker
Environment-directed pecking	Floor, litter, wall, perch or door-related pecking or scratching
Pecka-Block™ use	Pecking at Pecka-Blocks™
Feather pecking	Pecking at another bird's plumage
Aggression	Birds actively fighting with each other

lid of each compartment and viewing the birds inside. The chamber was not entered to avoid disturbing the birds.

The above procedures were repeated for both species when the birds were 2 and 6 weeks old. Birds that were tested at 2 weeks old were identified with coloured livestock spray marker and the same birds were returned to the chamber at 6 weeks. Between testing periods, the birds were kept in their rearing pens and the randomised lighting regime provided previously was continued.

Data recording

The videotapes of each 22 h period were analysed using 10 min sampling intervals. A pilot analysis had indicated that this interval produced estimates of behavioural time allocation that varied within ± 5% of those derived from 5 min interval sampling. An instantaneous scan/observation (Martin & Bateson 1990) was made of every bird to record both its behaviour and location within a particular compartment. Nine and 12 behavioural categories were defined and recorded for the ducklings and turkey poults respectively (described in Tables 1 & 2). These data were summed over each 22 h period (12 birds × 22 h × 6 observations per hour = 1584 data points per day) to obtain estimates of the total time spent in each compartment and/or illuminance treatment (occupancy), and the partition of behaviours between the different light environments. Due to a short power-cut during testing at 2 weeks for the ducklings, and the removal of one turkey poult from the chamber for treatment of minor wounds caused through injurious pecking at 6 weeks, some data were lost and were treated as missing values in the statistical analyses.

Data analysis

Data were tabulated in spreadsheets in which the total daily counts for overall occupancy and for each of the behaviour categories in the four illuminances were summarised. The total time spent in each of the four illuminance treatments was normally distributed and was analysed using ANOVA (Genstat Version 5 [Lawes Agricultural Trust 1989]). Occupancy data were blocked as follows: Age (2 and 6 weeks) was nested within batch (two rearing groups of thirty birds) since each batch of birds was tested at two ages. Compartment set (two sets of four compartments) was nested within age because each age was tested in each of the two compartment sets. The test days (1–4) and compartment per set (1–4) were cross-factored because each day each compart-

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ment received one illuminance treatment and over the four test days, all four. Since this interaction occurred within each compartment set it was nested within it. In Genstat notion this is: 'batch/age/compartment set/(test days*compartment)'. The treatment combination was all interactions between: age (2 and 6 weeks), flock (the two flocks each containing 12 birds tested concurrently) and illuminance (<1, 6, 20 and 200 lx); in Genstat notation: 'age*flock*light'. As an objective of the experiment was to investigate the effects of flock, age and illuminance treatment, these appeared in the treatment structure as fixed effects.

The distribution of individual behaviours amongst the four illuminances was not normally distributed and consequently the data were subjected to a logit transformation before being analysed using ANOVA. For the analysis of the behavioural partitioning, an additional blocking factor of 'behaviour' (nine or 12 categories for the ducks and turkey poults respectively) was nested with the blocking structure previously described. It was also included in the treatment combination, allowing all interactions between age, flock, light and behaviour to be examined. In Genstat notation this is: 'batch/age/compartment set/(test days*compartment)/behaviour' and 'age*flock*light*behaviour' respectively. The behavioural data were analysed in this way so that the overall change in the pattern of behaviour could be looked at, since a change in the amount of time spent performing one behaviour will necessarily change the time spent engaged in others. In this analysis, the standard error of the difference of the means is based upon all of the behavioural data combined at the highest level of significant interaction found, rather than that due to particular behaviours. The transformed means of the behaviour counts that were statistically analysed were back-transformed for presentation purposes.

In the design of this experiment, the experimental unit is the preference chamber compartment rather than the birds, and the response is the amount of time the birds as a group spend in each compartment overall, and in each compartment performing particular behaviours.

Results

Study 1: A survey of the light environment in duckling and turkey poult houses

Questionnaire of lighting practices and management

Summaries of the questionnaire responses are provided in Tables 3 and 4. All responses were from personnel representing the commercial duckling and turkey producers visited, with one response per house surveyed.

The majority of the 16 turkey poult houses surveyed used incandescent luminaires rather than conventional fluorescent tubes. In comparison, an equal number of duckling houses used incandescent and florescent tube luminaires, but compact fluorescent and mixes of luminaire types were also used. Coloured luminaires or filters were not used.

Daylight (Questions 3–4) was used in less than half of the duckling houses surveyed (9), and then in the majority of these (7), only from 14 days onwards. This was a consequence of the partially open-sided housing used for ventilation reasons rather than overt choice. None of the turkey poult houses surveyed admitted daylight during brooding (usually up to 49 days).

Whilst light meters were used by producers, they were used only on an occasional basis (less than once per flock) in the majority of duckling (15) and turkey (8) houses. Additionally, farm managers were requested to estimate the illuminance of the houses surveyed, and these estimates are shown in Tables 5 and 6, alongside the actual illuminance measurements taken.

Light measurements

Tables 5 and 6 show the illuminances measured in the duckling and turkey houses surveyed. The variation in illuminance within the duckling houses was greatest in the partially open-sided buildings that admitted daylight. These houses were most commonly used for birds after their initial 14–21 day brooding period, thus accounting for the higher illuminances for older birds in such housing. Within the light-controlled duckling buildings, the variation in illuminance was much less and changed little over the birds' production cycle. The exception to this was duckling producer 1, who decreased the illuminance for older ducks (>14 days).

In general, the illuminances measured in the turkey poult houses (overall mean = 5.3 lx; SD = 2.43) were lower than those recorded in the duckling houses (overall mean = 22.6 lx; SD = 13.82). The highest illuminances and greatest variation was noted for producer 1. After birds had been beak-trimmed, this producer later raised the illuminance for birds at 21 days of age. The three remaining producers did not make such changes to the levels of illuminance during the birds' production cycle, as observed in this survey until 49 days. Producer 4 did not beak-trim their birds and therefore used the lower illuminances to control feather pecking and cannibalism. Producer 2 beak-trimmed all birds and had a company policy of keeping illuminance as close to 5 lx as possible, given the need to control feather pecking and the capabilities of the lighting system used in the houses.

The spectral power distributions measured were typical of the light sources, and were similar to those presented by Prescott and Wathes (1999a) and Prescott *et al* (2003).

Study 2: The preferences of ducklings and turkey poults for illuminance

Overall occupancy of illuminances

There was a significant effect of light illuminance on the overall occupancy of compartments by the ducklings ($F_{3,60}$ = 2.76; P = 0.030). The birds spent least time in the dimmest light environment and most time in the three brighter illuminances. Figure 1 shows the combined values from testing at 2 and 6 weeks because there was no significant interaction with age.

The results for the turkey poults showed a highly significant interaction between illuminance and age on overall occupancy ($F_{3,60}$ = 37.8; P < 0.001). At 2 weeks of age, the

Table 3 Summary of the lighting practices employed by four major duckling producers, comprising 19 houses sited on 10 farms, for ducklings between 1 and 49 days old.

Question	Response	Number of houses
What type (source) of artificial lighting is used in the houses surveyed?	Incandescent	6
	Fluorescent	6
	Compact fluorescent	5
	Mix (incandescent and fluorescent)	2
What is the reason for using this type of artificial lighting?	Company policy	10
	Individual farm manager's choice	9
Do you admit daylight into your houses?	Yes, for part of the rearing period	7
	Yes, for all of the rearing period	2
	No	10
What age are birds when daylight is admitted?	1 day	2
	14 days	7
What photoperiods are employed?	1–14 days = 23L/1D; 14–28 days = 30 min daily reduction in light; 28–49 days = 17L/7D	4
	1–49 days = 23L/1D	13
	1–49 days = 24L	2
Is a dawn/dusk system used?	Yes	0
	No	19
How often is a light meter used to measure illuminance/intensity in the houses?	Never	4
	Occasionally (less than once per flock)	15
	At least once per flock	0
Are you satisfied with your lighting system?	Yes	17
	No	2
If no, what changes would you make?	Incorporate timers into the lighting circuits	2
Further comments	What are the light intensity requirements for ducks?	
	Would consider making changes to meet supermarket/welfare standards	

birds spent most of their time in the brightest environment and least time in the dimmest environment (Figure 2). However, at 6 weeks of age the birds preferred to use the two brightest light environments, whilst still spending least time in the dimmest.

Association between illuminance and behaviour

For the ducklings, illuminance had a significant effect on the partition of different behaviours amongst the light environments, and this was dependent on age (Table 7). At 2 weeks of age, the ducklings spent less time moving and performing environment-directed pecking in the dimmest light, and the most time in the three brighter illuminances. However, at 6 weeks of age the birds spent less time preening, feeding, moving and pecking in the dimmest light environment and the most in the three brightest. Standing and resting at 6 weeks were also found to occur more in 6 lx than in <1 lx.

For the turkey poults, illuminance had a significant effect on the partition of different behaviours amongst the light environments, and this was shown to be dependent on age (Table 8). At 2 weeks of age the birds preferred to spend most time performing all 12 behaviours in the brightest light environment. At 6 weeks of age their preference had changed and all behaviours except resting and perching were performed most in the two brightest illuminances. Poults spent less time resting and perching at 6 weeks of age in the dimmest environment, and most time in the three brightest illuminances.

Table 4 Summary of the lighting practices employed by four major turkey producers, comprising 16 houses sited on eight farms, for poults between 1 and 49 days old.

Question	Response	Number of houses
What type (source) of artificial lighting is used in the houses surveyed?	Incandescent	14
	Fluorescent	2
	Compact fluorescent	0
	Mix (incandescent and fluorescent)	0
What is the reason for using this type of artificial lighting?	Company policy	10
	Individual farm manager's choice	6
Do you admit daylight into your houses?	Yes	0
	No	16
What age are birds when daylight is admitted?	N/A	
What photoperiods are employed?	1–3 days = 23L/1D; 3–49 days = 16L/8D	2
	1 day = 23L/1D; 2–8 days = 1 h daily reduction in light; 8–49 days = 16L/8D	4
	Males: 1–3 days = 24L; 3–13 days = 1 h daily reduction in light; 14–49 days = 14L/10D (15 min gradual dimming of light). Females: 1–3 days = 24L; 3–11 days = 1 h daily reduction in light; 12–49 days = 16L/8D (15 min gradual dimming of light)	2
	Males: 1–3 days = 24L; 3–13 days = 1 h daily reduction in light; 14–49 days = 14L/10D. Females: 1–3 days = 24L; 3–11 days = 1 h daily reduction in light; 12–49 days = 16L/8D	4
	Males: 1–3 days = 21L/3D; 4–7 days = 19L/5D; 8–49 days = 16L/8D. Females: 1–3 days = 21L/3D; 4–49 days = 19L/5D	4
Is a dawn/dusk system used?	Yes	2
	No	14
How often is a light meter used to measure illuminance/ intensity in the houses?	Never	4
	Occasionally (less than once per flock)	8
	At least once per flock	4
Are you satisfied with your lighting system?	Yes	16
	No	0
Is beak trimming practiced?	Yes	7
	No	9
Further comments	Would consider making changes to meet supermarket/welfare standards	
	Would like to perform trials with blue and green coloured lights	

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Table 5 Illuminance measurements recorded in 19 different duckling houses belonging to four major producers.

Producer	House	Housing type	Lighting type	Age (days)	Managers estimate of mean illuminance (lx)	Measured illuminance				
						Min	Max	Mean	SD	n
1	1	Light controlled	IN; 60 W; GEC, Pearl	1–14	5	1	10	4.2	3.15	18
	2	Light controlled	IN; 60 W; GEC, Pearl	1–14	5	1	13	5.4	3.94	18
	3	Light controlled	IN; 60 W; GEC, Pearl	14–49	<5	0	3	1.3	0.84	18
	4	Light controlled	IN; 60 W; GEC, Pearl	14–49	<5	0	3	1.11	1.08	18
2	5	Light controlled	IN; 60 W; GEC, Pearl + FL^t; 20 W; Osram	1–14	20	5	27	16.7	7.20	18
	6	Light controlled	IN; 60 W; GEC, Pearl + FL^t; 20 W; Osram	14–49	20	6	30	14.3	7.21	27
	7	Partially open sided†	IN; 60 W; GEC, Pearl	1–21	>20	23	241	86.7	82.98	18
	8	Partially open sided†	IN; 60 W; GEC, Pearl	21–49	>20	27	261	92.9	83.90	18
3	9	Partially open sided*	FL^c; 11 W; Phillips	1–14	10–20	5	23	9.9	4.43	27
	10	Partially open sided*	FL^t; 11 W; Phillips	1–14	10–20	5	20	9.8	4.14	27
	11	Partially open sided†	FL^t; 11 W; Phillips	14–49	40	20	49	32.3	10.05	18
	12	Partially open sided*	FL^c; 11 W; Phillips	1–14	10–20	5	13	7.5	2.15	18
	13	Partially open sided*	FL^c; 11 W; Phillips	1–14	10–20	4	12	7.3	2.25	18
	14	Partially open sided†	FL^c; 11 W; Phillips	14–49	40	20	43	31.9	7.99	18
	15	Partially open sided†	FL^c; 11 W; Phillips	14–49	40	21	47	32.1	8.46	18
4	16	New light controlled	FL^t; 40 W GEC	1–49	No estimate	6	31	15.0	6.64	27
	17	New light controlled	FL^t; 40 W GEC	1–49	No estimate	7	27	14.0	5.91	27
	18	Old light controlled	FL^t; 40 W GEC	1–49	No estimate	9	49	24.9	11.73	27
	19	Old light controlled	FL^t; 40 W GEC	1–49	No estimate	10	39	22.4	8.52	27
Mean						9.2	49.5	22.6	13.82	

IN = Incandescent; FL^t = Fluorescent tube; FL^c = Compact fluorescent luminaire
* These houses had their sides boarded because at the time of recording the ducklings were less than 14 days of age and were being brooded.
† Daylight admitted to house.

Table 6 Illuminance measurements recorded in 16 different turkey houses belonging to four major producers.

Producer	House	Housing type	Lighting type	Age (days)	Managers estimate of mean illuminance (lx)	Measured illuminance				
						Min	Max	Mean	SD	n
1	1	Light controlled	IN; 100 W; GEC, Pearl	3–21	10	1	6	3.3	1.53	18
	2	Light controlled	IN; 100 W; GEC, Pearl	21–49	20	9	52	30.6	14.33	18
2	3	Light controlled	IN; 100 W; GEC, Pearl	1–49	3–4	1	3	2.8	0.67	18
	4	Light controlled	IN; 100 W; GEC, Pearl	1–49	3–4	1	3	2.2	0.65	18
	5	Light controlled	IN; 100 W; GEC, Pearl	1–49	3–4	1	5	2.4	1.15	27
	6	Light controlled	IN; 100 W; GEC, Pearl	1–49	3–4	1	6	2.7	1.48	27
	7	Light controlled	FL^t; 20 W; Osram	1–49	5–6	2	10	5.4	2.10	27
	8	Light controlled	FL^t; 20 W; Osram	1–49	5–6	1	8	5.0	2.08	27
3	9	Light controlled	IN; 60 W; GEC, Pearl	4–7	>5	1	16	5.4	5.24	18
	10	Light controlled	IN; 25 W; GEC, Pearl	8–35	>5	3	13	6.9	2.92	18
	11	Light controlled	IN; 25 W; GEC, Pearl	36–38	>5	4	11	7.1	1.78	18
	12	Light controlled	IN; 25 W; GEC, Pearl	39–49	<5	2	7	4.3	1.60	18
4	13	New, light controlled	IN; 60 W; Marathon, Pearl	8–49	1–5	1	4	1.6	0.92	18
	14	New, light controlled	IN; 60 W; Marathon, Pearl	8–49	1–5	1	3	1.4	0.70	18
	15	Old, light controlled	IN; 60 W; Marathon, Pearl	8–49	1–5	1	4	1.9	0.99	18
	16	Old, light controlled	IN; 60 W; Marathon, Pearl	8–49	1–5	1	3	1.7	0.75	18
Mean						1.9	9.6	5.3	2.43	

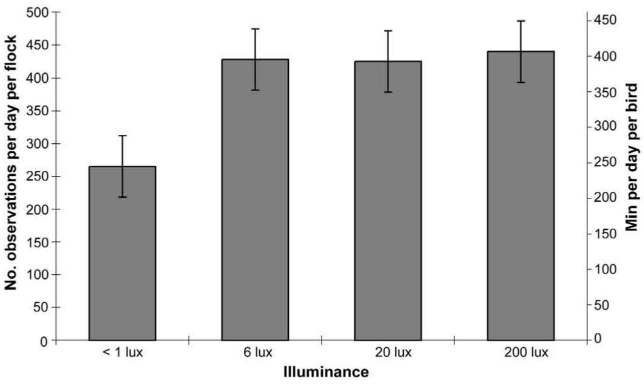
IN = Incandescent; FL^t = Fluorescent tube

Discussion

The illuminances measured in commercial duckling and turkey poult houses were much lower than daylight, and the spectral power distributions of the light sources were of a different quality. These results are similar to those found by Prescott and Wathes (1999a) for layer and broiler chicken houses. The wetlands or open plain and woodland environments in which the progenitor species of domestic ducklings and turkeys evolved would include a range of illuminances from areas of direct sunlight to patches shaded by vegetation, and, in the case of ducks, those found underwater. The colour balances would also be different depending on the light transmission through leaves (Monteith 1973) and vegetation, reflectance from other surfaces (Endler 1993) and through water. It seems reasonable to presume that the visual abilities of the birds are 'fine-tuned' with respect to their ecological niches. Therefore, the low illuminances and different colour balances found in commercial houses for these species may affect the performance of certain behaviours.

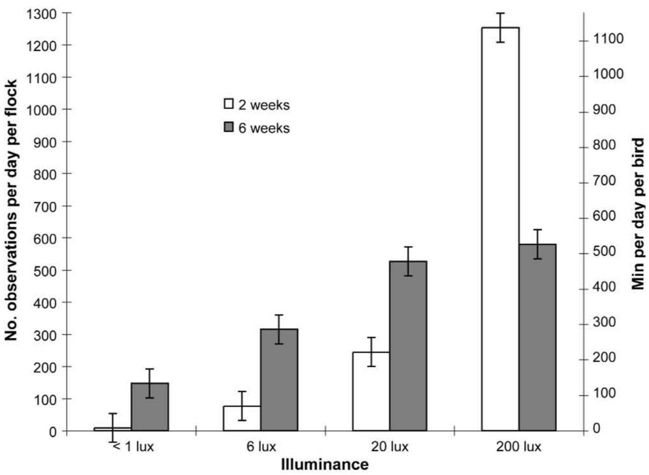
Both illuminance and wavelength are reported to have significant effects on poultry behaviour (reviewed by

Figure 1



Mean (± SEM) overall occupancy for ducklings at each illuminance.

Figure 2



Mean (± SEM) overall occupancy for turkey poults at each illuminance at 2 and 6 weeks of age.

Manser 1996), although many studies confound the two aspects. Low illuminances have been associated with changes in the morphology of turkeys' eyes, and Thompson and Forbes (1999) found that turkeys reared in illuminances of 2 and 5 lx were more likely to develop eye abnormalities than those reared in 50 lx. Many of the turkey houses surveyed in the current study used illuminances within the 2–5 lx range. These abnormalities would almost certainly adversely affect ocular accommodation, and thus have implications for welfare through their effects on behaviour and visual ability. These findings may account for the reduced food intake and activity found in turkeys in dim illuminances by Siopes *et al* (1984). Artificial lighting contains little, if any, ultraviolet wavelengths (UV_A = 320–400 nm). It is suggested that both turkeys (Hart *et al* 1999) and ducks (Parrish *et al* 1981) have UV_A vision, although in the duck other investigations have concluded that they are relatively insensitive to UV_A light (Jane & Bowmaker 1988). Moinard and Sherwin (1999) showed that turkeys prefer UV-enriched lights, and broiler breeder hens prefer to inspect cockerels illuminated with UV_A-enriched light (Jones *et al* 2001). These studies suggest that commercial light environments lacking UV_A may limit or deny birds the use of these visual cues, which may be important for the performance of a range of visually mediated behaviours. However, the use of this type of lighting for poultry is currently under debate and further investigations are required.

The RSPCA welfare standards recommend a minimum mean illuminance of 20 lx for ducks and turkeys (RSPCA 1999a,b), with the provision of at least 6 h darkness. This minimum illuminance was incorporated into the standards in order to stimulate the natural behaviour of the birds and allow adequate inspection by the stockperson. The RSPCA standards consider beak trimming, provided it is correctly performed, to be more acceptable than maintaining birds under lower illuminances throughout rearing. Eight of the surveyed duckling houses would have satisfied this criterion for illuminance, but only two of the turkey poult houses. With regard to photoperiod, only four duckling houses complied with this recommendation, compared to 12 of the turkey poult houses. The four houses that provided less than 6 h darkness did so only for female poults, whilst providing 8 h darkness for males. However, the FAWC (1995) recommend a lower minimum illuminance of 5 lx for turkeys and 8 h uninterrupted darkness, but state that illuminance should be as bright as practicable and reduced only in the event of aggression. Seven of the turkey poult houses met this level of illuminance, and indeed at least one producer used this recommendation as company policy. Twelve houses also complied with the recommendation for photoperiod, with four houses providing female poults with less than 8 h darkness.

The use of the lux unit is questionable for measuring illuminances perceived by animals (Nuboer *et al* 1992; Prescott & Wathes 1999a) because it is based on the human-specific spectral sensitivity curve. However, the spectral sensitivity curves derived from microspectrophotometry predict that turkeys (Hart *et al* 1999) and ducks (Jane & Bowmaker 1988) have a different spectral sensitivity to humans. Therefore, inter-species comparisons and comparisons between houses illuminated by different light sources may be inaccurate, although there is no information on which to base an accurate measure of illuminance as perceived by ducklings or turkey poults.

The results of this investigation indicate that ducklings and turkey poults demonstrate significant but different preferences when allowed to choose between a range of illuminances. Since ducklings spent most of their time overall in the three brightest light environments, it could be argued either that these birds did not show a clear preference for any particular illuminance above 6 lx, or that they chose to access all three of the brighter intensities provided. This reasoning illustrates the care required when interpreting the results of preference tests (see Dawkins 1976; Duncan 1978).

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Table 7 Mean total daily counts (per flock/day) for the behaviours monitored for ducklings at 2 and 6 weeks of age, in the four different light illuminances. Data presented in bold are the back-transformed means of behaviour counts. Data in brackets are the logit transformed means from the analysis (age*illuminance*behaviour interaction) $F_{24,740}$ = 2.74; s.e.d. = 0.34; P < 0.001.

Behavioural category	2 Weeks old				6 Weeks old			
	Illuminance (lx)				Illuminance (lx)			
	<1	6	20	200	<1	6	20	200
Standing	**7.35** (–5.37)	**12.29** (–4.85)	**7.62** (–5.33)	**11.24** (–4.94)	**22.17** (–4.26)	**52.43** (–3.36)	**30.15** (–3.94)	**42.43** (–3.59)
Resting	**139.70** (–2.34)	**192.88** (–1.98)	**148.68** (–2.27)	**194.94** (–1.96)	**92.75** (–2.78)	**221.03** (–1.82)	**132.81** (–2.39)	**161.44** (–2.18)
Stretching	**6.84** (–5.44)	**8.63** (–5.21)	**7.71** (–5.32)	**10.60** (–5.00)	**5.21** (–5.71)	**7.83** (–5.31)	**6.11** (–5.55)	**4.94** (–5.77)
Preening	**22.16** (–4.26)	**31.41** (–3.90)	**31.70** (–3.89)	**40.14** (–3.65)	**22.17** (–4.26)	**50.86** (–3.41)	**35.07** (–3.79)	**50.79** (–3.41)
Moving	**3.99** (–5.98)	**13.01** (–4.79)	**8.23** (–5.26)	**14.95** (–4.65)	**9.77** (–5.08)	**25.81** (–4.10)	**19.99** (–4.36)	**28.28** (–4.01)
Feeding	**6.12** (–5.55)	**14.43** (–4.69)	**9.63** (–5.10)	**10.75** (–4.99)	**5.20** (–5.72)	**11.34** (–4.93)	**10.30** (–5.03)	**12.77** (–4.81)
Drinking	**4.46** (–5.87)	**7.98** (–5.29)	**7.12** (–5.40)	**9.25** (–5.14)	**4.79** (–5.80)	**10.81** (–4.98)	**5.17** (–5.72)	**9.35** (–5.13)
Environment-directed pecking	**11.29** (–4.94)	**29.19** (–3.98)	**26.82** (–4.06)	**31.10** (–3.91)	**10.03** (–5.06)	**28.93** (–3.98)	**26.52** (–4.07)	**34.08** (–3.82)
Other	**1.66** (–6.86)	**2.01** (–6.67)	**0.75** (–7.66)	**1.02** (–7.35)	**0.33** (–8.46)	**1.85** (–6.75)	**1.24** (–7.15)	**1.44** (–7.00)

Table 8 Mean total daily counts (per flock/day) for the behaviours monitored for turkey poults at 2 and 6 weeks of age, in the four different light illuminances. Data presented in bold are the back-transformed means of behaviour counts. Data in brackets are the logit transformed means from the analysis (age*illuminance*behaviour interaction) $F_{33,1232}$ = 4.50; s.e.d. = 0.38; P = <0.001.

Behavioural category	2 Weeks old				6 Weeks old			
	Illuminance (lx)				Illuminance (lx)			
	<1	6	20	200	<1	6	20	200
Standing	**1.23** (–7.16)	**2.71** (–6.37)	**4.67** (–5.82)	**97.51** (–2.72)	**3.39** (–6.14)	**11.27** (–4.94)	**22.88** (–4.22)	**33.97** (–3.82)
Resting	**0.70** (–7.72)	**4.35** (–5.89)	**9.84** (–5.08)	**441.31** (–0.95)	**6.76** (–5.45)	**106.06** (–2.63)	**183.65** (–2.03)	**187.41** (–2.01)
Perching	**0.50** (–8.06)	**2.33** (–6.52)	**6.68** (–5.46)	**151.61** (–2.25)	**10.68** (–4.99)	**65.88** (–3.14)	**117.79** (–2.52)	**102.09** (–2.68)
Preening	**0.67** (–7.76)	**1.81** (–6.77)	**4.56** (–5.85)	**105.21** (–2.64)	**2.40** (–6.49)	**12.25** (–4.85)	**27.98** (–4.02)	**33.01** (–3.50)
Preen-perch	**0.50** (–8.06)	**0.99** (–7.38)	**2.51** (–6.45)	**29.55** (–3.96)	**4.41** (–5.88)	**8.52** (–5.22)	**31.64** (–3.89)	**26.54** (–4.07)
Moving	**0.87** (–7.50)	**2.13** (–6.61)	**4.83** (–5.79)	**59.99** (–3.24)	**2.82** (–6.33)	**5.82** (–5.60)	**19.10** (–4.41)	**21.62** (–4.28)
Feeding	**1.05** (–7.32)	**4.06** (–5.96)	**4.38** (–5.89)	**38.55** (–3.69)	**1.89** (–6.73)	**4.64** (–5.83)	**11.57** (–4.91)	**17.03** (–4.52)
Drinking	**0.54** (–7.99)	**1.15** (–7.23)	**3.00** (–6.27)	**52.13** (–3.38)	**0.75** (–7.66)	**2.09** (–6.63)	**11.52** (–4.92)	**19.92** (–4.36)
Environment-directed pecking	**0.97** (–7.40)	**3.48** (–6.12)	**7.08** (–5.41)	**176.60** (–2.08)	**2.32** (–6.52)	**17.17** (–4.51)	**42.47** (–3.59)	**75.38** (–2.99)
Pecka-Block™ use	**0.50** (–8.06)	**0.50** (–8.06)	**1.45** (–6.99)	**13.52** (–4.76)	**0.59** (–7.90)	**0.62** (–7.85)	**2.01** (–6.67)	**3.95** (–5.99)
Feather pecking	**0.50** (–8.06)	**0.50** (–8.06)	**0.62** (–7.84)	**5.11** (–5.73)	**0.58** (–7.91)	**1.00** (–7.37)	**2.87** (–6.31)	**4.91** (–5.77)
Aggression	**0.50** (–8.06)	**0.50** (–8.06)	**0.50** (–8.06)	**1.12** (–7.25)	**0.56** (–7.95)	**0.50** (–8.05)	**0.83** (–7.54)	**1.74** (–6.81)

The turkey poults, however, showed a more highly significant overall preference, and an effect of illuminance on the partition of different behaviours amongst the light environments. These results suggest that 2 week old turkey poults show a clear preference for 200 lx, but at 6 weeks of age prefer illuminances greater than 6 lx for the inactive behaviours of resting and perching, and illuminances greater than 20 lx for other activities. Such preferences are in contrast to the much lower illuminances provided for these birds in commercial housing, as described in the survey. Sherwin (1998) also found that turkeys spent the least time occupying <1 lx. This may be because they were fearful of entering an environment that handicapped their visual abilities, or because they found brighter light more attractive and visually stimulating.

A crude estimate of preference for photoperiod could also be obtained from the overall occupancy results. Ducklings spent 240 mins/bird/day in <1 lx, while turkey poults spent approximately 10 mins/bird/day at 2 weeks of age and 133 mins/ bird/day at 6 weeks. The time spent by turkey poults in <l lx is less than that spent by ducklings in this illuminance, although it must be stressed that this interpretation is tentative.

The results of the present study differ from those of Davis *et al* (1999), who found using similar methods, that broiler and layer chicks (2 weeks old) had a strong preference for bright light (200 lx) for drinking, feeding and litter-directed activity as well as for resting. At 6 weeks of age, their preferred illuminance for resting changed to a dim light (6 lx). The current study shows that the preferences of ducklings are quite different from those of chickens and turkeys, possibly indicating different illuminance requirements. A possible explanation for this difference could be the differing structure of the birds' eyes and/or their ecology.

The numbers of cone and rod photoreceptors in the retina of the duck eye are approximately 40% and 60%, respectively (Wells *et al* 1975). Ducks have also been shown to be able to attain full dark adaptation of the eye at low illuminance thresholds (0.15 lx), suggesting that these birds are adapted for photopic vision in a range of low illuminances (Wells *et al* 1975). Indeed, many species of duck are active in twilight and at night, as well as during daylight (Reiter 1997). In comparison, many diurnal birds such as chickens are found to have a higher proportion of cones (60%) to rods (40%) (Meyer & May 1973). There are no studies describing the proportions of cone and rod cells for turkeys, but it may be appropriate to assume that they also possess a cone-based retina, given the diurnal nature of these birds. This adaptation indicates that diurnal birds have better vision in brighter light conditions (King-Smith 1971), and may provide a reason for the apparent differences between these species in their preferences for illuminance.

As stated above, a certain amount of care needs to be exercised in the interpretation of preference experiments since these tests rely upon a number of assumptions. Preference tests rely on the animal having the capability to choose conditions that are biologically optimal for itself (Dawkins 1976, 1990). The present study assumed that the birds were able to move through the chamber compartments freely and were able to make the association between any negative or positive state they were experiencing and the light environment. The study was undertaken with consideration of these assumptions and the experimental methodology was designed to control or eliminate several other potentially confounding factors.

Familiar environments are usually preferred to new or novel ones (Dawkins 1980, 1983). Therefore, to make an informed choice, an animal must have experienced the consequences of each alternative (Hughes 1976; Blom *et al* 1993). Previous experience can also influence the results of behavioural tests similar to the present study (Duncan 1978). Therefore, the choice of rearing environment prior to testing was designed to give the birds equal levels of previous exposure to light environments that they were later required to choose between. While this form of light presentation was unrepresentative of commercial practice in respect to the changing illuminance during the day, the illuminance ranges and luminaire types were similar to those used on some farms, as described in the survey.

In preference experiments with socially grouped animals, dominance status can influence the response (Dawkins 1980) since the preferences shown may be those of the dominant member of the group. In the current experiment, detailed social analysis was not possible because the birds were not individually marked and because social behaviour was difficult to identify on the videotapes, particularly when the birds were young. During the experiment, birds of both species predictably behaved as a group, and it is conceivable that a few key birds affected the preferences recorded. However, it was thought that the testing of a group of birds would provide a more accurate picture than the testing of individuals, because the latter would possibly have had welfare implications through stress caused by social isolation.

The decision to use incandescent luminaires to provide the illuminance treatments in this study was based on the findings of the survey, which showed that a higher proportion of the surveyed duckling and turkey houses (combined) had this light source installed (see Tables 5 & 6). Thus, the use of incandescent light sources was chosen to reflect commercial practice. Whether the effects found in the preference experiment are also applicable to fluorescent or other types of luminaire is unknown, since light sources differ markedly in their spectral power output or colour balance (Prescott & Wathes 1999a). Therefore, there may be interactions between illuminance and wavelength depending on the light source used. It is also likely that the illuminance of different light sources will be perceived differently by ducklings and turkeys, even if lit to the same illuminance as measured in lx, since this unit does not consider the spectral sensitivity of these birds (Nuboer *et al* 1992; Prescott & Wathes 1999b). Therefore, other types of luminaire, lit to the same illuminance (measured in lux) as the incandescent luminaires used in this experiment, may not produce the same behavioural effects in these species.

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Animal welfare implications

The difference between farm mangers' estimates of illuminance and the actual measured values, suggests that the use of a standard method and guidelines for quantifying illuminance in poultry houses could benefit the welfare of ducks and turkeys by improving the assessment and monitoring of illuminance.

Ducklings and turkey poults showed different preferences for illuminance, and these also differed from those displayed by chickens (Davis *et al* 1999); possibly indicating different illuminance requirements. Ducklings spent least time in <1 lx and most in 6, 20 and 200 lx. Our survey shows that whilst the lower illuminances of this preferred range are often catered for in commercial duckling houses, the higher illuminances are often not. These findings indicate that ducklings prefer to have access to illuminances that are lower than the RSPCA's recommendation of a minimum of 20 lx (RSPCA 1999a), as well as to much higher illuminances. Another interpretation of these results is that the provision of illuminance of 6 lx or greater would satisfy the birds' preference for light illuminance.

Turkey poults showed an overall preference for 200 lx at 2 weeks of age and for illuminances >20 lx at 6 weeks. These findings compare favourably with the recommendations of the RSPCA to provide turkey poults with a minimum of 20 lx (RSPCA 1999b). However, the results of our survey show that such high illuminances are rarely used commercially because of the increased risk of injurious pecking. The FAWC's recommendation of illuminances of 5 lx (FAWC 1995) is contrary to the preferences of the birds tested here, particularly at 2 weeks of age (although the FAWC do advocate brighter illuminances if practical). These results have implications for welfare because illuminances that satisfy the birds' preference are associated with increases in injurious pecking and aggression (Manser 1996). Beak trimming apparently allows turkey poults to be reared in higher illuminances, although the consequences of beak trimming and perhaps beak tipping may have significant welfare implications (Gentle 1986; Hughes & Gentle 1995).

These results alone do not prescribe the optimum illuminance for ducklings and turkeys, but they do imply that some variation in ambient illuminance, either spatially or temporally, might be beneficial for the welfare of these poultry species. The identification of an illuminance preference is an important first step in determining optimum light conditions. Further work to test the motivation of ducklings and turkey poults for illuminance is required. Furthermore, the determination of the spectral sensitivities of these species may aid in the correct measurement of perceived illuminance for these birds. This will enable future recommendations to be made based on the birds' visual abilities, behaviour and preferences.

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