REVIEW ARTICLE

Use and husbandry of captive European starlings (*Sturnus vulgaris*) in scientific research: a review of current practice

Lucy Asher* and Melissa Bateson†

*Epidemiology Division, Royal Veterinary College, Hawkshead Campus, Hatfield, Hertfordshire AL9 7TA, UK; †School of Biology and Psychology, Newcastle University, Newcastle upon Tyne, UK

Summary

We reviewed the use of captive European starlings (*Sturnus vulgaris*) in scientific research published between 2000 and 2004. We estimated the numbers of birds used and documented their origin and the range of husbandry regimes employed with the aim of comparing current practice with the new European guidelines for husbandry of laboratory animals. Over the five-year period, 106 primary articles report the use of an estimated total of 2490 captive starlings. The majority of birds were caught from the wild either as adults or fledglings, and only 3% were hand-reared from chicks. There was considerable variation in husbandry. In the majority of cases, standards fell below those currently recommended as best practice in the UK and cited in new European guidelines. The median volume of home cages employed was 0.42 m^3 (0.13–5.1 m^3, interquartile range), whereas current recommendations suggest a minimum of 1.0 m^3 for a singly-housed bird. The median volume of space allowed per bird was 0.13 m^3/bird (0.08–1.05 m^3/bird, Q1–Q3), whereas current recommendations suggest a minimum of 0.33 m^3/bird. Only 27% of the articles mentioned providing any form of environmental enrichment for birds in their home cages. We recommend that more research be conducted into the welfare of starlings to inform legislation and guidelines, and thus maximize the welfare of captive animals.

Keywords Husbandry; laboratory animal welfare; legislation; starling; *Sturnus vulgaris*

The European Union (EU) is currently drafting revisions of legislation relating to the housing of laboratory animals. Major changes under consideration include mandatory minimum cage sizes, environmental enrichment and group housing, and limitations on the use of wild-caught animals in research (European Commission 2006). For commonly used laboratory species, these specifications are often evidence-based and are claimed to reflect current practice in many laboratories. However, this is not the case for many less common but nevertheless important laboratory species, in which there has been little welfare research, and for which husbandry is not standardized between laboratories. We review the use and husbandry of European starlings (*Sturnus vulgaris*) to quantify current practice, and thus assess the impact of adherence to new animal welfare guidelines in laboratories using this species.

The European starling is arguably the most widely used passerine species in fundamental biological research. A search on ISI Web of Knowledge reveals 392 articles listing 'Sturnus vulgaris' in the topic field in the five-year period from 2000–2004 (compared with only 276 listing 'Taeniopygia guttata', the zebra finch). For many years now starlings have been an important model species in studies of behavioural ecology, ecophysiology and the neuroecology of song production and perception (e.g. Powell 1974, Tinbergen 1981, Lima 1983, Kalcelnik 1984,

Correspondence: L Asher. Email: lasher@rvc.ac.uk

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Cuthill & Hindmarsh 1985, West & King 1990, Eens *et al.* 1991, Mountjoy & Lemon 1991). The popularity of starlings stems from a number of features that make them ideal experimental animals. Starlings acquire new tasks rapidly and can readily be trained on operant schedules making them ideal subject for studies of foraging behaviour (e.g. Bateson & Kacelnik 1995). Their complex songs and propensity for vocal mimicry make them interesting subjects for studies of bird song. Although not easy to breed in captivity, wild starlings are common in both North America and Europe populating nearly 30% of the world's land surface excluding Antarctica (Feare 1984), and are easy to catch in large numbers. They adapt well to a captive environment, and due to their social nature can be housed at relatively high densities in the laboratory.

The welfare of starlings housed in the laboratory is of particular concern for three reasons. First, as non-domesticated species starlings have not been selectively bred to cope in captive environments. Secondly, starlings used in laboratory research are often caught from the wild, and have therefore experienced the loss of their natural environment. Thirdly, wild starlings travel more than 20 km daily to and from their roosting sites (Feare 1984), and in carnivores a large natural range is a risk factor for poor welfare in captivity (Clubb & Mason 2003). There is currently little data available on the welfare of captive laboratory birds (Poole & Dawkins 1999). In starlings specifically, a handful of studies have addressed the effects of lighting quality (Greenwood *et al.* 2002, 2004) and environmental enrichment (Gill 1994, Gill *et al.* 1995) on welfare, but to date there are no studies on the effects of developmental history (wild-caught versus hand-raised or captive-bred), cage size or stocking density.

Laboratory animal research in many countries falls under the Council of Europe Convention, ETS 123 and the European Union Directive 86/609/EEC for the protection of vertebrate animals used for experimental and other scientific purposes. Appendix A of ETS 123 has recently been revised with the aim of increasing standards of welfare for laboratory animals and harmonizing practice across laboratories. Although the situation remains unresolved, it is possible that the revised Appendix A of ETS 123 may be transcribed into Annex II of European Union Directive 86/609/EEC. Also under consideration is the possibility of making elements of Annex II minimum standards that would be legally binding for all EU member states (European Commission 2006). In the revised version of ETS 123, general provisions for birds include group housing, environmental enrichment and use of captive-bred birds wherever possible (Hawkins *et al.* 2003). Although there are no specific provisions for undomesticated passerines such as the starling, readers are referred to the *Laboratory Animals*' supplement *Laboratory birds: refinements in husbandry and procedures* (Hawkins *et al.* 2001) that does provide guidelines specific to starlings. A minimum cage size of 1 m^3 is recommended for a singly-housed starling, although group housing is preferable with a minimum cage size of 2 m^3 for a group of two to six birds (i.e. a minimum space allowance of 0.33 m^3/bird). Enrichment with natural branches, water baths, provision of cover, live invertebrate prey and a substrate of bark chippings are also recommended. Although adherence to these guidelines is not compulsory in the revised Council of Europe Convention (ETS 123), husbandry that strongly diverges from those recommended in this document is unlikely to be viewed as acceptable by the responsible authorities, at least until further research is produced. Furthermore, should the changes to Directive 86/609/EEC outlined above be agreed, general provisions could become mandatory for starlings housed in laboratories in EU countries. Therefore, all researchers in Europe will need to attend to both the Hawkins *et al.* (2001) and Hawkins (2003) documents (henceforth referred to as 'new European guidelines').

In this article, we review the use of captive European starlings in scientific research. A specific aim is to quantify current practice in the husbandry of starlings in relation to new European guidelines.

Materials and methods

Studies and extraction of information

Studies using captive European starlings (*S. vulgaris*) published between 2000 and 2004 were identified from searches on databases Agricola, Biosis, CAB, Cambridge Scientific Abstracts (BioSciences), PubMed (Medline), Web of Science and Zoological record. Searches were made between January and April 2005 using only the term 'Sturnus vulgaris' in the title/subject/keywords, and then relevant articles were selected by scanning the abstract or entire article if necessary. Articles were included in this review if they reported holding European starlings in captivity for one day or longer. A starling was deemed as captive if it was confined by a cage, aviary, room, box or any other form of restraint.

Basic information on the country of the research institution and any legislation or ethical guidelines reported, were extracted from each relevant article. We also extracted the number of male, female and total starlings used in the study, the origin of the birds, the length of time they had spent in captivity, any procedures carried out on the birds, the type of science being investigated and the fate of birds used. Details on husbandry and care included: the housing type and size, stocking density, type and availability of food and water, temperature, details of lighting and if any environmental enrichment was provided. Whether lighting was artificial or natural was noted. If lighting was artificial the hours of light and dark (lighting schedule), whether there was a gradual transition between these, the brightness, spectrum and rate of flicker, were also recorded.

Classifications, definitions and analysis

We used the database Biosis' Major Concept Terms to classify the type of science. The specific types of research conducted on captive starlings were identified by determining institutions with four or more publications in the review. Numbers of birds were calculated by summing the total numbers of birds in relevant studies. Medians (M) and interquartile ranges (Q1–Q3) were calculated for many aspects of husbandry using the number of articles.

Dimensions were calculated for the home cage, defined as the enclosure the birds spent most time in during the experiment. The length was defined as the longer of the two horizontal dimensions and the width the shorter (the height is assumed to be reported as the vertical dimension). The space available to captive starlings was expressed in four ways: total cage volume and cage volume per bird, floor area and cage aspect ratio. Volumes were calculated by multiplying the three cage dimensions and are always expressed in cubic metres. Home-cage volumes were divided by the maximum number of birds held in that home cage, to provide the volume per bird, which was expressed in m^3/bird. Floor areas were calculated by multiplying the length and width (m^2). Finally, aspect ratios were calculated to describe the shape of the profile of the cage, by dividing the length by the height. A cage with an aspect ratio <1 is taller than it is long; an aspect ratio of exactly one has a square profile; and a cage with an aspect ratio of >1 is longer than it is tall. Environmental enrichment was operationally defined as any item provided with the goal of improving the animals' welfare.

Scientific procedures were described as either invasive or non-invasive according to the UK Animals (Scientific Procedures) Act (1986). Non-invasive procedures fall into two categories: handle and restraint only, and attaching a foreign object. Non-invasive procedures were not included if they were deemed to be part of usual husbandry routines, such as trimming claws or bills.

Results

Studies: number, subject and geographical location

Information concerning the husbandry and care of captive starlings was extracted from a total of 106 research articles (see Table 1 for summary). The articles were published in 32 different journals, with the most articles sourced from *Animal Behaviour* (8 articles), *General and Comparative Endocrinology*

Table 1 Summary of the articles reviewed

	Science	Origin	Home-cage dimensions (cm)			Birds per cage	Country	Number of birds
			Length	Width	Height			
Absil *et al.* (2003a)	Neural coordination	Wild					Belgium	15
Absil *et al.* (2003b)	Neural coordination	Wild				1	Belgium	34
Ataserver and Gumussoy (2004)	Animal care	Wild					Turkey	24
Auger *et al.* (2002)	Sensory reception	Wild				1+	USA	16
Bateson (2002)	Behaviour	Wild	45	75	44.5	1	UK	8
Bautista *et al.* (2001)	Behaviour	Wild	510	200	50	1	UK	4
Bee and Klump (2004)	Neural coordination	Wild					Germany	4
Bentley (2003)	Chemical coordination	Wild	49	95	51	6	USA	20
Bentley *et al.* (2000)	Chemical coordination	Wild	60	50	40	4–6	UK	12
Blackwell *et al.* (2002)	Pest control	Wild	240	240	180		USA	12
Braaten (2000)	Sensory reception	Wild				1	USA	4
Buchanan *et al.* (2003)	Sensory reception	Wild	180	180	90	12	UK	48
Butler *et al.* (2001)	Virology					4	USA	8
Clark *et al.* (2000)	Pest control	Wild	61	36	41	1	USA	40
Congiu *et al.* (2000)	Pest control					1	Italy	33
Cousillas *et al.* (2004)	Neural coordination	Wild					France	8
Cuthill *et al.* (2000)	Behaviour	Wild	100	30	40	1	UK	6
Dawson (2001)	Chemical coordination	Wild				14	UK	95
Dawson (2003a)	Reproduction	Wild	200	300	400		UK	10
Dawson (2003b)	Physiology	Wild				10	UK	16
Dawson (2004a)	Sensory reception	Wild				4/5	UK	69
Dawson (2004b)	Physiology	Wild	310	310	260		UK	14
Dawson *et al.* (2000)	Reproduction	Wild				8	UK	16
Dawson *et al.* (2002)	Chemical coordination	Wild	60	40	40	4	UK	126
Dawson and Van't Hof (2002)	Chemical coordination	Wild/hand-raised				4	UK	34
De Cock and Matthysen (2001)	Sensory reception	Wild	135	175	200	1	Belgium	11
De Ridder *et al.* (2002)	Chemical coordination	Wild	700	400	250		Belgium	15
Devereux *et al.* (2004)	Behaviour	Wild	90	70	60	2	UK	20
Duffy and Ball (2002)	Evolution and adaptation	Wild	250	250	150	1–4	USA	16
Duffy *et al.* (2000)	Chemical coordination	Wild					USA	40
Fawcett *et al.* (2002)	Behaviour	Wild	60	66	37		UK	48
Fernández-Juricic and Kacelnik (2004)	Behaviour	Wild	90	70	60	2–3	UK	24
Fernández-Juricic *et al.* (2004)	Behaviour	Wild	90	70	60	1–3	UK	24
Gentner and Hulse (2000a)	Sensory reception	Wild	150	500	200	1–5	USA	22
Gentner and Hulse (2000b)	Sensory reception	Wild				1–6	USA	14
Gentner and Margoliash (2003)	Neural coordination						USA	11
Gentner *et al.* (2000)	Neural coordination	Wild				1–6	USA	20
Gentner *et al.* (2001)	Sensory reception	Wild	200	200	150		USA	27

Gentner *et al.* (2004)	Sensory reception	Wild					USA	17
George *et al.* (2004)	Sensory reception	Wild					France	6
Goslow *et al.* (2000)	Physiology	Wild					USA	10
Greenwood *et al.* (2002)	Animal care	Wild	130	65	120	8	UK	132
Greenwood *et al.* (2003)	Sensory reception	Wild/hand-raised	140	65	120	12	UK	8
Greenwood *et al.* (2004)	Animal care	Wild	130	65	120	12	UK	40
Gwinner *et al.* (2002)	Chemical coordination	Wild/hand-raised	400	200	300		Germany	52
Hambly *et al.* (2004)	Physiology	Wild	540	70	80	1	UK	9
Hausberger *et al.* (2000)	Neural coordination	Wild					France	4
Henry and Hausberger (2001)	Sensory reception	Wild/captive born/ hand-raised	180	1000	400		USA	17
Hile (2004)	Pest control	Wild	33	33	61	1	USA	24
Hile *et al.* (2004)	Pest control	Wild				1	USA	24
Hodgeson *et al.* (2001)	Virology		30	30	30	1	USA	5
Hofer and Klump (2003)	Neural coordination	Wild	35	27	52		Germany	8
Kacelnik and Marsh (2002)	Behaviour	Wild	120	50	53	1	UK	12
Kumar *et al.* (2000)	Chemical coordination	Wild	81	50	31	1	Germany	8
Langerman and Klump (2001)	Neural coordination		80	40	40	1	Germany	5
Lucas *et al.* (2002)	Sensory reception	Hand-raised	100	100	100	1	USA	8
Maddocks *et al.* (2001)	Sensory reception	Wild	40	30	30	8	UK	32
Maddocks *et al.* (2002a)	Animal care	Wild	70	120	50	4	UK	8
Maddocks *et al.* (2002b)	Animal care	Wild	67	120	50	8	UK	8
Maddocks *et al.* (2002c)	Sensory reception	Wild	70	90	180	8	UK	48
Marsh and Kacelnik (2002)	Behaviour	Wild	158	56	53	1	UK	16
Marsh *et al.* (2004)	Behaviour	Wild	120	60	50	1–6	UK	12
Nephew and Romero (2003)	Chemical coordination	Wild	34	38	45		USA	24
Nephew *et al.* (2003)	Reproduction	Wild				4–12	USA	24
Nieder and Klump (2001)	Neural coordination	Wild	25	53	35	1	Germany	8
Oberweger and Goller (2001)	Physiology	Hand-raised	32	24	25	1	USA	3
Olsson *et al.* (2001)	Behaviour	Wild				3	Sweden	12
Olsson *et al.* (2002)	Behaviour	Wild	100	100	50	5	Sweden	10
Pilz *et al.* (2004)	Development	Hand-raised					USA	60
Pinxten *et al.* (2000)	Chemical coordination		175	135	200	1	Belgium	18
Pinxten *et al.* (2002)	Chemical coordination	Wild	500	200	250	2–12	Belgium	35
Pinxten *et al.* (2003a)	Neural coordination	Wild	175	135	200	1–2	Belgium	24
Pinxten *et al.* (2003b)	Reproduction	Wild	175	135	200	1–4	Belgium	23
Poirier *et al.* (2004)	Sensory reception	Wild/hand-raised	40	60	52	1–5	France	23
Rafacz and Templeton (2003)	Behaviour	Wild	60	45	45	1	USA	22
Rayner *et al.* (2001)	Physiology					1	UK	1
Remage-Healey and Romero (2000)	Chemical coordination	Wild				1	USA	11
Remage-Healey and Romero (2001)	Chemical coordination	Wild				1	USA	10
Remage-Healey and Romero (2002)	Chemical coordination	Wild				2	USA	10
Riters and Alger (2004)	Sensory reception						USA	20
Riters and Teague (2003)	Chemical coordination	Wild	51	97	51		USA	24

(*Continued*)

Table 1 Continued

	Science	Origin	Home-cage dimensions (cm)			Birds per cage	Country	Number of birds
			Length	Width	Height			
Riters *et al.* (2000)	Sensory reception	Wild	600	400	250	12	USA	44
Riters *et al.* (2001)	Neural coordination	Wild				12	USA	74
Riters *et al.* (2002)	Sensory reception	Wild					USA	58
Romero and Remage-Healey (2000)	Chemical coordination	Wild				1	USA	25
Rothery *et al.* (2001)	Physiology	Wild					UK	10
Sayre and Clark (2001)	Pest control	Wild	36	23	28	1	USA	40
Schuck-Paim and Kacelnik (2002)	Behaviour	Wild	60	50	120	1	UK	18
Schuck-Paim *et al.* (2004)	Behaviour	Wild	120	60	50	1	UK	28
Seibels *et al.* (2003)	Virology	Wild	180	90	120	15	USA	61
Sockman *et al.* (2002)	Reproduction	Wild				4	USA	20
Sockman *et al.* (2004)	Reproduction	Wild				2	USA	32
Staples *et al.* (2002)	Sensory reception	Wild/hand-raised				1	USA	10
Swaddle and Lockwood (2003)	Physiology	Wild	350	120	200		USA	43
Swaddle and Pruett-Jones (2001)	Sensory reception	Wild				1	USA	12
Swaddle and Ruff (2004)	Sensory reception	Wild	100	60	70	1–4	USA	8
Swaddle *et al.* (2004)	Behaviour	Wild	90	40	40	1–3	USA	34
Talling *et al.* (2002)	Behaviour	Wild	710	300	250	1–6	UK	6
Templeton and Gonzalez (2004)	Sensory reception	Wild	46	60	40	1	USA	12
Van Meir *et al.* (2004)	Neural coordination	Wild	140	220	210	5	Belgium	10
Vasquez and Kacelnik (2000)	Behaviour	Wild	150	50	50	1	UK	8
Výboh *et al.* (2001)	Chemical coordination	Wild/hand-raised					Slovakia	6
Ward *et al.* (2001)	Physiology	Wild/hand-raised	200	200	200	3–4	UK	15
Ward *et al.* (2004)	Physiology	Wild				1	UK	4
Williams and Swaddle (2004)	Physiology	Wild	250	250	300	1–7	UK	7
Young *et al.* (2001)	Reproduction	Wild	49	95	51	1–20	USA	71

(9 articles) and *Hormones and Behaviour* (7 articles). Studies spanned 11 categories of scientific research (Figure 1). Specific areas of research include: behavioural and cognitive ecology of foraging behaviour and mate choice (e.g. Maddocks *et al.* 2002a–c, Fernández-Juricic *et al.* 2004), song perception (e.g. Langemann & Klump 2001, Gentner *et al.* 2004), behavioural neuroendocrinology of singing and the stress response (e.g. Auger *et al.* 2002, Nephew & Romero 2003, Pinxten *et al.* 2003a,b) and photoperiodic control of reproduction (e.g. Dawson 2001).

The research was produced by 32 institutions, with the vast majority being conducted in either the UK (37 articles) or the USA (45 articles), the remaining research being conducted in other European countries, Belgium (9 articles), Germany (6 articles), France (4 articles), Sweden (2 articles), Italy (1 article), Slovakia (1 article) and Turkey (1 article).

Although no articles specifically cited European legislation, 44 articles did reference some type of guidelines the study had adhered to, most commonly national legislation; seven articles mentioned UK Animals (Scientific Procedures) Act (1986) (covering an estimated 375 birds) and 10 articles mentioned other national legislation (175 birds). Seventeen articles reported coverage by university guidelines or ethics committees (364 birds). The National Research Councils' *Guide for the Care and Use of Laboratory Animals* (1996) was cited by 16 articles (341 birds). Nine articles (322 birds) also cited the body that granted permission for capture of wild birds, and included English Nature, Scottish Natural Heritage and the US Department of Agriculture.

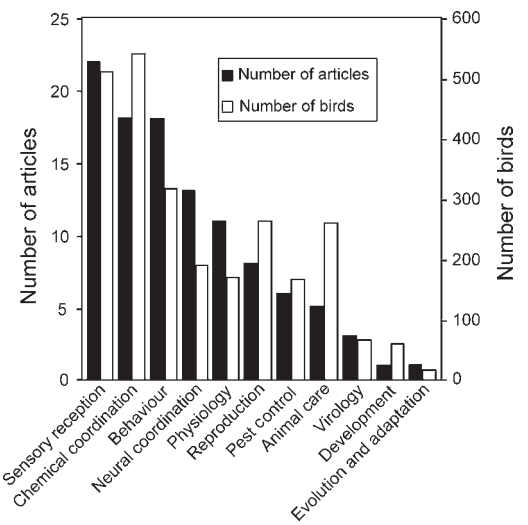

Figure 1 Histogram of the types of science conducted with captive European starlings 2000–2004 for the number of articles and the number of individual birds involved. Categories are the Major Concept Terms used in the Biosis' database

Bird numbers and origins

A total of 2490 starlings were used in the studies reviewed with 18, 8–29 birds (M, Q1–Q3) used per article. Number of birds used per article varied from a single bird in an experiment concerning the physiology and mechanics of flight (Rayner *et al.* 2001) to 132 birds used in Greenwood *et al.*'s (2002) study concerning preferred lighting environments. Birds were predominantly male, 742 males when compared with 346 females, although only half the articles reported information on sex.

Ninety-eight out of the total 106 articles provided some information concerning the origins of the birds used. Most studies used wild-caught birds (87 articles, 2153 birds), three articles used hand-raised birds (71 birds) and eight articles used a combination of hand-raised and wild-caught birds (165 birds). Only one article (2 birds) used captive-bred birds (Henry & Hausberger 2001).

Home cage

Of the 106 articles reviewed, 100 provided some information concerning the type of housing, but only 65 of these gave the exact cage dimensions. The enclosures varied in size and volume, ranging from 0.02 (Sayre & Clark 2001) to 720 m^3 (Henry & Hausberger 2001; Figure 2). Many of the values fall within the lower range of volumes (M, Q1–Q3 = 0.42, 0.13–5.1 m^3) with 65% (42 articles) falling below the 1 m^3 threshold. The distribution of floor areas (Figure 3) was also positively skewed (M, Q1–Q3 = 0.75, 0.32–3.78 m^2). Most enclosures were longer

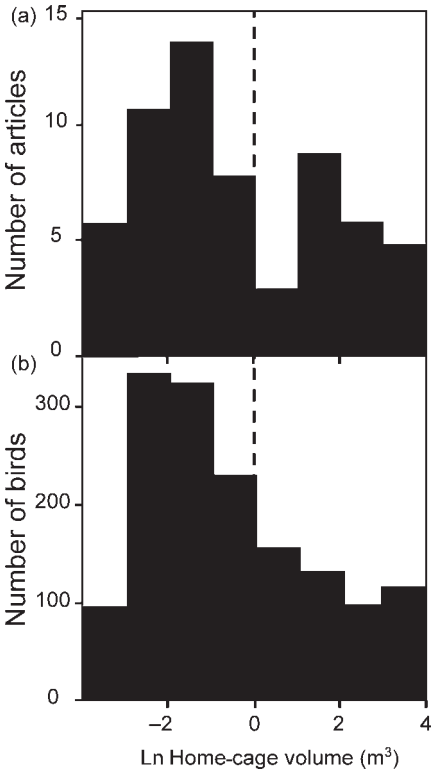

Figure 2 Frequency distributions of home-cage volumes for (a) the number of articles, and (b) the number of individual birds involved. The dashed line indicates a cage volume of 1 m^3 (minimum cage size recommended in new European guidelines)

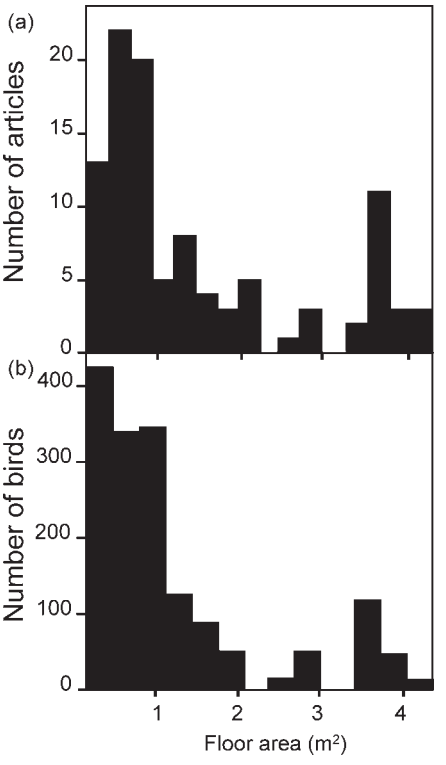

Figure 3 Frequency distributions of home-cage floor areas for (a) the number of articles, and (b) the number of individual birds involved

than they were tall (Figure 4), with a median aspect ratio of 0.88, 0.32–0.63 (M, Q1–Q3).

In the majority of articles birds were either housed singly (49 articles, 862 birds) or in small groups of 3–10 birds (38 articles, 1086 birds), although during the course of many studies birds experienced several different groupings (Table 2). For the 54 articles that included information on both home-cage dimensions and number of birds per cage, the volume of space per bird was 0.13, 0.08–1.05 m^3/bird (M, Q1–Q3, Figure 5).

Food

In 54 out of 71 articles that provided the information, birds received food *ad libitum* (1455 birds). The remaining 17 articles (352 birds) used some degree of food deprivation. The basic diet most fed to captive starlings was dry food (63 articles, 1589 birds). Dry food included, turkey starter crumbs, Orlux pellets (Orlux, Wielsbeke-Ooigem, Belgium), Purina chick food (Purina, St Louis, USA), poultry pellets, dog food and wheat or barley. The diet of many birds was supplemented with fruit (7 articles, 193 birds), processed meat (6 articles, 179 birds), vitamin supplements (5 articles, 105 birds). Twenty-three articles reported feeding live invertebrate prey to captive starlings. Mealworms (*Tenebrio molitor*) were fed to birds in 22 articles (339 birds), six of these also provided the birds with natural forage (101 birds), and one article provided the birds with just natural forage (6 birds).

Environmental enrichment

The most commonly used forms of enrichment were nest boxes (16 articles, 468 birds) and water baths (15 articles, 306 birds). Fewer articles reported presenting birds with toys (3 articles, 88 birds), natural branches

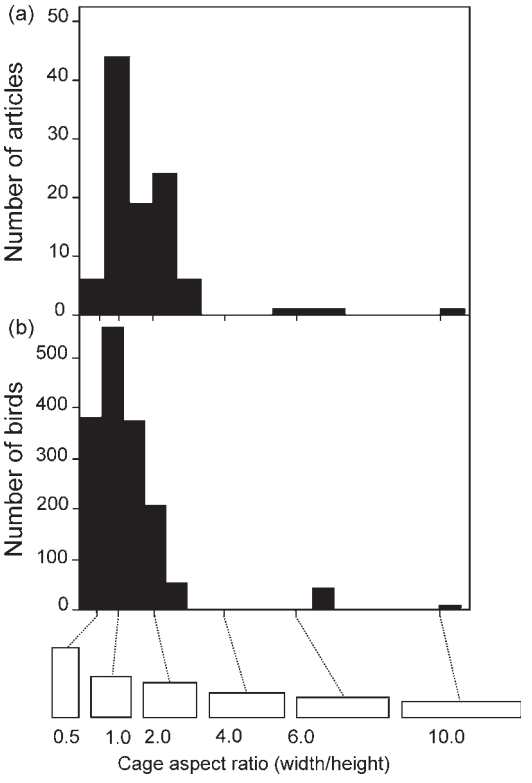

Figure 4 Frequency distributions of home-cage aspect ratios for (a) the number of articles, and (b) the number of individual birds involved

(3 articles, 45 birds) or foraging substrate (5 articles, 58 birds). A total of 29 articles reported the use of some form of environmental enrichment.

Environmental variables

All 106 articles provided information about lighting regimes used, but 41 gave information about temperature. Temperatures

Table 2 Number of captive starlings per enclosure

	Articles	Birds
Single	27	386
Pair	2	80
Small group*	24	766
Colony†	8	349
Single + small group	13	312
Single + colony	9	164
Pair + colony	2	67
Group + colony	1	8

*A small group consists of 3–10 birds per enclosure
†A colony is more than 10 birds per enclosure

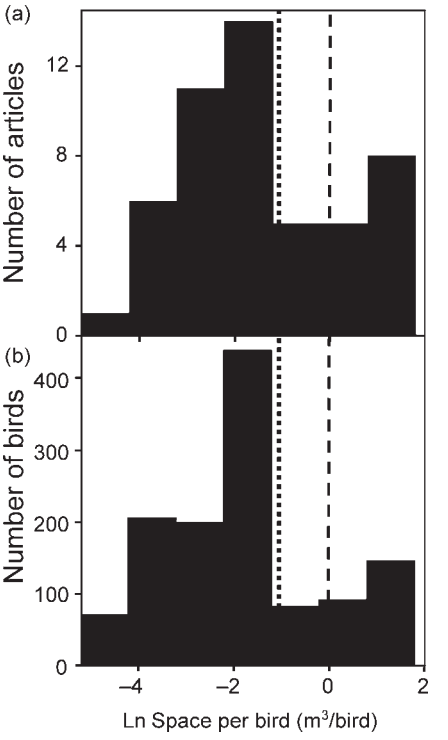

Figure 5 Frequency distributions of the amount of space per bird in the home cages for (a) the number of articles, and (b) the number of individual birds involved. The smaller dashed line indicates the new European guidelines space allowance per bird for a group-housed bird (0.33 m^3/bird) and the larger dashed line the space allowance per bird for a singly-housed bird (1 m^3/bird)

ranged from 12–28°C, with a median of 18 (15.75–21.50°C, Q1–Q3). A total of 95 articles used artificial lighting and although most reported the lighting schedule (83 articles; Tables 3 and 4) only 10 articles mentioned details of the lighting quality (e.g. light to dark transition, flicker rate, UV, spectrum, fluorescence, luminance).

Table 3 Number of different lighting schedules used in the articles reviewed and the number of birds this covers

Number of lighting schedules	Articles	Birds
1	60	1274
2	14	364
3	7	222
4	1	69

Table 4 Lighting schedules used and the number of birds

Lighting schedule	Articles	Birds
8L:16D	18	88
9L:15D	2	259
10L:14D	3	384
11L:13D	10	24
12L:12D	17	229
13L:11D	2	180
14L:10D	5	56
16L:8D	5	655
18L:6D	9	480
19L:5D	4	77
20L:4D	1	56
Continuous	1	69
Ambient	18	6

L=light; D=dark

Scientific procedures

Non-invasive procedures that involved attaching a foreign object included, coloured leg rings, eye rings and in one particular study a gas mask fixed to a bird's head. Handle and restraint procedures involved measuring feathers with callipers, weighing, restraint in a cloth bag for up to 30 min and restraint in a wing cuff and head holder. Little consistency over reporting these non-invasive procedures was found and frequency of handling was never comprehensively reported, e.g. some articles referred to a regular weighing scheme but few specified whether weighing was remote or involved handling.

Invasive procedures were more reliably reported. More than half (56) of the articles reviewed involved some type of procedure that would in the UK need to be covered by a Home Office licence (Figure 6).

Only 33 articles reported information about the fate of birds after involvement in research. In 26 articles (754 birds), birds were euthanized at the end of experiments either by an overdose of anaesthetic or decapitation. Birds were released upon completion of six studies (84 birds) and two articles reported birds being retained for further study (42 birds).

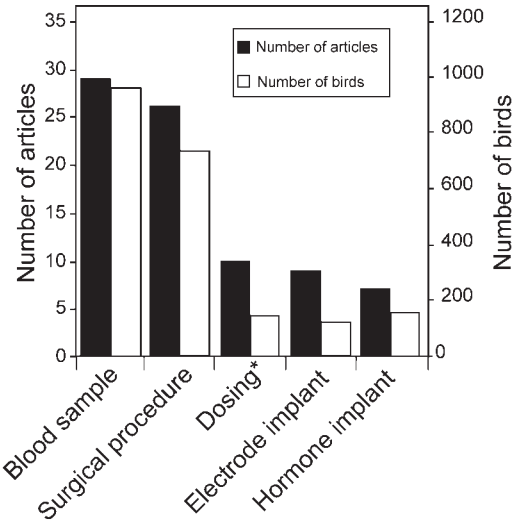

Figure 6 Histogram of the types of invasive experimental procedures conducted on European starlings for the number of articles and the number of individual birds involved. *Dosing includes the injection of any type of substance into the bird

Discussion

Out of the 106 articles and 2490 birds in this review, 61 articles (1383 birds) were conducted in EU countries that will be subject to new European guidelines for starling husbandry. A comparison of these new guidelines with current practice reveals that birds were only group-housed for the duration of experiments in 43% of articles, only 27% of articles referred to the use of environmental enrichment and only two birds in the entire review were captive-bred. Furthermore, the species-specific recommendations represent a departure from common practice, with the 1 m^3 minimum cage volume not observed in 42 articles (1099 birds). The median volume of home cages was 0.42 m^3, and the median space allowance per bird was 0.13 m^3/bird, compared with the recommended 0.33 m^3/bird. The advised enrichment with live prey was used in 23 articles (345 birds), water baths in 15 articles (306 birds), foraging substrate in five articles (58 birds), natural branches in three articles (45 birds) and the provision of cover was not mentioned in any article reviewed.

It is difficult to interpret how this divergence from recommended guidelines may impact the welfare of the birds involved, as there is so little literature concerning starling welfare. One factor that has been investigated is the effect of lighting quality on both starling welfare and behaviour (Maddocks

et al. 2002a–c, Greenwood *et al.* 2004, Evans *et al.* 2006). Less than 10% of articles mentioned details of lighting environment aside from lighting schedules. This suggests that researchers may not be aware of the particular welfare needs of their study species, and raises concerns about the reporting of husbandry in published papers.

Although the husbandry standards reviewed in this article did fall below new European guidelines, it is not surprising given these guidelines arise from the first document to relate directly to starling welfare published in 2001 (Hawkins *et al.* 2001). Perhaps, a more surprising finding was the amount of methodological detail relating to the birds and their husbandry that could not be obtained from the articles. Basic information that was consistently not reported included: only half of the articles reported the sex of birds, only 41 articles reported temperature and only 33 articles reported the fate of birds. Journals differ in the amount of methodological detail required (Table 5). Many details not included in guidelines for authors are implicitly required for replication, but as this review demonstrates there is a lack of consistency in the reporting of methodological detail (for similar argument see Wurbel 2007).

We found considerable variance in the husbandry of captive starlings between institutions. Enclosure volumes, for instance, varied between 0.02 and 720 m^3, aspect ratios varied from 0.31–10.20 and 12 different lighting schedules were employed from continuous lighting to 8 h of light. Minimum standards must be met to safeguard the welfare of experimental animals, for instance the cage mentioned above with a volume of 0.02 m^3 (dimensions: 0.36 × 0.23 × 0.28 m) is clearly unacceptable for housing starlings since it is smaller than a starling's wingspan. However, optimal conditions will vary depending on the experiment being conducted. For example, in the case of cage size, the largest cages may not be preferable (for either birds or experimenters) if birds need to be caught on a regular basis. Within acceptable ranges, some degree of variance may actually be desirable to reveal interesting and unforeseen effects. For example, Bateson (2002) found small uncontrolled variations in temperature accounted for individual variation in foraging decisions.

It is clear from this review that current practice in laboratory starling husbandry is far from meeting new European guidelines. For example, the majority of articles used cages below the new minimum size recommended. It is vital that more research be conducted into the welfare of starlings, and other less commonly used species, to inform

Table 5 Information required by journal's guidelines to authors

	Animal behaviour	General and comparative endocrinology	Hormones and behaviour
Sex	√		
Origin	√		√
Time in captivity			√
Procedures – non-invasive			
Procedures – invasive	**?**		√
Fate	**?**		
Housing type	√		
Housing dimensions	√		
Stocking density	√		
Enrichment	√		
Food/Water – access	**?**		
Food/Water – other details	√		
Lighting – schedule	√		
Lighting – other details			
Temperature	√		
Legislation/Guidelines	**?**	√	**?**

√ = requirement, **?** = possible requirement

future guidelines and legislation, and thus maximize the welfare of captive animals.

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