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An assessment of laboratory mouse welfare in UK animal units

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Abstract

The welfare of conventional stock laboratory mice has been assessed in 46 UK animal units using an expert-defined welfare assessment protocol containing 119 measures of mouse welfare. These were recorded using a questionnaire and observations made during a one-day visit to each unit. The standard of mouse welfare was considered to be good with widespread use of substrate and nesting material and space allowances in most cases well above the minimum recommended levels. Education and training was available and encouraged by the majority of animal units. The health and welfare of laboratory mice was being frequently assessed by animal care staff using daily inspections/observations, health records, and health monitoring schemes. Overall the mice assessed could be considered to be in good health, as indicators of poor health and welfare were exhibited at low levels, and the mice were observed exhibiting a wide range of positive natural behaviours. A number of environmental conditions (humidity, noise and light intensity) were outside recommended ranges in some animal units. The provision of cage resources such as shelters, gnawing material, floor food and other enrichment items were found to be variable. A high proportion of the units surveyed housed at least some of their mice (mainly males) singly and handling of mice by care staff varied between units. In some units there may be an opportunity for some staff to improve in some aspects of mouse handling. Finally, a number of interesting correlations were found between various behaviours and potential indictors of abnormal health or welfare, which require further investigation.

Keywords: *animal-based outcome measures, animal welfare, assessment, laboratory mice, resource-input measures, UK animal units*

Introduction

Recently there have been recommendations/requirements put forward for valid and feasible methods of assessing laboratory animal welfare by various regulatory and advisory bodies. For example, in the UK, the Home Office in a review of the Local Ethical Review Process (Home Office 2001), Recommendation 31 of the House of Lords Select Committee on Animals in Scientific Procedures (House of Lords 2002) and Paragraph 53 of the Government's response to this Committee's recommendations (UK Government 2003). Although post-operative and post-procedural monitoring schemes are now in widespread use, such welfare assessments do not normally extend to assess the effect of housing and husbandry on laboratory animals, which is considered to have the most profound effect on these animals' quality of life (Smith & Boyd 1991). A broad definition of animal welfare refers simply to an animal's quality of life (Fraser *et al* 1997), which takes into account all aspects of an individual's life that could affect its welfare, including the animal's evolutionary history, experiences, ontogenic development, as well as its current physical and psychological state.

Husbandry and housing can affect welfare in a wide variety of ways that can be broadly classified into several categories according its causation. These include, for example, as the environmental conditions (temperature, humidity, and sound levels), the design of the cages (material, size, floor type, and stocking density), materials placed into animal cages (substrate, nesting material, shelters, gnawing material, and other enrichments), routine husbandry practices (cage cleaning, handling and transport), and establishments' policies on monitoring animals and their environment (frequent inspection, health records, standard operating procedures, and health screening).

The comprehensive evaluation of health and welfare requires a holistic assessment that includes not only the factors relating to husbandry and housing, which ultimately affect what animals experience (resource inputs), but also their behavioural, physiological and pathological reactions to these experiences (animal-based outcomes). A wide variety of animal-based outcome measures have been used to assess welfare, including unprovoked behaviours, provoked responses, and the physical appearance of individuals. The aim of this project was to evaluate the welfare of conventional stock laboratory mice in UK animal units using a welfare assessment scheme that was developed through expert consultation (see Leach *et al* 2008) and pilot testing (see Leach *et al* 2006).

Materials and methods

Development of the protocol

The resource-input and animal-based outcome measures used to assess laboratory mouse welfare were chosen through expert consultation using the Delphi technique (for details, see Leach *et al* 2008). These measures were then thoroughly pilot tested and refined at 3 units to ensure that they were valid and feasible for assessing mouse welfare (for details, see Leach *et al* 2006). Consequently, the assessment protocol comprised a total of 119 measures of mouse welfare, of which 68 are resource-input and 51 animal-based outcome measures. The assessment protocol comprised a resource questionnaire and direct observations.

Establishments

This assessment was carried out by visiting 46 animals units comprising 22 commercial, academic, animal breeding and research facilities. Some of the facilities had more than one animal unit, and the proportion surveyed was dependent on the number of units and their biosecurity status. The establishments were recruited through contact with either animal services managers, Named Animal Welfare and Care Officers (NAWCO) or Named Veterinary Surgeons (NVS). Potential establishments were approached by the authors and given a detailed description of the project and then asked to participate in this study. Only four of the establishments approached chose not to participate due to biosecurity concerns.

Resource questionnaire

The questionnaire was sent to and completed by those directly involved in animal care at each establishment (NACWO, NVS, technicians and management) 2 weeks prior to a scheduled visit. It contained questions concerning the resources provided by the establishment, including: cage specifications, animal room environment, monitoring, husbandry procedures, provision of food and water, competence and training of care staff, cage resources, and health and welfare monitoring. It also contained questions relating to the effect of these resources on the mice, including their behaviour, appearance and health status.

Direct observations

The direct observations were carried out by one observer (MCL) during a one-day visit to each animal unit. These can be classified into three categories: 1) all of the animal-based outcome measures (Table 1); 2) those resource inputs that were not covered in the questionnaire, including details of the animal rooms, environmental conditions and a handling assessment of the animal care staff and 3) some of the resource inputs that were covered in the questionnaire were to determine differences between the reported and observed levels, including cage specifications, animal room environment, husbandry procedures, and the resources found inside the cages.

The number of cages and rooms assessed depended upon the size and amount of time available within each unit. An equal number of cages were selected from each animal room at random within a unit. On entry into a room, details about it were recorded (eg environmental conditions, cage types etc). Cages were then selected at random and the information contained on the cage cards was recorded (group size, sex etc). The cage was then pulled out from the rack by half its length and observations were made immediately on the cage contents and physical appearance of the mice. No further observations were made for a period of 5 min in order for mice to resume normal activity after being disturbed. This period was chosen following pilot tests of these measures. Unprovoked behaviour was then observed for 5 min per cage. During this time, the number of mice exhibiting each behavioural pattern (see Table 1) was recorded every 30 s by scan sampling. Finally, wherever possible, the routine handling that occurs as part of the normal husbandry procedures was observed. Permission was sought from the animal care staff (noone refused), and they were observed handling a total of 5 mice in their own time, with the reactivity of the mice also being recorded.

Data analysis

The data presented in the results section has been summarised; firstly, as proportions of animals, cages, rooms or units that fulfil a specific criterion. Secondly, as quartile distributions, where the range of results split into four equal quarters (1st: 0–25%, 2nd: 25–50%, 3rd: 50–75% and 4th: 75–100%). Thirdly, the number of mice per full-time equivalent member of staff was calculated using the number of care staff coupled with the number of animals housed per unit reported by the units. Finally, the behavioural data are presented as the average number of bouts of a specific behaviour observed over a 5-min period divided by the number of animals observed. In order to calculate the space allowance per animal, the floor area (cm^2) reported in the questionnaire was divided by the observed group sizes. The environmental conditions are also presented in terms of compliance with the appropriate codes of practice (Home Office 1989, 1995) and recommendations (National Research Council 1996; UFAW 1999). The National Research Council recommendations refer to the USA and have been used in this UK survey as they represent the only recommendations for these environmental conditions that are currently available.

The data were then further analysed using SPSS (version 12) to identify relationships between outcome measures (ie physical appearance and behavioural measures). Only behavioural and appearance observations found in more than 1% of animals or cages were analysed.

Results

A total of 143 rooms, 1,333 cages and 5,897 individual mice were surveyed, with a mean number of 29 cages per unit. The term 'reported' will be used to refer to the results of the questionnaire and the term 'observed' will be used to refer to the results of the one-day visits. The results of 102 of the 119 specific measures used in the assessment protocol will be reported in this paper. The remaining 17 measures, although assessed, were removed from the protocol, as they were either considered ineffective for evaluating mouse welfare or were not relevant in the units surveyed.

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Table 1 Animal-based outcome measures recorded.

Measures	Definition
Unprovoked responses	
Positive active	Any active behaviour that would be considered positive and is not specifically listed below, such as feeding, drinking, locomotion, grooming, inquisitive and social interactions etc
Aggression	Any form of aggressive behaviour eg chasing or biting a conspecific
Stereotypy	An unvarying, repetitive behaviour with no apparent goal or function eg circling, somersaulting on the cage lid
Inactivity	Inactivity refers to inactive behaviours such as sleeping, resting etc
Climbing	Climbing on the cage lid and/or any objects within the cage
Digging	Digging in the cage substrate
Gnawing	Gnawing on the cage bars
Out of sight	Mouse/mice are not visible due to being under the food hopper and/or inside/under cage enrichment
Wheel use	Using the running wheel if present
Positive parental	Postive parental behaviours include pup cleaning, feeding, protection, retrieval and nest building etc
Negative parental	Negative parental behaviours include ignoring pups, failing to retrieve or being aggressive towards them etc
Appearance	
Barbering	The removal of whiskers and/or hair from discrete areas around the head and face
Wall hugging	The repeated movement along the walls of a cage rather than across open areas in a cage
Physical damage	Damage such as lesions, swellings and wounds on the body, limbs, ears and/or tail
Starey coat	A coat that is pilo-erected, ruffled, rough or unkempt
Chromodacryorrhea	The discharge from nose and eyes that often dries into red, blood-caked appearance
Obese/Normal/Thin	The body condition score of the mouse
Abnormal skin colour	Abnormal discolouration of the skin on limbs, ears and/or tail
Ocular/nasal discharges	Any form of discharge from the eyes or nose
Sunken abdomen	The abdomen on an individual is pulled in or sunken
Hair loss	Diffuse areas of thinning or baldness on the body
Pinched face	The face is screwed up, used as an indicator of pain
Abnormal gait	Abnormal locomotion of a mouse, which indicates presence of physical injuries or morphological problems

Cage specifications

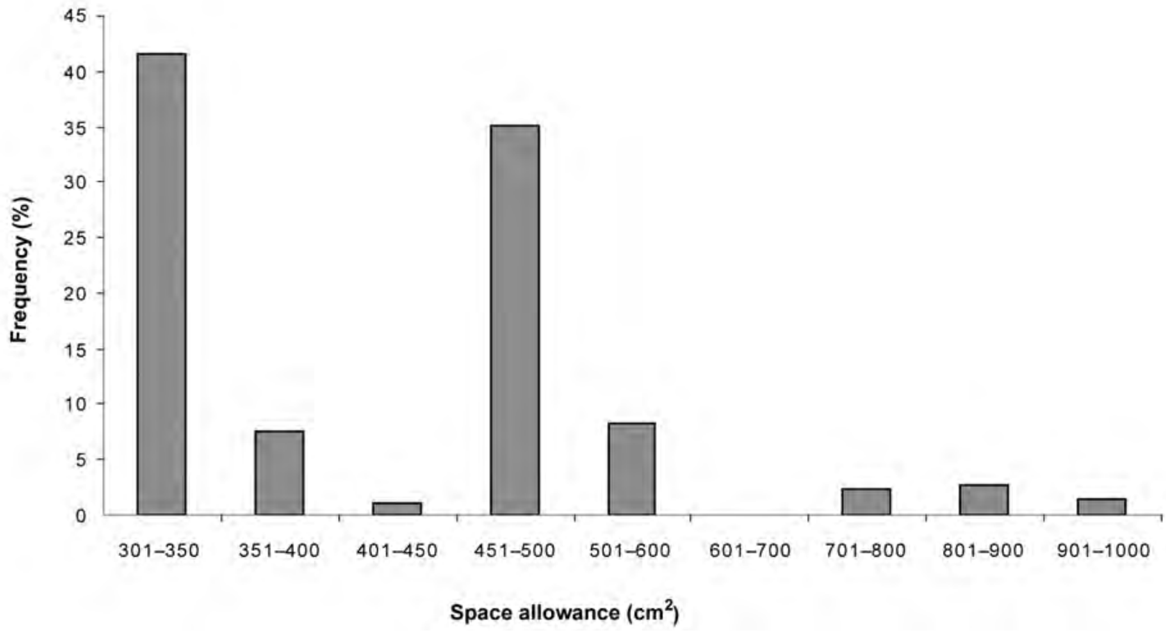
Seventy-one percent of the units reported details on the types of cages that they use to house mice. Overall (single and group housed) the space allowance per animal ranged from 22.1 to 960 cm^2 per mouse (see Figures 1 to 3). 95.9% of cages were above 60 cm^2 per mouse. All cages below 60 cm^2 per mouse contained post-weaned stock mice with only 1% of cages below 30 cm^2 per mouse.

Of the units observed, 78% housed some mice singly to varying degrees, with 21% of non-breeding mice observed to be singly housed. Of these, male mice comprised the vast majority, with 37% housed singly compared with only 6% of female mice, with the remaining male mice being group housed (57%). The strain of the male mouse had a significant effect ($P < 0.001$) on whether mice were singly housed, with CD1 mice being housed singly more than expected as a proportion of that strain of mice analysed, and all others strains being less than expected. Cage transparency, floor types and construction material were also reported and observed (Table 2).

Environmental conditions

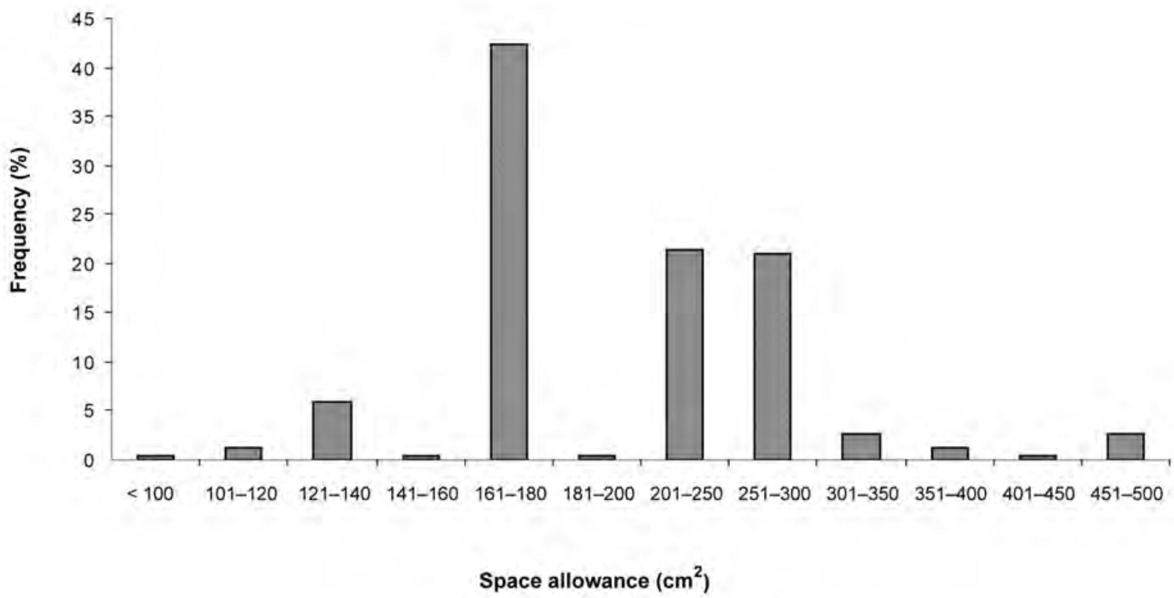
The biosecurity status of the units and their animal rooms and the ways in which mouse cages were ventilated can be seen in Table 3. The range in animal room environmental conditions (temperature, humidity, audible noise level, light intensity) and cage light intensity observed can be seen in Table 4 and Figures 4 to 8. Background music was observed in 68% of units, and equates to 31% of cages being exposed to varying levels of music. The mice in the top row of cages were observed to have some form of protection from room lights in 46% of units, which equates to over 66% of the cages observed. Although, all units reported that they used fluorescent lighting in their animal rooms. Fifteen percent of units were observed to also have windows through which natural light could enter the room, which equates to 15% of animal rooms and 12% of cages observed.

Figure 1



Space allowance per animal for singly-housed, non-breeding mice (n = 211 cages).

Figure 2



Space allowance per animal for breeding mice (n = 311 cages).

Husbandry

The method and frequency of monitoring environmental conditions, health, welfare, and disease status can be seen in Table 5. The method and frequency of cage cleaning reported can be seen in Table 3. All the units visited reported that they assessed their staff's handling techniques, with 70% of these units using a one-off assessment at the end of the training, 19% using continuous assessment of their staff, and 11% re-assessed their staff after a set period.

The variety of methods of individual identification and mouse euthanasia that were reported by the units surveyed can be seen in Table 6. Overall 7% of units reported that they

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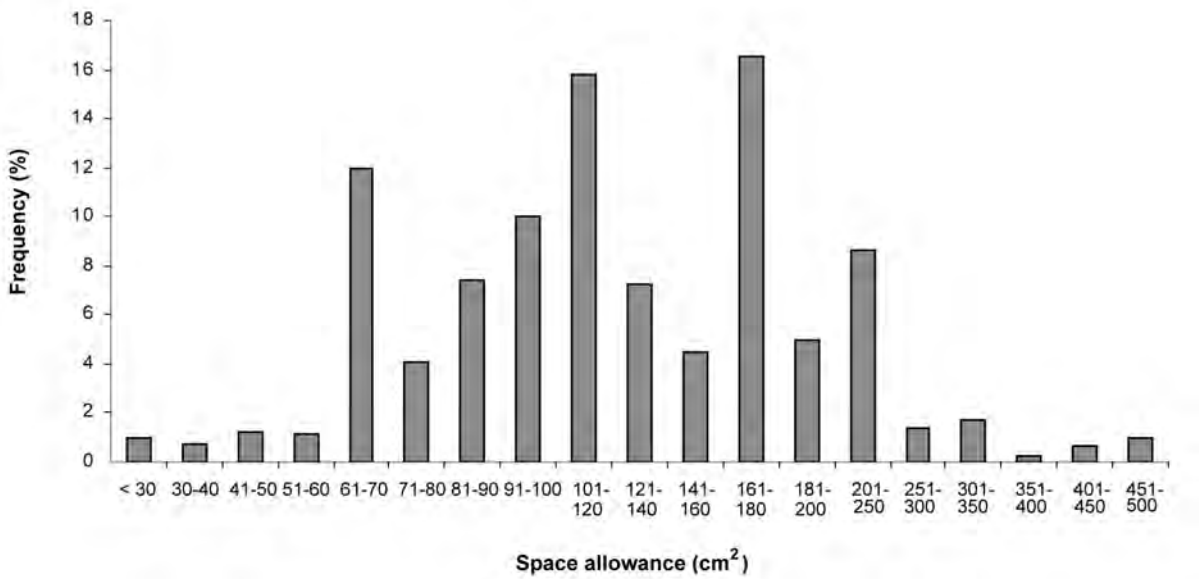
Figure 3



Space allowance per animal for grouped, non-breeding mice (n = 1,022 cages).

euthanised laboratory mice in the presence of their conspecifics (within sight, hearing and smell of other mice), although the method of euthanasia employed in these cages was not identified. The weaning age for mice reported, varied (Table 3). Over 46% of the animal units visited reported that mice were regrouped after initial grouping on arrival or after weaning. Twenty-one percent of the units surveyed reported that mice were housed in the same room as other laboratory animal species, with 17% of units housing a total of 4% of the mice with rats, and 4% of units housing a total of 0.01% of mice with hamsters.

Provision of food and water

All the units reported that they either feed their mice commercially-available pelleted (98%) or powdered diet (2%). The provision of additional food placed on or in the cage substrate was reported by 32% of the units (equivalent to 6% of cages). Of these units 88% reported that they provide this additional food once a week and 12% for a short period after weaning only.

Water was reportedly provided via water bottles in 93% of units (equivalent to 97% of mice), with automatic watering systems reported in 7% of units (equivalent to 3% of mice). Cage flooding was reported by 36% of units, and was due to water bottle spillage in all cases. Seven percent of units reported that they experienced no cage flooding at all, with the remaining 57% of units failing to answer this question.

Staffing

The number of mice per full-time equivalent member of staff ranged from 24 to 3,077 mice per person with the median being 570. The method and frequency of inspection

Table 2 The reported and observed proportions of cage transparency, floor type, construction material, ventilation and resources.

Measure	Reported (units)	Reported (cages)	Observed (cages)
Cage transparency			
Transparent	68%	n/a	37%
Opaque	68%	n/a	63%
Floor type			
Grid	18%	n/a	0.1%
Solid	100%	n/a	99.9%
Construction material			
Plastic	98%	n/a	98%
Metal	2%	n/a	2%
Ventilation type			
Room ventilation	89%	n/a	n/a
Individually ventilated cages	43%	n/a	n/a
Isolators	32%	n/a	n/a
Rack ventilation	4%	n/a	n/a
Nesting material			
Shredded paper	71%	36%	n/a
Enviro-Dri	14%	0.5%	n/a
Nestlets	54%	58%	n/a
Shelters			
Plastic houses	39%	8%	n/a
Des-Res	21%	13%	n/a
Igloo	10%	2%	n/a
Tubes	57%	43%	n/a

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Table 3 The observed proportions of unit and animal room biosecurity status type, cage cleaning types and frequencies, weaning ages, mouse inspection methods and frequencies.

Measure	Definition	Units
Unit biosecurity		
Minimal	Overshoes and lab coat, plus equipment must be sterilised	22%
Barrier	Minimal, plus a change of clothes, cap, gloves and mask	32%
Specific pathogen free	Barrier, plus everyone entering must shower in	46%
Animal room biosecurity		
Conventional	No additional precautions to change overshoes and lab coat	61%
Specific pathogen free	Minimal, plus a change of clothes, cap, gloves and mask	36%
Isolators	Number of units that have cages contained within isolators	39%
Individually ventilated cages	Each cage is individually and separately ventilated	43%
Type of cage cleaning		
Complete cage clean	A clean cage with clean bedding, nesting material and items	36%
Transfer of some 'dirty' bedding material into a clean cage	A clean cage with clean nesting material and items but dirty bedding	14%
Transfer of some 'dirty' nesting material into a clean cage	A clean cage with clean bedding and items but dirty nesting material	25%
Transfer of 'dirty' objects into a clean cage	A clean cage with clean bedding and nesting material but dirty items	25%
Frequency of cage cleaning		
Twice a week	Cages cleaned twice a week	25%
Once to twice a week	Cages cleaned once to twice a week	14%
Once a week	Cages cleaned once a week	57%
Once every two weeks	Cages cleaned once every two weeks	4%
Weaning age		
Before 19 days	Weaned before 19 days old	7%
19–23 days	Wenned between 19 and 23 days old	63%
After 23 days	Weaned after 23 days old	15%
Not applicable due to no breeding mice	Not applicable as unit does not house breeding mice	15%
Type of mouse inspection		
Simple observation through cage	Simple observation through cage walls or top; minimal disturbance	78%
Animals removed from cage	Removal from cage for inspection; considerable disturbance	22%
Frequency of mouse inspection		
Daily	Mice inspected daily	75%
Every 2–3 days	Mice inspected every 2 to 3 days	11%
Weekly	Mice inspected weekly	14%

Table 4 The range in room temperature, humidity, light intensity and audible noise intensity observed at the centre of each animal room at 1.5 m from the floor and the light intensity in the centre of the cage lid.

					Units affected		Cages affected	
Measure	**Min**	**Median**	**Max**	**Recommended guidelines**	**Below**	**Above**	**Below**	**Above**
Room temperature (°C)	18.0	21.9	24.0	19–23°C (Home Office 1989, 1995)	4%*	9%*	2%*	5%*
Room humidity (%)	28.0	51.0	59.5	55 ± 10% (Home Office 1989, 1995)	24%	9%	6%	18%
Room light intensity (lux)	60	430	1,126	< 400 lux (National Research Council 1996)	n/a	74%	n/a	32%
Room audible noise level (dB)	35	53	78	< 50 dB (National Research Council 1996)	n/a	74%	n/a	61%
Cage light intensity (lux)	1	18	1,063	< 30 lux (Wolfensohn & Lloyd 2003)	n/a	83%	n/a	32%

Table also shows the proportion of units and mouse cages that were above and below the recommended ranges for these environmental conditions.
* All 1°C outside recommended range.

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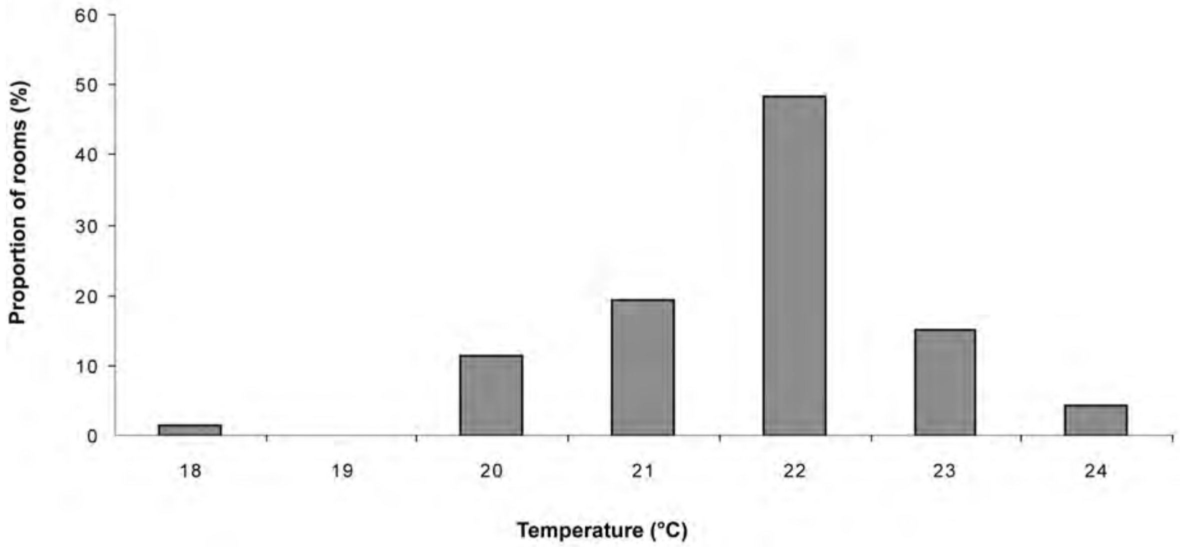
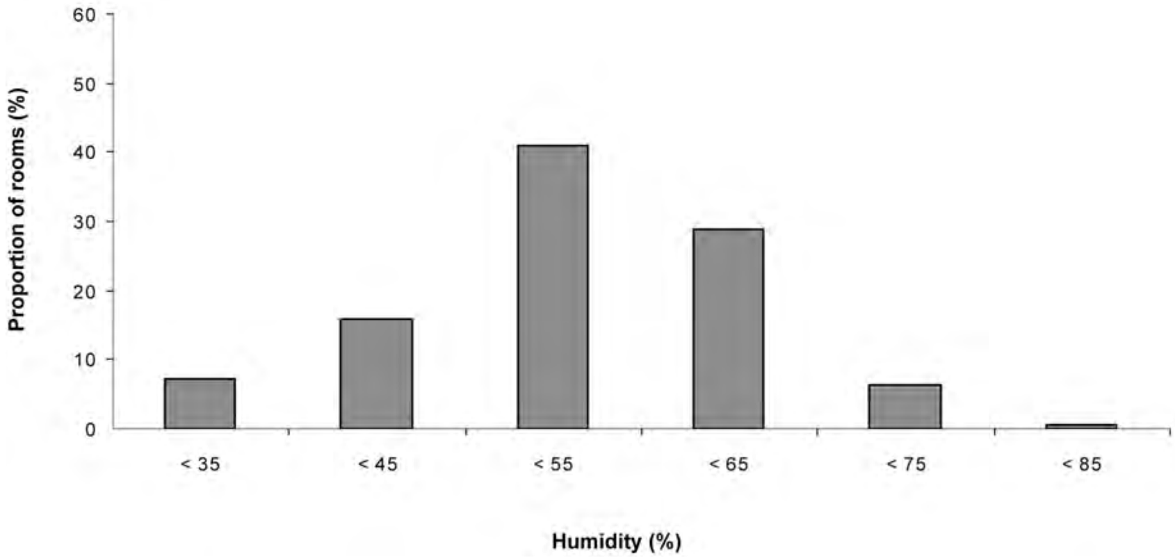
Figure 4



Proportion of animal rooms at each temperature level (n = 143 animal rooms).

Figure 5



Proportion of animal rooms at each humidity level (n = 143 animal rooms).

of the mice varied between units and can be seen in Table 3. Ninety-three percent of animal units reported that they provided training for their animal care staff, such as internal, IAT and Home Office courses. Of these units, 57% assessed effectiveness of training.

The results of the assessment of handling techniques demonstrated by unit staff can be seen in Table 7. The majority of the mice (93%) that were handled during this assessment were passive (non aggressive and non-fearful) and located in 95% of the units visited. The time taken to capture the mice ranged from 0–8 s, with the vast majority of staff (98%) taking less than 2 s.

Mouse cage resources

All cages observed had either substrate or nesting material. Ninety-six percent of units reported that they provided substrate/bedding materials such as sawdust, woodchips, woodshavings and shredded shoe-liner off-cuts. Of the units observed, 13% did not provide cage substrate or bedding material for some of their mice (equivalent to 4% of cages). All cages without substrate had nesting material (including those with grid floors). Ninety-two percent of units reported that they provided a variety of nesting materials, which can be seen in Table 2. Of the units observed, 20% did not provide nesting material for some of their mice (equivalent

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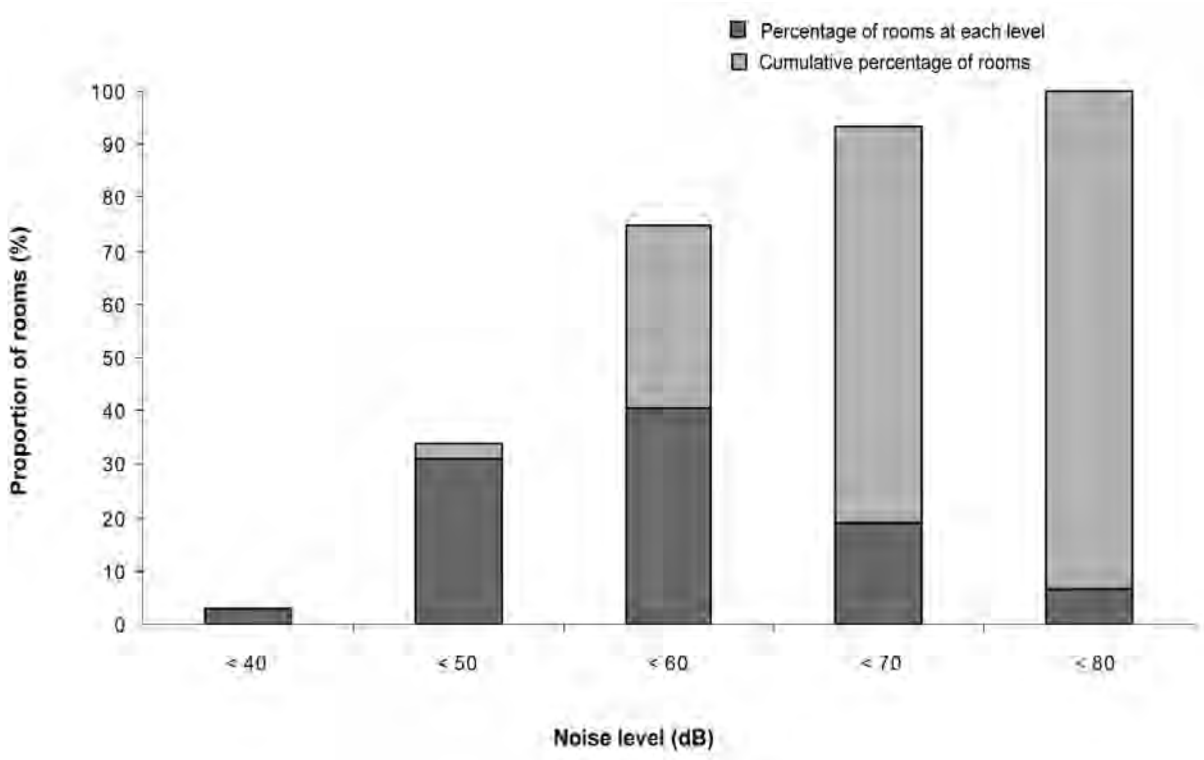
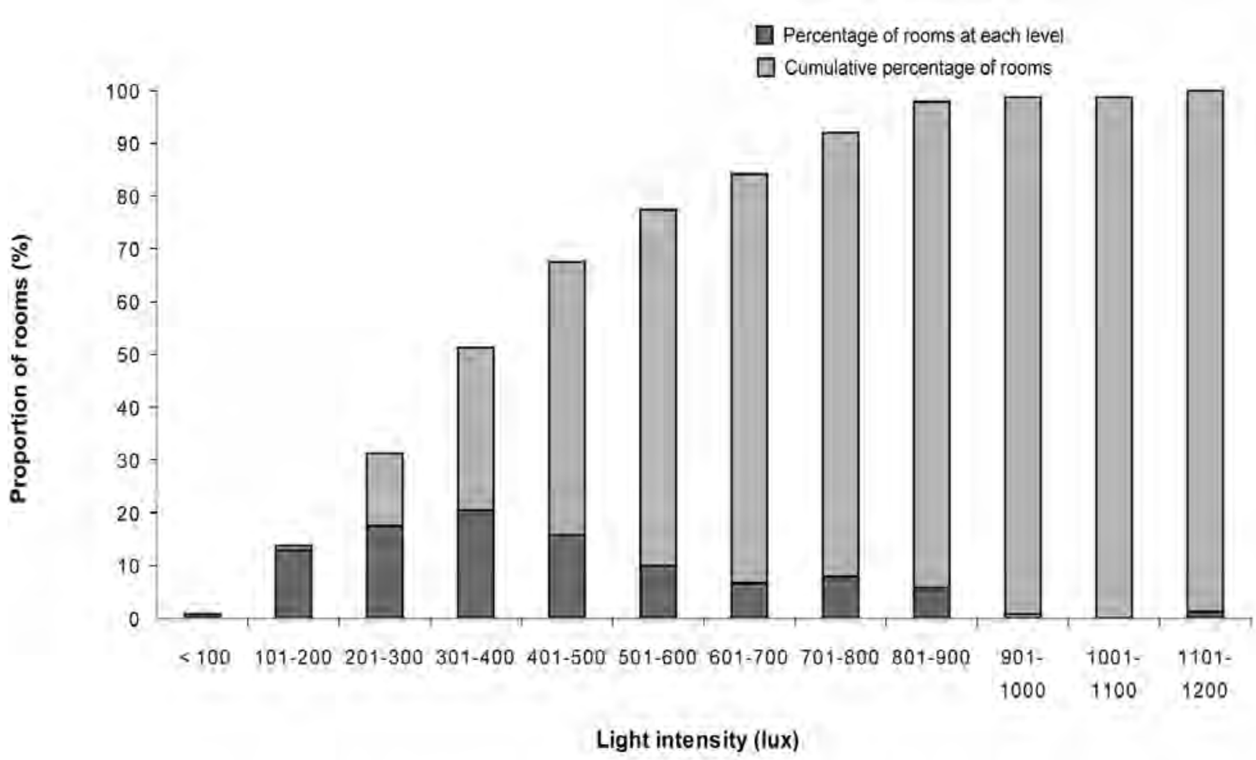
Figure 6



Proportion of animal rooms at each noise level (n = 143 animal rooms).

Figure 7



Proportion of animal rooms at each light level (n = 143 animal rooms).

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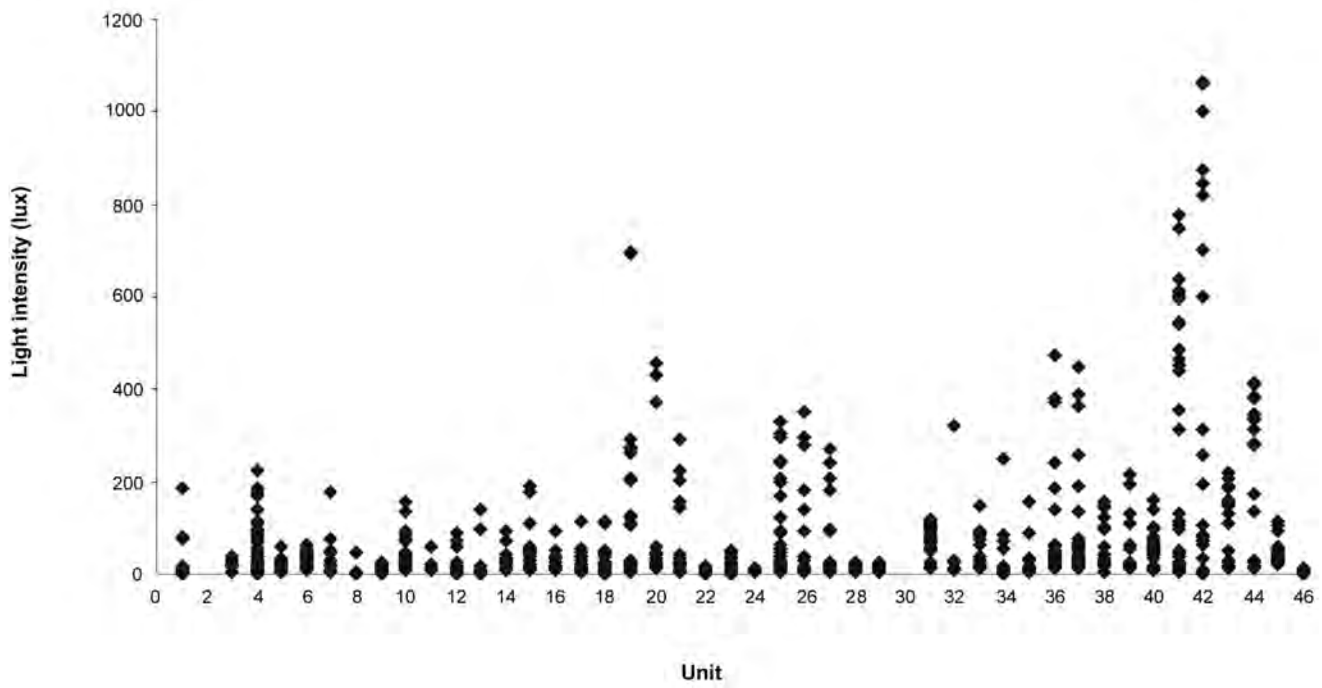
Figure 8



Distribution of cage light intensities in the different units (n = 1,333 cages).

to 8% of cages). All the cages without nesting material had solid floors and contained cage substrate. Of the cages containing breeding animals, 6% did not contain any nesting material, although substrate/bedding material was always present.

Overall, 37% of the cages surveyed contained no additional resources (shelter, gnawing material, other forms of enrichment) other than sawdust and/or nesting material. The provision of a variety of shelters for mice was reported by 75% of the units (equivalent to 48% of the cages), and can be seen in Table 2. Some form of shelter in mouse cages was observed in 63% of units (equivalent to 47% of cages). Of these, shelters were not observed in 57% of the cages containing breeding animals, and 47% of the cages containing non-breeding animals. Of the cages containing shelters, the majority (90%) used opaque types, with only 10% of cages being transparent (equivalent to 80% of units using opaque and 20% using transparent cages).

Twenty-one percent of establishments (equivalent to 4% of cages) reported that they provide gnawing material for their mice (eg wood blocks, nylon bones and shelters). However, 63% of the units visited were observed to have a shelter that could be chewed (equivalent to 47% of cages). The use of other forms of enrichment was reported by 21% of the units surveyed and included egg boxes, cardboard houses cut in half and metal rings hanging from the cage top. The use of running wheels was only reported by 4% of units (equivalent to less than 0.5% of cages).

Behaviour and appearance

A wide range of unprovoked behaviours were observed, with the results for aggression, stereotypy, and climbing being presented here, as they can be considered the most welfare relevant (see Table 8). Stereotypy was defined as any behaviour that was considered abnormal, either in appearance or exhibition, for example, somersaulting, gnawing on the cage bars, twirling on the cage bars, excess wheel running, etc. In addition, all of the breeding animals exhibited positive but not negative parental behaviour. The units reported that their mice, at certain times, exhibited a range of potentially abnormal or detrimental behaviour, which can be seen in Table 7.

A significant positive correlation (Spearman Rank correlation) was found between stereotypy and climbing behaviour, such that higher levels of stereotypy were associated with higher levels of climbing behaviour ($P < 0.001$). Logistic regression showed a significant effect of strain on stereotypic behaviour, with C57 mice exhibiting significantly less stereotypy than other strains ($P < 0.001$, OR: 0.3), and BALB/c mice exhibiting significantly more stereotypy than the other strains ($P < 0.01$, OR: 2.8). In addition, this analysis showed that the frequency of stereotypy was significantly lower in cages that contained a shelter ($P < 0.001$, OR: 0.5), but significantly higher in cages that contained gnawing material ($P < 0.01$, OR: 6.7).

Table 5 The reported details of the monitoring of environmental conditions and animals, health records and types of standard operating procedures used and staff involved in their generation.

Measure	Units
Temperature measurement	100%
Frequency of temperature measurement	
Automated	71.4%
Daily	28.6%
Humidity measurement	100%
Frequency of humidity measurement	
Automated	74.1%
Daily	25.9%
Light intensity measurement	35.7%
Frequency of light intensity measurement	
None	37.5%
Automated	12.5%
More than monthly	50%
Behavioural monitoring	82.4%
Monitoring of appearance	74.1%
Monitoring weight changes	25%
Last health record review	
Daily	47.4%
Weekly	10.5%
Monthly	15.8%
Annually	26.4%
Health screening process	92.3%
Health records	
Specific unit health record	96%
Record of health problems	46%
Record of health screening problems	43%
Record of study data	14%
Standard operating procedures (SOP)	
Disease prevention	68%
Dealing with disease outbreaks	37%
Staff involved SOP generation	
Named Animal Care and Welfare Officer	92%
Named Veterinary Surgeon	88%
Unit management	75%
Animal technicians	58%

The physical appearance of the mice varied between units both in the reported and observed frequency of the conditions (see Table 7). Chromodacryorrhea was not observed during visits to the animal units; however, 2% of the units reported it, which equates to about 0.01% of the animals. Alternatively, abnormal gait was observed in 20% of the units visited, which equated to about 2% of the mouse cages however, abnormal gait was not reported in any of the units surveyed. The remaining physical conditions listed in the questionnaire were not observed or reported.

Chi-square analysis shows that barbering (hair loss on the face and head) was observed significantly more frequently in cages containing mice with higher levels of hair loss (on body) ($P < 0.05$), general signs of disease ($P < 0.001$) and obesity body scores ($P < 0.001$). In addition, hair loss was observed significantly more frequently in cages containing mice with higher levels of general signs of disease ($P < 0.001$) and physical damage ($P < 0.01$). Mann-Whitney U tests showed that barbering and physical damage were observed more frequently in cages containing mice exhibiting higher levels of aggression ($P < 0.05$, $P < 0.001$, respectively). In addition, cages containing mice exhibiting higher levels of climbing exhibited lower levels of high body score and higher levels of physical damage ($P < 0.05$).

Establishment policies and procedures

All the establishments surveyed reported that they kept and used one or more types of health record (see Table 5). The NVS was reported to review health records in 86% of units. A variety of standard operating procedures reportedly used by units can be seen in Table 5, along with the staff involved in Standard Operating Procedures (SOPs) generation.

Disease problems within the last 12 months were reported by 32% of units surveyed, and included *Helicobacter* spp, *Pasteurella* spp, *Trichomonas* spp, *Entamoeba* spp, *Syphacia* spp, and Mouse Hepatitis Virus outbreaks. The monitoring of mouse mortality was reported to occur in 68% of units surveyed. The level of pre-weaning mortality was reported in 50% of units. The mean pre-weaning mortality was reported to be 11.3% of mice, with the minimum 0%, the median 3.5% and the maximum 25% of mice. The level of adult mortality was reported in 60.7% of units. The adult mortality was reported to be 2% of mice, with the minimum 0%, the median 1% and the maximum 10% of mice. The Local Ethical Review Committee was reported to discuss animal welfare issues in 96% of the units surveyed. Welfare information was reported to be readily available to animal care staff by 89% of the units, and includes the internet, training courses, library, ethical review committee, and Institute of Animal Technology (Association for animal technicians).

Discussion

The aim of this survey was to assess the welfare of laboratory mice housed in UK animal units. In general, the authors consider that the level of mouse welfare in the animal units visited was of a good standard although there are areas of potential concern.

Environmental conditions

All animal units monitored their room temperature and humidity either automatically, using environmental control systems or, daily, using thermometers and humidity meters

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Table 6 The proportion of units reporting the use of the different methods of mouse identification and euthanasia.

	Proportion of mice				
Measure	**Mean**	**Min**	**Median**	**Max**	**Proportion of units**
Identification method					
No method	74.4%	0%	0%	100%	84.8%
Ear notching	10.3%	0%	37.5%	100%	23.9%
Data chipping	6.3%	0%	0%	90%	4.3%
Fur/tail marking	7.1%	0%	0%	20%	19.6%
Tattooing	3.9%	0%	0%	100%	4.3%
Euthanasia method					
Overdose of anaesthetic	1.4%	0%	0%	95%	24%
Carbon dioxide	76.0%	2%	90%	100%	100%
Dislocation of the neck	22.3%	0%	5%	98%	78.6%
Concussion	0.3%	0%	0%	6%	25%
Other methods	0%	0%	0%	0%	0%

in each animal room. The temperature and humidity of the animal rooms within some units were outside the optimum ranges recommended by the appropriate Code of Practice (Home Office 1989, 1995) for temperature (19–23°C) and humidity (55 [± 10%]). For temperature, it seems unlikely that these deviations will have a detrimental effect on welfare as they were only 1°C above or below the optimum range. However, for humidity, the deviations can potentially cause health and welfare problems, as high humidity levels could be associated with an increased risk of disease transmission and a reduction in heat loss (Clough 1984), and low humidity levels are associated with dermatological problems such as ringtail (Crippa *et al* 2000), although no such health problems were observed in these units during this survey.

Excess sound has been considered to be detrimental to mouse welfare (Sales *et al* 1999). The audible noise levels in the animal rooms surveyed ranged from below 40 to 80 dB, therefore all the animal rooms surveyed were below the 85 dB recommended by the National Research Council (1996) in the USA as a general species upper limit for populated animal rooms (currently the only standard available worldwide). However, the vast majority of units, animal rooms and cages were exposed to higher noise levels than the maximum level recommended (50 dB) for unpopulated animal rooms (Home Office 1989). Although the hearing range of mice (100–100,000 Hz) differs from that of humans (20–20,000 Hz), this could still be detrimental if animals are subjected for long periods, as the ranges do overlap so high human audible noise levels could potentially be within the hearing range of mice. Although background music was played in the majority of units visited, there was no correlation between high audible noise levels and the presence of background music, suggesting that the likely source is other animals, plant machinery and staff activities.

Table 7 Handling assessment observations in terms of the proportion of units and handlers observed.

Handling	**Handlers**	**Units**
Method of picking mice up		
Tail	92.3%	100%
Body	7.7%	20%
Mice are supported	30.9%	42.5%
Method of replacing mice		
Put down	85.1%	97.5%
Dropped	14.9%	32.5%
Handling type		
Gentle[†]	85.8%	95%
Rough[‡]	14.2%	30%
Handling speed		
Slow[§]	37.9%	57.5%
Rapid[#]	62.1%	82.5%
Capture aggression	0.5%	2.5%
Capture vocalisation	1.6%	7.5%

[†] Gentle refers to the careful picking up, handling, restraint and depositing of an individual mouse.
[‡] Rough refers to occasions where animals were picked up, handled, restrained and deposited with little care and attention.
[§] Rapid signifies the picking up of an individual taking less than 2 s.
[#] Slow signifies the picking up of an individual taking more than 2 s.

The light intensity to which laboratory mice were exposed varied considerably between units, animal rooms and cages, with the majority of units having rooms with light intensities that exceeded published recommendations of 325 to 400 lux at 1 m from the floor (Clough 1984;

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Table 8 Prevalence of potential measures of abnormal behaviour and observed and reported physical appearance.

	Proportion of cages				
Behaviour	**Mean**	**Minimum**	**Median**	**Maximum**	**Proportion of units**
Aggression					
Overall	1.7% (3.8%)	0.0% (0.0%)	0.0% (5%)	9.4% (20%)	
Non-breeding	1.9%	0.0%	0.0%	10.7%	37% (92.3%)
Breeding	0.6%	0.0%	0.0%	10%	
*Stereotypy**					
Overall	12.2% (0.7%)	0.0% (0.0%)	11.8% (0.5%)	55.2% (5.0%)	
Non-breeding	13.7%	0.0%	11.8%	55.2%	78.3% (51.9%)
Breeding	1.2%	0.0%	0.0%	16.7%	
Climbing					
Overall	22.8%	0.0%	20.6%	83.3%	
Non-breeding	25.6%	0.0%	24.4%	83.0%	97.8%
Breeding	3.1%	0.0%	0.0%	50%	
Barbering					
Overall	4.2% (2.4%)	0.0% (0.0%)	0.0% (1.0%)	11.2% (10%)	47.8% (66.7%)
Physical damage					
Overall	1.7% (2.4%)	0.0% (0.0%)	0.0% (1.0%)	17.7% (30%)	21.7% (59.3%)
Starey coat					
Overall	0.5% (6.5%)	0.0% (0.0%)	0.0% (0.0%)	6.5% (75%)	10.9% (29.6%)

* Stereotypy was defined as any behaviour considered abnormal in either appearance or exhibition eg somersaulting, twirling on cage bars.

National Research Council 1996). In addition, a considerable proportion of the mouse cages (all containing albino mice) were exposed to levels above 60 lux, which is the maximum recommended for albino mice by Wolfensohn and Lloyd (2003). Exposure to such high light intensities could potentially have a number of detrimental effects on rodents, particularly those that are albino, including physiological, morphological, and behavioural changes such as aversion (Blom *et al* 1995), reduction in explorative behaviour (Garcia *et al* 2005), reduction in reproductive capability (Brainard *et al* 1986) and retinal degeneration (Clough 1984; Rao 1991). The high room light intensities observed may relate to the relatively low proportion of units (36%) surveyed that actually monitor light intensity levels, and, of these, most only do so when the room is being set up or on a more than monthly basis.

Cage specifications

The vast majority of cages (98%) were constructed of either polycarbonate or polypropylene, which is likely to provide a warmer, more comfortable and less noisy environment than metal cages. Both rats and mice have shown a preference for solid floors (van de Weerd *et al* 1996, 1998). Grid floors were used in very small numbers in only 18% of the units visited, with the majority of these cages being used to identify when mating had taken place in breeding mice that are only housed in these cages for a period of 12–24 hours. Avoiding the long-term use of grid flooring is likely to be important for mice. Deleterious effects of grid floors on rats has been shown with foot and leg damage (Saibaba *et al* 1996) and increased abnormal behaviour (Kaliste-Korhonen *et al* 1995).

The space allowances provided by the animal units were well above the minimum levels recommended for breeding mice (300 cm^2 for pairs and trios, 300 + 180 cm^2 for each additional female litter for breeding animals [Home Office 1995]) and for singly-housed mice (200 cm^2 [Home Office 1989]). This suggests that the space allowance needs of these mice are being met and exceeded in these units. Since it was not possible to assess the bodyweights of the individual mice observed during the survey we were unable to directly compare the space allowances provided for non-breeding group-housed mice with the code of practice (Home Office 1989). However, the vast majority (96%) of animal units surveyed used cages that provide space allowances above the minimum recommendation of 60 cm^2 per mouse at < 30 g. The remaining cages, all contained post-weaned stock, and all but one unit were observed to

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provide space allowance above that of the minimum recommendation of 30 cm^2 at < 20 g (Home Office 1995). Insufficient space allowance was observed in one unit in recently weaned animals for a very short period before being re-grouped or sent out.

Housing laboratory mice in compatible groups can be considered one of the fundamental ways of promoting good welfare, as they are gregarious animals. Despite this, the majority of units (78%) housed at least some of their non-breeding mice singly, with male mice comprising the vast majority of these animals, presumably due to the higher levels of aggression. Strain differences were found to influence the likelihood of male mice being housed singly, with CD1 mice significantly more likely to be housed singly than other strains. This is not surprising as CD1 mice are often regarded as exhibiting high levels of aggression when housed together (Parmigiani *et al* 1999). Surprisingly, male BALB/c mice, which are also considered a very aggressive strain, were not found to be housed singly more often than other strains. The potential exists for an inherent welfare conflict in separating fighting male mice as subordinate animals, that are the targets of aggression, seem likely to benefit from the removal of dominant animals; however, whether this outweighs the dominant animal's need for social contact is difficult to identify and should be carefully considered in each individual case. Mice were reportedly housed with other laboratory animal species (such as rats and hamsters) in 21% of the units. The relevant codes of practice (Home Office 1989, 1995) recommend that rats and mice are not housed in the same room, as rats naturally prey on mice and therefore the continual presence of a predator may be distressing for the mice and the continual presence of prey may be frustrating for the rats.

Mouse cage resources

The provision of utilisable mouse cage resources (bedding and nesting material, shelters, and gnawing material) can help fulfil the basic requirements of laboratory mice. Only a small proportion of the mouse cages surveyed did not contain some form of substrate, although the solid floor cages did contain nesting material. However, nesting material alone cannot provide the benefits of substrate, including absorbance of urine, comfortable material on which to live (Ago *et al* 2002), and promoting digging and foraging (Hobbs *et al* 1997; Leach *et al* 2000).

A small proportion of the mouse cages containing both non-breeding and breeding mice did not contain nesting material. Although all these cages had substrate of some kind, it cannot adequately function as a nesting material, which is thought to aid to temperature regulation (Brain 1994) and could also provide a sense of security. This is likely to be of particular importance for breeding females during parturition and the raising of young, and for singly-housed mice. All mice (breeding females, males and non-breeding females) at a range of ages will not only construct nests if given the opportunity (van de Weerd 1997; Nevison *et al* 1999), but also work to gain access to nesting material (Olsson & Dahlborn 2002), which indicates that the act of building a nest is important to mice.

Almost 40% of the cages surveyed did not contain any resources other than substrate and/or nesting material. The use of additional enrichment by only a small number of units (21%) is surprising considering the large body of research that exists demonstrating the positive effects of a variety of enrichments, including introducing complexity to the environment and promoting natural behaviour and activity (eg Würbel *et al* 1998; Harri *et al* 1999; Leach *et al* 2000; Olsson & Dahlborn 2002; Farlin & Baumans 2003; Robertson & Roland 2005).

Shelters were observed in 42% of the cages surveyed; however 37% of the units did not place a shelter in some of their mouse cages. Shelters are considered to provide a more complex and utilisable environment as they: cater for the thigmotactic nature of mice (Anzaldo *et al* 1995), offer a place to escape from external disturbances and conspecifics (Sherwin 1997; van de Weerd *et al* 1997), offer the ability to create a separate microclimate and so control the environment (van de Weerd 1998), and provide an object to be interacted with, chewed and climbed upon. Although the food hopper may be considered a form of shelter, it is not an enclosed space, cannot be manipulated and does not allow escape from conspecifics, all of which seem important to mice (Sherwin 1996; van de Weerd *et al* 1997). The lack of shelters is also a particular concern with the high room and cage light intensities observed in many of the animal units however, opaque cages make observation of mice by care staff more difficult without causing disturbance to them.

Although, the majority of units surveyed reported that they did not provide additional gnawing material, many provided shelters that could also be gnawed upon. Gnawing material is considered an important resource (Chmiel & Noonan 1996). It has been suggested for natural prevention of tooth overgrowth (Sørensen *et al* 2004), for reduction of gnawing damage to the cage and gnawing of cage bars (Würbel & Stauffacher 1998), and for reducing wastage of food pellets, which are gnawed on but not ingested.

Husbandry

Cage cleaning is considered to have a profound effect on the welfare of laboratory mice (Gray & Hurst 1995; van Loo *et al* 2000), as it is not only a frequent source of considerable disturbance, but is often associated with an increase in aggression, particularly in male mice. As a result, a wide variety of cleaning methods have been suggested to reduce aggression, from using a completely clean cage (Gray & Hurst 1995) to the transfer of some 'dirty' objects or material into a clean cage, eg nesting material (van Loo *et al* 2000). This range in advice may explain the wide variety of methods reported by the units surveyed. The frequency of cage cleaning also varied between the units however, this is not surprising as the frequency of cleaning will depend on the method of cleaning, the type of cage, the number of animals housed per cage and the sex of the mice in question.

The majority of units surveyed (84.8%) did not use individual identification methods but, for those that did, a variety of methods were used (Table 6). All methods (except tail and fur marking) also involve some degree of tissue injury. A variety of euthanasia methods were used, including carbon dioxide, even though there is concern and controversy over its use in laboratory rodents (Danneman *et al* 1997; van Luijtelaar & Coenen 1999), which we would have expected to lead to increasing use of other methods. Although the codes of practice (Home Office 1989, 1995) recommend that animals should not be euthanised in the presence of their conspecifics, 7% of units reported that they did not follow this recommendation. This is not surprising as there is little or no evidence that killing of individuals in the presence of their conspecifics causes any distress for many laboratory animal species (Gärtner *et al* 1980).

A small number of units weaned mice before the earliest recommended age of 19 days, which may cause problems for these animals later in life, including anxiety and aggression towards conspecifics (Kikusui *et al* 2004). Although a few units weaned after 23 days this is unlikely to cause a problem unless offspring remain with their parents for an extensive period after they would naturally disperse at around 28 days (UFAW 1999), eg parents exhibiting aggression towards offspring. The regrouping of mice after they were initially grouped together was reported by almost half of the units. The removal and addition of animals to established groups could lead to considerable increases in aggression and distress, particularly in adult mice where the hierarchical order will be re-established. Therefore, once again, potential exists for an inherent conflict of welfare between the desire/need to regroup singly-housed mice and the fear that this will lead to elevated levels of distress and aggression in the subsequent new group.

Provision of food and water

All of the animal units surveyed fed their mice on either standard pelleted or powdered laboratory animal diet via a food hopper which should fulfil the nutritional requirements of the mice. However, feeding animals via a food hopper is unlikely to fulfil all of the behavioural needs for foraging and feeding. Less than half of the units provided food on the floor of the cage, eg pellets, grain etc, which is considered to be a simple method of enriching the cage environment of mice as it promotes natural foraging and feeding behaviour, exploration and physical exercise (Leach *et al* 2000). In addition, old animals will find it easier to locate and consume food from the floor of the cage compared with having to reach up to the food hopper, thereby improving their welfare. Cage flooding was reported by a relatively high proportion of the units surveyed; however it is unlikely to have a detrimental effect on welfare. Almost all the units surveyed used water bottles which restricts the quantity of water should flooding occur. None of the small proportion of units using automatic watering systems (which in the event of a flood can cause considerable suffering and death) reported cage flooding.

Staffing

Considerable variation was seen in the number of mice per full-time equivalent member of staff which could have a significant influence on the welfare of the mice. After all, as the number of mice per member of staff increases, the amount of time available to adequately observe and inspect the mice will decrease, particularly when one considers that the majority of animal units surveyed reported that they inspect each of their mice once per day. Under UK legislation it is a legal requirement to inspect animals on a daily basis. The 25% of units that reported that they did not conduct detailed inspections may have been observing each animal through the cage wall or lid rather than disturbing each animal every day. Such disturbances may have a detrimental effect on the health and welfare of the animals, for example, causing infanticide if carried out too soon after animals are born or an increase in aggression between conspecifics. This question could have been phrased more precisely to define the exact nature of the inspection.

The attitude and skill of the staff during handling can have a critical effect on welfare, as it is an integral component of virtually all the husbandry and scientific procedures to which animals are subjected. Although there were many cases of best practice, less than 31% of the handlers supported the mice when they picked them up, more than 14% dropped the mice back into their home cages from a height greater than 2 cm after handling them, and more than 14% were considered to have handled the mice roughly. However, other handling-related measures were more positive, as mice were caught quickly with the minimum of disturbance and there was very little aggression shown towards the handlers or vocalisation from the mice. A contributing factor to the variability of handling skills may have been the failure to monitor handling skills on a regular basis. However, the vast majority of units seem to be promoting education, as they make welfare information readily available to their staff, they ensure welfare issues are discussed via the local ethical review process and they ensure staff are sent on various types of training courses.

Establishment policies and procedures

The effectiveness of health monitoring, disease prevention and control strategies were demonstrated by the relatively low proportion of units that reported disease outbreaks in the last 12 months and the active treatment of these diseases by those that suffered a disease outbreak. Almost all of the establishments used one or more type of health monitoring and record keeping, enabling them to both effectively monitor and control specific health problems and maintain a good state of general health within their establishment. The monitoring of mortality can also be considered to be a useful method of monitoring the overall state of health and welfare in a unit. The highest level of mortality was reported to occur before weaning and was most likely to be related to strain-specific problems such as infanticide, poor parental skills, non-infectious health problems etc. The lower level of mortality recorded in adult animals was more likely to be due to aggression and/or disease in these animals. For health and mortality records to be truly effective, disease surveillance must be in place and records must be reviewed routinely in order that any changes can be identified quickly and remedied. The majority of units surveyed reviewed records at least every month if not more frequently and the majority did so in consultation with the NVS, who is likely to be in the best position to interpret records and give advice accordingly. However, standard operating procedures are less widely used by the establishments, particularly ones for controlling disease outbreaks. The use of SOPs has been advocated for both the prevention and control of the spread of disease in other animal-based industries, eg veterinary health plans for farmed species (Main & Cartledge 2000).

Behaviour and appearance

Effective evaluation of welfare in a comprehensive and holistic way requires not only the assessment of resources (resource inputs), but also the behavioural, physiological and pathological reactions (animal-based outcomes) of animals to these resources. All of the mice observed during this survey exhibited a wide range of unprovoked natural behaviours that are considered indicators of good welfare including: positive active behaviour, positive parental behaviours (breeding animals only) and periods of inactivity. The fact that these behaviours were similar between units and cages or were not correlated with the other behavioural measures is not surprising as they were seen in all animals during the observation periods.

The overall levels of aggression (1.7% of cages), stereotypy (12.2% of cages) and climbing (22.8% of cages) may be of concern. Aggression in mice, particularly in males, is considered to be a serious problem for animal units, as it can lead to physical injury and animals being individually housed; both of which are likely to cause distress to the animal. The considerable variation between units in the levels of aggression observed did not correlate with, or correspond to, any other factor measured in this assessment.

The considerable variation between units in the levels of stereotypy observed may relate to differences in the strains held and resources placed into mouse cages between the units. BALB/c mice exhibited significantly more stereotypy and C57 mice exhibited significantly less stereotypy than expected. BALB/c mice are considered more anxious than C57 mice (Belzung & Griebel 2001). A lower level of stereotypy was associated with the presence of a shelter which is in accordance with the findings of Würbel *et al* (1998), highlighting the importance of some form of separate shelter, and that the absence of a shelter could lead to distress. Providing animals with resources such as shelters and gnawing material, which may be used infrequently, could be argued to be a welfare benefit because mice have demonstrated a behavioural preference for them (van de Weerd *et al* 1998). However, it is also important to consider the influence of these cage resources on other behaviours, as a higher level of stereotypy was associated with the presence of gnawing material which is in direct contrast with a separate study that showed a reduction in gnawing on the cage bars when gnawing material was provided (Würbel & Stauffacher 1996). It is outwith the scope of this study to provide a possible explanation for this correlation. For example, provision of gnawing material may either have exacerbated stereotypy or the units may have added gnawing material in response to an increase in stereotypy. Therefore we feel that this finding requires further examination.

Climbing behaviour was observed relatively frequently in the mice surveyed and is often considered a positive natural behaviour that is associated with exploration of the environment and physical exercise. However, in this study, increased levels of stereotypy were associated with increased levels of climbing. This is perhaps unsurprising as a high proportion of mouse stereotypies occur at or on the bars of the cage lid, eg gnawing on the cage bars, circling, somersaulting etc. Therefore, high levels of climbing may form an integral part of certain stereotypies, a conclusion reached by other studies (Würbel *et al* 1996; Würbel & Stauffacher 1998).

The considerably lower levels of aggression, stereotypy and climbing exhibited by breeding compared with non-breeding animals are very interesting, and may suggest that allowing mice to breed reduces the exhibition of potentially 'negative' behaviours. This could have one or more potential explanations including reduction in the amount of time available to exhibit abnormal behaviour due to increased time involved in parental care, an increase in the number of animals to interact with, or a lack of stimuli to trigger aggression.

Physical appearance is a well-established method of assessing the health and welfare of laboratory mice undergoing scientific procedures (Morton & Griffiths 1985; Hawkins 2002). Unkempt coat, general disease signs, postural problems and high body scores were seen at relatively low levels which is not surprising as one would expect these stock animals to be in a generally good state of health. Barbering, hair loss and physical damage, however, seem to be fairly widespread problems as many animal units had some mice exhibiting these signs, but they seem to affect only a relatively small number of mice in each unit (for a more detailed discussion of barbering see Garner *et al* [2004] and Kalueff *et al* [2006] and for aggression and physical damage see van Loo *et al* [2000, 2004]). The association between barbering, hair loss, general signs of disease and obesity are worthy of further investigation. There were also interesting associations between increased aggression and increased barbering and physical damage. Similarly, climbing behaviour was also associated with increased physical damage and a decrease in numbers of obese mice. Again it is beyond the scope of this study to explain these relationships but it would be interesting to examine the interaction between these measures and the social interactions that take place.

As with the resources there were some differences between the information reported in the questionnaire and those observed during the assessment. Aggression was observed less frequently than reported however aggression occurs at its highest frequency after mice are disturbed, eg cage cleaning, regrouping etc and the one-day visit to each unit did not coincide consistently with these disturbances. Conversely, incidences of stereotypy during observations were much higher than reported by the units, this difference

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may have occurred due to the inherent difficulties and time needed to make these assessments as well as uncertainties over the definition of the behaviour. Some staff described somersaulting, circling, gnawing on the cage bars, barbering, and excessive food chewing as 'abnormal behaviours' whereas they were included as stereotypies for this assessment.

The difference in the proportion of units in which the appearance signs were observed compared with the proportion that reported them may relate to the fact that observations were not carried out on every cage in an animal unit, whereas the levels reported refer to every cage in an animal unit. Random sampling of 30–40 cages during the one-day visit may be insufficient as a representative sample of a unit. Therefore, a revised assessment of appearance will need to be developed, recording, for example, the number of animals exhibiting these parameters in all of the cages in an animal unit or at least the majority of cages in the units housing very large numbers of mice. The sample size chosen in this study was based on extensive pilot testing in order to identify the ideal sample size that would provide sufficient data for analysis, whilst being practical and efficient within the constraints of an animal unit. A snapshot assessment such as this study constitutes an inevitable compromise between scientific rigour and feasibility. A longitudinal assessment of fewer units may be useful in defining the optimum frequency of inspection.

Animal welfare implications

Laboratory mice comprise the vast majority of research animals, and their number is increasing dramatically with the growth in work using genetically-modified strains. This survey has shown that laboratory mouse welfare in UK animal units is of a generally good standard and will hopefully provide positive feedback to these animal units, encouraging them to maintain good welfare standards. However, it has also highlighted some potential areas of concern, which can hopefully be addressed in the future. Further work will be needed to define the optimum inspection frequency if this system is to be used as a regulatory tool however, the authors view this technique's principle benefit being its incorporation into unit staff's daily or weekly monitoring as opposed to a snapshot external assessment.

We feel that the core principles of this welfare assessment could be further applied to: 1) mice that are undergoing scientific procedures with the addition of procedure-specific measures; 2) genetically-modified mice with the addition of strain-specific measures and 3) other laboratory animal species with addition of species-specific measures.

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