Laboratory birds: refinements in husbandry and procedures

Fifth report of the BVAAWF/FRAME/RSPCA/UFAW Joint Working Group on Refinement

Members of the Joint Working Group on Refinement

Dr Penny Hawkins (Editor)
Research Animals Department, RSPCA, Wilberforce Way, Southwater, West Sussex RH13 7WN, UK

Professor D B Morton (Chair)
Department of Biomedical Sciences & Biomedical Ethics, University of Birmingham,
The Medical School, Edgbaston, Birmingham B15 2TT, UK

Mr David Cameron
HLS, PO Box 2, Huntingdon, Cambridgeshire PE18 6ES, UK

Professor Innes Cuthill
Centre for Behavioural Biology, School of Biological Sciences, University of Bristol, Woodland Road, Bristol BS8 1UG, UK

Mr Roger Francis
The Medical School, University of Bristol, University Walk, Bristol BS18 1TD, UK

Dr Raf Freire
Department of Animal Sciences, Purdue University,1151 Lilly Hall, West Lafayette, IN 47907–1151, USA

Dr Andy Gosler
EGI, Department of Zoology, University of Oxford, South Parks Road, Oxford OX1 3PS, UK

Dr Sue Healy
University of Edinburgh, Institute of Cell, Animal & Population Biology, Ashworth Laboratories, Kings Buildings, Edinburgh EH9 3JT, UK

Ms Anne Hudson
Central Science Laboratory, Sand Hutton, York YO4 1LZ, UK

Dr Ian Inglis
Central Science Laboratory, Sand Hutton, York YO4 1LZ, UK

Dr Alex Jones
Oatridge Agriculture College, Ecclesmachan, West Lothian EH52 6NH, UK

Dr James Kirkwood
UFAW, The Old School, Brewhouse Hill, Wheathampstead, Herts AL4 8AN, UK

Mr Martin Lawton
Exotic Animal Centre, 12 Fitzilian Avenue, Romford RM3 0QS, UK

Professor Pat Monaghan
Divison of Environmental & Evolutionary Biology, IBLS, Graham Kerr Building, University of Glasgow, Glasgow G12 8QQ, UK

Dr Chris Sherwin
Division of Animal Health & Husbandry, University of Bristol, Langford House, Langford, Bristol BS18 7DU, UK

Mr Paul Townsend
Veterinary Laboratories Agency, Woodham Lane, New Haw, Addlestone, Surrey KT15 3NB, UK

Preface

Whenever animals are used in laboratories, minimizing pain and distress should be as important an objective as achieving the experimental results. This is important for humanitarian reasons, for good science, for economic reasons and also for satisfying broad legal principles such as those stated in the European Convention and Directive on animals used for experimental and other scientific purposes (Council of Europe 1986, European Community 1986), the New Zealand Animals Welfare Act 1999 (New Zealand Government 1999), the United States Animal Welfare Act and Health Research Extension Act (see National Research Council 1996) and specific national legislation, e.g. the UK Animals (Scientific Procedures) Act 1986 (www.homeoffice.gov.uk/animact/aspag5.htm).

It is possible to make significant and immediate improvements to animal husbandry and procedures in a number of ways, and this can be greatly facilitated by ensuring that up-to-date information is readily available. The need to provide such information led the British Veterinary Association Animal Welfare Foundation (BVAAWF), the Fund for the Replacement of Animals in Medical Experiments (FRAME), the Royal Society for the Prevention of Cruelty to Animals (RSPCA) and the Universities Federation for Animal Welfare (UFAW) to establish a Joint Working Group on Refinement under the chairmanship of David Morton and with a secretariat provided by the RSPCA. The aim was to set up a series of working parties to define ways in which husbandry and scientific procedures can be refined to improve laboratory animal welfare and reduce suffering. The members of each Working Party are drawn from experts in industry, academia and animal welfare organizations.

The present report is the fifth in the workshop series. The first report, Removal of blood from laboratory mammals and birds (*Laboratory Animals* (1993) 27, 1–22), was concerned with refining techniques. The second and third reports concerned refinements in rabbit and mouse husbandry, respectively (*Laboratory Animals* (1993) 27, 301–329; *Laboratory Animals* (1998) 32, 233–259), while the fourth report was on refining procedures for the administration of substances (*Laboratory Animals* (2001) 35, 1–42).

Although this report was produced in the UK, it is intended for an international readership. It therefore makes reference to international legislation on research animal use and wildlife protection, where appropriate, as well as to the UK Animal (Scientific Procedures) Act 1986 (A(SP)A). Some of the statements and recommendations are made with reference to 'cost/benefit analysis' which is critical in the implementation of the UK Act. The A(SP)A states that, when deciding whether to grant a project licence for a programme of research, the UK Secretary of State must 'weigh the likely adverse effects on the animals concerned against the benefit likely to accrue as a result of the programme to be specified in the licence'.

The Working Party understands that not all animal research regulations mandate a cost/benefit analysis, but believes that it is an extremely important concept and one that many people and establishments employ, regardless of whether it is a requirement of their national legislation. 'Costs' in this context are generally taken to refer to suffering caused by procedures alone, but many factors other than the scientific procedures themselves can have an adverse effect on animal welfare. Inadequate or unempathetic catching, handling, transport, husbandry, socialization and euthanasia will all cause avoidable pain, suffering, distress and lasting harm that can be serious enough to exceed that caused by experiments.

This report aims to help minimize all of these adverse effects by encouraging the application of the 'Five Freedoms' developed for farm animals (see Farm Animal Welfare Council 1993) to laboratory birds wherever this is possible. These are: freedom from hunger and thirst; freedom from discomfort; freedom from pain, injury or disease; freedom from fear and distress; and freedom to express most normal behaviours. Particular emphasis is placed on the fifth freedom and the potential to give birds a sufficient quantity and quality of space to behave naturally and to exercise a degree of control over their environment (Poole & Stamp Dawkins 1999).

It should be noted that some of the Working Party members are opposed to the use of animals in experiments that cause pain, suffering, distress or lasting harm. However, they share with many in science the common aim of reducing animal suffering wherever it occurs. The reports of the refinement workshops are intended to help achieve that aim, particularly if they are read in conjunction with other recent reports on the recognition, measurement and alleviation of pain or distress in animals.

PART 1 GENERAL SECTIONS

1 Introduction and aims

Avian intelligence, behavioural complexity and capacity to suffer physical pain have often been regarded as inferior to those of mammals. Despite a growing body of evidence that such assumptions are not justified (Elzanowski 1991, Gentle 1991, 1992, Ristau 1991, Marler 1996, Skutch 1996), there is comparatively little information available on husbandry refinements for laboratory birds (Poole & Stamp Dawkins 1999). The literature largely relates to companion or zoo birds (Coulston *et al*. 1997, VanHoek & King 1997, but see King 1993) or to birds reared for meat or egg production (Bell & Adams 1998, Jones & Carmichael 1998).

This report provides basic guidance on laboratory bird housing and husbandry, on bird health care and on refining procedures both in the laboratory and the field. It recommends husbandry improvements to current guidelines (where they exist) for most birds that are commonly housed and used in laboratories, focusing especially on the needs for appropriate environmental stimulation and for pen or cage sizes which are devised with reference to the ecology and natural behaviour of each species. Very few studies have aimed to evaluate space requirements for birds, and so it was frequently difficult for the Working Party to decide upon specific recommendations for pen sizes and space allowances.

The guidelines within the present report were therefore drawn up by considering current good practice, in combination with the professional experience and views of Working Party members and a review of the published literature on bird behaviour, husbandry, health and use in research. Each table of pen sizes and space allowances sets out two separate standards: one that reflects common practice and another which sets out what the Working Party considers to be good practice, the latter to guide those establishments that have sufficient space and resources to achieve it. The addition of appropriate and sufficient perches will effectively increase the area available to the birds for exercise and rest, which is especially important where space is limited.

The introductory General Sections of this report set out the context in which the recommendations in the Species Sections (16–27) were made. In order to derive maximum benefit from this report, the introductory sections should therefore be read in full first. A summary of the recommendations appears as Appendix 4 at the end of the report. The report as a whole should not, however, be regarded as a substitute for wider consultation of books and other published literature, which will still be necessary for obtaining current and detailed information on the principles of husbandry and veterinary care and the requirements of individual species. This includes reading publications intended for ornithologists and companion bird keepers as well as ecological papers (Appendix 1), and approaching organizations such as the UK Royal Society for the Protection of Birds (RSPB), the British Trust for Ornithology (BTO), the Wildfowl and Wetlands Trust (WWT), and their equivalents in other countries, national and regional zoo and wildlife veterinary associations and companion bird societies for advice (Appendix 2). Other publications (listed in Appendix 1) contain guidelines on brooding, rearing, and environmental conditions (e.g. temperature and day length) and the use of birds in field studies, so these will only be covered briefly in the present report. A glossary of technical terms (printed in bold within the text) is given on pp S1:145 to S1:147.

The recommendations for each species will help in the design of housing and care systems that will help to:

- Identify behavioural requirements: Husbandry protocols should encourage a range of behaviours and time budgets broadly similar to that observed in the wild. Some behavioural requirements cannot be fulfilled in the laboratory; for example, migratory birds regularly become physiologically and psychologically prepared for

long flights that are clearly impossible in captivity. It is often possible, however, to accommodate and encourage the expression of natural behaviours that require less space, such as dust bathing.
- Simulate appropriate wild conditions: There is limited scope for replicating field environments in the laboratory, but features of the environment within which the species forages or hides, such as turf or brush cover, can often be provided.
- Include compatible conspecifics (for social species): Many birds, e.g. waterfowl, are strongly gregarious and do not respond well to single housing. Stable and compatible groups of such species with appropriate numbers of each sex should be formed, monitored and maintained in the laboratory.
- Allow sufficient space for exercise: This is especially important if the birds are to be used for physiological studies (Weathers *et al.* 1983). Ideally, flapping flight should be possible for volant birds, although running exercise may be more important for some species such as domestic fowl. Aquatic birds should be able to swim and dive as appropriate.
- Provide good quality space: Most birds will benefit from the addition of pen furniture and objects such as perches for fowl, refuges for quail and objects to manipulate for many species, including Psittacines (parrots) and corvids.
- Encourage foraging behaviour: Time budgets in the field are liable to vary due to factors such as habitat and prey quality, but a major difference between wild and captive animal behaviour is that the latter spend more time inactive and less time foraging. Increasing foraging time, for example by scattering food or making the animals work to obtain it, has been shown to reduce stereotypic behaviour (Coulson *et al.* 1997, Field 1999, Poole & Stamp Dawkins 1999). Mammals and birds prefer to work for their food, even when it is freely available (Inglis *et al.* 1997).
- Promote good health: High health standards are vital in ensuring good welfare, yet this does not necessitate housing animals in sterile, barren environments. It should be possible to design high-welfare housing systems that also permit adequate health maintenance, monitoring and care.

The Working Party recognizes that it may never be possible to provide all species of bird with housing that will fully meet their needs (Nicol 1995). It should be possible, however, to design a practical and workable husbandry system that will provide birds with a good standard of welfare and, where there is no objective evidence as to their needs, give them the benefit of the doubt.

The effects of the system of husbandry and associated manipulations should be considered as part of the experimental protocol and be taken into account when potential adverse effects are weighed against predicted scientific benefits by ethics committees (e.g. the US Institutional Animal Care and Use Committee (IACUC) or the UK local Ethical Review Process and Home Office Inspectorate). If it is not possible to achieve a husbandry system that permits birds to exercise adequately, express a range of natural behaviours and exercise a degree of control or choice with respect to their environment, then they should not be kept in the laboratory at all.

Finally, the economic impact of an experiment which fails through bad planning, faulty or outmoded equipment, poor husbandry or poor practice is an enormous waste of valuable resources both in economic terms and sometimes in loss of wildlife. It is important that attention is paid to providing the best resources available for a research project, within reason, and also to ensuring that staff are well trained, empathetic, competent and well versed in the latest developments in their field. We hope that this document will help in this regard.

2 Bird use in research

The only country currently to provide detailed information on avian species used in research and the purposes of bird use is the UK (Home Office 2001). Over 100 000 procedures are carried out on birds every year under the Animals (Scientific Procedures) Act 1986

(A(SP)A). The majority of birds used in UK research are domestic fowl, with fewer turkeys and quail (*Coturnix* spp. and others) being listed in the annual Home Office Statistics on animal use (Fig 1). The category 'other birds' covers a range of species including pigeons, starlings, finches and waterfowl; but records are not collected of individual species, so this information is not available within these statistics. The most recent statistics for the European Union record animal usage in 1996 (Commission of the European Communities 1999) and list 459 132 birds (not classified by species), of which the UK used 25%. Over 200 000 domestic birds (mainly fowl) and 16 000 wild birds were used during 1996 in Canada, mainly for fundamental research (Canadian Council for Animal Care 1996). There are no national data on research animal use in Australia, but recent data for New South Wales listed almost 70 000 fowl and over 5000 other birds as being used in 1996 (New South Wales Agriculture 1998), and over 10 000 birds were used in New Zealand in 1998 (New Zealand National Animal Ethics Advisory Committee 1999). Birds, together with rats, mice and farm animals, are not represented in US statistics on animal use (USDA 1997).

Most procedures on birds conducted in the UK relate to applied veterinary medical studies or fundamental research (Fig 2), whereas most mammals are used for applied human medical or dental studies. Domestic fowl and turkeys are used for research into animal welfare issues, which reflects concerns regarding the welfare of these birds when reared and kept within intensive husbandry systems. Fowl and turkeys are also used in developmental studies and for the production of biological materials such as tissue and antibodies. Eleven per cent of all birds used in experiments in the UK in 2000 were used in toxicological procedures, and these were mostly domestic fowl used for pharmaceutical safety and efficacy evaluation. Almost 95% of the toxicology procedures involving birds were undertaken to satisfy national or international legislative requirements (Home Office 2001). Quail and other birds were also used to safety test agricultural substances which, together with psychology and zoology research, is a major use of the 'other' species of bird in the UK.

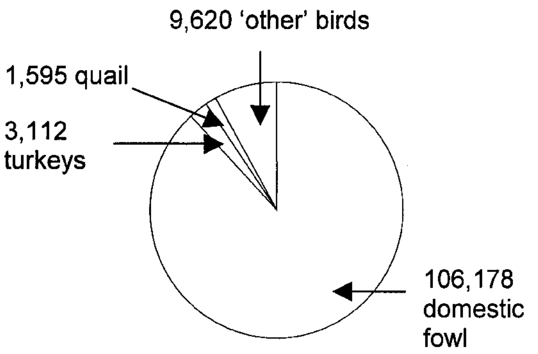

Fig 1 Bird use in UK research and testing, 2000 (Home Office 2001)

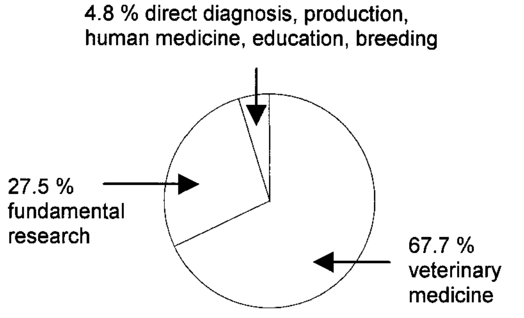

Fig 2 Purposes of procedures using birds in the UK, 2000 (Home Office 2001)

3 Avian diversity

There are over 9700 species of bird currently believed to be in existence, of which about 1000 are considered to be threatened with extinction (Stattersfield *et al.* 1998). Some 116 avian species became extinct between the years 1600 and 1990, but the rate of loss is now believed to be exponential. Birds are divided into 23 orders (Sibley & Monroe 1990), the largest of which is the Passeriformes or 'perching birds', comprising over 60% of all living bird species (del Hoyo *et al.* 1992). Orders commonly used in research are the Galliformes, which includes the domestic fowl *Gallus domesticus* and turkey *Meleagris gallopavo*; Columbiformes, such as the pigeon *Columba livia* and Anseriformes, or waterfowl.

All birds are essentially built for flight (even species that have lost the ability to fly) and so share the same basic body plan despite their extremely diverse range of adaptations for locomotion and feeding. Most species are adapted to range over relatively large, three-dimensional areas by one or more means of locomotion including flying, walking, running, swimming or diving, both while foraging and during migration. This can make it especially difficult to provide housing that can adequately meet their needs in the laboratory. Even species that have been fully domesticated, such as the domestic fowl, retain similar behaviour patterns to the wild type (McBride *et al.* 1969, Duncan *et al.* 1978) although they may commonly be housed in conditions that do not permit the expression of such behaviour.

4 The brain and senses

Every animal inhabits a world of its own, the nature of which is shaped by information received from its sense organs (Manning & Stamp Dawkins 1998). Birds are primarily adapted for flight and have arguably been evolving separately from mammals for around 250 million years, so their brains are organized differently from those of mammals. Avian perceptions of the world and their needs and requirements are, therefore, also likely to differ.

4.1 Cognition

Cognition describes how animals understand their world. It involves the process of perceiving the internal and external environments, of prioritizing current and future needs and desires, of integrating this information in the brain along with the benefit of experience, and then of behaving accordingly.

Birds show many different types of cognitive abilities which vary in complexity. Some are able to categorize objects in a fashion similar to humans. For example, pigeons can be trained to discriminate between images on slides and to place these into categories of objects such as 'cats', 'flowers', 'chairs' and 'cars', even when cues are presented in a variety of ways; e.g. 'water' is recognized whether it is in the form of droplets, a turbulent river or a placid lake (Bhatt & Wasserman 1989).

It is generally accepted that animals may suffer if prevented from carrying out actions that they are strongly motivated to perform, for example broody fowl being prevented from building nests. Some behavioural studies using birds have suggested that they possess 'object permanence', i.e. they can remember objects that are no longer there, so that 'out of sight' is not 'out of mind'. This object permanence would warrant birds with the ability to suffer due to the absence of a valued resource, such as a nest box. Parrots have highly developed object permanence abilities that are comparable to those in 2-year-old humans, and can locate a goal by predicting its concealed movement and position (Pepperberg & Funk 1990). Pigeons (Neiworth & Rilling 1987), domestic fowl (Freire *et al.* 1997) and chicks (Vallortigara *et al.* 1998) are also able to mentally represent the hidden movement and position of objects and thus to accurately locate a goal after it has been moved out of sight. This suggests that out of sight is not necessarily out of mind, and so birds' cognitive capacities should be considered along with behavioural and motivational studies when trying to predict whether frustration and suffering are likely to occur.

Birds have a great capacity for social learning, i.e. learning by watching the activities of others. It is generally considered that this is an 'advanced' form of learning and indicates higher cognitive capacity. Most social learning has been related to foraging or feeding activities learnt by watching parents (Stokes 1971, Sherry 1977, Hatch & Lefebvre 1997), siblings (Tolman 1964, Tolman & Wilson 1965, Johnston *et al.* 1998, Nicol & Pope 1999) or models (Turner 1964, Tolman 1967, Fritz & Kotrschal 1999). This form of learning can lead to the rapid spread of novel behaviours such as the opening of milk bottle tops by blue tits *Parus caeruleus* (Fisher & Hinde 1949, Sherry & Galef 1990). Vocal learning has evolved (probably independently) in at least three avian orders; the Passeriformes, Psittacines and Apodiformes (e.g. swifts *Apus* spp. and hummingbirds) (Dooling 1992).

Teaching by an animal could indicate that it is aware of the consequences of the 'student' animal's behaviour and so may be capable of identifying with another animals' thought processes, i.e. possess a form of empathy. Nicol and Pope (1996) showed that when a hen saw her chicks eating food which she believed was distasteful (though in reality it was perfectly appetizing) she increased her vocalizations and pecking activity, apparently attempting to direct her chicks to a dish containing more palatable food.

Tool use occurs amongst many bird species including thrushes (*Turdus* spp.), finches (Fringillidae), ravens (*Corvus corax*) and vultures (Cathartiformes) (McFarland 1993). Recently, keas (*Nestor notabilis*) have been used in studies on imitation by giving them the opportunity to open artificial fruit puzzles (Huber *et al.* 1998) and the ability of birds to count has been investigated using an African grey parrot (*Psittacus erithacus*) (Pepperberg 1994). Locomotory, social and object play have also been observed in birds, particularly corvids (Skutch 1996).

The range of cognitive skills now known to exist in birds indicates that birds have a higher mental capacity than has been previously thought. We must therefore recognize the considerable potential for birds to experience suffering and distress, and take preventative measures wherever possible. A stimulating environment is likely to be a very important contributor to good bird welfare and should always be provided.

4.2 Vision

The eyes and optic region of the brain are highly developed in birds, which reflects their adaptation for vision during flight. The avian retina is considerably more complex than that of mammals (Bowmaker *et al.* 1997) and so photoreception and vision in birds are very different from humans. Birds have excellent colour vision; the visual acuity of some species (e.g. raptors) exceeds that of old world primates, and some species also have specialized areas of the retina for different visual tasks. There are four types of single cone in the avian retina, so it is possible that birds have tetrachromatic vision as opposed to old world primates who have trichromatic vision (three cone types sensitive to 'red', 'green' and 'blue' light). This may mean that birds can see colours that humans cannot imagine. Most diurnal birds can also see ultraviolet (UV) light and many species have UV reflecting plumage (Bennett & Cuthill 1994). It has been suggested that UV colouration may turn out to be an important component of bird communication; a 'private channel' from which some mammals, such as humans, are excluded (Manning & Stamp Dawkins 1998). White objects, such as laboratory coats, will fluoresce in UV light, but this is thought to be unlikely to cause welfare problems. It is more important that coats are all the same colour and that the colour is not changed.

4.3 Magnetic fields

Some birds can perceive magnetic fields, although it is uncertain exactly how they do this. Two hypotheses are that photopigments in the retina could act as magnetoreceptors, or that magnetite particles within the head could align themselves with the earth's magnetic field. It has been suggested that, in birds, the two mechanisms interact so that light-dependent processes provide information for a magnetic 'compass' and magnetite-based receptors help to provide a navigational 'map' (Wiltschko *et al.* 1997). The effect of localized magnetic fields (e.g. from equipment) on birds is not currently known; they could either cause confusion, provide additional information to assist with orientation, or have no significant effect. It is therefore not possible to make recommendations with respect to the siting of sources of magnetic radiation, such as electrical apparatus, near bird housing.

4.4 Hearing

Most birds can hear sounds between 1 and 5 kHz, with a high frequency hearing limit of about 10 kHz for passerines and 7.5 kHz for non-passerines (Dooling 1992, see also

Heffner 1998). Birds do not utilize high frequencies for sound localization (apart from owls (Strigiformes), who can hear up to 12 kHz) and none studied to date can equal even human high frequency hearing (Heffner 1998), so ultrasound is unlikely to cause welfare problems. Sensitivity decreases gradually below 1 kHz but some birds, e.g. the pigeon, are thought to be able to hear very low frequency sounds (Kreithen & Quine 1979, Hagstrum 2000). Although infrasound (sound below 16–20 Hz) is unlikely to cause distress, birds should be given the benefit of the doubt and whenever possible should be housed away from any equipment that emits low frequency vibrations (J Sales, personal communication). Some birds are stressed by the sound of vacuum cleaners, so a damp mop should be used for routine cleaning.

Birds tend to show poor absolute localization of sound sources, but they can localize the songs of conspecifics and are better at detecting changes in the location of sounds (Dooling 1992). Although excessive noise is likely to stress birds, bird housing should not be approached too quietly as the sudden appearance of a human can be frightening. If birds can hear and locate approaching humans, they may be less likely to be startled when they appear.

4.5 Smell and taste

The sense of smell has been thought to be less important for birds than mammals in general, as the olfactory organs and areas of the avian brain are relatively small and the degree of development of olfactory areas of the brain is highly variable in birds (Jones & Roper 1997). Species with relatively large olfactory bulbs include ducks, domestic fowl and (especially) kiwis *Apteryx* spp., and the sense of smell has been shown to be important in the domestic fowl (Jones & Roper 1997). The threshold for olfactory sensitivity in most birds lies at around 1 ppm, which is near the bottom of the range for vertebrates with moderate olfactory sensitivity. Some passerine species have a threshold similar to that of rats or rabbits (Clark *et al.* 1993), so it should be assumed that birds can smell at least as well as humans and that they will be capable of smelling conspecifics and other animals, e.g. predators. Birds do not appear to respond to olfactory cues after eggs have been touched (or even replaced with dummies) but they do, however, use odours as orientation cues and to choose food and nesting materials (Waldvogel 1989). Some studies have also suggested that homing pigeons use olfactory cues to assist with navigation (Papi 1991, Walraff 1996, Bingman *et al.* 1997).

Birds have relatively few taste buds in comparison with mammals (e.g. blue tits have 24, domestic fowl 340, mallard ducks *Anas platyrynchos* 375 and rats 1265) but nevertheless appear to have an acute sense of taste (Welty & Baptista 1988). Fowl can taste well (Gentle 1971) and the taste of food appears to be important to the pigeon (Zeigler 1975). Birds also learn to avoid unpalatable substances and chicks learn to associate the consequences of eating foods with their taste. While some species are specialist feeders that are adapted to eat a narrow range of food items, generalists may benefit from dietary enrichment (see also Section 9).

4.6 Touch and pain

It was previously thought that birds possess relatively few peripheral nociceptors and so have a higher pain threshold than mammals, but nociceptors that respond to mechanical and thermal stimulation have been found all over the avian body including the skin and beak (Welty & Baptista 1988, Gentle 1992). The rim of the bill, bill-tip, palate and tongue are especially sensitive, particularly in species that dabble or probe sand or mud for food such as ducks, geese and waders, and also in granivorous birds that manipulate and shell seeds. Avian physiological and behavioural responses to painful stimuli resemble those of mammals (Gentle 1992) and so it should be assumed that if a stimulus would cause pain to a human or other mammal, it will also cause pain to a bird.

There is no reason to believe that birds feel pain to a lesser degree than mammals. Birds must be given the benefit of the doubt and any potential pain must be prevented or alleviated as appropriate.

Recommendations:

- Assume that avian cognitive skills are equivalent to those of mammals and that birds need an appropriately stimulating environment.
- Make sure that the lab coats everyone wears are of the same colour and that the colour is not changed.
- Remember that birds can detect changes in sound direction, so make sure that your approach is audible to birds to avoid startling them.
- Assume that the hearing range of birds is similar to humans and protect them from noises that would adversely affect human welfare.
- Do not subject birds to infrasound (low frequency noise) unnecessarily.
- Assume that the ability of birds to smell and taste is at least similar to that of humans.
- When housing birds indoors, do not situate them where they will be able to smell mammalian or other avian predators.
- Try providing species that eat a diverse range of foods in the wild with a balanced diet including a choice of different foods; monitor individuals' preferences very carefully and adjust the diet accordingly.
- Assume that birds feel pain to the same degree as mammals.
- Consider how you would recognize when a bird is suffering discomfort or pain.
- Prevent or alleviate pain in birds wherever possible.

5 Training

Adequate and appropriate training is essential for everyone who will be using or caring for birds in the laboratory or field. Bird behaviour, environmental requirements and veterinary care are very different from those of mammals, and insufficient knowledge or experience can cause serious welfare problems. Specialist training in catching and handling birds, recognition of pain and distress, avian nutrition and experimental techniques is vital, and it will be necessary to use expert trainers when planning projects with new species. Expert advice on training should be sought from organizations such as the UK British Trust for Ornithology or US Fisheries and Wildlife Service.

Recommendation:

- Ensure that everyone who will be caring for or using birds is adequately trained and competent before any projects begin.

6 Obtaining eggs or birds

Whether experimental birds should be acquired as adults or reared from hatch will depend on the nature and duration of the project, the behavioural characteristics and conservation status of the study species and the intended fate of the birds, i.e. whether they will be killed or can be rehomed or released (see Section 13). For long-term projects that involve close contact between birds and humans, e.g. taking labile physiological measurements such as heart rate or blood pressure, it may be preferable to rear birds from hatch and imprint them on an object or a human carer. This will reduce the birds' psychological stress and fear of humans, which will improve welfare and can generate more accurate physiological data. Imprinting may be a disadvantage in some behavioural studies, however, and may have other negative consequences (see Section 8.4), so whether to imprint or not must be considered on a case-by-case basis. For short-term studies where the variables under investigation are less affected by psychological stress or contact with humans is limited, it may be more appropriate to buy or catch adult birds. Handling and related procedures are likely to be extremely stressful for naïve adults, but rehoming or releasing them following the study may be easier (see Section 13).

Recommendations:

- Assess the welfare costs and benefits associated with rearing birds from hatch versus obtaining adults for each project.
- Consider the birds' quality of life after the procedures have ended, and their eventual

fate, i.e. rehoming, release or euthanasia, when making a decision.

6.1 Removing eggs or birds from the wild

No eggs or birds should ever be taken from the wild unless it is impossible to obtain them from commercial breeders. A number of conservation, legal and welfare issues must be addressed in full before any eggs or birds can be removed. At the project planning stage, the conservation status of the study species must be checked against the World Conservation Union (IUCN) Red List of Threatened Species (www.redlist.org/) and the relevant legislation regulating the taking of eggs and birds must also be researched (see Section 6.1.1 below). The use of rare or threatened species should, in general, be avoided.

Entering the habitats of wild birds and catching individuals or disrupting breeding colonies will inevitably have an impact on wild populations which must be carefully considered and kept to a minimum (Åhlund & Götmark 1989, Hockin *et al.* 1992). These adverse effects should be regarded as part of the welfare 'cost' of a project, both in ecological terms and in terms of any physical and psychological distress caused to the remaining birds, and should be taken into account by ethics committees considering such work.

Recommendations:

- Avoid taking eggs or birds from the wild unless it is impossible to obtain them from a breeder.
- When removing eggs or birds from the wild, consider carefully and minimize the potential for disrupting remaining individuals—this should be regarded as constituting part of the welfare 'cost' of the project.
- Pay full regard to the conservation cost of the project, where disturbance and removing individuals may have an impact on the population as a whole.
- In general, avoid using species that are rare or threatened.

6.1.1 The law and CITES

The taking of eggs or birds from the wild is regulated by national and international laws. Regulations must be thoroughly researched and all necessary licences and permits must be obtained before planning studies that require collection from the wild.

European Union: Under Council of Europe Directive 79/409/EEC (European Community 1979) on the conservation of wild birds (ratified in the UK as the Wildlife and Countryside Act 1981), a licence must be granted by an appropriate authority before eggs, chicks or adult birds may be taken from the wild for scientific or educational purposes.

United Kingdom: Applications for licences in the UK should be made to English Nature, Scottish Natural Heritage, the Countryside Council for Wales, or the Northern Ireland Department of the Environment, depending on the location of the population in question (see also RSPB 1998). Special justification is also required and appropriate welfare safeguards must be in place before the UK Secretary of State will license a project that involves taking animals from the wild for scientific purposes (Home Office 1998).

US and Canada: Within the US and Canada, the Migratory Bird Treaty Act stipulates that a scientific collecting permit from the US Fish and Wildlife Service (USFWS) or Canadian Wildlife Service (CWS) is required before taking *all* native birds (except for some Galliformes, which require a state permit only) from the wild for scientific purposes. Federal and state permits (in the USA) and provincial permits (in Canada) are also required before eggs or birds can be collected for scientific purposes. Guidance should be sought from the USFWS or CWS when planning projects with respect to current US and Canadian laws on taking, transporting and housing wild birds (see Gaunt & Oring 1999).

Australia and New Zealand: Many wild Australian species are protected by State laws, and Officers of State and Territory conservation authorities must always be consulted so that permits can be obtained where necessary (National Health and Medical Research Council 1997). The New Zealand Wildlife Act 1953 allows the Director-General of Conservation to authorize the taking of birds or eggs for scientific purposes and the Department of Conservation should be contacted for advice.

CITES: Some species of bird are protected by the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). CITES Appendices I, II and III stipulate that Government permits are required for trade in certain species and provide three levels of protection for those species in international commercial trade. The UK A(SP)A does not permit research on any species listed in CITES Appendix I (the most endangered species), unless the purpose of the project is to preserve that species or the project constitutes essential biomedical research and no other species is suitable (Home Office 1993). Current listings of species in CITES Appendices I to III can be searched at www.CITES.org/.

Recommendation:

- Make sure that you are fully aware of current national and international laws and codes of practice with respect to taking eggs or birds from the wild.

6.1.2 Taking eggs or chicks from the nest

Knowledge of the laying and reproductive performance of a species is essential to minimize disruption when taking eggs or chicks. Before applying for a licence to collect eggs, the literature and appropriate organizations listed in Appendix 2 should be consulted to see whether the mean rate of egg failure in the wild or captivity has been recorded for the species. It may be necessary to collect a surplus of eggs to ensure that there are sufficient birds for the study and to avoid further disturbance to nesting sites, but the number of eggs removed should be kept to a minimum to reduce the possibility of hatching unwanted birds.

Taking eggs or chicks from the nest should be done while it is unattended if at all possible, as this will reduce the stress and disruption caused by displacing adult birds from the nest and removing (predating) their offspring. The number of eggs taken from each nest should be related to clutch size; as a general rule, no more than half the clutch should be taken from any nest without strong scientific justification. Nesting material or down should be replaced as it was found, to conceal remaining eggs or chicks from predators and prevent chilling. It may be necessary to displace parent birds, for example in species such as geese that remain on the nest throughout incubation. Where this occurs, birds should be approached tangentially rather than directly and direct eye contact should be minimized to reduce stress and the risk of nest abandonment (see Ristau 1991, Gaunt & Oring 1999). Eggs or chicks should be removed as quickly as possible and care should be taken to cover those remaining in case the parent does not return immediately. Selecting populations that are already habituated to human activity may also reduce disruption.

Developing bird embryos are very vulnerable to disturbance and can easily be shaken from the inner shell membrane if eggs are handled roughly. Eggs should therefore be removed from the nest before incubation has commenced or, if this is not possible, when the chicks are almost fully developed and have penetrated the air space, or when 'pipping' has begun (see Section 8.3). Species that lay clutches of two or more eggs generally do not begin to incubate them until the clutch is completed. Collecting from nests that contain just one egg therefore increases the likelihood that it will not have been incubated. Some birds lay one egg only, in which case it may be preferable to select eggs that either contain well developed embryos or are hatching.

In some species, a fixed number of oocytes ripen into ova each season, so clutch sizes are fixed and lost eggs cannot be replaced. Such species, including many passerines, pigeons and shore birds, are referred to as 'determinate' layers. Other birds are 'indeterminate' layers, where the development of ova is sequential and only inhibited by the presence of the 'proper' number of eggs in the nest. Lost eggs can be replaced, although replacement whole clutches tend to contain fewer eggs. Ducks, Galliformes and some passerines are indeterminate layers. Advice should be sought from relevant organizations, e.g. the BTO or RSPB, their equivalents in other

EU Member States or the US Fisheries and Wildlife Service on the optimal collection protocol with reference to the reproductive strategy of each species.

Recommendations:

- Check published hatching and rearing failure rates when deciding how many eggs to collect—do not take too many (or unwanted birds may be hatched) or too few (or you may have to disrupt the colony again).
- Remember that you are a predator and your interference will be highly stressful and disruptive. Alter your behaviour to reduce stress.
- Observe nests carefully and try to take eggs that have not been incubated or that are very close to hatching, to avoid damaging embryos during vulnerable stages of development.
- Seek advice from appropriate organizations on the best collection protocol with respect to the reproductive strategy of each species.

6.1.3 Trapping adult birds in the wild

Catching adult birds and removing them from the wild has the potential to cause substantial distress and physical damage, both to the birds and to the local habitat, so it needs to be done with great care. Birds should only be caught under the supervision of someone experienced in trapping and handling any species which may be caught, not just the target one. There is no guarantee that a trap set for small passerines will not catch larger species or raptors. In the UK, the BTO regulates the capture and ringing of wild birds, and the best point of contact for information and expert guidance is the local bird ringing group. Careful consideration must be give to the collecting protocol with respect to the ecology of each species, and birds who are incubating or caring for young should never be taken without strong scientific justification.

A huge variety of trapping methods exist (see Redfern & Clark 2001). Perhaps the least stressful and easiest to operate are large walk- or fly-in traps built around the same principle as a lobster pot. The birds are attracted by food and/or a decoy through a single funnelled entrance into a large cage, and the funnel makes departure by the same route difficult, or the exit hard to find. The benefits of this method is that the bird is caught passively and, as long as food, water and shelter are provided, the trapped bird is no more stressed than in normal captivity. This method is particularly effective with flocking species where large numbers can be caught rapidly, but care must be taken to monitor the trap regularly and remove captives swiftly.

By far the most common method for trapping small- to medium-sized birds is mist-netting, where a fine meshed net is attached between poles and placed in a regular fly-way of the target species. However, this method should only be used by trained bird-ringers, as it takes considerable experience and training to disentangle trapped birds swiftly and humanely. It is illegal to use mist nets in the UK and Ireland without a licence, and relevant national authorities should always be consulted when considering trapping methods. Mist nets need especially frequent monitoring, especially during the breeding season or in adverse weather conditions (Gaunt & Oring 1999, Redfern & Clark 2001). It is therefore important not to set out more nets than can be effectively monitored.

Active trapping techniques, such as cannon-netting or spring-loaded traps are useful for larger or more wary species but should only be operated by experts, as the possibility of injury or stress to the bird is higher with such methods. Techniques where the birds are actively driven towards traps, which are sometimes used with waterfowl and songbirds that stick to dense cover, are also more likely to be stressful and so should be avoided unless passive methods are unsuitable. See also Gaunt & Oring (1999), Redfern & Clark (2001). For guidance on handling birds, see Section 10.

If birds are to be removed from the field and housed in the laboratory, a period of at least 28 days of acclimatization (and habituation) and quarantine will be necessary (see Section 11.2.1 on quarantine and disease prevention). Standards of husbandry and care while the birds are in quarantine should be as high as those for when they are in their permanent accommodation. The impact of psychological stress caused by the transition to captivity on both the birds and the particular experimental protocols they are to undergo must be taken into account and minimized.

Recommendations:

- Do not attempt to trap adult birds unless experience has been gained with an expert in attendance.
- Reduce stress by using passive walk- or fly-in traps wherever possible.
- Monitor traps and nets regularly and do not set out more than can be checked effectively.
- Minimize stress to birds taken from the field by allowing a period of acclimatization and quarantine before projects begin.

6.1.3.1 Field studies

A broad range of research projects are conducted exclusively in the field. Their degree of invasiveness ranges from simple observation or studies that alter normal behaviour (e.g. brood manipulation, playing back calls or food supplementation), to more invasive techniques including feather plucking, administration of hormones or drugs, tissue sampling and the attachment of external or internal telemeters (N.B. Forceful removal of feathers purely for scientific purposes in the UK requires licensing under the A(SP)A). All of these techniques have the potential to cause disruption, suffering or distress, especially if they are incompetently performed. They also raise ethical concerns aside from their immediate effect on individuals (see Cuthill 1991). For example, brood manipulation experiments may affect the parents' ability to raise their brood, which may have a negative impact on welfare; cross-fostering chicks of the same age and number between nests may alter the gene ecology of the population, which has ethical implications. It is also essential to consider the impact of any disruption on population viability. In general, studies likely to cause stress to individuals should not be conducted on rare or threatened species.

It is essential to check whether procedures conducted in the field require licensing, and to ensure that all appropriate licences have been granted before studies begin. All experimental work, including field studies, carried out on birds for a scientific purpose in Europe (as defined in European Directive 86/609 (European Community 1986) or under the UK A(SP)A) must be authorized under Member State regulations. In the UK, this means obtaining both project and personal licences from the Home Office and specifying the areas where the research is to be carried out (by Ordnance Survey referencing).

Trapping, handling and short-term holding: It is vital to ensure that trapping and handling techniques and all procedures (even observation) have been refined so as to minimize the potential to cause physical or psychological harm or stress to experimental birds, the study population and other animals living in the same habitat, as all of these constitute part of the welfare 'cost' of a project. There are a number of ways in which the environmental impact of the investigator can be reduced, and it is up to the individual researcher to ensure that this is done (see Gaunt & Oring 1999; III: Investigator impact).

Bird bags or sacks can be used to hold birds temporarily where studies involve very short procedures such as tissue sampling. Bird bags should be made from absorbent material that permits an adequate air flow (e.g. cotton) but which is fairly opaque, so as to minimize disturbance to the birds (see Redfern & Clark (2001) for dimensions and guidelines on use of bird bags). If birds are to be kept in bags for longer periods or overnight, they should be kept in a dark, well-ventilated area and the bags should have internal frames to support them so that birds can preen and adopt normal roosting postures. Larger birds such as waterfowl will require temporary enclosures that have been designed to minimize stress and the risk of injury (Davis & Allen 1989).

Surgical procedures: Any manipulation that directly causes pain or distress, however mild or transient this is believed to be, has the potential to reduce the fitness of the individual following release. Great care must therefore be taken to make sure that all such procedures are refined as far as possible and competently carried out. Sterile instruments (and sterile gloves) must always be used when carrying out tissue sampling and anaesthesia, and analgesia should always be administered as appropriate. Wounds should be closed using non-capillary attracting sutures. Some procedures, such as the doubly-labelled water method for estimating CO_2 production, require repeated trapping and sampling which is likely to increase stress and reduce fitness. It is extremely important to minimize the welfare impact of such studies on individuals and populations by ensuring that doses and sampling intervals are correct and that statistically appropriate numbers of subjects are used.

If more invasive surgical procedures, such as laparotomy to implant internal telemeters or data loggers, are to be carried out, it is essential to do so under sterile conditions and using anaesthetics, analgesics and wound care preparations. Wild birds may appear to be resilient but this is likely to be a consequence of adaptations to hide signs of pain or distress rather than a reflection of their true physical and psychological fitness or resistance to infection (see Section 12.6). Consequently, every attempt must be made to replicate sterile operating conditions and protocols as far as possible. No attempt should be made to operate on birds in the field unless at least one assistant is present to monitor anaesthesia and it is essential to ensure that supplies of drugs, sterile instruments and drapes and disinfectants are adequate. The smallest telemeters or loggers available that can achieve the aims of each project should be used, and all devices should be fully tested before any birds are caught. If all these conditions cannot be met, surgical procedures should not be carried out in the field.

External devices: Externally mounted instruments such as transmitters or data loggers may not have a significant effect on the behaviour or welfare of large birds provided that they are used carefully. However, if they are employed inappropriately or used in smaller birds, external devices can potentially cause stress by artificially increasing body mass and thus adding to the 'cost' of flight (Gessaman & Nagy 1988), by abrading the feathers (Perry 1981) or by altering the behaviour of conspecifics or predators towards the subject. They should therefore only be used if their likely effects can be predicted and it is not possible to obtain the required data in other ways (see Gaunt & Oring 1999).

The size and mass of any external instruments should be minimized, but the most appropriate size, colour, method of attachment and position will need to be researched for each study and species and these are also likely to vary seasonally. For example, back-mounted radio transmitters have been found to decrease the likelihood that pre-nesting female ducks will breed, possibly by interfering with courtship displays or copulation (Rotella *et al.* 1993, Gammonley & Kelley 1994), but they did not appear to affect female wood ducks (*Aix sponsa*) who were already incubating or brood-rearing (Gammonley & Kelley 1994). External devices attached to diving birds are likely to increase drag, thereby reducing swimming speed, dive depth, foraging range and the number of prey encountered (Wilson *et al.* 1986, Watanuki *et al.* 1992). Abnormal behaviour leading to emaciation and excessive attention to external transmitters has been reported in a diving duck, the canvasback *Aythya valisineria* (Perry 1981), so the use of external devices on diving birds is not recommended.

Recommendations:

- Make sure that all necessary licences have been granted before conducting field procedures.
- Ensure that birds kept in bird bags for other than short periods are held in dark, well-ventilated areas and can preen and roost comfortably.
- Always use sterile instruments when tissue sampling.
- Never carry out surgical procedures in the field unless a sterile area can be set up

and effective anaesthesia and analgesia administered.

- Do not use external devices unless there is evidence that (i) they will not adversely affect behaviour in the study species and (ii) they provide the least harmful way of obtaining the necessary data.

6.1.3.2 Releasing birds following field studies

Following short procedures, birds should be released at the site of capture. If they have been captive for several hours, they should be released early in the day and during favourable weather conditions so that they will be able to feed and locate roosts before dark (see Gaunt & Oring 1999, also Section 13). Before release, each bird must be carefully examined for signs of shock or injury, especially to the wings and legs (see Redfern & Clark 2001). Training and expert guidance will therefore be necessary to ensure that fitness is effectively assessed. There are five main potential causes of morbidity that must be prevented.

(i) Inadequate recovery from anaesthesia—ensure that the bird has fully recovered.
(ii) Infection—always use sterile instruments and a 'no touch' technique unless sterile gloves are worn.
(iii) Haemorrhage—make sure that birds have stopped bleeding before release and take care not to form haematomas when sampling.
(iv) Broken limbs—handle carefully and perform an adequate clinical examination before release.
(v) Shock—handle carefully and empathetically, observe behaviour before release (see also Section 12.6).

If there is any doubt, the bird should be taken to a veterinarian for treatment and released or rehomed later, or humanely killed if the injury is severe. It is therefore necessary to ensure that suitable transport containers and the means and expertise to kill birds humanely are available when undertaking any study that involves catching and handling birds.

Small birds should never be thrown into the air, but allowed to gather their senses and be fully conscious so that they can take off in their own time or be placed onto a suitable level surface. Hirundines and large birds with long wings and short legs may need to be held by the tarsi and gently launched into the wind (see Redfern & Clark 2001). After release, birds must be observed for a sufficient period to ensure that they can fly or walk normally, as appropriate, and that the effects of the experimental manipulations or surgical procedures have not reduced fitness and will not endanger the bird (it is also important to read Section 13 to obtain more detail on the factors that must be considered before releasing birds). If it is necessary to mark birds for subsequent identification, careful consideration must be given to the possible impact on the behaviour of the marked individual, conspecifics and potential predators. Identification methods that may make individuals more conspicuous or impede movement are likely to impair survival in the wild and should not be used (see also Section 10.7).

Recommendations:

- Examine birds carefully for signs of shock or injury before releasing them.
- Make sure that appropriate transport containers and the means to euthanase birds humanely are always available when undertaking any study that involves catching birds.
- Allow birds to move away in their own time on release and observe them to ensure that they can walk or fly effectively.
- Give careful consideration to the impact of external and internal marking methods on birds in the field.

6.2 Bird breeders and suppliers

It is preferable to buy birds from breeders wherever feasible, as they will have had at least some contact with humans. It is generally only possible to obtain purpose-bred laboratory domestic fowl and quail, so it may be necessary to buy other species such as waterfowl, pigeons and finches from commercial breeders. When purchasing birds of any species, it is important to obtain information on the conditions in which they have been hatched and reared so that any stress caused by removal to a different environment can be minimized by making changes gradually. Husbandry and welfare standards in place at the breeder or supplier should be at least as good as those at the establishment in which the birds will be used.

Annex I to EU Directive 86/609 (European Community 1986) stipulates that European quail, *Coturnix coturnix*, may only be purchased from a designated breeder or supplier for use in the EC. Birds with surgical mutilations such as debeaking (see Section 11.2.3) should not be purchased unless a project specifically requires it.

Recommendations:

- Buy birds from reputable breeders or suppliers whenever possible.
- Find out as much as possible about their natural history, husbandry and care before obtaining birds, and make sure that the breeder's welfare standards are good.
- Minimize stress by introducing changes to the birds' environment and/or husbandry gradually.

7 Transport

Anyone who wishes to transport birds must be aware of and understand all the relevant legislation that applies in each case. The transport of all vertebrate non-human animals within Europe is regulated by European Directive 95/29, which is ratified in the UK as the Welfare of Animals (Transport) Order 1997. Conditions of transport for laboratory animals in the UK must comply with those set out by the Department for Environment, Food and Rural Affairs (DEFRA) and in the Home Office Codes of Practice (Home Office 1989, 1995; www.homeoffice.gov.uk/animact/hcasp.htm and hcadb.htm).

The Laboratory Animal Breeders Association/Laboratory Animal Science Association (LABA/LASA) guidelines (1993) set out general requirements for the adequate care of laboratory animals in transit, although birds are not specifically mentioned. For further guidance on transporting laboratory animals, see the UFAW Handbook (Poole 1999).

Relevant US laws are the Animal Welfare Act 1970 and its 1976 amendments; and the USDA should be contacted for advice on current legislation. The transport of all animals used for scientific purposes in Australia and New Zealand must comply with guidelines set out in the Australia and New Zealand Codes of Practice for the Care and Use of Animals for Scientific Purposes (AWAC 1995, NHMRC 1997) and the Code of Recommendations for Minimum Standards for the Welfare of Animals Transported in New Zealand (AWAC 1994, amended 1996).

Other national or international regulations may apply when transporting or importing wild birds, including CITES for species that are endangered or at risk (see Section 6.1.1). DEFRA should be consulted before importing birds into the UK. The International Air Transport Association (IATA; www.iata.org) publishes Live Animals Regulations for transporting live animals by commercial airlines. These standards have been accepted by CITES and are enforceable worldwide (IATA 1999).

7.1 Transporting eggs

Wasting eggs is in effect wasting animals, so eggs should always be transported with extreme care. Embryos are particularly vulnerable to mechanical damage throughout the first two thirds of incubation and should not be transported during this period if possible. The safest time to transport eggs is before they have been incubated. If this is not possible, chicks in eggs that are 'pipping' or close to hatching are less vulnerable than those transported during the first two thirds of incubation.

If the journey from the nest site to the establishment is short, eggs can be insulated with cotton wool or down and gently placed in a thick polystyrene box with a lid. The rate at which eggs lose heat depends on their size, but small (e.g. tit) eggs can be transported for up to an hour without artificial heat provided that they are well insulated. For longer journeys, a portable incubator or a small polystyrene poultry incubator that can be adapted to plug into a car cigarette lighter socket will be necessary for eggs of all species. The eggs will need to be wrapped and insulated as above and quickly placed into the incubator which should be pre-heated. There should be no need to increase humidity within the incubator during the journey, and the use of water trays or soaked cotton wool may lower the temperature so that the eggs lose heat (note that humidity control is vital after the eggs have been transferred to the fixed incubator).

7.2 Transporting birds

'Bird bags' can be used for short journeys up to around half an hour (see Redfern & Clark (2001) for appropriate sizes and materials). During longer journeys birds must have sufficient space to assume normal postures and engage in preening and feather maintenance during transport, but it is not advisable to allow enough space for flight as this could lead to injury. Group housing during transport is acceptable, provided that it is known that the birds will not fight. It may benefit some social species such as domestic fowl or waterfowl to be grouped with familiar conspecifics. Padding the ceilings of containers may be necessary for excitable or delicate species. Flooring should be non-slip and will also need to be padded for species with easily damaged feet. Travelling containers should be dimly lit but birds must be able to see sufficiently well to move safely and to find water and food. Small passerines, e.g. finches, can be transported in low boxes with low level perching. Water can also be provided for some species in the form of moist sponge cake or, if appropriate, sliced fruit and vegetables for longer journeys.

For domestic fowl, transportation is especially traumatic and measures should be taken to avoid or reduce journeys wherever possible (Broom *et al.* 1986). Care should be taken to ensure that physical conditions throughout the journey are as similar as possible to those in the laboratory for all species. It is especially important to avoid heat or cold stress during the journey. In hot weather (over 20°C), birds should be transported at night or in the coolest parts of the day (RSPCA 1999). Temperature and humidity rise very rapidly in crates, so all birds should ideally be transported in a vehicle with a forced air ventilation system. Temperature and humidity must be maintained at optimal levels throughout all journeys to avoid heat or cold stress. If captive waterfowl are to be transported, they should have access to water until the time when they are caught.

For longer journeys it is necessary to provide food and water for all species, and rest periods may be necessary or may be a legal requirement (see also Gaunt & Oring 1999). Note that the number of birds being transported may alter the legal requirements. Routes and stopping places should always be planned well in advance, and at least one person who is trained in bird husbandry and care should be in attendance throughout the journey. Specialist animal transport firms can also be used for long distance transport; for air transport regulations see IATA 1999 (Appendix 2).

Recommendations:

- Obtain advice from relevant authorities on all applicable legislation, guidelines and codes of practice before transporting or importing each species.
- Wasting eggs means wasting animals so take great care to minimize risks to them.
- Try to avoid transporting eggs during the first two thirds of incubation—transport them before they have been incubated or wait until they are 'pipping'.
- Always insulate eggs or transport them in an incubator unless incubation has not yet begun.
- When transporting birds, ensure that containers are of an appropriate size and construction for the species and journey length.
- Take care to ensure appropriate physical and environmental conditions if transportation is unavoidable.
- Plan the journey thoroughly in advance, making contingency plans in case of delays.
- Ensure that trained personnel are always in attendance.

8 Breeding or rearing birds from hatch

Rearing birds from hatch, either by breeding them or acquiring eggs, may be the preferred option if a project requires repeated close contact with humans, or if it involves taking physiological measurements that are affected by stress, such as ECG or measuring plasma cortisol levels. Breeding or rearing may also be the best option for projects that require birds to be killed at their conclusion, although this will depend on the species, its availability and its environmental and behavioural requirements during development.

8.1 Breeding

There are several factors that should be considered when deciding whether it would be appropriate to breed birds: is there an ongoing requirement for eggs or birds of this species; can the correct conditions for stress-free breeding be supplied; and can the risk of overbreeding be minimized or will it be possible to find homes for surplus birds? If a species is relatively easy to breed and keep, and there is likely to be a sustained use, then it may be better practice to breed birds on-site rather than transport them from a breeder.

Birds will need to be sexed before breeding programmes can be set up. Some species have sexually dimorphic plumage or can be sexed by behaviour, e.g. singing in males. More invasive sexing methods include cloacal eversion, karyotyping, analysing DNA obtained from a blood sample, or by plucking a growing feather, and surgical sexing (note that these require a Home Office licence in the UK if done solely for a scientific purpose). Once breeding groups appropriate for the species have been established, suitable nest boxes and/or nesting material should be supplied at the beginning of the breeding season and the behaviour of the birds carefully monitored. Breeding birds are likely to be especially nervous, and disturbance including handling and cleaning may need to be reduced, although it is important to watch for clinical signs of conditions such as egg-binding (retention of eggs). Most fertile eggs that are allowed to incubate naturally will go on to hatch successfully, so it is generally best practice to allow the birds to hatch and rear the chicks themselves.

Recommendations:

- Before making a decision to breed birds, consider whether there will be a sustained requirement for the species, whether appropriate conditions can be supplied, and how the risk of overbreeding will be minimized.
- Eliminate all unnecessary disturbance to breeding birds, without compromising health monitoring.
- Allow birds to hatch and rear chicks themselves whenever possible.

8.2 Storing and incubating eggs

Incubation systems need to maintain eggs at the correct temperature and humidity for the species and keep eggs moving so that the developing embryo does not become stuck to the inner shell membrane, but not so fast or erratically as to damage the developing birds or shake them loose. Still air incubators provide a physical environment that closely approximates to that of an incubating bird, but they can only take a limited number of eggs before CO_2 levels rise and the developing embryos are at risk of suffocation. Forced air incubators can hold greater numbers of eggs, but maintain them at a temperature which is more consistent and which is usually set lower than in still air incubators. It is vital to obtain advice on incubating systems, temperature and humidity from books, breeders or zoos, as appropriate, before obtaining incubators and eggs. It may be necessary to buy a new incubator if existing models are not suitable for a new species. Most incubators have automatic egg turners, and incubators with turners should be purchased wherever possible.

Incubators incubate pathogens as effectively as they incubate eggs, so it is vital to disinfect the eggs as soon as possible after collection, and always wash your hands before handling them. Eggs can be sterilized using ultraviolet light (Monachon 1973) or commercially available egg sanitizing solutions. Periods of immersion should be minimized and eggs should not be placed in water to test for fertility.

The incubator should be fumigated before it is used for the first time and between batches of eggs. Anti-bacterial tablets can also be added to water baths during incubation. Hygiene is very important within the facility in which the incubator and hatcher is housed, and in large-scale enterprises it can be monitored using microbiological settle plates (Forbes 1996). Eggs that have not yet been incubated can be stored in racks with the small end up, but it is essential to obtain information on the correct storage temperature and relative humidity for each species. The storage conditions should reflect the planned period of storage, i.e. eggs stored for longer periods should be kept at cooler temperatures and higher humidity (Butler 1991, Wilson 1991). Storage periods should always be kept to a minimum to avoid wasting eggs.

The still-air gradient, oscillating temperatures and gentle egg turning of an incubating bird are difficult to replicate with a machine (Kuehler & Good 1990). Allowing broody hens to incubate eggs is another option. Many strains of domestic fowl used in intensive production are bred to reduce broodiness but this behaviour occurs naturally in 'traditional' breeds. The welfare of broody hens used for incubating eggs is important. They should be group housed and provided with good standards of husbandry and care (see Section 19). It is especially important to provide sufficient bedding and secluded spaces to prevent competition between birds. Eggs may be left with a hen until hatching and beyond, or removed a few days before hatching for development to be completed in an incubator. Distress caused to the hen when 'her' eggs are taken can be reduced by replacing them with fake eggs, which she will sit on until it becomes obvious that they are not going to hatch. Other broody birds, e.g. pigeons, can be used for smaller eggs. It is vital to consider the risks of infections carried by brooder species causing disease in the species being brooded. For further guidance on incubation see Batty (1997).

Recommendations:

- Obtain advice on the type of incubation systems and optimum conditions before acquiring eggs. Buy new equipment if necessary.
- Ensure that egg shells, incubators and hatchers are all sterilized and wash your hands before handling eggs, both before incubation begins and routinely during it.
- If using broody birds to incubate eggs, make sure that their welfare is given equal importance to that of experimental birds.

8.2.1 Temperature and humidity

Eggs must be incubated at the optimal temperature and relative humidity for the species to which they belong. Some commercially available forced air incubators designed for poultry and other Galliformes instruct users to incubate eggs from any species at the same temperature, but this may be unsuitable for passerines or wild birds. It is important to obtain accurate information both on natural incubation periods and on the appropriate temperature, since chicks will hatch early if the temperature is too high and late if it is too low (Kuehler & Good 1990). Unincubated eggs can tolerate cooling to a greater extent than those that have begun to develop, and the eggs of different species have variable tolerances to cooling. It is bad practice to risk wasting eggs and they should never be allowed to cool once incubation has begun, so provision should be made for incubator failure as appropriate. Some effects associated with incubation at inappropriate temperatures have the potential to cause serious health and welfare problems including neurological disorders, stunted growth and head abnormalities (Wilson 1991). Causing such disorders as a result of inadequate research into incubation requirements and/or poor husbandry is unacceptable.

A humidity meter should be placed in the incubator, preferably so that it can be seen without having to open the door, and regularly checked to ensure that relative humidity is at an acceptable level. If humidity is too high, chicks may be swollen or sticky on hatching and precocial birds may hatch before the yolk sacs have been fully absorbed. If humidity is too low, the chicks may become dehydrated or malformed due to an inadequate calcium metabolism (Kuehler & Good 1990). If humidity needs to be increased, only water that has been warmed to the temperature of the incubator should be used, as cold water will chill the eggs. Extra trays of warm water can be added to the bottom of the incubator and warm, damp cotton wool can be placed near the eggs. Eggs can also be sprayed with a mister containing warm water which should be kept in the incubator.

Recommendations:

- Always ensure that incubators are set for the correct temperature and humidity for each species, regardless of instructions (which are likely to be for domestic poultry).
- Check the temperature and humidity regularly and rectify any problems immediately.
- Make appropriate back-up provisions for incubator failure.

8.2.2 *Monitoring development*

Accurate records should be kept so that reasons for poor hatchability can be determined. Information on laying dates (if available), incubation periods, fertility rates, weights of eggs throughout incubation, hatchability, hatchling weight and survival are essential to pick up poor performance at an early stage (Forbes 1996). Eggs should therefore be individually labelled with a wax or graphite pencil following disinfection. The development of the embryo can be monitored by 'candling' the eggs, preferably using an egg candler manufactured for the purpose. Eggs should be candled for the first time at around a quarter of the way through the incubation period to check for non-viable, cracked or infected eggs, which should be discarded. Periodic candling will enable eggs containing dead embryos to be removed before they cause infections or explode in the incubator. Such 'dead in shells' should be investigated to see whether the loss was preventable (protocol in Forbes 1996).

Eggs should also be weighed throughout incubation to monitor whether they are losing water at an appropriate rate. Mean water loss during incubation (up to pipping) over a range of species is 15% of the initial egg mass. A further 6% of the initial mass is lost between pipping and hatching, so the overall mean water loss at the end of hatching should be around 21% (Ar 1991). A graph should be plotted for each egg, if possible, with the start mass and desired end mass. If the egg is too heavy at any time during incubation, the humidity is too high, and if it is too light, the humidity is too low (Forbes 1996). Such close monitoring may not be feasible where large numbers of eggs are being incubated, but a representative sample can be weighed. Care must always be taken not to chill eggs during monitoring procedures. The eggs of different species should not be incubated in the same machine unless their requirements are known to be equivalent.

Recommendations:

- Keep accurate records so that development can be monitored and egg wastage minimized.
- Label eggs clearly with a wax or graphite pencil and candle regularly to check for non-viable eggs or 'dead in shells'.
- Monitor deviations from expected mass throughout development, wherever possible, and adjust humidity accordingly.
- Do not incubate eggs from different species in the same machine unless it is known to be safe to do so.

8.3 Hatching

The hatching process consists of four phases (Oppenheim 1972):

(i) tucking, where the head moves under the right wing and into the air space;
(ii) membrane penetration, where the shell membrane into the air space is broken and true lung-breathing begins;
(iii) 'pipping'; and
(iv) emergence of the chick from the egg.

Phases (ii) and (iii) are assisted by the 'egg tooth', a calcareous temporary tooth on the upper mandible. A hatching muscle at the back of the head and neck provides additional force to break the shell and then reduces in size following hatching.

Eggs should be removed to a hatcher with a clear plastic lid at stage (ii) or (iii) so that their progress can be observed without repeatedly opening the incubator door and risking chilling other eggs. The hatcher needs to be warm and should be maintained at about 37°C, but humidity is still important and will need to be maintained at around 60 to 70%, as dry shell membranes are harder to break through. Individual species will have different requirements and these should be checked before incubation has begun. A mister filled with warm water, which should be kept in the hatcher, can be used to moisten shell membranes if they become dry. For hygiene, empty shells should be removed promptly.

Chicks hatch at a range of developmental stages that require varying amounts of parental care. Most precocial birds hatch with their eyes open (O'Connor 1984) and will require attention immediately if the chance to imprint them on the chosen object or human is not to be lost (see Section 8.4). Regular checks are necessary to ensure that hatching proceeds normally and that hatchlings do not become impeded when leaving the egg. A suitable flooring material that chicks can grip, such as ribbed rubber matting or a wire grid with mesh less than 6 mm (0.25 inches) apart, will help to prevent splay-legs and slipped tendons. It will also be necessary to check that each chick is strong enough to hatch and that the process is not taking too long, in which case assistance may be needed.

Recommendations:

- Ensure that temperature and humidity are maintained at appropriate levels for the species during hatching.
- Check hatchlings at least twice a day to ensure that they can leave the egg without obstruction.
- Provide suitable flooring in the hatcher that chicks can grip.

8.4 Rearing and imprinting

Rearing: Chicks should be removed from the hatcher as soon as they are fluffed up and alert, and then reared as set out in the individual species sections below. A brooder lamp will be required for most species, although altricial species will in general require a longer brooding period than precocial ones. Some species such as diving ducks may not require brooding at all and so may choose not to use a lamp, but should still be supplied with one so that they can choose whether or not to use it.

The growing birds should be weighed and measured regularly to ensure that they are growing at an appropriate rate and that their body components are attaining adult size in the correct order. There is an extensive literature on growth rates in wild birds that will provide useful guidance, but care should be taken to ensure that chicks are being compared with the correct sex (in dimorphic species) and race. It should also be noted that, although growth rates are ultimately under genetic control, they are also strongly influenced by environmental factors such as temperature, weather, parental care, food quality and exercise. The growth rates of wild and hand-reared birds may therefore differ to an extent, but adequate monitoring and checking is vital to ensure correct development.

Imprinting: Imprinting birds onto a human is a serious commitment, the consequences of which require planning in advance and a great deal of time, and which also have implications for rehoming or release (see Section 13). While it is true that precocial birds become attracted to the first large moving object they see, in practice the attachment must be reinforced and maintained. It is necessary to spend at least several hours a day with the birds and maintain this over a period of weeks. This will obviously not be realistic in all laboratory situations, but may be appropriate and worthwhile where small groups of birds will be reared for studies requiring high levels of interaction with humans.

Although the hand-rearing of young birds may be beneficial in terms of reducing stress during subsequent interactions with humans, rearing chicks apart from conspecifics can have negative consequences for the birds' welfare. Exposure to conspecifics is a crucial aspect of normal behavioural development for most species of bird (review in Lickliter *et al.* 1993). Deprivation of this opportunity for normal social interactions can lead to abnormal behaviours in the adult bird. Hand-reared birds may be unable to perform normal courtship and sexual behaviour or may display excessive aggression. The extent of the problem will vary between species, and it is likely that the effects of isolation from conspecifics will be greater for those that are highly gregarious (ten Cate 1995). Moluccan cockatoos (*Cacatua haematuropygia*) provide an extreme example, where very few hand-reared birds are known to have produced young and cases are frequently reported of such males killing their mates (Low 1987). For most species, interaction with humans is preferable to social isolation during rearing (Preiss & Franck 1974), and no chick should ever be reared in total social isolation without strong scientific or veterinary justification.

Where chicks are to be hand-reared, efforts should be made to minimize any detrimental effects. Hand-rearing chicks with their siblings may go some way to aiding normal social development while still allowing them to become habituated to the laboratory and possibly become imprinted on their human carer. Hand-rearing groups of chicks from behind a screen can discourage imprinting on humans if this is not wanted. However, it is essential to research the behaviour of juvenile birds when considering rearing and managing them as a group, in case there is a risk of innate sibling rivalry or fratricide.

If chicks are to have a human 'parent', the imprinting process can begin before the birds have hatched. Precocial chicks can often be heard calling once the beak has entered the air space and adult birds will call back, which helps to synchronize hatching within broods and enables chicks to recognize the calls of their parents as soon as they have hatched. Prehatch vocalizing is unknown in altricial birds, possibly because exact synchrony of hatching is not relevant for them (O'Connor 1984). Precocial chicks are also highly responsive to human speech and may call back if spoken to within the egg. It is probable that birds will recognize the same human voice after hatching, so it may make imprinting on humans easier if the carer regularly speaks to the chicks before they have hatched.

An alternative is to supply the chicks with a model or decoy bird, which can be left with them continually. It is vital to ensure that chicks left with a model are able to feed and drink adequately in the absence of a living 'parent'. Some species are taught how to drink and feed, and what is acceptable food by their parents, so will need guidance from a human (e.g. tapping a pencil or the beak of the model bird among their food). Advantages with this option are that it may be possible for experimental apparatus to be set up so that birds can see their 'parent' during procedures, more than one parent can be supplied if birds have to be split into groups and an accurate model of a conspecific may encourage birds to seek appropriate breeding partners should they be rehomed or released after procedures. Different species vary in their willingness to become imprinted on other species or on objects (see Welty & Baptista 1988) so it is vital to obtain information and advice on this before acquiring eggs.

Recommendations:

- Check growth rates against published growth curves regularly, allowing for differences between wild and hand-reared birds.
- Plan imprinting on a human well in advance—the consequences require serious commitment.
- Research the behaviour of juvenile birds when considering rearing them as a group, in case there is a risk of fratricide.
- Rear chicks in broods or groups of conspecifics, never in isolation unless there is strong scientific or veterinary justification for doing so.
- Talk to birds in the eggs before they hatch (where appropriate) to assist with imprinting.

- If chicks are imprinted onto a model bird ensure that they are feeding.

8.5 Feeding chicks

Precocial birds retain internal yolk sacs after hatching, which help to sustain them while they are learning how and what to eat. Altricial birds normally use up their yolk before hatching and are fed by their parents, so most species will require food within 4 h. Parent birds have a variety of strategies for feeding chicks and it is vital to be aware of the feeding behaviour of a species when hand-rearing birds. Many precocial species such as ducks and shorebirds are self-feeding and learn by trial and error; others such as quail lead their young to individual items; and others uncover food for their chicks by scratching the ground (e.g. fowl) or by cutting vegetation (e.g. swans). Altricial birds and some precocial or semi-precocial species such as auks (Alcidae) and gulls (Laridae) are fed by the parents directly placing food into their mouths or regurgitating food in front of them (O'Connor 1984).

When hand-rearing birds, the literature must be consulted to see how naturally reared chicks of that species are fed, and the hatchlings must be provided with food accordingly, teaching them how to feed if necessary. Another important consideration is that chicks may be fed different sized food items at different stages of development: for example, young bullfinches (*Pyrrhula pyrrhula*) are fed crushed seeds and young blackbirds (*Turdus merula*) are given segments of earthworms, but they are given whole items when they are older. The time of day at which food is presented or made available should also be considered when rearing species that feed their chicks at certain times in the wild.

Young wild birds are generally fed on protein-rich diets, even if this differs from the adult diet (O'Connor 1984), and so commercial chick crumbs can be suitable for a range of species. However, care must be taken when feeding birds on commercial chick feeds as these are formulated specifically to support the very rapid growth of broilers or for the growth of 'layer' strains of poultry. These formulations are certainly not appropriate for all precocial species.

The most common nutritional problem during the rearing of wild birds in captivity is nutritional bone disease due to absolute dietary calcium deficiency or, less commonly, vitamin D deficiency or inappropriate levels of dietary phosphorus (Kirkwood *et al.* 1999). Due to the very rapid growth rates of altricial species, severe skeletal abnormalities can develop within days, and so great care must be taken to ensure there is an adequate calcium intake (Kirkwood 1996). Some precocial species fed *ad libitum* on diets containing unsuitably high protein or energy concentrations are prone to twisting and bending deformities of the limb bones (Kirkwood 1996, Forbes & Richardson 1996).

Recommendations:

- Teach hand-reared birds to forage or to feed soon after hatching if necessary.
- Research the feeding strategies of each species and provide appropriate food at each life stage, giving consideration to feeding times.
- Formulate diets carefully for growing birds to ensure appropriate dietary concentrations of nutrients, especially of calcium, phosphorus, vitamin D and protein.

9 Diets for juvenile and adult birds

Juvenile birds should be gradually introduced to their adult diet after the period of rapid growth is completed. Adult birds should be fed on the food that they would eat in the wild, as far as possible, although supplements may be necessary, for example thiamin supplements for sea birds (see Section 16.4). However, mineral and vitamin supplements should not be used without careful consideration of the balance of the diet. Some minerals and vitamins are harmful if provided in excess, and the aim should be to correct specific dietary deficiencies with specific quantities of specific supplements (Kirkwood 1996).

Many laboratory animal diet manufacturers produce pelleted food that can maintain birds but this may not be suitable for all species and can be bland and uninteresting. The protein content per unit mass may also be too high for grazers or species that ingest large amounts of indigestible material such as mollusc shells or insect exoskeletons.

Feeding patterns of wild birds vary widely and consideration will need to be given to the nature of the food, the way in which it is presented and the times at which it is made available. Some species are more adaptable than others and advice should be sought on appropriate dietary regimens. Companies that manufacture diets for zoo animals should be able to advise on feeding unusual species. Taste is likely to be important to many birds; for example wild Psittacines, starlings and corvids eat a range of animals, fruits, vegetables and seeds, and junglefowl will take seeds, grain, shoots and insects (Lint & Lint 1981). Some form of dietary enrichment such as fruit, vegetables, seeds or invertebrates should be considered where appropriate, even if it is not possible to feed birds on their 'natural' diet (see Section 4.5). Food can also be presented so as to provide both dietary and environmental stimulation, e.g. by pushing seeds into an apple or orange (Association of Avian Veterinarians 1999).

Diet preferences are shaped by early experience, so any new foods should be introduced gradually and as an extra option, especially where birds have previously been fed on bland or uniform diets. The previous diet should always be available so that birds will not go hungry if they are unwilling to eat new foods. Wide food bowls, rather than deep cups, display food more attractively and may encourage birds to eat new foods (Association of Avian Veterinarians 1999). For further ideas on dietary enrichment and introducing new foods see Burgmann (1993); for guidance on essential nutrients see Klasing (1998).

Recommendations:

- Feed birds with their 'natural' diet as far as possible, and with supplements when necessary.
- Assume that taste and variety will be important to some species.
- Provide dietary enrichment where appropriate, but avoid abrupt changes in diet.

9.1 Grit

Many species of granivorous and herbivorous birds ingest small pieces of insoluble grit which they retain in their gizzards and which assist in the process of degradation, grinding and breaking up of seeds and other fibrous plant matter prior to chemical digestion. It is essential that appropriately-sized grit is made available to species that require it. Birds will select grit of the size they prefer if material of various sizes is provided.

Recommendation:

- Supply grit in a range of sizes for birds to choose from if this is a requirement for the species.

9.2 Calcium and phosphorus

Nutritional bone disease is a potential problem in many species of birds maintained in captivity. Because of their very rapid rates of skeletal growth compared with mammals (Kirkwood *et al.* 1989) birds tend to have requirements for higher dietary calcium concentrations during growth and can develop skeletal pathology (including poorly mineralized bones and pathological fractures) very rapidly if calcium intake is inadequate. Although the dietary calcium concentrations of the main components of the diets of many species of birds are relatively low (e.g. many invertebrates, grains, fruits, and green plants), nutritional bone disease is rare in free-living birds. It is known that some species include calcium-rich items such as fragments of bone or snail shell in the diet they feed to their chicks (e.g. Seastedt & Maclean 1977) and this behaviour may be more common among birds than has previously been realized. It is widely recommended that the calcium concentration of diets for precocial birds should be 1% of dry matter, or slightly more (e.g. Scott 1986). There has been relatively little work to determine the calcium requirements of growing altricial birds (Kamphues & Meyer 1992), but 1% of dry matter may be the lower limit. It is important to estimate dietary calcium concentrations carefully because deficiencies and excesses can both cause severe skeletal pathology. Where calcium supplementation is judged to be necessary, quantities should be calculated and administered with precision (Kirkwood 1996).

When growth is complete, the dietary calcium concentrations needed for maintenance are lower. Concentrations in the range of 0.5 to 1% of dry matter are likely to be adequate and safe for many if not all species. Bone disease can also be caused by excess or insufficient phosphorus. Dietary phosphorus deficiency is unlikely since most natural and compounded feeds contain adequate phosphorus concentrations. The ratio of calcium to phosphorus in the diet should be about 1.5:1 to 2:1, and not less than 1:1 (Scott 1986).

Calcium requirements increase during egg laying. Wild birds meet this extra requirement by storing calcium as new bone prior to the start of laying and, at least in some species, by selecting calcium-rich diets. It may only be domestic poultry species, which have been selected for extraordinary rates of sustained egg production, that need exceptionally calcium-rich diets during laying. The dietary calcium concentration recommended for laying hens is 3.6% of dry matter. Dietary phosphorus is not correspondingly increased in these diets, and the recommended concentration is 0.6% of dry matter (Scott 1986).

Recommendations:

- Ensure that dietary calcium and phosphorus is provided in an appropriate form and at an appropriate level for each life stage.

9.3 Moulting

The periodic replacement of feathers, or moulting, is necessary to maintain the basic functions of plumage, including efficient flight, insulation and waterproofing. All birds shed and replace at least part of their plumage once a year; many species moult twice a year and some three times. Some birds, e.g. waterfowl, lose all their flight feathers simultaneously and are incapable of flight during moulting (see Section 17.1), whereas others, e.g. many passerines, replace their flight feathers in sequence and retain the ability to fly. In many sexually dimorphic species of bird, males moult into an 'eclipse' or 'post-nuptial' plumage that resembles the female of the species. This is particularly noticeable in waterfowl and also occurs in passerines such as whydahs (*Euplectes* spp.) and some sunbirds (suborder Oscines). In addition to feathers, some species also moult other structures of epidermal origin such as scales, wattles, claws or horny sheaths of the bill (e.g. the puffin, *Fratercula arctica*).

Moulting is under hormonal control and the interaction between day length and hormonal balance in birds has been extensively investigated, although moult cycles are retained in some species when they are held under conditions of constant light. Some species moult following the breeding season, but this is not always the case and it is not possible to generalize about the timing of moulting in relation to breeding. It is therefore necessary to research the moulting strategy of each species and ensure that their behavioural and nutritional requirements are provided for. Requirements for some nutrients, e.g. essential sulphur-containing amino acids such as methionine, increase during moult but it is unlikely that these requirements would not be met by providing the usual diet *ad libitum*, provided that it is properly balanced.

The duration of moulting in captive birds is often longer than that observed in wild birds of the same species, which may result in increased energy requirements and possibly psychological stress if the ability to fly is absent or impaired over long periods. Stress may render birds more susceptible to disease and parasitic infections, so efficient and empathetic monitoring will be necessary to ensure that good health is maintained but disturbance minimized.

Abnormal moulting: Unexpected patterns of moulting or abnormal feather structure can be caused by a number of factors and can usually be prevented by thoroughly researching the environmental and nutritional requirements of each species. Moulting appears to be more susceptible to variation in day length than to either light duration or light intensity, so it is important to ensure that light:dark cycles replicate the annual variation at the latitude where each species would normally live, when housing birds under artificial lighting regimes, e.g.

short day lengths and lower temperature graduating to increased day length and warmer temperatures for temperate species. It may be necessary to take into account migration to different latitudes in some species. Maintaining birds under constant day length and temperature can lead to them undergoing a 'soft moult', where plumage (other than the flight feathers) is continually shed over a prolonged period.

Other forms of abnormal moult may be caused by factors other than environmental conditions. These include hormonal deficiencies, nutritional imbalance or physical damage caused by poor caging or rough handling. Feather loss due to self-mutilation as a result of boredom may occur if the captive environment is not sufficiently complex.

Irritation due to parasitic infections can also cause birds to strip their feathers. For example, 'depluming itch' may occur in pigeons or Psittacines infested with *Knemidocoptes* spp. mites, usually affecting the underside of the throat or upper breast. Other non-pathogenic feather mites may also be found in growing feathers, especially in blood quills. In addition to damage to feathers caused by mites, damage may also occur due to stress or poor nutrition; this may show as 'stress bands' or 'fret marks' across the feathers and be especially noticeable on the larger flight feathers. Other parasites that feed on the blood of the bird but do not live on the host can further exacerbate the stress of the moult, leading to loss of condition and possibly to death if untreated.

Patterns of abnormal feather loss may be due to nutritional, hereditary and infectious causes. For example, 'Psittacine beak and feather disease', which causes abnormal growth of feathers in young Psittacine birds, is caused by a circovirus infection. Various other feather abnormalities may occur, e.g. dry or brittle feathers due to either poor nutrition or a blocked uropygial (preen) gland. Abnormal patches of colour, usually white or grey, are often caused by stress and nutritional problems when feathers are forming. Imperfectly formed feathers can also fail to grow out normally, leading to the development of cysts in the feather follicles. 'False moulting' may be caused by over production in laying hens or by the improper use and administration of drugs. The attending veterinarian should always be consulted if birds are moulting abnormally or their plumage appears to be damaged.

Forced moulting: Laying hens in commercial situations may be 'force moulted' to increase egg production. This is commonly done by withholding food (to starvation levels), manipulating lighting regimes or using hormones (e.g. thyroxine). This practice is inhumane and cannot be justified in laboratory (or farmed) birds.

Recommendations:

- Thoroughly research the moulting strategy for each species and ensure that you can provide appropriate temperatures, day lengths, housing and nutrition before obtaining any birds.
- Make sure that moulting birds are carefully monitored but are not subjected to unnecessary disturbance.
- Always seek veterinary advice if moulting patterns or feather growth are abnormal.
- Do not force-moult birds.

10 Catching and handling in the laboratory

This Section relates to captive birds only; see Section 6.1.3 for recommendations on trapping birds in the field. Catching and handling should be carried out confidently, only when necessary, and only by those who are competent to do it. Training is essential for those who will be handling birds, to ensure competence with each species, for which expert advice from outside the establishment may be necessary. Adequate equipment is also vital, i.e. using well maintained nets in appropriate sizes and darkened nets with padded rims for small birds.

All birds are liable to find restraint and handling extremely stressful, perhaps because handling by humans may be interpreted as a close encounter with a predator. The bird's point of view must be considered at all times before and during handling. Competent handling is also vital not only for the safety of the human handler but also because attacking birds may be dropped or mishandled, which could result in bruising or broken bones. Even if there is no physical damage, the psychological distress will lead to greater fear, anxiety and aggression the next time the bird has to be caught.

Some individuals, especially hand-reared birds, may habituate to handling but others may never accept it and so should be handled infrequently and as firmly and competently as possible. Many birds struggle and attempt to beat their wings when caught, so preventing or stopping this should be a priority to avoid wing damage and unnecessary stress. The wings should be folded into their natural resting position and gently but firmly restrained, which may be done with one hand for small birds but requires a strong grip with both hands for large waterfowl. Birds should never be caught by the wings or carried by the wings or legs alone.

It is vital to apply the correct amount of restraint when handling birds. Great care must be taken to ensure that their breathing is not restricted or that the restraint itself does not cause injury (Fig 3). Breathing in birds differs from mammals in that birds lack a muscular diaphragm and the lungs are fixed to the chest wall. Air within the avian respiratory system flows in one direction through a series of thin-walled air sacs which assist respiration. Breathing is powered by the action of the sternum, so movement of the sternum must never be impeded or the bird will rapidly suffocate. The trachea of birds is reinforced with cartilaginous rings so it is not easily crushed, but may become kinked if the head is twisted, which will impede air flow (Fowler 1995). Care must also be taken not to obstruct the mouth or nostrils unless it is certain that the bird will still be able to breathe. Some species cannot breathe through the nares, whereas the nares of others may become blocked with exudate or feed (Fowler 1995).

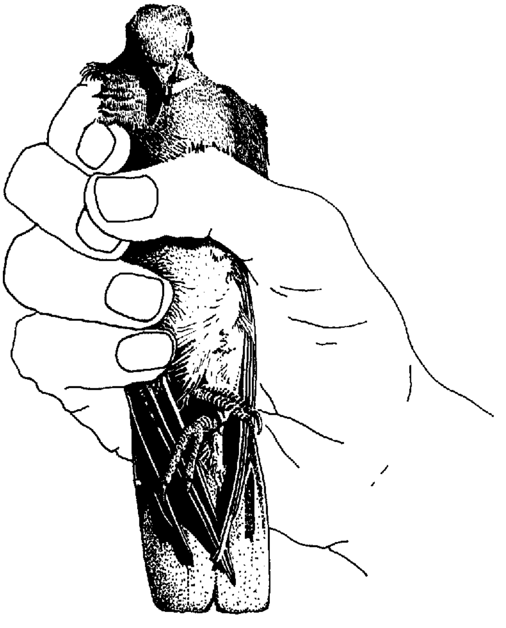

Fig 3 Example of poor restraint—the bird's body is completely enclosed and the movement of the sternum is impeded

Birds are extremely well insulated, especially those of temperate or polar species, and many maintain a relatively high body temperature. Adult birds are liable to hyperthermia during handling, especially if they become stressed and begin to struggle, whereas chicks may become hypothermic. Birds commonly react to being handled by becoming aggressive or vocalizing and may also employ anti-predator strategies such as panting, gaping, closing the eyes and fluffing up the feathers (Redfern & Clark 2001). Bird handlers must be trained to recognize signs of genuine distress that could indicate shock, wing sprain, leg or wing fractures, skin damage or heat stress and know the appropriate actions to take (see Redfern & Clark 2001, also Section 12.6). A veterinary surgeon should always be consulted if birds become distressed.

Recommendations:

- Ensure that everyone who will be handling birds is trained and competent, and that all equipment is well maintained.
- Remember that some birds will view humans as predators and may find handling extremely stressful.
- Never catch birds by the wings or carry them by the wings or legs alone.
- Hold birds securely so that they cannot damage their wings but never obstruct the

movement of the sternum or allow the neck to kink.

10.1 Small birds (<0.5 kg)

Small birds kept in cages can become very stressed when caught by hand. Distress can be reduced by catching birds in dim light and approaching them from above and behind. When catching by hand, a towel may be used to obscure the bird's view of the approaching hand. The 'ringer's grip' is recommended for very small birds, where the bird is held with the neck between the first and second fingers and the thumb and third or fourth finger hold the legs still at the tibiotarsal joint (Fig 4; Redfern & Clark 2001). For larger individuals, the other hand will be needed to support the body and restrain the legs (Fig 5; Fowler 1995). Chicks and ducklings or goslings can be carried in one hand with the fingers under the body, taking care not to squeeze them.

It can be difficult to hold very small birds safely, and expert guidance is likely to be necessary. Nets must be used correctly to avoid damaging the bird during capture or removal. Once caught, the head and wings should be carefully restrained before the bird is removed from the net. Small birds are especially liable to injury should they escape, so there should be no open windows, open drains, exposed heating elements or exhaust fans in the room (Fowler 1995). Windows should be closed, and either blinds or curtains drawn or the glass made visible to the birds by covering it with netting or sticking on strips of tape. Following handling, small birds should be released gently and quietly onto the floor of the pen or cage and allowed to move away in their own time.

Recommendations:

- Catch small birds in dim light and approach from behind, obscuring the hand if necessary.
- Take great care not to let small birds escape, as it is especially easy to injure them.
- Ensure that the room has been made safe in case birds do escape.
- Obtain expert guidance before handling very small birds.

Fig 4 The 'ringer's grip'—hold the bird with the neck between the first and second fingers and the thumb, using the third or fourth finger to hold the legs still at the tibiotarsal joint

10.2 Large birds (>0.5 kg)

Large birds such as waterfowl and domestic poultry can have powerful wings and legs and must be handled firmly and empathetically to avoid injury. Those housed in pens can be caught using a large, deep net, such as a

Fig 5 Grip for larger passerines—use the thumb of one hand to exert pressure under the jaw (without enclosing the neck) and the other hand to support the body and restrain the legs if necessary

primate net, which can be safely dropped over them. If birds are housed in pens large enough to permit flight, they should be approached while calm and caught before they take off (two people may be necessary to 'walk' the birds into a corner). Group-housed birds will tend to flock, but a single bird can be caught with a net or by hand if the flock is approached slowly and deliberately.

When catching by hand, approach from the rear and quickly grasp the base of the neck and then quickly place the other forearm around and under the body (Fig 6). Struggling ducks and geese often become still if the beak is held down with one finger, avoiding the nares, and the feet are allowed to grip the handler's arm. Catching and handling has a considerable effect on domestic fowl as they are fearful of close contact with people. If the experimental procedure requires adult birds to be handled regularly, it may be beneficial from a welfare and experimental perspective to handle chicks frequently during rearing as this reduces later fear of humans (Jones 1994, see Section 10.5). Adult birds of any species over 0.5 kg should ideally be picked up by placing both hands firmly over the wings to prevent flapping. If this is not possible, gently holding both legs with one hand and placing the other on the bird's back is an alternative way of catching, but the former method is to be preferred. Birds should be carried under the arm, with one hand under the body, palm uppermost, so that the legs are restrained, and with the other hand placed gently over the back and wings to prevent flapping.

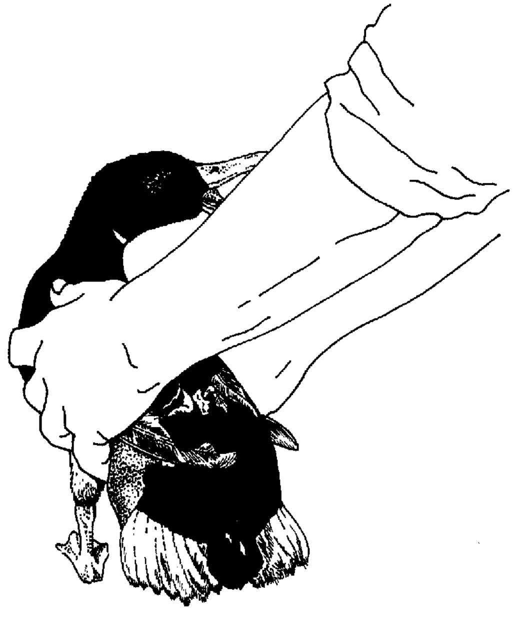

Fig 6 Catching a duck or goose manually—approach the bird from the rear and quickly grasp the base of the neck so that the other forearm can be placed around and under the body

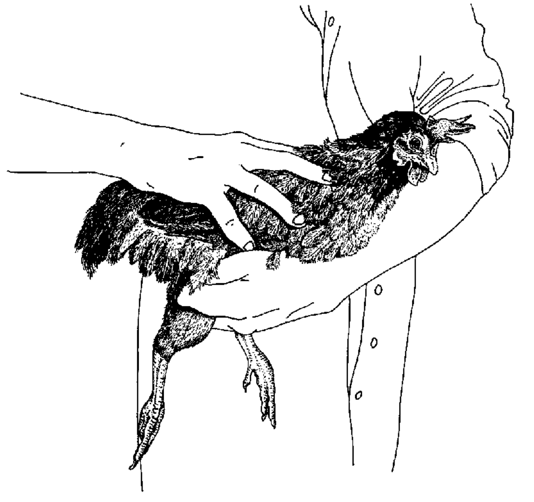

Fig 7 Carrying a duck or chicken—maintain a firm grip around the body but take care not to impede breathing

It is necessary to restrain the legs of domestic fowl and turkeys, especially male birds with sharp spurs, but no bird should ever be carried upside down by the legs, and the wings should not be interlocked to restrain them. Most large birds can be carried for short distances either under one arm or held in both hands, maintaining a firm grip around the body but taking care not to impede breathing. Ducks and geese should never be carried hanging head downwards or by the legs or wings alone (Fig 7). If large birds persistently react to attempts to catch them by flying, it may be necessary to use temporary or permanent methods to prevent them from flying into the walls of the pen and injuring themselves (see Section 11.2.3).

Releasing large birds into the holding pen or cage after capture or procedures can cause stress and physical damage if not done carefully. Birds may be disoriented following handling and should be released from a sitting position on the floor and allowed to regain their balance and composure, never released in mid air.

Recommendations:

- Handle large birds firmly and empathetically to avoid injury to birds and handlers.
- Approach flocking birds slowly and deliberately.
- Do not catch birds by the wings or interlock the wings.
- Restrict the legs and prevent wing flapping when handling domestic fowl.
- Consider early and frequent, gentle handling of young birds as a way of minimizing stress if much handling is required at later ages.
- Do not carry birds upside down by their legs.
- Release large birds onto the floor.

10.3 Human safety

As most birds are extremely averse to handling, they are liable to defend themselves in a variety of ways by a combination of pecking, kicking, scratching and beating with the wings. Many fish-eating birds have hooked and serrated beaks that can cause injury to the handler, especially if they pull away. If birds are large and aggressive, it may be necessary for an assistant to hold the mandibles closed. A less preferable alternative is to use a rubber band to hold the beak closed, but this should only be done if there is absolutely no chance of the bird escaping and *never* in the field. It is also vital to ensure that the bird can breathe through the nares when the beak is closed. Other birds can also inflict injuries through fighting spurs on the tarsi (male Galliformes) or wings (e.g. spur-winged geese, *Plectropterus gambensis*).

The correct way to catch and handle each species must be demonstrated to everyone who is likely to have to do so. Although some individual birds can be dangerous, it should not be necessary to wear thick gloves when handling them. Such gloves reduce sensitivity and may mask the fact that the handler is squeezing the thorax too hard (Fowler 1995).

Recommendations:

- Make sure that correct handling techniques for each species have been demonstrated to everyone and that handlers are competent and empathetic.
- Remember that birds will defend themselves. Be prepared to restrain them firmly but do not risk obstructing their breathing or causing them physical damage.

10.4 Tonic immobility

Many species of bird appear to 'freeze' when experiencing acute fear or distress. This 'freezing', or tonic immobility (TI), is normally elicited by an encounter with a known or perceived predator and is often used as an indicator of acute fear in birds, especially poultry (Jones *et al*. 1998). The duration of TI is believed to be correlated with the level of fear experienced by the bird, although it is also affected by its social environment (Bilcik *et al*. 1998). Birds may enter a state of TI while being handled or during procedures, but TI should not be deliberately induced (e.g. by turning birds into a dorsal recumbent position) solely to keep them still, as this will cause unnecessary stress. TI should never be used in the place of chemical restraint (Section 10.6) and it must not be assumed that birds in a state of TI are unaware of what is being done to them or cannot suffer. TI is not a state of 'hypnosis'.

Recommendation:

- Do not induce TI deliberately—it imposes extra stress and is not 'hypnosis'. Birds are aware and capable of experiencing pain and fear while in a state of TI.

10.5 Reducing stress

It may be possible to reduce handling stress by habituating birds to human contact and handling from hatch (if possible), using positive reinforcement and rewards (Jones 1994, see Laule 1999). Habituation is probably the most humane approach where experimental protocols require repeated handling. Domesticated birds should therefore be used in studies unless there is a specific scientific requirement for wild species. Habituation necessitates a high degree of contact with humans so that it will not be possible to release the birds into the wild following projects, but rehoming in a private collection may be possible as an alternative. The nature, frequency and duration of habituation procedures will depend on the project, species and whether the birds were wild caught or hand reared. Some species (especially domesticated strains) readily habituate to interactions with humans, whereas others never will. A habituation programme should be set out and agreed before birds are acquired.

Rewards can be given after procedures or cleaning out, and 'treats' should also be given regularly by humans to encourage birds to view humans positively. All rewards should be positive additions to the birds' normal diet and husbandry such as favoured food items or objects, or extra positive interactions with a human (e.g. showers or games). Routine food rations or water, or conspecifics (in the case of social species) should not be withheld and used as 'rewards' without strong scientific justification. If food or water are withheld from birds, others should not be fed or given water in front of them.

Examples of rewards or treats are: water baths and turf for starlings (Gill 1994, Gill *et al.* 1995), water in food for domestic fowl, mealworms for any species that includes invertebrate food in its diet, water showers for waterbirds, games for Psittacines and corvids, and millet for seed eaters such as the zebra finch.

Recommendations:

- If protocols require a lot of handling, begin habituating birds as early as possible and reward them regularly.
- Rewards should be positive additions over and above routine food, water and social interactions wherever possible.

10.6 Chemical restraint

Chemical restraint may be necessary when undertaking scientific or veterinary procedures that should not cause pain (if competently undertaken) but which appear to stress birds, such as feather trimming or the carrying out of some physical examinations. It may also be appropriate when accuracy is required and a sudden movement may jeopardize the bird's welfare, e.g. for a biopsy under local anaesthetic. A specialist should always be consulted on the best way to restrain each species. Many of the sedatives used will be prescription-only medicines (POMs) and so will have to be administered under the direction of a veterinarian. There are several books giving advice on this, (e.g. Beynon & Cooper 1991), see also Section 12.5 for further references. Care should be taken if sedation has to be done regularly as there may be a build-up of the chemical, or alternatively birds may become tolerant to the agent and the dose may have to be increased. Often, skilled handling can obviate the necessity for chemical restraint and is probably preferable, as recovery from chemical restraint is nearly always stressful.

Recommendations:

- Do not use chemical restraint if competent and empathetic handling will have the same result and be less stressful.
- Always obtain veterinary advice when considering using chemical restraint.

10.7 Identifying individual birds

Most research projects will require individual identification of birds. There may also be legal requirements for birds to be marked in specific ways; for example, many native British birds must be close ringed (see below) when held in captivity in the UK under Section 6 of the Wildlife and Countryside Act 1981.

Birds may be identified by several methods including (from least to most invasive):

(1) Noting physical differences.
(2) Ringing.
(3) Staining the feathers.
(4) Electronic tagging.
(5) Wing tagging.

The appropriate method for each situation will depend on the nature of the project, why the identification is required, and how skilled the marker is in applying the chosen technique. These factors should be carefully considered and the least invasive method of identification should be chosen. Highly invasive marking methods such as toe clipping or web punching cause suffering and should not be used.

Observing plumage and morphological differences: Some species or strains of bird have a variety of different plumage colours and patterns, or differently shaped combs or wattles. It may therefore be possible to make a note of these and so avoid having to mark the birds at all. Such birds should therefore not be artificially marked unless there is a legal requirement to do so (e.g. for release).

Ringing: There are two main ringing systems: (i) closed rings, and (ii) split rings and either metal or plastic bands. Leg ring colours and symmetry may affect behaviour in some species (see Section 27.5.3), so it is especially important to research this before marking birds and to observe them closely afterwards.

Closed rings: Closed rings are continuous bands made of metal, plastic or a combination of both materials. The correct size ring can only be applied when the bird is a chick and the foot has not fully grown, as the ring must be able to slide over the metatarsus. The foot should be lightly lubricated before inserting all forward pointing toes into the ring, gently easing it over the ball of the foot and up the leg until all rear pointing toes are released (Fig 8). The fitted ring should be able to move freely up and down the leg but it should not be possible to remove it when the foot has fully grown. If working with birds that carry out nest sanitation, care must be taken to ensure that ringing occurs at approximately the same time as nest cleaning ceases, or an over zealous parent may attempt to throw the ring out of the nest complete with the chick.

Split rings: Split rings or bands can be applied to a bird at any stage of development. Plastic split rings come in a range of sizes and colours and are normally applied by sliding them onto a 'V' shaped applicator which opens the ring and allows the bird's leg to be placed into the opening (Fig 9). The ring can then be slid off the applicator and closed around the leg of the bird. Metal split rings are usually open in a 'C' shape and the ring is placed around the leg and closed with a pair of specialist pliers with openings appropriate to the ring size. Other types of band are spirals of plastic that can be wound onto the bird's leg or thin bands of aluminium that can be rolled around it. Larger leg bands may have clips or locking devices.

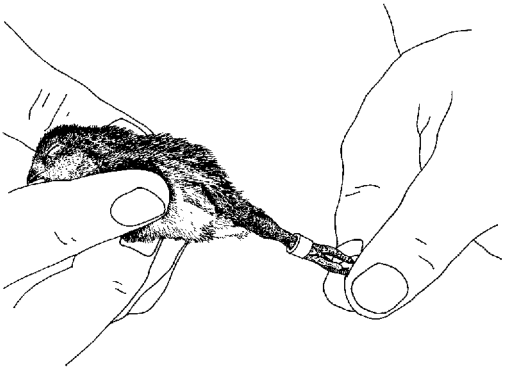

Fig 8 Fitting a closed ring—lightly lubricate the foot before inserting all forward pointing toes into the ring, gently easing it over the ball of the foot and up the leg until all rear pointing toes are released

Whichever method is chosen to ring the bird, care must be taken to ensure that the correct size of ring is chosen for the species being identified, as there are currently over 70 sizes of ring available. When using rings as temporary marking for rapid growing chicks, regular checking is essential to ensure that the ring is not impeding the growth of the

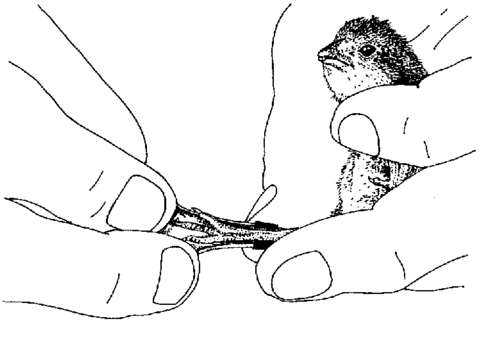

Fig 9 Fitting a split ring—use a 'V'-shaped applicator to open the ring, then slide it off the applicator and close it around the leg of the bird

leg, which could cause serious health and welfare problems, including the loss of the foot. In fast growing species such as the domestic turkey, rings should be checked every day.

Staining: Stains or dyes may be used for temporary identification, but great care must be taken when selecting colours. Red may be mistaken for blood and lead to feather plucking or cannibalism, and some colours may alter social or breeding behaviour. It is also important to ensure that all staining agents are non-toxic and non-irritant. Stains should always be applied to small areas and allowed to dry completely before returning birds to their groups. Birds with light coloured plumage may have numbers stamped onto their wing feathers with an ink stamp. All marking using stains and dyes will be lost when the birds moult and will need to be reapplied.

Electronic tagging: Electronic tagging is now commonly used for identifying birds, especially raptors and Psittacines kept in collections and as companions. Tags are either used on their own or in conjunction with external rings. A transponder is inserted into the bird using an implanting needle and gun or specialist syringe. Most suppliers recommend the insertion of the transponder into the pectoral muscle, and Kummerfeld (1998) describes a technique for intraosseous implantation, presumably relevant in cases of theft. It is certainly more difficult to remove transponders from these sites, but implantation into bone is likely to cause pain and suffering and is not justified. The left pectoral muscle has been widely used as an insertion site in birds (Nind 1999), although this may not be appropriate for small birds likely to spend a significant amount of time flying. If it is considered that intramuscular implantation could cause pain or impair movement, transponders should be implanted subcutaneously at the base of the neck.

Once implanted, the transponder can be read by an appropriate reader (Nind 1999). There are several reader systems available that are not all compatible and may have different functions. Some have the ability to record and download information into computers, which reduces operator error, others can automatically record when a bird passes a reader location point, and some can measure body temperature. This type of system may be extremely costly to set up, but running costs are minimal and transponders can often be reused.

Wing (patagial) tags: Tagging or wing banding may be carried out to permit identification of individuals either close up or from a distance, which requires larger wing badges. Wing tags are normally self-piercing and are fitted using an applicator, ensuring that they have been inserted in the correct way, so that the pin passes through a hole in the tag and rolls to lock the tag in place. Alternatively, the tag may be squeezed together by hand and the pin bent over to lock it. The larger wing badges are also self-piercing but consist of two pieces, a pin and a badge, which are applied using a pair of plier-like applicators. Both wing tags and wing badges should be placed on the patagium, taking care to ensure that the edge of the tag does not fold over the skin on the leading edge of the wing or protrude to an extent that the bird could catch a claw in it when preening (Fig 10). Wing badges should not impede flight and should always be as small as possible. Even small wing tags are likely to interfere with normal behaviour to a greater extent than the alternative methods outlined above (provided that

Fig 10 Correct placing of a wing tag—place the tag on the patagium, ensuring that the edge of the tag does not fold over the skin on the leading edge of the wing or protrude so that a bird could catch a claw in it when preening

they are competently employed), so markers should not be fixed to the wings unnecessarily.

Recommendations:

- Do not mark birds that are morphologically different or can be identified from their plumage markings unless there is a legal requirement to do so.
- Always use the least invasive identification method possible.
- Research the possible influence of leg ring colour and symmetry on behaviour in each species.
- Ensure that leg rings will not become too tight and cause injury.
- If using electronic tags, implant them subcutaneously or into the pectoral muscle, never into bone.
- Consider the effects of external, visible markers on behaviour (and predation if the bird is to be released into the field).
- Do not toe clip or web punch birds—this is unacceptable.

11 Housing and husbandry

A good standard of well-being and welfare cannot be achieved without appropriate housing, husbandry and care. This Section provides an overview of general considerations when housing birds and preventing and recognizing disease. More detailed species-specific recommendations on housing are set out in Sections 16 to 27.

11.1 Housing—general considerations

In common with many other laboratory animals, birds may spend the majority of their time in their holding cages or pens, rather than undergoing procedures. Good housing should make them feel safe, secure and able to exercise, to control their environment to a degree and to express a range of natural behaviours including interactions with conspecifics (Nicol 1995, see also FAWC 1993). Poor quality and quantity of space is likely to lead to boredom and frustration which may be expressed as stereotypic behaviour (see Section 12.6). Stereotypies should be regarded as unacceptable and are to be prevented, not just ameliorated when they occur.

Pens or aviaries vs cages: In general, birds should be housed in pens or aviaries as opposed to cages (Coles 1991). While some birds, e.g. small passerines, can be provided with an acceptable quality of life by being group-housed in large, enriched cages, larger species will require more space and should be housed in aviaries or pens. Aviary shape is also important; long, narrow aviaries that permit flight should be provided for species where this is an important behaviour. Many birds will benefit from being kept outdoors, and the feasibility of this should be evaluated case by case, with respect to the potential to cause physiological or psychological stress or to conflict with experimental aims. Birds housed in aviaries outdoors will be at some risk of contracting disease from wild populations, although this does not necessarily outweigh the advantages associated with being housed outside. Careful health monitoring and regular worming should minimize health risks. Most species are social for at least part of the year and are highly sensitive to kin relationships (Marler 1996), so the formation of stable, harmonious groups should be a priority.

Pen or cage position: Birds feel more secure and less stressed if their cage or pen is open to the room on only one side (Coles 1991), although being able to see into adjacent pens containing conspecifics will benefit social species. Most birds spend the majority of their time above the level of the human head (except for ground living species such as the quail), so cages should be well above ground level, although caretakers must be able to see inside them. This will also enable habituation to human faces, which is likely to reduce stress during routine handling and procedures.

Flooring: Species that spend a significant proportion of their time walking, such as quail or fowl, should be housed on solid floors with substrates to avoid foot lesions. Suitable substrates include chipped bark or white wood shavings but not sandpaper, which abrades the feet and may be ingested for the grit when it is faecally contaminated (Coles 1991). Birds can be prone to foot problems, e.g. overgrown claws, faecal accumulation and foot lesions, on any type of flooring, and so frequent monitoring of foot condition is always necessary. In practice, it may be necessary to consider a compromise between solid and grid flooring for scientific purposes. In such cases, birds should be provided with solid floored resting areas occupying at least one-third of the pen or cage floor. Grid areas should be located under perches if faecal collection is required. To reduce the incidence of foot injuries, all wire mesh areas should be of a suitable grid size adequately to support the foot, and the wire should have rounded edges and be plastic coated. This is especially important where large areas of wire flooring are deemed necessary, for example in toxicology or metabolism studies.

Perches: Passerines require perches of varying diameters to exercise the feet, but these should not be covered with sandpaper tubes, as these cause foot excoriation and infection and do not trim the claws (Coles 1991, Association of Avian Veterinarians 1999). Natural branches from pesticide-free and non-toxic trees may be preferable to wooden dowelling or plastic perches and can be regularly replaced (Coles 1991). Domestic fowl require perches that are flattened on the top surface. Perch positioning is very important; a single, well-placed perch may be adequate for agile climbers who prefer to roost on the highest perch, e.g. Psittacines, whereas species that fly or jump, such as finches, will require at least one perch at each end of the cage (Association of Avian Veterinarians 1999).

Good quality environments: Whether birds are kept in cages, aviaries or pens, providing them with an adequate quantity of space is not enough. Good quality space is vital for good welfare. Space can be made more complex and interesting by providing separate areas for different activities such as dust bathing, bathing in water, perching and play, as appropriate. Plants and shrubs in aviaries and pens will provide cover and a refuge for the birds, but plants poisonous to the species must be avoided.

It is fairly common practice to provide toys for mammals and to rotate toys to prevent boredom. Many birds are also likely to benefit from access to toys, but rotating them could cause unnecessary stress if birds are neophobic or have favourite toys. Careful observation of individuals will be necessary to ascertain which objects are preferred and whether there is an ongoing requirement for 'new' ones. The recommendations for environmental stimulation for each species in this report list suitable items that will help to provide an interesting indoor environment. Some individuals, especially Psittacines and corvids, may seek and enjoy interactions with humans, and provision should be made for this.

Toxicology: In general, toxicity testing is characterized by the use of relatively large numbers of birds for relatively short periods. Some current regulatory requirements are rather prescriptive in terms of what may be provided for the animals, and so their rigid interpretation may limit the application of some of the recommendations made in this report. The justification for such requirements should always be challenged and a degree of compromise introduced wherever possible, e.g. a decision may be made to house birds in groups instead of singly at the expense of individual food consumption data.

Commercial space allowances: Some research using domestic poultry needs to approximate 'farm' conditions for the purposes of the study, e.g. animal welfare projects or research into farm animal husbandry or pathologies. It may therefore be necessary to obtain strains with inherent welfare problems, and to house birds using the same space allowance that birds in commercial units would be given. This should only be done if the project is justified and directly applicable to the commercial situation. Otherwise, birds should always be given a more generous space allowance or should not have their space so restricted (see Sections 18 to 20), and strains should be selected that do not suffer from inherited pathologies or behavioural problems.

Recommendations:

- Provide a good quality and quantity of space—these are essential for good welfare.
- Choose flooring carefully to ensure good health and welfare.
- Supply birds with perches appropriate to the species.
- Position housing to minimize stress, blocking in one or more sides if necessary.
- Provide areas for activities such as dust-bathing, bathing in water, play, etc.
- Question regulatory requirements in toxicology studies if they restrict the potential to provide a good quality environment for animals.
- Do not house birds under intensive conditions.

11.1.1 *Environmental conditions*

There are a number of guidelines and codes of practice that set out appropriate temperature and humidity levels (see Appendix 1). The Working Party believes that providing birds with a range of temperatures so that they can exercise a degree of choice can often be more important than ensuring that all of their accommodation is at a prescribed, uniform temperature. For species where there are no published guidelines on temperature and humidity, the climate in captivity should be matched as closely as possible to that experienced in the field. If birds are subjected to the physiological stress of attempting to adapt to inappropriate climates, both welfare and experimental results are likely to be affected.

The avian eye functions well over the full range of light intensities at which humans function, so lighting of a brightness suitable for humans should be adequate for diurnal species, i.e. around 500 lux. A photoreceptor within the thalamus coordinates photoperiodic responses to changing day lengths in birds, and is activated when light passes through the thin avian skull (Follett 1984). Consequently, light quality and quantity may be critically important for some species at certain times of the year for normal physiological functioning. Expert advice should be sought when considering housing nocturnal or crepuscular species. Nocturnal birds such as owls may need to be able to roost in the dark during the light phase of the light/dark cycle. It is best to avoid subjecting any species to a sudden 'dawn' to 'dusk' transition by dimming and raising the lights in a ramped fashion, or by providing dim 'night lights'. This allows the birds time to find a roosting place rather than being plunged suddenly into darkness, possibly in mid flight.

The welfare implications of other aspects of light quality are less well researched, but a logical case can be made from what we know of avian vision. The 'critical flicker fusion frequency', or frequency at which a strobe light is no longer perceived as flashing, is notably higher for birds than humans (reviewed by D'Eath 1998). It would seem likely that normal fluorescent tubes, which flash at 100 Hz, would be perceived as flickering to a bird such as a starling (*Sturnus vulgaris*). High-frequency fluorescent tubes, or incandescent lighting, would therefore seem preferable on these grounds. However, a further problem is that most commercially available artificial light sources have considerably less ultraviolet (UV) light than full daylight, so that their colour balance would be likely to appear unnatural to birds. There is experimental evidence that some species make different mate choice decisions when the UV waveband is not present, most probably because the plumage (which reflects UV as well as human-visible wavelengths) appears an odd colour to the bird (Bennett *et al.* 1997).

Thus, although birds can be, and have been, kept successfully under artificial lighting, it is possible that any visual tasks based on colour (social signals, displays, foraging) are rendered more difficult. Direct effects of light on stress and welfare in birds are, as yet, little researched. However, if outdoor housing is not possible, use of special daylight-mimicking fluorescent lighting, running at high frequencies, would seem advisable (N.B. this will necessitate a DC power supply).

Recommendations:

- Research the range of temperature and humidity that each species would be subject to in the wild and match this as closely as possible, providing a degree of choice.

- Use gradual transitions from dawn to dusk for birds kept under artificial lighting, or dim 'night lights'.
- Seek expert advice before attempting to house nocturnal or crepuscular species.
- Consider using high frequency fluorescent light sources, preferably with a spectral composition mimicking daylight (i.e. with some UV component).

11.2 Routine husbandry and health care

This Section is intended to provide general guidance on bird health care; a veterinarian should always be consulted immediately if there is any doubt as to a bird's current or future health status. Everyone who is involved in using or caring for laboratory birds should be fully aware of their normal behaviour and also of behavioural signs that could indicate a departure from a state of well-being (see also Section 12.6). Stock birds should be routinely monitored at least twice a day, and those on studies should be monitored more frequently depending on the nature and severity of procedures.

The responsibility for the health and welfare of birds used in scientific procedures is primarily that of the person carrying out the research in conjunction with their veterinarian and animal technicians. For those birds being held in establishments but not being used on procedures, the responsibility lies with the technician in charge (e.g. the Named Animal Care and Welfare Officer in the UK). However, in both cases, the job of preventing, diagnosing and treating disease remains that of the attending veterinarian. Thus, the basis of a good healthcare policy will be a good relationship between these three key players and an understanding of the issues involved on all sides.

A healthcare strategy should be drawn up in consultation with the attending veterinarian for each project while it is in the planning stages (i.e. long before any birds have been acquired). This should set out how health and adverse effects will be monitored, which diseases and pathologies the species is especially susceptible to, and which preventive medicines, parasiticides and vaccinations may be necessary. A number of diseases are related to suboptimal management in birds and particular care should be taken to avoid conditions that engender these (Kirkwood *et al.* 1999).

The following references will be helpful when setting out a healthcare strategy: Beynon & Cooper (1991), Ritchie *et al.* (1994), Beynon *et al.* (1996), Fowler & Miller (1999), Samour (1999) and Swayne (1999). Virus infections and their control have been reviewed by Ritchie (1995) and McFerran & McNulty (1993). Valuable reviews of the epidemiology, dignosis, treatment and control of bacterial diseases of birds have been provided by Dorrestein (1997), Gerlach (1994) and Reavill (1996). For an introduction to parasitic diseases of birds and the control of these diseases the reader is referred to Greiner (1997). The epidemiology, diagnosis, treatment and control of chlamydia infections (ornithosis) have been described by Flammer (1997).

Recommendations:

- Monitor birds at least twice daily and make sure that everyone is aware of normal and abnormal behaviour and the clinical signs of disease in that species.
- Draw up a comprehensive healthcare plan with the attending veterinarian before any birds are acquired.
- Always consult a veterinarian at the earliest opportunity if there is any doubt as to health status.

11.2.1 Disease prevention

Regardless of whether an establishment houses a few individuals or is a large-scale user, the fundamental principles of disease prevention should always be applied. These are as follows:

- Appropriate environment
  In the sections on the different species, there is much information on accommodation requirements. However, the fundamental point that the birds kept in the laboratory are usually totally dependent on humans for their environment means

that attention must be paid to the control of temperature, humidity and especially ventilation. The stocking density will be determined by the species and the effectiveness of the ventilation system. If birds are overstocked and underventilated there will be a build-up of noxious gases and a predisposition to respiratory disease.

- Cleaned and sanitized accommodation and furniture
  Before birds are housed, the room should be thoroughly cleaned and decontaminated using an appropriate disinfectant. Useful information is to be found in Jordan and Pattison (1996) and a list of suitable disinfectants is available from DEFRA in the UK. Any utensils or caging should also be similarly cleaned. Where environmental enrichment items are included in the cage, old material is best disposed of and fresh material used.
- Good management practices
  These will include limiting access to the birds to only those people necessary; requiring coats and footwear to be changed and hands to be washed before handling birds; ensuring food and water provided is regularly changed and utensils are cleaned and sanitized.
- Source of birds
  (i) *Conventional sources:* Apart from *Coturnix coturnix* within the EU, birds used for research do not have to be obtained from designated breeders or suppliers, i.e. they can be obtained from commercial sources which include poultry breeding companies normally supplying agricultural producers. It is important, however, that as much as possible is found out about the health status and vaccinal history of birds before they are obtained. If domestic fowl are to be used for the production of egg yolk antibodies it is best, if possible, to obtain them as day-old chicks from commercial hatcheries and rear them to point of lay (16–18 weeks) at the laboratory so they are habituated to the environment. Alternatively they can be obtained as point-of-lay pullets from laboratory animal suppliers.

  The hygiene standards in commercial hatcheries are very high, and day-old chicks in the UK are vaccinated against Marek's disease if they are commercial layers and against other diseases if broilers. The normal process in both industries is to continue with a programme of vaccination which is appropriate for the end use. However, in the laboratory bird this is both impractical and probably unnecessary, provided the principles outlined here are followed. However, it is important to know the vaccinal history, both from the point of view of the scientific procedure and as background information for the attending veterinary surgeon.

  It is also worth noting that many commercial birds will be carriers of zoonotic organisms, especially *Salmonella* spp. and *Campylobacter* spp. The issue of hygiene when handling birds is therefore important for reasons of human health and safety as well as for the possibility of cross-contamination in multi-species units, e.g. salmonella may be transferred from birds to rodents.

  It may be possible to screen individual animals for the presence of zoonotic organisms, and the onus is on the recipient either to obtain birds from a source which can guarantee freedom from these organisms or to screen the animals accordingly. However, a sensible use of minimum hygiene precautions should be sufficient (Health & Safety Executive 1997).

  (ii) *Specific pathogen free (SPF) poultry:* There are a number of commercial suppliers of SPF eggs laid by domestic fowl. These can be imported as fertile eggs and hatched at the establishment if required. Again, it is important that high levels of incubator and hatchery hygiene are maintained (see Section 8.2) and, if the birds are to remain 'SPF', that they are maintained in positive pressure isolators and maintained on sterile consumables, e.g. enrichment items, bedding, feed and water.

  (iii) *Minimal disease (MD) poultry:* MD poultry are not kept under SPF conditions, but nevertheless are free from those diseases more commonly seen in conventionally kept flocks. Most birds used for research should in practice be free from any notifiable disease, any infectious diseases seen in conventional flocks and any zoonotic diseases.

(iv) *Wild birds:* Wild birds may present special problems in terms of the effects of captivity on their behaviour and health when in the laboratory situation. The health of these birds will depend to a large extent on the ability to satisfy the species' requirements in terms of environment and diet. Both the husbandry and the experimental interference can be significant causes of stress and consequently may well be associated with morbidity or even mortality if they are inappropriate or are not carried out by experienced and well-practised staff.

- Quarantine of newly introduced birds
A period of 28 days should normally be allowed where possible. During this time the birds can become adapted to the laboratory conditions and their health monitored prior to experimental work commencing. Monitoring should be agreed with a veterinary surgeon and may consist of faecal sampling and examination for the presence of parasites and bacteria, including potential zoonoses such as those caused by *Salmonella* spp. and *Campylobacter* spp. During this period birds may be treated for the presence of endo- and ectoparasites on advice from the attending veterinarian.
Ideally, groups of birds should be kept separate from other batches throughout, and an all-in/all-out policy practised, thus reducing the chance of infectious disease being passed from group to group and circulating continuously. This latter system relies on the rigorous application of the principles described above.

Recommendations:
- Obtain birds of a high health status.
- Where this is not possible, e.g. with wild birds, apply appropriate quarantine and hygiene procedures after consultation with the attending veterinarian.
- Use a structured and agreed approach to observation and, ideally, maintain objective measurements of animals (e.g. body mass).
- Quarantine new birds for 28 days where possible, monitoring health and treating for parasites.

11.2.2 Health monitoring

Early recognition of a sick bird is essential and this will most often be noticed by an animal technician looking after the birds or the scientist handling them as part of a procedure. A review of the items listed below each time a cage is inspected or room entered will help to ensure that ill-health is identified in individuals or the group at an early stage. All of the features listed require that a person is familiar with the normal activities and appearance of the species and the individual bird. The approach is based on that put forward by Morton and Griffiths (1985); also see Section 12.6 on recognizing adverse effects due to procedures or husbandry.

Diseases that pass from birds to humans are not uncommon (zoonoses) and a health monitoring system should be drawn up with the advice of the attending veterinarian and occupational health physician. Species of birds known to be carriers of certain diseases (e.g. ornithosis in Psittacines) should be monitored routinely in quarantine and regularly thereafter. Those coming into contact with these birds should wear personal protective equipment until the birds are cleared. Standard tests for zoonoses are set out in National Research Council (1997).

(i) *Observation of the individual/group at a distance:* Observation of the group without birds being aware of the observer's presence gives the opportunity to notice animals who are not behaving normally. Behaviour giving cause for concern includes birds separating themselves from the group; animals being bullied; animals with abnormal gait, swimming, flight or wing movements; birds with breathing difficulties exhibited by their mouths being open, and by gasping or tail bobbing in smaller birds, or by abnormal appearance of any sort. Identification of such changes is often necessary before disturbing the animals, as otherwise the individual affected may 'hide' the sign.

(ii) *Changes in the cage environment:* Factors that require monitoring include the appearance of the cage or room, the presence of faeces (i.e. more or fewer than normal), the colour and consistency of faeces, whether blood is present and whether the food has been eaten (N.B. a reluctance to eat may mean that there is no water).

(iii) *Changes in provoked behaviour:* When entering the room or approaching the cage, do any of the birds appear to be behaving in a manner not usually associated with that species or individual, e.g. if the birds are gregarious and normally approach a handler, are any isolating themselves from the others and showing no interest in the human's presence? More often the opposite may be the case, e.g. birds who would normally exhibit a fear response to human presence do not attempt to escape or hide.

(iv) *Clinical examination:* On handling and examination of the bird any obvious abnormalities can be noted. Some typical signs of 'ill-health' in birds include:

- raised body temperature, respiratory or heart rate;
- ruffled or soiled plumage, especially soiling around the vent;
- closed or half-closed eyes and ocular discharge;
- breathing difficulty, e.g. the mouth being open, gaping, increased rate and effort of breathing movements;
- shivering;
- discharge from the nostrils;
- failure to sit normally, e.g. adopting a hunched posture; sitting on the floor of the cage rather than perching, in some species;
- presence of lumps on the body.

(v) *Changes in physical parameters:* These may occur in the individual bird, e.g. loss of body weight, or in the group, e.g. a general increase in chick mortality or reduced egg production.

It is important that good records of these parameters are kept so that changes that may indicate a disease problem are noted at an early stage in order that advice can be sought. Any suspected injury or disease must be treated promptly and the attending veterinarian must be consulted. Consider removing the bird from the pen or cage only if problems are exacerbated by its remaining there, e.g. if conspecifics begin feather pecking. It is usually better for the veterinarian to see the bird *in situ* rather than out of the normal environment, as isolation may alter behaviour or increase stress and make the condition worse.

(vi) *Postmortem examinations:* It is important to carry out detailed *postmortem* examinations on any birds who die, in order to determine the cause(s) of death and also to detect incidental pathology which might also be indicative of suboptimal husbandry and poor health and welfare.

(vii) *Regular review of health records:* Clinical, behaviour and *postmortem* records should be subject to regular review to facilitate the detection of clusters of cases that may indicate suboptimal husbandry and welfare but which may not be apparent when dealing with incidents on a case-by-case basis (Kirkwood 1999).

Whenever such abnormal clinical or behavioural signs are observed, the investigator should investigate the cause. If it is an adverse effect expected from the scientific procedure, then its impact on the scientific validity of the experiment and the question of whether that animal may have exceeded any severity limit should be considered as a matter of urgency. If adverse effects were not expected then the attending veterinarian and the stockperson or animal technician should be consulted to ascertain the reason and whether any treatment or removal from the experiment is the best course of action. In any event, the bird should be regularly monitored and observed, and possibly isolated from the others, and if no longer scientifically useful, or is suffering excessively, should be humanely killed at the earliest opportunity.

Recommendations:
- Ensure that everyone is familiar with the signs associated with ill-health in birds.
- Keep detailed health records and review them regularly.
- Always investigate the causes of morbidity or mortality, in consultation with veterinarians and animal technicians.

11.2.3 Physical modifications

Most bird behaviours that cause or indicate welfare problems, such as stereotypies (see Section 12.6), can be reduced or eliminated by providing appropriate housing and care. Some behaviours may persist even where every attempt has been made to optimize welfare, for example large birds may attempt to fly and risk injuring themselves on pen walls, or some strains of domestic poultry may feather peck. If all attempts to eliminate these behaviours by improving husbandry and care are unsuccessful, or the species or strain is known to be prone to behavioural problems, it may be necessary to perform temporary or permanent physical modifications such as wing clipping, pinioning, tenotomy or beak tipping (as opposed to debeaking). None of these procedures should ever be performed unless it is certain that well-being will be worse if birds are left intact, i.e. they should only ever be done for veterinary reasons. Anaesthesia and analgesia must be given for all surgical procedures, including those performed on hatchlings. The development of descending inhibitory neural pathways occurs postnatally in mammals, and this lack of inhibition means that responses to all sensory inputs including pain are exaggerated (Fitzgerald 1994). We have assumed that the same is true for birds, and so pain in hatchlings must be taken seriously and alleviated wherever possible.

Where adult birds persistently attempt to fly and risk injury, flight can be limited by clipping some flight feathers from the wing with sharp scissors following each moult (Forbes & Glendell 1999). This is not a minor procedure and should be undertaken with great care, cutting the minimum number of feathers to ensure that lift and forward propulsion are limited. It is generally possible to leave the outermost four flight feathers on each wing. Permanent mutilations such as pinioning and tenotomy are usually done when chicks are less than a week old. The potential of these procedures to cause chronic pain and distress is uncertain, but they should never be performed routinely, and alternative methods of preventing flight should always be considered very carefully first. There are advantages and disadvantages associated with both temporary and permanent methods of preventing flight. Repeated cutting of primary feathers is likely to cause birds distress, which must be judged against that likely to be experienced by pinioned or tenotomized birds who will be unable to fly and may also experience chronic pain. The long-term implications for the birds' welfare and survival must also be considered, as a permanent inability to fly may also affect the potential to rehome them.

Birds kept in 'farm' conditions (see Section 11.1) may well develop stereotypic or abnormal behaviours that will cause welfare problems, such as feather or vent pecking. Many instances of abnormal behaviours are due to underlying management problems that should always be addressed before resorting to permanent physical modifications. If there is a justifiable reason (i.e. one not relating to staff levels or expense) for not giving the birds more space, using less aggressive strains or otherwise improving their environment, then it may be necessary to address this using beak tipping or by fitting 'spectacles' to prevent feather pecking in fowl (see Gentle 1992). The welfare impacts of stress caused during the procedure and any resulting chronic pain constitute part of the welfare 'cost' of a project, and so beak tipping or fitting 'spectacles' should never be carried out without strong veterinary justification.

As these procedures involve sensitive tissue and will cause pain, appropriate anaesthetics and analgesics should always be administered and animals monitored closely for subsequent adverse effects. However, no analgesic has yet been found to be fully effective for alleviating the chronic pain that can occur following debeaking in adult birds, just as phantom limb pain in humans is very difficult to treat (M Gentle, personal communication). The justification for beak tipping should therefore always be questioned very strongly, all other means of preventing feather pecking should be evaluated first and no more than the 'hook' of the beak should ever be removed. Similarly, gonadectomy procedures should be taken as seriously as any experimental procedure and effective anaesthesia and analgesia should be given (see Section 12.5).

Recommendations:

- Choose strains of birds that are less likely to develop behavioural problems such as aggression.
- *Always* administer appropriate anaesthetics and analgesics to all birds undergoing surgical procedures, regardless of their age.
- Pinioning and tenotomy are mutilations and should rarely be necessary unless they are fully justified on veterinary grounds.
- Do not beak tip birds without strong veterinary justification, as this can cause chronic pain that is impossible to treat.
- Do not use domestic poultry strains with behavioural problems or pathologies unless the project is directly applicable to improving the welfare of that strain.

12 Routine scientific procedures

Birds are used in research for a variety of different purposes (see Section 2), but care should always be taken to ensure that experimental procedures are refined to reduce suffering as fully as possible. In this report, procedures have been broadly divided into blood sampling, substance administering and surgical procedures, but it is the responsibility of the investigator continually to obtain up-to-date knowledge on best practice for each procedure in each species.

12.1 Blood sampling

There are three sites in birds that are commonly used for collecting blood samples: the right jugular vein, the ulnar vein and the medial metatarsal vein. Blood sampling from the left jugular vein should not be attempted in birds, due to its relatively small size, but the right jugular can usually be seen beneath the skin to the side of the trachea by blowing under the neck feathers to expose the skin. Once the course of the vein is visible, feathers can be parted to expose the skin by gentle wiping with cotton wool soaked in surgical spirit. The ulnar vein runs across the ventral surface of the elbow (Fig 11) and can be readily seen at this site in almost all species—in penguins it can be palpated but cannot be seen due to the dense plumage. Here again, feathers can be parted by wetting with surgical spirit to provide a good view and uncluttered access to the vein. The medial metatarsal vein can be seen or palpated on the medial aspect of the tarsus in larger birds. There should be no need to remove feathers when blood sampling from birds. Pressure above the vein will cause a

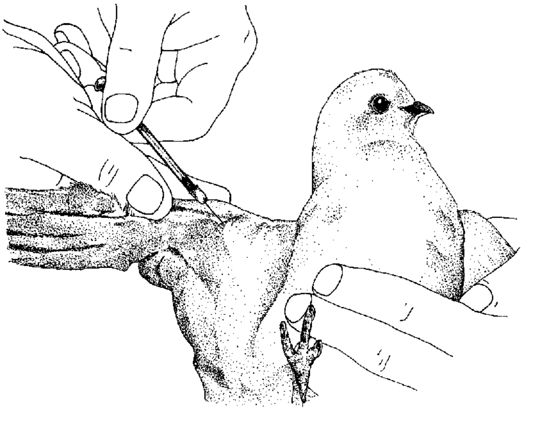

Fig 11 Locating the ulnar vein—this runs across the ventral surface of the elbow and can be readily seen in almost all species

back pressure of blood and make it easier to palpate and see the vein.

The choice of site depends upon the size of the bird, the ease with which the vein can be located, and the ease of access to the veins in the restrained bird. The easiest site to access is often the right jugular in smaller birds (<100 g), the medial metatarsal vein in larger birds (>1–2 kg), and the ulnar in mid-range birds. The number of serial samples required and the intervals between them are also factors in deciding sampling sites. Repeated sampling from the same vein or site may cause the vein to collapse or become partially occluded, resulting in necrosis of the tissues supplied by the vein. This can be avoided by changing sampling sites, e.g. by alternating between ulnar and medial metatarsal veins, but sampling must be discontinued if veins become damaged. Long-term venous cannulae can be implanted in larger species such as the domestic fowl. The right jugular vein is the preferred site, otherwise the ulnar vein is also acceptable (Morton *et al.* 1993).

It is easy to tear the fragile wall of a vein if the bird struggles during venepuncture, and this can lead to blood loss or haematoma formation. This is a particular risk when the ulnar vein is used. Bleeding or haematoma formation can be minimized by using a fine needle (e.g. 25- or 27-gauge), by gentle pressure with cotton wool on the venepuncture site for a few moments following withdrawal of the needle, and then by very careful gentle lifting off of the cotton wool so as not to disrupt the clot. It is important that the bird is carefully restrained by an assistant and that the person taking the sample is in a comfortable and stable position, preferably with both elbows resting on a solid surface to steady the hands.

Sampling methods that are likely to cause moderate or substantial suffering, such as toe clipping in small birds, should never be used as there are more humane alternative routes. Cardiac puncture should only be carried out under terminal anaesthesia, and not be done with recovery and repetition unless there is compelling scientific justification. Birds permitted to recover from anaesthesia following cardiac puncture should always be carefully monitored for compromised heart function due to bleeding into the pericardial sac (see also Section 12.5 on postoperative care).

The blood volume in birds is approximately 7 ml per 100 g, and a useful rule of thumb is that for a one-off sample 0.5 ml blood per 100 g body weight can be safely withdrawn. Great care must be taken to avoid haematoma and bleeding in very small birds, as the loss of a couple of extra drops of blood can represent a significant proportion of the circulating blood volume and hence prove fatal. Even small volumes removed at too frequent an interval will cause anaemia. This should be avoided whenever possible, and it is essential to be able to recognize the signs and symptoms of anaemia and to be able to take appropriate action (Morton *et al.* 1993).

For further guidance on blood sampling in general see Harrison & Harrison (1986) and Ritchie *et al.* (1994); and on refinements in blood sampling with particular reference to the domestic fowl see *Removal of blood from laboratory animals and birds* (Morton *et al.* 1993).

Recommendations:

- Select a site appropriate for the size of the bird and experimental protocol.
- Reduce the risk of haematoma formation by ensuring that the bird is carefully restrained, using a fine needle and applying pressure to stop bleeding effectively.
- Do not perform cardiac puncture unless the bird is under general anaesthesia and not allowed to recover, unless there is compelling scientific justification otherwise.

12.2 Administering substances

It is not necessary to pluck feathers when administering substances by injection. Dampening feathers with alcohol and parting them gives adequate access to the skin and permits the bird to preen them back into place following the procedure.

Intravenous injection: Commonly used sites for intravenous injection are the ulnar, right jugular or medial metatarsal veins. Adequate restraint is vital and the smallest gauge needles possible should be used for injecting birds intravenously. The injected volume should be no more than 5 ml/kg for all species (Morton *et al.* 2001).

Subcutaneous injection: Subcutaneous injections can be given under loose skin in the back of the neck, the medial aspect of the thigh, or at other sites as appropriate. The maximum dose is 2 to 5 ml/kg in all species (Morton *et al.* 2001).

Intramuscular injection: Intramuscular injections can be given into the pectoral or thigh muscles, although for caged birds the pectoral muscles are usually the site of choice since the birds are not dependent on flight. Intramuscular injections are painful, can interfere with mobility, and have the potential to cause necrosis if inappropriate volumes are administered, so subcutaneous injection is to be preferred where possible. If intramuscular injections cannot be avoided, large volumes should be divided among separate sites, e.g. at least 4 cm apart in the domestic fowl, and the total dose should not exceed 0.05 ml/kg in any species (Morton *et al.* 2001). Great care must be taken to avoid nerves and blood vessels by (i) researching their positions in each species, (ii) not inserting the needle too deeply and (iii) withdrawing the plunger slightly to check that a blood vessel has not been penetrated (Morton *et al.* 2001).

Intraperitoneal injection: Intraperitoneal injections should not normally be administered to birds as the substance may enter air sacs and affect their function (Morton *et al.* 2001).

Oral administration: Oral preparations (solid or liquid substances) can be administered fairly easily and safely to most birds. Administration by including the substance in food (e.g. treats) or water is to be preferred wherever possible, but oral gavage may be necessary for unpalatable substances or where precise dosing is required. The opening to the trachea is, in most birds, readily visible in the floor of the mouth, and easily avoided provided due care is taken when passing a tube into the oesophagus or when gently pushing solid substances down into it (Fig 12). These procedures require two persons: one to restrain the bird and open the beak, and the other to pass the tube or administer the substance. The bird should be handled firmly but gently in these procedures, and catheters to be inserted into the oesophagus should be lubricated adequately and handled carefully to avoid trauma to the pharynx and oesophagus. The maximum oral dosing volume is 10 ml/kg for all species (Morton *et al.* 2001).

For guidance on administration by all routes, see Harrison and Harrison (1986), Ritchie *et al.* (1994), *Refining procedures for the administration of substances* (Morton *et al.* 2001).

Recommendations:
- Ensure that the least invasive method of administration is always used and only exceed the recommended doses with good scientific justification.
- Never pluck feathers.
- Avoid intramuscular injections wherever possible; but if this is unavoidable then do not exceed the recommended total dose and split large doses between sites.

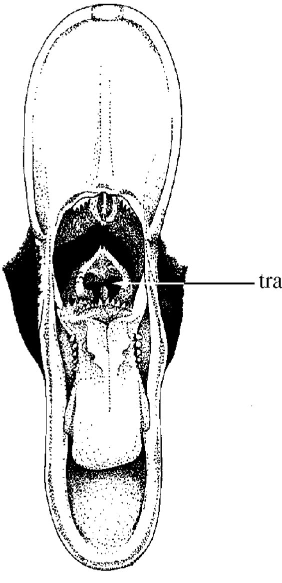

Fig 12 Locating the oesophagus—care must be taken to avoid the trachea when inserting a tube or substance into the oesophagus

12.3 Surgical procedures

Surgical procedures may be carried out on birds for a number of reasons, for example to carry out sexing or gonadectomy, to perform biopsies, to implant telemetry devices for physiological studies or to introduce labelling compounds for fundamental neurological research. Refinement of both the surgical procedures and postoperative care so that stress and suffering are minimized is vital both for good welfare and for obtaining reliable scientific data. It is essential that anyone who is responsible for performing surgical procedures on birds or for their postoperative care is fully trained and competent to carry out the procedure successfully and aseptically, and to recognize adverse effects that may occur as a result. Sections 12.4 to 12.6 below apply equally to surgical procedures in the laboratory and the field. When undertaking surgery in the field, there must be a designated operating area which functions to aseptic standards (see Section 6.1.3.1).

12.4 Pre- and intraoperative care

Some differences in approach are needed in avian anaesthesia compared with that of mammals because of differences in anatomy and physiology. However, the aims of anaesthesia should still be to provide a smooth, reliable induction with adequate restraint, muscle relaxation, and analgesia, followed by a fast, but full, uneventful recovery (Lawton 1996a,b).

12.4.1 Pre-anaesthetic considerations

There are some important characteristics of avian anatomy and physiology that have a direct bearing on the management and maintenance of anaesthesia. Listed below are the most important considerations for preparing for avian anaesthesia:

(i) *Trachea:*

- The avian trachea has complete interlocking rings, which are cartilaginous in some species and ossified in others. When intubation of birds is to be undertaken it should therefore not be carried out with a cuffed endotracheal tube as this could damage these complete rings (Fitzgerald & Blais 1993).
- The tracheal length and volume is greater in birds, giving a dead space some 4.5 times that of mammals. Conscious birds compensate by increasing their tidal volume and decreasing respiratory frequency (Fedde 1986). This increased tidal volume must be maintained during anaesthesia, to prevent hypercapnia, and this is best achieved by intermittent positive pressure ventilation (IPPV).

(ii) *Air sacs:*

- These are present in all birds and act as bellows and reservoirs when breathing. Most birds have nine air sacs; some penetrate the bones and some extend outside the body cavity and terminate subcutaneously (Fedde 1986).

(iii) *Lungs:*

- These are relatively rigid and do not move appreciably during respiration. Birds have no diaphragm and so the lungs do not collapse when the coelomic cavity (thoracic cavity) is entered surgically (or with an endoscope).
- Expiration and inspiration is on muscular movement which causes a 'pumping' effect by compressing and expanding the thoracic skeleton (keel), and so a tightly held bird will have great difficulty in breathing. A deeply anaesthetized bird may not generate sufficient muscular contractions to allow adequate pumping of air back through the lungs. Sinn (1994) advised the routine use of IPPV (20–40/min at 15 mmHg) to overcome any possibility of hypercapnia and to maintain adequate oxygenation.
- The avian lung is a 'flow-through' system (i.e. air flows in one direction only, as contrasted with the tidal

system in mammals). This arrangement allows the bird to be artificially ventilated via either the trachea or an abdominal air sac tube.

(iv) *Gaseous exchange:*

- Gaseous exchange within the avian lung relies on a cross-current exchange system which causes a potential increase in the partial pressure of carbon dioxide (PCO_2) in expired air and an increase in the partial pressure of oxygen (PO_2) within the blood. Avian lungs are considered to be 10 times more efficient than mammalian lungs (James *et al.* 1976).

(v) *Ventilation triggers:*

- Inhalation of CO_2 stimulates ventilation (breathing). There are known to be CO_2 receptors in the carotid bodies and the intrapulmonary chemoreceptors, and CO_2 also directly stimulates the nervous system (Fedde 1986).
- A reduction in the PO_2 stimulates the carotid bodies.
- Pain will stimulate respiration.
- Increases in body temperature will cause a thermal polypnea, but not usually hyperventilation. Under anaesthesia, subjecting the larynx and trachea to cold gases is known to slow breathing or may even produce apnoea.

(vi) *Pre-ananesthetic starvation:*

- Birds are prone to hypoglycaemia and should not be starved prior to gaseous induction (Lawton 1997). Cooper (1989) stated that small birds should never be deprived of food for longer than 3 h.
- Starvation may reduce hepatic detoxification of certain anaesthetic agents (Carter-Storm 1988).
- Regurgitation is seldom a problem in granivorous Psittacine birds, unlike waterfowl or frugivorous birds, where a period of starvation has previously been recommended (Mandelker 1987).

12.4.2 Anaesthesia

Anaesthesia can be induced with gaseous or injectable agents. If isoflurane is used, anaesthesia can be induced in the majority of birds (but not in some diving birds) with minimum stress using a face mask applied directly over the beak and nares. There may, however, be occasions when an injectable agent may be required. If an injectable agent is to be used, then the bird must be accurately weighed. Without an accurate weight it is not possible to calculate an accurate dose, and there will be the possibility of an overdose or even a fatality.

Endotracheal intubation should be used once anaesthesia has been induced, although it is possible to maintain anaesthesia with a face mask alone. Endotracheal intubation allows maintenance of anaesthesia and also assisted ventilation should apnoea occur. Intubation of birds is easy, due to the forward placed glottis behind the base of the tongue (see Fig 12).

Where an endotracheal tube is likely to restrict access, air sac intubation should be performed. Air sac tubes can be placed in a number of sites. A site on the left side, just behind the ribs is traditionally used, although Sinn (1994) has suggested the use of short endotracheal tubes or rubber tubes inserted into the clavicular or caudal thoracic air sacs. The placement of the air sac tube is usually performed after induction of anaesthesia by face mask or anaesthetic chamber. As large a tube as possible (French gauge 14) should be placed and attached to the anaesthetic circuit. IPPV via the placed tube is required whilst the bird is under anaesthesia, as birds with air sac intubation will usually stop breathing spontaneously due to the expulsion of all carbon dioxide from the respiratory system (Korbel *et al.* 1993). In the recovery procedure, the ventilated bird will not breathe again spontaneously until perfusion via the air sac has been terminated and the blood carbon dioxide levels have risen.

There are a number of anaesthetic agents that historically have been used for the induction and maintenance of birds.

- Ether can be dismissed on the basis that it is unsafe. The safety margin is below that of more modern anaesthetic agents and there is a risk of explosion. Ether is irritant to the mucosa and may predispose to respiratory infections.
- Methoxyflurane has previously been used with very good results. However, the lack of its availability and the requirement of a specific vaporiser, together with the disadvantage of a relatively prolonged recovery period, have virtually removed its use from avian practice.
- Halothane is not as safe for use in birds as it is in mammals, and residue in the air sacs can lead to prolonged recovery or overdose. It has also been found to cause muscle myopathy in poultry, but this can be reduced by minimizing the duration of anaesthesia and ensuring that post-operative care and monitoring are of a high standard (Mitchell *et al.* 1999).
- Isoflurane is the agent of choice. It is safe (Rosskopf *et al.* 1992), and the blood gas partition coefficient is very low (1.4 at 37°C) which allows rapid induction and rapid recovery from anaesthesia, with less retention in the body tissues than compared with halothane. Virtually no metabolism occurs, so recovery is by exhalation. For example, isoflurane (2%) has been used for the maintenance of anaesthesia for a period of 4.5 h in a golden eagle (*Aquila chrysaetos*) yet recovery was still rapid, occurring within 6 min, and the bird was considered to be fully recovered within 21 min (Clutton 1986).
- Ketamine (20–50 mg/kg s.c., i.m., or i.v.) was first used in birds in 1972 (Mandelker 1972). It was widely used but is now used less often in avian practice. Recovery is dose related. Ketamine used by itself is a good sedative but a poor anaesthetic agent, providing poor muscle relaxation and little analgesia, although there is little respiratory or cardiovascular depression.
- Ketamine 10–30 mg/kg i.v. with diazepam 1–1.5 mg/kg i.m. or 0.2 mg/kg midazolam s.c., i.m. is a better combination when compared with ketamine alone, allowing a smooth induction and recovery. The benefit of midazolam is that it can be mixed in the same syringe as ketamine, while diazepam has to be given as a separate injection.
- 1.5–2 mg/kg ketamine + 60–85 μg/kg medetomidine i.m. has the advantage that it can be partially reversed using atipamazole (250–380 μg/kg i.m.). The addition of medetomidine provides sedative and analgesic properties, with good muscle relaxation but no cardiac arrhythmias or respiratory depression (Jalanka 1989). Medetomidine has hypotensive, bradycardic and hypothermic effects.
- Alphaxalone/Alphadalone was considered a relatively good anaesthetic agent (Harcourt-Brown 1978). There is a wide safety margin but the agent has a relatively short duration (Mandelker 1987). The large volumes required (5–10 mg/kg) make i.v. the preferred route, but there are now better alternatives to this agent.
- Propofol (1.33–14 mg/kg i.v.) has a very high safety margin and is rapidly metabolized. This agent produces a very smooth, rapid induction of anaesthesia with good muscle relaxation. The anaesthesia has a short duration of 2–7 min (Heard 1997).
- Tiletamine/Zolazepam (5–10 mg/kg i.m.) provides good immobilization and is considered to be safe (Kreeger *et al.* 1993).

12.4.3 Intraoperative monitoring

The depth of anaesthesia may only be correctly controlled if the bird is carefully and continuously monitored. The approach to anaesthetic monitoring in birds is the same as for mammals, although it is considered to be more challenging (Flammer 1989). Monitoring should not be restricted just to the state and depth of the anaesthesia but also to the condition of the bird.

(i) *Reflexes:* The best reflexes to monitor are the palpebral, corneal, cere, toe pinch and wing twitch reflexes. As the bird becomes more deeply anaesthetized, the standard reflexes usually slow and decrease in strength, or will eventually disappear. The toe, cere and wing reflexes disappear as the bird enters a medium plane of anaesthesia. The corneal reflex is usually the last reflex to be abolished and shows that the bird is very deeply anaesthetized (Lawton 1996a).

(ii) *Circulatory volume:* Birds are thought to be better able to tolerate blood loss than mammals (Heard 1997) although haemorrhage should still be regarded as a serious problem and should be avoided. The amount of blood loss during surgery should be carefully monitored (if necessary by weighing swabs) and fluid therapy or even a blood transfusion should be considered if there are any concerns regarding blood loss.

(iii) *Heart rate:* Wherever possible, the use of a cardiac monitor is recommended, although an oesophageal stethoscope can be of use (Lawton 1993). The standard lead placements for use of an ECG are over the distal lateral tarsometatarsus and the carpal joints of each wing (Burtnick & Degernes 1993) using atraumatic clamps or silver needles. Sudden elevations in heart rate during surgery are useful indicators of an inadequate depth of anaesthesia. The heart rate should never fall below 120 bpm in any species of bird (Doolen & Jackson 1991). Doppler flow apparatus can also be used to monitor heart rate and may also give an audible signal of arterial blood flow (Heard 1997). Pulse oximeter usage is also advantageous. The pulse oximeter probe can be placed in the cloaca or oesophagus or, in non-pigmented or lightly-pigmented birds, a standard 'C' clamp probe across the tarsus can be used.

(iv) *Respiration:* The pattern of respiration is also important; it should be continually monitored during anaesthesia to ensure that it is stable (Lawton 1993). Electronic monitoring of respiration is considered to be the best indicator of the depth and stability of anaesthesia in the absence of response to pain. A sudden change in the pattern, and especially in the depth of respiration (from shallow to deep) may indicate that the bird's plane of anaesthesia is lightening or the bird is feeling pain. As the bird enters a deeper plane of anaesthesia, the rate and depth usually decrease. Depending on the bird's body size, the respiration rate should not fall below 25–50 bpm (Doolen & Jackson 1991); below this there is a risk of hypercapnia. The respiratory rate of any anaesthetized bird should never fall below half the normal resting rate (Coles 1985).

(v) *Temperature:* Warmth should be provided before induction, during anaesthesia, and in the recovery period. Anaesthetized birds may not be able to maintain their core body temperature adequately. Hypothermia can cause peripheral vasoconstriction, bradycardia, hypotension and, when severe, ventricular fibrillation (Heard 1997). The core body temperature of birds is usually between 40 and 44°C (Carter-Storm 1988), and 41°C in smaller birds (Cooper 1989). Excessive removal of feathers or preoperative washing or application of surgical spirit at the site of surgery will result in lost insulation and heat loss. Anaesthetized birds should be placed onto a towel or insulated 'Vetbed'; the use of heating pads or lights can also help to reduce heat loss but care must be taken to prevent overheating or burns. Bubble wrap or 'space' sheets can also be used for wrapping most of the bird up to prevent unnecessary heat loss. The use of Op-site (Smith and Nephew) will reduce the need to pluck a bird, and yet will maintain an adequately clear surgical site. Cold anaesthetic gases will also have a chilling effect on the bird, but there is little that can be done to prevent this other than keeping the overall length of anaesthesia time to the shortest possible.

(vi) *Pain:* The response of the bird during surgery to painful stimuli will often show as a change in respiration, heart rate or movement. The control of pain both during and after an anaesthetic is essential.

12.5 Analgesia and postoperative care

Analgesia: Postoperative analgesia should be administered routinely to all laboratory animals. However, some may argue that this is not necessary, giving reasons such as the perception that there are no objective criteria for assessing pain (but see Section 12.6), or the belief that pain benefits animals because it immobilizes them and prevents them from causing further damage, or because of concerns about the side effects of analgesics. All of these beliefs have been discredited (Morton & Griffiths 1985, Flecknell 1996, Blogg *et al.* 1998, Flecknell & Waterman-Pearson 2000), and the current consensus is that analgesia should always be provided for animals undergoing surgical procedures unless there is a very strong scientific justification not to do so. Pain relieving agents should be administered to birds before anaesthesia is terminated so that analgesia can become effective before they regain consciousness. Pain relief is likely to be necessary for the first 24–48 h, depending on the invasiveness of the surgical procedure.

The provision of analgesia postoperatively can be of concern because of the apparently hyperalgesic effects of morphine-like compounds in some strains of domestic fowl. However, by combining careful monitoring of the parameters outlined above, such as food and water intake, and the bird's physical condition, e.g. body weight, it should be possible to produce a reasoned case for the administration of analgesic drugs after surgery that would normally be required in other species.

Kappa opioid agonists appear to be most effective in some species of bird, so if an opioid is to be used, an agent such as butorphanol may be most effective. Alternatively, non-steroidal anti-inflammatory drugs (NSAIDs) such as carprofen, ketoprofen or flunixin can be administered. The following agents are commonly used:

- Buprenorphine (0.02 mg/kg i.m.) is an opiate analgesic which provides effective pain relief in mammals. In birds, its efficacy and duration of action are uncertain.
- Butorphanol (2 mg/kg i.m.)—its efficacy has been demonstrated in analgesiometric tests in Psittacines, but no controlled studies of its clinical efficacy or duration of action are available.
- Carprofen (5–10 mg/kg i.v., i.m. or p.o.), ketoprofen (5–10 mg/kg i.m.) and flunixin meglumine (1–10 mg/kg i.m.) have all been recommended for the provision of postoperative analgesia in birds. Although no controlled studies of its efficacy and duration of action have been undertaken, carprofen is currently considered to be the most effective agent. In situations where severe pain is anticipated, or where analgesia appears inadequate, opioids and NSAIDs should be given in combination.

For further information on bird anaesthesia and analgesia, see Flecknell 1996, Coles 1997, Heard 1997, Clyde & Paul-Murphy 1999, Flecknell & Waterman-Pearson 2000 and Paul-Murphy & Ludders 2001.

Postoperative care: The provision of postoperative care in birds has to be based on a clear understanding of the physiological differences between birds and mammals. The implication of having a fixed-lung volume and a uni-directional airflow is that birds are prone to hypercapnia during anaesthesia and in the recovery period and, therefore, it is important to ensure that they are well oxygenated on recovery from anaesthesia. This can be done by supplying oxygen to the bird during anaesthesia and on recovery. Birds also lose a lot of water from the respiratory tract, especially during gaseous anaesthesia, which causes dehydration. Thus it is appropriate to humidify anaesthetic gases by passing them through warm water. Dehydration is an especial postoperative problem in small birds, and they should be encouraged to drink early on in the recovery period either by drip-feeding water or by ensuring they have free access to water. They should also be given fluids before recovery, administered by a slow, intravenous route during surgery and/or subcutaneously following surgery, depending on the nature and duration of the surgical procedure.

Because of their high metabolic rates, birds maintain relatively high body temperatures. During anaesthesia, control of thermoregulation is lost, and there is a risk of hypothermia especially in small birds. This hypothermia should be prevented by careful insulation of the bird where possible and by supplemental heating, but with care being taken to monitor the body temperature. This should be continued into the postoperative phase for as long as is necessary to ensure the return to a normal temperature. Care must also be taken to ensure that well-insulated temperate or polar species do not become hyperthermic during recovery.

Postoperative husbandry: This will depend in part on whether birds have been hand-reared or obtained as adults. For example, hand-reared birds may respond well to being spoken to and stroked for 30 min to one hour, placed in a heated box for 30 min to one hour (depending on their speed of recovery) and then returned to their group in their usual holding pen. Such a protocol requires a high level of supervision, as the birds will need to be watched closely to ensure that the post-operative birds continue to recover and are not attacked by conspecifics, but recovery may be faster (Blogg *et al.* 1998). Birds who are less habituated to humans may find such close attention stressful (although not always), so interactions with them should be kept to the minimum necessary to ensure that they are recovering safely. The most appropriate postoperative husbandry regime for particular groups of birds will also depend on their housing, e.g. birds with ponds will need to be monitored for longer in case they might drown.

Studies in domestic fowl with experimentally-induced sodium urate arthritis have found that birds subsequently housed in large pens with litter and companions exhibited less pain-related behaviour and lameness than those housed in standard cages (Gentle & Corr 1995, Gentle & Tilston 1999). This suggests that it is especially important to provide a complex environment for birds who may be experiencing discomfort or pain, as mental stimulation will help to divert attention and aid endogenous analgesia (Gentle 2001).

Recommendations:

- Take the special needs of birds into account during anaesthesia, surgery and when providing postoperative care—do not assume that their physiology or requirements are the same as those of mammals.
- Give all birds postoperative pain relief, administering the first dose before the birds recover consciousness.
- Ensure that birds do not become dehydrated; fluids must be available and administered via a drip if necessary.
- Place birds in a heated incubator or cage for recovery, housed in a quiet area with subdued lighting.
- Monitor and maintain body temperature closely throughout recovery.
- Leave most birds alone to recover with minimum interference apart from necessary monitoring, but try speaking to and stroking hand-reared birds during recovery.
- Maintain adequate supervision after the birds have regained consciousness and been returned to their group.
- Consider how a stimulating postoperative environment could be provided to aid endogenous analgesia.

12.6 Monitoring for adverse effects

It is reasonable to assume that procedures or conditions that would cause suffering to humans will also cause animals to suffer, so it is humane to treat birds as one would wish to be treated oneself, and relieve pain, suffering or distress wherever possible. It seems likely that many species of bird have evolved so as to conceal obvious signs of pain, distress or disease, which could result in avoidable suffering if an effective system for monitoring adverse effects is not in place. This includes postoperative pain, experimentally induced and naturally occurring disease, adverse side effects of pharmaceuticals, and effects of toxic substances in safety tests. Rapid recognition of pain and distress is absolutely vital if humane endpoints are to be employed effectively in toxicological and pharmacological studies. Birds should never be placed in conditions where they are unable to display signs of discomfort, e.g. a bird placed in a small box may not move either because there is insufficient space for normal movement or because of experiencing pain.

A 'score sheet' approach has been successfully used to evaluate adverse effects, including postoperative pain, in many animals including tufted and mallard ducks (see Morton & Griffiths 1985, Morton 1990, 1997, Blogg *et al.* 1998, Morton 1998a,b; see also Appendix 3 for sample observation sheet). Following procedures, body mass, temperature and simple behaviours including eating, drinking and preening should be monitored as well as more subtle, species-specific indicators such as interaction and communication with other birds, posture, e.g. whether ducks' tails are held down on the water, and other gross indicators of malaise in birds such as 'slitty' eyes. Behaviours and other indicators can only be allocated a negative (–) mark if they are deemed to be 'normal', or a positive (+) mark if they are not normal and so giving cause for concern. A score sheet with predominantly negative signs is an indicator that a bird is well, although the scoring system must only be regarded as a recording tool to provide useful guidance rather than a definitive measure of well-being (Blogg *et al.* 1998).

Similar scoring systems could easily be devised for all species of bird and types of procedure as well as for general record keeping, but they must be specific for each species and experimental procedure. Note that observation sheets are flexible and can continually be reviewed and updated using the comment boxes; it may not be necessary to include the large number of clinical signs set out in Appendix 3. Other indicators of suffering that could be useful score sheet entries include unusual tameness, reduction in behavioural repertoire, sudden quietness (especially with Galliformes), a 'fluffed up' appearance, or hiding. It is essential that staff devise and work through the sheets together to ensure that everyone is scoring the same clinical signs and behaviours in the same way. Descriptions for normal and abnormal behaviours need to be agreed and it may be necessary to obtain guidance on measuring bird behaviour (Miller 1988, Martin & Bateson 1993).

Acute fear and chronic distress: Acute fear may be expressed by escape behaviours or a bird entering a state of tonic immobility (TI); see Section 10.4. Exaggeration of 'comfort' behaviours, e.g. preening, after exposure to a potential stressor is less obvious but can provide a retrospective indicator of the nature and intensity of distress. Chronic distress may be indicated by stereotypic behaviour. A stereotypy has been defined as a repeated pattern of movements which shows little or no variation and has no obvious function (Manser 1992), such as circling, pacing or pecking at one spot. Stereotypies are generally associated with poor welfare (inappropriate husbandry or environment) and are regarded as indicators of an inability to cope with physiological or psychological stressors. Stereotypies may have different causes (Keiper 1969) but most can usually be greatly reduced or eliminated by improving animals' environments, for example by providing better quality and quantity of space and companions where appropriate. Any abnormal behaviours should be taken seriously as being indicative of a welfare problem and should be regarded as unacceptable.

Examples of abnormal behaviours that should cause immediate concern are: apathy, aggression, autophagia (self-biting), back somersaults (in the case of starlings), feather plucking or 'feeding' feet (in the case of parrots), head weaving, pacing (e.g. in the case of broody fowl without a nest box), route-tracing, self-mutilation, spot-pecking, twirling and wing flicking.

Recommendations:

- Take pain in birds seriously: many species have evolved so as to conceal pain but this does not mean that they are not suffering or that there is no need to do anything about it.

- Make sure that everyone responsible for bird welfare can recognize pain and distress in order to alleviate suffering and employ humane endpoints.
- Devise and agree observation sheets for each species and type of procedure; and also for general record keeping of well-being.
- Make sure that everyone is aware of indicators of acute distress such as tonic immobility and exaggerated 'comfort' behaviours.
- Regard all abnormal behaviour as an indicator that birds are unable to cope with their environment, and therefore unacceptable—ensure that strategies are in place for dealing with this.

13 Rehoming or release following procedures

The period when birds are housed in a laboratory and undergoing procedures should be regarded as one episode in their lives rather than their reason for existing, and so every attempt should be made to rehome or release them after experiments have finished unless there is a legal or compelling welfare or scientific reason not to do so. Many species of bird could potentially live for another 15 to 20 years after the projects have ended, and killing healthy animals is ethically questionable and frequently regarded as distressing by those whose job it is to do it. The potential for releasing birds to the wild or, if this would not be humane, rehoming them to private care (e.g. to join a bird collection or as a companion animal) should therefore be given serious thought when planning a research project.

The future quality and quantity of life that rehomed or released birds will experience should be weighed against the likelihood of the birds suffering as a consequence of having been involved in research, and decisions should be made on a case-by-case basis. Consultation with the attending veterinarian is vital when planning a rehoming strategy. The UK Home Office will consider releasing animals from the controls of the A(SP)A, but it has to be authorized by the Project Licence. The animals have to be certified fit for rehoming or release by a veterinary surgeon (or other suitable person with knowledge of the species), i.e. they are not suffering or likely to suffer and will have an acceptable quality of life (see Home Office 1998). The last three criteria will also apply to other countries where research is regulated differently. For an example of veterinary checks and procedures conducted as part of a falcon release programme, see Lierz and Launay (2000).

If birds are to be released, human responsibilities toward them do not end as soon as the cage door is opened. There are a number of ethical and legal factors that must be considered and expert guidance must be sought from organizations such as the RSPB, US Fish and Wildlife Service, or their equivalents. The welfare and environmental implications are broadly similar to those that apply when releasing a rehabilitated wild bird (based on BWRC 1989, Scullion 1991, Kirkwood & Sainsbury 1996, 1997, see also Cuthill 1991):

- Was the bird captured from the wild? In general, only birds taken from the wild should be released, although some species may be able to adapt if supported initially.
- Is the bird fit and not likely to suffer as a consequence of reduced fitness?
- Is the bird imprinted on humans and if so will this affect its ability to survive (Section 8.4)?
- Has the bird learned inappropriate reponses to predators?
- Is the environment suitable—are adequate food and unoccupied territories available?
- Is the bird healthy and not carrying any infectious diseases that could be spread (Section 11.2.2, IUCN 1999)?
- Is the bird of a different genetic strain from those in the area where it is to be released—will its offspring be adapted to the local environment?
- Is the bird an indigenous species—could it damage the local ecosystem?
- Is the bird a 'pest' species that it would be illegal to release (e.g. non-native species

such as the Canada goose (*Branta canadensis*) in the UK)?
- Will it displace a resident of the same species, to the detriment of the latter?
- If the bird is of a highly social species, are there conspecifics living in the area?
- Is it an appropriate time of year—should the bird be about to migrate, or is it the breeding season, when territorial conflicts are more likely to occur?

If there is any doubt regarding any of these criteria and the problem cannot be resolved (e.g. by releasing somewhere else or at another time), then birds should not be released. They should be rehomed in a collection, provided that they are sufficiently fit, where conditions can be more closely controlled and monitored. It is then the responsibility of the user to ensure that they will continue to receive a good standard of husbandry and care, including veterinary treatment should they need it, and that the owner of the collection will not routinely carry out mutilations such as pinioning or tenotomy (see Section 11.2.3).

Birds taken from the wild and kept in the laboratory for short periods should be released at the site of capture early in the morning and during favourable weather (Gaunt & Oring 1999). If birds have been hand-reared or kept for longer periods, great care must be taken when considering releasing them. It may be necessary to hold them in an enclosure and feed them artificially while they are adjusting to their new conditions. For example, seabirds and several terrestrial species (e.g. desert birds) have accessory salt secreting glands above the eyes that assist the kidneys with osmoregulation (Simon 1982). Adaptation to salt stress is a slow process, so birds reared with access to only fresh water must be given an acclimatization period before they can be released into salt- or brackish-water habitats (Baudinette *et al.* 1982). Each release of hand-reared birds must be considered on a case-by-case basis and expert advice should be sought from organizations such as the RSPB, WWT and equivalent European organizations or the US Fisheries and Wildlife Service.

The likelihood that the change of environment when birds are released or rehomed will cause excessive stress can be greatly reduced by providing an interesting environment with novel stimuli in the laboratory. It has been known for a long time that animals such as rats who have been reared and kept in a complex environment have more highly developed brains than those kept in a barren environment (e.g. Bennett *et al.* 1964) and more recent studies indicate that the same is true for marsh tits, *Parus palustris* (Clayton & Krebs 1994) and garden warblers, *Sylvia borin* (Healy *et al.* 1996). Animals reared and housed in a stimulating environment may consequently be better able to cope with change and novel stimuli (Wemelsfelder & Birke 1997). It is therefore vital to provide a stimulating environment not only to improve welfare while birds are kept for research but also to fulfil the moral responsibility to enable them to have an acceptable quality of life afterwards.

Recommendations:
- The welfare of individuals must be paramount when considering the fate of birds.
- The possibility of rehoming or releasing should be fully considered both at the project planning stage and when research has ended; birds should not routinely be killed.
- When making a decision, the probable quality of life that the birds can be expected to have after release or rehoming should be weighed against their likelihood of suffering.
- If rehoming to a collection, welfare standards must be as good as, or better than, those at the establishment where the birds have been housed previously.
- All legal, practical and ethical considerations (with respect to the bird as an individual and to the environment) must be fully considered before releasing birds to the wild.
- A stimulating environment should be provided to enable birds to adjust more rapidly when rehomed or released.

14 Euthanasia

In this Section, 'birds' refer to all adult and juvenile birds and hatchlings and also to embryonic birds. Humane killing will be necessary if it would be unethical or illegal to release or rehome birds, if a study requires their tissues, if they are suffering unpredicted adverse effects during a study, or if a determined humane endpoint is reached. It is essential that anyone who is required to kill animals is humane and competent, handling the animals empathetically and ensuring that they lose consciousness as quickly as possible. Nobody should be asked to kill animals unless they are fully trained and willing to do so.

Chemical agents: The most humane method for killing birds is the administration of an overdose of a suitable anaesthetic agent by an appropriate route, i.e. by intravenous, intraperitoneal, intramuscular or subcutaneous injection, or by inhalation. Inhalation is suitable for all birds, using either a face mask for large birds or a chamber for smaller species. Diving birds and some others, e.g. mallard ducks, can slow their heart rates and hold their breath for long periods, so care must be taken to ensure that they do not recover from the anaesthetic. Injectable agents e.g. sodium pentabarbitone can be administered intravenously into the ulnar or medial metatarsal vein for medium or large birds such as pigeons or domestic fowl, and this is probably the most preferable method, in the opinion of the Working Party. The agent may have to be injected intraperitoneally in smaller birds and embryos, so that handling stress is reduced but loss of consciousness takes longer.

Physical methods: The preferred physical method of killing for birds (up to 3 kg only) is dislocation of the neck. This technique is humane provided that it is carried out competently and in an environment that is familiar for the birds, but has the potential to cause substantial suffering if performed inefficiently. It is therefore vital that nobody should attempt to kill birds using physical methods unless they have practised extensively on dead birds and are confident and willing to proceed. It is good practice not to kill birds within the sight of others and this is especially important where physical methods are used. There are several guidelines for the humane killing of animals, e.g. Schedule 1 to the UK Animals (Scientific Procedures) Act 1986 (Home Office 1997, www.homeoffice.gov.uk/animact/hc193.htm), European Union Guidelines (Close *et al.* 1996, 1997). Instantaneous mechanical destruction (IMD) devices, i.e. rollers or macerators, are frequently used to kill chicks in commercial hatcheries (Humane Slaughter Association 1999), but the Working Party does not believe their use in a laboratory situation to be justified.

Carbon dioxide: Exposure to carbon dioxide is a widely used method of euthanasia for mammals and birds (Close *et al.* 1996, 1997). Opinion is divided on its acceptability as it appears to be aversive to some animals, which is likely to cause distress (e.g. Raj 1996, Humane Slaughter Association 1999, Leach *et al.* 2001). Ducks and diving birds should never be killed using carbon dioxide because they possess physiological mechanisms that enable them to withstand hypercapnia and can therefore take a comparatively long time to die. Very young chicks are also highly resilient to carbon dioxide because it accumulates in the air space before hatching (Jaksch 1981) and so can also take a long time to die (M Raj, unpublished observation on domestic fowl and turkey chicks during exposure to concentrations of less than 80% in air). Little research has been carried out to evaluate the aversiveness of CO_2 in adult birds of other species, but studies in rats and mice have shown that carbon dioxide is severely aversive and that halothane is the least aversive of a range of inhalational anaesthetics (Leach *et al.* 2001). Responses in birds are likely to be similar (M Raj, personal communication), so the Working Party recommends that birds should be given the benefit of the doubt and euthanased with injectable or inhalational anaesthetic agents (e.g. halothane) wherever possible, perhaps followed by CO_2 when they are unconscious.

Embryonic birds: It is possible to kill embryonic birds using an overdose of anaesthetic, and this is the preferred method in the opinion of the Working Party.

Recommendations:
- Do not ask anyone to kill animals unless they are fully trained, competent, confident and willing to do so.
- Do not kill birds within the sight of others.
- Kill birds using an overdose of a suitable anaesthetic agent administered by intravenous injection or inhalation wherever possible.
- If a physical method must be used, dislocation of the neck is the most humane method. Ensure that persons carrying this out are fully competent and adequately trained.
- Avoid carbon dioxide euthanasia as this could cause distress; use injectable or inhalational anaesthetics instead or until consciousness is lost.

15 Reporting bird use

Good animal welfare is absolutely essential for good science, and so refinements to husbandry and procedures are both central to the experimental protocol and should always be reported in published papers. It is therefore unfortunate that the 'methods' section of scientific reports often omits information on sources of animals, husbandry, methods of euthanasia and even numbers of animals used (Smith *et al.* 1997). Detailed communication about husbandry and procedures is especially important when reporting studies on unusual or wild species of bird, but papers on all birds should include the following minimum information within the methods section.

- Source of birds (with reasons for choosing that source).
- Species, race and age.
- Number of each sex (unless determining sex would cause avoidable distress).
- Date and duration of experiments (which is especially important for physiological studies on wild species).
- Whether the birds were moulting.
- Incubation and rearing, where applicable.
- Diet, including dietary enrichment.
- Housing, including pen or cage sizes.
- Environmental conditions.
- Environmental stimulation.
- Training and rewards, where applicable.
- Anaesthetic and analgesic agents and doses, where applicable.
- Postoperative care, where applicable, with score sheets on cardinal clinical signs and actions.
- Eventual fate of the animals (with reasons).

It is commonly believed that such detail is inappropriate and that journal editors would refuse to include more information on refinement due to lack of space or because it is not the convention. The Working Party believes, however, that it is the responsibility of those using animals to make a case for including more detail on both scientific and welfare grounds. Information on husbandry and care can also easily be summarized so that length is not an issue (GV–SOLAS 1985, Morton 1992, Smith *et al.* 1997).

Recommendation:
- Include information on refinements in housing, husbandry, scientific and veterinary procedures when publishing the results of studies using birds.

PART 2 SPECIES SECTIONS

16 Seabirds

Most research on seabirds involves field studies, and they are rarely kept in the laboratory for anything other than very short periods. Research projects using seabirds are generally energetic studies where precise measurements of energy balance and assimilation efficiency are required, or investigations of particular aspects of foraging behaviour such as diving performance. The difficulties in replicating natural conditions, and the changes in behaviour and physiology that are likely to occur, make seabirds unsuitable subjects for prolonged study in captivity.

There are a number of considerations that are particularly important when planning studies involving any species of seabird. Wild-caught seabirds are likely to be very nervous and some species will become highly stressed when kept in captivity. Many species are especially liable to feather damage, due to handling or abrasion, loss of waterproofing, respiratory and digestive disorders and malnutrition (Swennen 1977). Seabirds are generally monomorphic, and thus it is difficult to distinguish males and females. It can also be very difficult to rear physiologically and behaviourally normal seabirds from eggs or nestlings (see below). These factors can lead to serious welfare problems and significantly increase the severity of a project, so very strong justification indeed is needed for such studies. Specialized, outdoor housing will be required for most species, and the maintenance will be time consuming and expensive.

A broad range of expert advice should be sought when planning a project, and no attempt should be made to rear or keep any species of seabird unless it is certain that appropriate husbandry and care can be provided. A number of species, particularly penguins, are often kept in zoos, either outdoors or in refrigerated indoor facilities. Individual research projects can rarely emulate the enclosure facilities provided by a good zoo, and researchers should therefore endeavour to cooperate with such an establishment wherever possible. Swennen (1977) set up a large-scale research facility for keeping seabirds in The Netherlands. His publication provides a detailed account of the conditions required and of the problems likely to be encountered, but is poor in its guidance on environmental stimulation. Robinson (2000) provides guidance on water quality, seabird husbandry, parasites and diseases. It is also essential to search the literature to obtain as much information as possible on the ecology and behaviour of seabirds in general and the study species in particular (e.g. see Ashmole 1971, Nettleship & Birkhead 1985, Furness & Monaghan 1987 and references therein for general information; also detailed reference works such as Snow & Perrins (1998) for individual species accounts).

Recommendations:

- Avoid studies that involve keeping seabirds in captivity wherever possible.
- Consider consulting a good zoo about bird husbandry.

16.1 Natural habitat and behaviour

The term 'seabird' covers a broad range of avian species that feed in marine environments from the high polar regions to the tropics. The main seabird groups, involving some 274 species, are distributed across four taxonomic orders: the Sphenisciformes or penguins; Procellariformes or tube-nosed birds such as albatrosses and petrels; Pelecaniformes, which includes gannets, cormorants, shags, tropic birds, frigate birds and pelicans; and Charadriiformes, a large and diverse order of birds within which the gulls, terns, noddies, skimmers, alcids and skuas are placed. Certain sea ducks and divers are also sometimes termed seabirds. Seabirds vary considerably in their physiology, behaviour and ecology and therefore also in the extent to which they can be successfully kept in captivity, and in their welfare requirements. While this section will set out broad recommendations that apply to seabirds in general, it is important to obtain specialized information for the particular species in question.

Seabirds may inhabit inshore or offshore zones, either remaining in one zone or varying their habitat during the year, e.g. by moving inshore during the breeding season. Some families, including the Alcidae (alcids or auks), exclusively inhabit marine areas, whereas species such as the cormorant (*Phalacrocorax carbo*) and many of the gulls can occupy marine and freshwater habitats and can often be found well inland.

Particular consideration should be given to providing opportunities for seabirds to express their typical foraging behaviour when devising housing and husbandry protocols. For example, some species, such as the gulls, often feed by scavenging, as well as surface plunging, while others, such as penguins and alcids, generally dive for their prey. Information on diet and feeding behaviour can be obtained from the literature and by consulting ecologists and zookeepers. Social behaviour and time budgets vary widely between species, so accurate information on the species in question is vital to ensure that birds' behavioural and physiological needs can be adequately met.

Recommendations:

- Do not make any assumptions about habitat or behaviour without thoroughly researching individual species and seeking expert advice.
- Find out about diet and feeding behaviour in the wild and provide appropriate food.

16.2 Housing and water quality

It is extremely difficult and expensive to provide good quality housing for seabirds that permits the expression of a wide range of natural behaviour. Some seabirds have been reported to survive well in captivity if they are kept in dry cages, protected from rain and wind, and either only permitted to enter water occasionally or not at all (Swennen 1977). However, this is not compatible with the Five Freedoms or with current thinking about laboratory animal husbandry. Seabirds should not be kept in such unnatural conditions unless there is reason to believe that survival would be poor (i.e. more suffering would be caused) if they were housed otherwise and the project is likely to provide direct ecological or veterinary benefits.

Pens or aviaries vs cages: Seabirds should be housed in large outdoor pens or aviaries rather than in cages wherever possible. A generous space allowance is necessary, both to include a pond and to allow sufficient space for short flights (if appropriate). The size and behaviour of seabirds vary considerably, but the minimum pen area should be 20 m^2, including a pond of at least 15 m^2. The pond should be at least 50 cm deep for surface feeders and shallow plunge divers and at least 1.5 m deep for divers.

Some projects may require accurate monitoring of food intake and faecal output, in which case it may be necessary to house the birds in cages. The potential for soiling and feather damage is greatly increased when seabirds are kept in cages, and it may be necessary to house the birds on grid flooring to minimize this. Birds should only be kept in these conditions for very short periods of time (hours or days, never weeks) and must be monitored carefully for foot lesions and welfare problems throughout the study. Environmental stimulation should be provided for birds housed in cages (see Section 16.5).

Water quality: Ideally, seabirds should be housed with constant access to salt water. It is vital to maintain the quality of the water surface to ensure that the birds' feathers retain their integrity and waterproofing. In the absence of vertical turbulence generated by waves and tidal action, a film of organic molecules forms at the surface, reducing the surface tension. Seabird feathers are no longer water repellent at low surface tensions, and this is evidenced by spreading wet patches that may lead to chilling and drowning if the birds cannot leave the water (Swennen 1977). Continuously circulating water with a system of filters and skimmers must therefore always be provided for seabirds (see Swennen 1977). A salinity of 34 parts per thousand should be aimed for, although a degree of hypersalinity can be tolerated (Swennen 1977). It may be necessary to control algal growth in outdoor pools, but care should be taken to ensure that any chemical algicides are non-toxic and will not cause respiratory problems.

Many species of seabird regularly drink and bathe in fresh water, and some, e.g. the cormorant and many gulls, can thrive equally well on salt or fresh water (Finney 2000). However, this cannot be applied to all species. Failure to fulfil the criteria for good water quality is liable to cause many species substantial suffering and distress. No birds should be obtained until the pool has been demonstrated to run efficiently, and water quality should be monitored continuously. In periods of very cold weather, some heating may be required to prevent pools from freezing.

Flooring and substrate: Although many seabirds spend extended periods at sea, some flooring will always be necessary to enable them to leave the water for roosting and preening. A ramp with a non-slip surface should be provided, which is especially important for juvenile birds. Some species, such as the petrels, do not walk well, and need to be closely monitored to ensure that they are not spending protracted periods out of the water. Foot lesions and infections (bumblefoot), infection of the legs and joints with *Staphylococcus* spp. and pressure sores may occur if seabirds are forced to spend long periods on hard flooring.

Suitable substrates for seabirds should be textured or uneven so as to spread the birds' weight variably over the weightbearing surface of the lower limb. Suitable materials include pea gravel, textured rubber or plastic matting (solid or perforated), clay, cat litter, swimming pool 'anti-fatigue' matting and natural or artificial rocks (Robinson 2000). Heavier bodied species such as gannets (*Sula bassana*) are also vulnerable to feather abrasion and pressure sores around the sternum. Foam rubber sheets (or camping bedrolls) will help to prevent this, but some species, e.g. alcids, will remain vulnerable to feather soiling and damage if they do not have constant access to good quality water for bathing and swimming. All substrates must be easy to clean so that accumulation of guano and waste food, which can cause gastrointestinal infection and infection of any lesions that occur, can be minimized. New 'oxygen disinfectants' are generally safe and effective for cleaning flooring and substrates (Robinson 2000).

Preventing aspergillosis: Many seabirds, other than some gulls and terns, rarely come into prolonged contact with vegetation, so they are especially susceptible to infection from microorganisms that reproduce on vegetation such as the fungus *Aspergillus* spp. Exposure to untreated wood and damp vegetable matter should therefore be minimized or eliminated for such species, and seabirds should never be handled after other birds. Stressed birds are particularly susceptible to infection, so their husbandry should meet their needs, and disturbance should always be kept to a minimum and procedures should be refined to reduce stress as far as possible (Moberg 1985).

Birds may not exhibit clinical signs of aspergillosis until the disease has progressed to an untreatable stage, but surviving birds can be dosed with itraconazole (10 mg/kg/day) to suppress any latent infections. Species that are particularly susceptible to aspergillosis, such as alcids and penguins, can be dosed with itraconazole as a prophylactic during stressful periods e.g. before transport or rehousing, or while on procedures (I Robinson, personal communication, see also Redig 1993, Stoskopf 1993). Note that veterinary advice and supervision is essential when setting up management regimes to minimize the risk of, and to treat, all diseases.

Recommendations:

- Do not keep seabirds in dry cages without access to water unless health and welfare would be worse if they were housed otherwise and the project is likely to provide direct ecological or veterinary benefits.
- House seabirds in outdoor pens or aviaries rather than cages wherever possible.
- Provide constant access to good quality salt water pools, and fresh water as

appropriate, but enable birds to leave the water at any time.
- Do not obtain any birds until the water system is running efficiently.
- Ensure that birds' feathers are waterproof and that birds are spending sufficient time on the water.
- If a project requires caging, monitor behaviour and conditions carefully and provide environmental stimulation.
- Ensure that stress and infection are minimized, with veterinary input as appropriate.

16.3 Rearing and feeding chicks

Rearing: Breeding seabirds in captivity for research projects is usually not a realistic proposition, due to their low reproductive rate and deferred maturity. Most species produce only a small number of eggs, and do not breed until they are at least 2 or 3 years old, and sometimes not for 8 or 9 years. It may be possible to obtain eggs or chicks from the wild, but many seabird species are highly protected and it is important to consult the relevant licensing authorities at an early stage (see Section 6.1.1). It is generally very difficult to rear seabird chicks, as they require a great deal of parental attention and specialized diets, and are prone to foot lesions and diseases such as aspergillosis (see Section 17.2). Unexplained mortality, stunted growth and poor waterproofing have been reported in alcids reared from eggs (Hawkins *et al.* 1995), which can cause serious welfare problems. Greater success has been reported when rearing from chicks collected when between 3 and 13 days old (see Swennen 1977), but hand-reared birds will not be suitable for release and it may be difficult to locate an establishment with suitable facilities for rehoming. It is therefore preferable to use fully grown birds, unless the project specifically requires juveniles or involves a long-term study. Bear in mind however that seabirds are generally very long lived, and in captivity many species will live well in excess of 20 years.

Feeding chicks: Most seabird chicks are semi-precocial and are fed by one or both parents several times a day while they remain on the nest. It will be necessary to ascertain how many times a day chicks are fed and whether they receive whole fish or regurgitated fish or oil, so that whole or mashed fish can be provided as appropriate. In many of the gulls, very young chicks are fed mashed earthworms in the wild, and this may be because of particular digestive, handling or nutritional requirements. Seabird chicks may take food from tweezers and this method should be attempted first every time the chicks are fed; if the chicks will not take food voluntarily then they will need to be force-fed. The beak should be opened by gently pressing at the base, never the tip, taking care not to twist the mandibles. The fish should be pushed partly down the oesophagus, avoiding the glottis, which can be seen opening and closing as the bird breathes. The bird should be allowed to swallow for itself wherever possible, although it may be necessary to massage the throat. One person should generally be able to do this unassisted, and chicks may find the procedure less distressing if they are allowed to remain on the floor rather than being picked up. Birds may need to be distracted after swallowing to prevent them from disgorging the fish, or it may be necessary to hold the head up and the mandibles closed for a short period. The chicks should be encouraged to eat for themselves by offering fish in shallow bowls of salt or fresh water. Dark coloured bowls will draw the birds' attention to the fish, and communal species may be stimulated to eat in the presence of others (Robinson 2000).

Recommendations:
- Use wild-caught full-grown seabirds if necessary.
- If birds must be reared, collect chicks near to fledging as distinct from very young chicks or eggs.
- Do not force-feed birds unless they refuse to take fish for themselves.
- If birds must be force-fed, do so empathetically and encourage them to eat for themselves.

16.4 Diet

Expert advice should be sought from zoos or wildlife rehabilitators on appropriate food species at each life stage, supplemented with guidance from the ecological literature. Many fish eaten by seabirds in the wild are commercially available for either human or animal consumption, such as sandeels (*Ammodytes* spp.), sprats (*Sprattus sprattus*), herring (*Clupea harengus*) and some invertebrates, e.g. the blue mussel (*Mytilus edulis*). Crustaceans such as crabs and prawns are suitable for some species. Many species take fish offal as part of their natural diet, and some such as gulls and cormorants often take freshwater fish also (Finney 2000). Gulls are omnivorous, and will usually take a wide range of food, including commercial cat and dog food. Some seabirds occasionally take small pieces of seaweed such as *Fucus* spp., which can be collected from the field, although care must be taken to ensure that any foods collected for birds are free from contamination. Consideration should also be given to the size of fish and invertebrates offered to birds, as alcids prefer to take fish far below the maximum size that they can physically swallow (Swennen 1977, Swennen & Duiven 1991), and species feeding on invertebrates may also select prey of a smaller size than is commercially available. It should be noted that the nutritional composition and fat content of fish can vary considerably throughout the year. For example, the fat content of sprats is ~25% in August, but decreases to around 11% in February (P Budd, personal communication). It may be necessary to buy fish when the fat content is optimal and freeze it for consumption later. Many species can be fed to appetite, but some, e.g. gulls and skuas, may overeat and become obese if fed *ad libitum* (Robinson 2000).

Thiamine: Thiaminase, which breaks down the vitamin thiamine, is present in the tissues of some fish. Feeding birds on stored fish alone may therefore present a risk of thiamine deficiency. However, there is little evidence that this is a problem in practice in seabirds (although it can be fatal in sea mammals). The common practice of feeding seabirds thiamine supplements tucked into the opercula or gut of fish is also likely to be of little benefit, as thiaminase is present in high concentration in the gills and guts and will rapidly break down all the thiamine in the supplements. If there is a genuine concern that birds are not getting sufficient thiamine, supplements should be given either on their own an hour before feeding, in gutted and degilled fish an hour before feeding, or parenterally (I Robinson, personal communication). Birds may still benefit from the addition of multivitamin supplements to the diet, but care should be taken to ensure that vitamin levels are appropriate (see Section 9). The attending veterinarian should be consulted to help make an accurate diagnosis.

Recommendations:

- Feed birds on the same type of food that they would take in the wild wherever possible.
- Ensure that food offered is of an appropriate size and nutritional composition.
- Make sure that any supplements given to seabirds are necessary and appropriate.

16.5 Environmental stimulation

Many seabirds spend much of the year at sea, actively foraging in an extremely complex environment. It is therefore vital to provide them with good quality space in captivity, even though this may result in an environment that differs from the marine habitat to which a species is adapted.

16.5.1 Good quality environment

Suitable environmental stimulation for seabirds can be provided in the form of objects to manipulate, or water features. Objects include 'Kong' toys on ropes, plastic floating toys and stones. Some ideas for water-based enrichment are misting, soaker hoses, waterfalls, SCUBA bubbles, ice piles, snow balls, ice in trays and dripping water. Other possible enrichments are recordings of bird sounds and moving or rearranging the birds' loafing areas (A Sandos, personal communication). Cormorants have also been observed passing twigs and pieces of bark to one another (Finney 2000).

Recommendation:

- Experiment with (and evaluate and publish) environmental stimulation in the form of both toys and water features.

16.5.2 *Foraging behaviour*

Seabirds exhibit a range of foraging behaviours, but species can be roughly divided into four groups; surface dipping from the air (e.g. terns), surface feeders (e.g. fulmars), plunge divers (e.g. gannets), and pursuit divers (e.g. alcids). Many gulls regularly take prey in terrestrial habitats. Natural feeding behaviour can be encouraged in many species by throwing the birds' food onto the water so that they can plunge dive as it sinks or retrieve it from the bottom. Wing-propelled divers such as alcids should never be pinioned, as this will seriously compromise their ability to behave naturally (see also Section 11.2.3). The Working Party does not recommend the feeding of live vertebrate prey; foraging time can be prolonged instead by using slow release PVC feeders, floating feeders or floating rafts stuffed with fish (A Sandos, personal communication). Traffic cones suspended upside down under water and filled with fish, so that one fish at a time can be removed from the tip, have been found to increase fitness, time spent in the water and natural foraging behaviour in zoo penguins (UFAW 1999). Regular weighing will ensure that birds are feeding adequately.

Seabirds housed with access to salt water can be provided with 'live' rocks, i.e. rocks covered with seaweed, barnacles, limpets and other invertebrates for foraging, although the scope for providing this is likely to be more limited in the laboratory. Holes can be drilled in logs and filled with mealworms, grubs or refrigerated crickets (Neistadt & Alia 1994), although care should be taken to avoid aspergillosis. It may be preferable to construct feeders from lengths of plastic pipe as an alternative. Fresh or frozen bivalves also encourage foraging, and some species may benefit from seaweed being thrown into their pool, especially if it contains small arthropods (Neistadt & Alia 1994).

Alcids are inquisitive and will play with and manipulate plastic or rubber toys, especially when they are buried in piles of shaved ice (Sandos 1998). A floating feeder constructed of marine foam used for building boats and covered with sculpting epoxy, attached to the poolside with metal hooks can be filled with a portion of their usual diet (Sandos 1998).

Recommendations:

- Extend foraging time using a variety of feeders.
- Do not give live vertebrate prey.

16.5.3 *Group size and composition*

Social conditions will very much depend on the species involved, the size of housing areas and the age of the birds. In general, most people who have kept seabirds in captivity have found that they prefer to be housed at least in twos. Even some relatively aggressive species, such as skuas, have been found to do better in small conspecific groups than alone (Furness & Bearhop, personal communication). Most species feed and roost in flocks, and are likely to find solitary confinement stressful. Providing there is sufficient access to food, dominance-related problems are unlikely to occur. In some species, such as gulls, adults may attack young chicks so care should be taken if housing small chicks with unrelated adults.

Recommendations:

- Do not house seabirds singly.
- Ensure that individuals have adequate access to food.
- Take care to avoid possible predation on young chicks by older birds.

16.6 Training and rewards

The potential for training and habituation to humans varies considerably between species. Gulls habituate very easily, and often breed and feed around humans, but interpretations of work on penguins which monitored their heart rate has suggested that they may not habituate so well (see Culik & Wilson 1995). Behavioural passivity may not be a good indicator of stress levels (see Section 12.6), so close monitoring will be required to ensure that the husbandry system is appropriate and that birds are not unduly stressed (see also Section 11.2.2). Suitable rewards for seabirds include mealworms, frozen fish cubes and squid (heads or whole) (A Sandos, personal communication).

Recommendation:
- Try using rewards to habituate seabirds to handling and procedures, but minimize handling if this is stressful.

16.7 Potential health and welfare problems

- Feather damage and loss of waterproofing—keep birds on salt water, ensure that water quality is good and that they can leave the water to preen and roost if necessary. Ensure that the flooring substrate can be kept clean and will not abrade the feathers (see 16.2).
- Foot lesions, joint infections, pressure sores—do not provide uniform, hard surfaces; flooring should be uneven to spread the birds' weight or made from soft materials if necessary (see 16.2).
- Aspergillosis and other opportunistic infections—minimize or eliminate exposure to untreated wood and damp vegetable matter; never handle seabirds directly after other species and reduce stress wherever possible. Consider dosing with itraconazole as a prophylactic (see 16.2).
- Stunted growth—use adult birds if possible; if chicks must be reared then collect them when as near to fledging as possible (see 16.3). Ensure that the nutrient content of the diet is appropriate (see 16.4).
- Boredom/stereotypic behaviour—group-house birds and provide good quality and quantity of space (see 16.5).

17 Ducks and geese

Wild and domestic geese and ducks are often used in fundamental research, for example to study the physiological responses to flight or diving, thermoregulation or avian neuroanatomy. This often involves surgery with recovery, to implant telemetry or data logging devices or to introduce neurotracers. Fundamental research using waterfowl may have a direct ecological application or may be undertaken to add to biological knowledge. Domestic ducks are used in medical studies as models for human hepatitis, although they do not show clinical signs of the disease (Jilbert 1999), and in toxicology studies relating to environmental impact assessment.

Waterfowl have been used by humans for eggs, meat and feathers for thousands of years, and varieties of ducks and geese have been domesticated for at least 4000 years. Domestic geese and ducks have been selected for meat and egg production, but all breeds retain most of their 'wild type' behaviour and are generally more nervous and easily upset than other domestic fowl.

17.1 Natural habitat and behaviour

Ducks, geese and swans belong to the family Anatidae, which includes over 140 species distributed worldwide. All are wetland specialists, so are primarily adapted to locomotion and feeding in water and have varying abilities to walk and feed on land. Most species live on or near freshwater ponds, rivers and lakes, although many inhabit or feed at brackish estuaries and some are marine. Ponds and lakes are used by ducks and geese for feeding, mating (in large-bodied domestic birds) and as a refuge, particularly at night. Water is also very important for 'comfort' behaviours such as bathing and preening.

All geese (and swans) belong to the Anserini, a tribe within the subfamily Anserinae. Geese are sexually monomorphic and are exclusively vegetarian. They are adapted mainly for feeding and grazing on land, so their legs are positioned centrally under the body for efficient walking and running. Ducks are mostly sexually dimorphic and different species may be vegetarian, carnivorous or omnivorous. The several tribes of duck within the subfamily Anatinae are adapted for feeding on land and/or water to varying degrees, ranging from the Anatini or dabbling ducks (e.g. the mallard *Anas platyrhynchos*), which feed mainly in shallow water and walk well on land, to the

Mergini or sea ducks (e.g. the surf scoter *Melanitta fusca*), which have wide bodies with the legs set far back for powerful swimming and diving and are rarely seen far inland. Food habits vary within each species, depending on local food availability, the season and whether the birds are growing, moulting or breeding (Cantin *et al.* 1974, Brown & Fredrickson 1986, Paulus 1988).

Migration and breeding: Some species of ducks and geese migrate between summer and winter habitats, which are typically north temperate or Arctic and temperate zones, respectively. Birds become physiologically prepared for long flights, which includes building up the pectoral muscles and laying down subcutaneous and visceral fat reserves. The body mass of waterfowl can therefore fluctuate considerably throughout the year (Owen & Black 1990, Saunders & Fedde 1994).

Many species of waterfowl live in large flocks during autumn and winter and most form pairs while at their wintering grounds and migrate to the breeding grounds together. The breeding season for most temperate species lies between February and July, and mating follows a species-specific courtship display. Females lay clutches of eggs that range in number from around four (e.g. barnacle geese *Branta leucopsis*) to 15 or more (e.g. mallards, tufted ducks *Aythya fuligula*). Incubation is undertaken by the female alone in the majority of species, beginning when the penultimate or final egg is laid and lasting between 22 and 36 days (Owen & Black 1990). Most ducks can partially replace a clutch of eggs if it is lost during the early stages of incubation, but this is rare in geese. All ducklings and goslings are precocial and receive a varying degree of parental care.

The majority of waterfowl are monogamous, i.e. one male and one female pair remaining together exclusively for at least one breeding season and sometimes for life. Duck pairs remain together until the female has begun incubation, when the males leave; pairs may reform on the wintering grounds, but long-lasting bonds are rare. Geese, however, often form stable pairs that last for a number of years and barnacle geese have been found to pair preferentially with birds from their own breeding areas (Choudhury & Black 1994). Male geese usually help to rear goslings, and family groups may remain together for extended periods, whereas most female ducks are left to care for the young alone and the brood disperses after the ducklings have fledged (Owen & Black 1990).

Moulting: Geese moult once a year after the breeding season, whereas most ducks moult twice a year so that their breeding (nuptial) and non-breeding (eclipse) plumages are different. The eclipse plumage is displayed during the moult of flight feathers and is less colourful than the breeding plumage. All geese and some ducks shed all the flight feathers simultaneously during moulting and are flightless until the new feathers have grown. This is often associated with 'moult migrations', where birds move to safer areas during the flightless period. This lasts for between 3 and 5 weeks and is often accompanied by a decrease in flight muscle mass (Owen & Black 1990, Saunders & Fedde 1994). The behaviour patterns of some species may also alter while their mobility is restricted, which includes changes in feeding times and stronger responses to stimuli interpreted as threatening (Kahlert *et al.* 1996). Moulting birds may therefore require extra consideration, i.e. they should always have a refuge where they can feel secure, and disturbance should be minimized.

Recommendations:

- Find out about the habitat and natural behaviour of each species of duck or goose at the project planning stage, before any birds are obtained.
- Be aware that birds will become prepared to migrate and that their mass will fluctuate seasonally.
- Give special consideration to birds who are moulting and keep disturbance to a minimum.
- Remember that all waterfowl are liable to be nervous and need kind, empathetic handling and husbandry.

17.2 Housing and space requirements

Ducks and geese should always be kept outdoors or have access to outdoor runs unless there is a strong scientific or veterinary justification for keeping them indoors. Birds housed outside should be kept secure from predators and should be supplied with a shelter. They should also have a pond and vegetation for cover and/or grazing as applicable.

Flooring: Waterfowl should be housed on solid floors. Rough concrete surfaces are unsuitable as they can cause foot trauma and infection such as bumblefoot (Forbes & Richardson 1996, Humphreys 1996), and species with heavy bodies can damage the feathers and keel if they sit out of the water on rough surfaces for long periods (Martin *et al.* 1984). The waterproofing properties of feathers are due to their structure, not the oil produced by the preen (uropygial) gland that the bird applies to them, so it is vital that good feather structure is maintained, particularly as feathers will not be replaced until the next moult (Robinson 1996). More suitable surfaces include plastic artificial turf, smooth rubber matting or deep pile rubber car mats (UFAW 1993) that are comfortable and easy to clean. If litter is used it must be maintained in a dry, friable condition and be sufficiently deep to dilute and absorb faeces. If waterfowl cannot be housed on solid floors, soft plastic mesh should be used rather than wire grid and a solid resting area should be provided that covers at least one-third of the pen floor. Ducks and geese drink and excrete large amounts of water, so they should be cleaned out at least once daily. Drinkers and ponds should be located over grid areas with drains beneath to prevent flooding.

Preventing aspergillosis: Aspergillosis, a mycotic infection caused by *Aspergillus fumigatus* and spread *via* spores, is a particular risk for water birds especially diving and sea ducks (Brown & Forbes 1996). Contact with mouldy feed and bedding must be minimized, although this does not justify keeping the birds in barren conditions. If straw is used for bedding, it must be of a good quality and it must be replaced when wet. If bedding is necessary for birds during illness, travelling or for postoperative care, it should be made from shredded paper, wood wool or peat. Stressed birds are especially susceptible to aspergillosis (Brown & Forbes 1996) so it is vital to minimize any distress caused to the birds by housing, husbandry or procedures. For more information on fungal, parasitic, viral and bacterial diseases of ducks and geese see Wobeser (1997).

Space requirements: Ducks and geese should have sufficient space to permit walking, running and wing flapping (Table 1) and should be supplied with a pond large enough for swimming and diving as appropriate (Table 2). Flight may not always be possible or desirable, as the manoeuvrability of many waterfowl in the air is not especially good, and so flight could lead to injury. Whether or not safe flight is possible will depend on the size of the birds, the size of the pen or compound they are housed in and how they react when attempts are made to catch them. It may be necessary to clip the wings of some species but this should never be done without good reason; they should be monitored to see whether they are liable to injure themselves first. Small ducks e.g. *Aythya* spp. can fly quite safely in large enclosures and still be caught when necessary. Birds should never routinely be pinioned without considering alternatives (see Section 11.2.3). Geese are adapted to walk while grazing and so will require a greater proportion of walking and grazing land than dabbling and diving ducks. Swimming exercise is more important for ducks, and diving ducks need sufficient depth of water to dive in. Some diving ducks, e.g. stifftails such as the ruddy duck, *Oxyura jamaicensis*, are very poorly adapted for walking and rarely leave the water so they will need large ponds.

Recommendations:

- Keep waterfowl outdoors whenever possible.
- House waterfowl on solid floors with a suitable substrate whenever possible; if plastic mesh must be used then provide a solid resting area.

Table 1 Space allowances for ducks and geese

	Minimum (Home Office 1989)[a]			Common practice			Good practice		
	Area per bird: singly housed (m^2)	Area per bird: group housed (m^2)	Minimum height (m)	Area per bird: singly housed (m^2)[b]	Area per bird: group housed (m^2)[bc]	Minimum height (m)	Area per bird: singly housed (m^2)[b]	Area per bird: group housed (m^2)[bc]	Minimum height (m)
Small/medium ducks (up to 1.2 kg)	0.125	0.083	0.5	1	0.33	2	N/A	0.6	3
Larger ducks (over 1.2 kg)	0.280	0.190	0.75	1.5	0.5	2	N/A	0.9	3
Geese	–	–	–	1.5	0.5	2	N/A	1.0	3

[a]The space allowances in rows 3 and 4 are taken from the Home Office guidelines for chickens or ducks of mass 600–1200 g, and over 2400 g, respectively
[b]This should include a pond (Table 2)
[c]The minimum pen size for group housed ducks or geese is 2 m^2
N/A = not available

- Do not house ducks or geese on rough flooring.
- Allow sufficient space for walking, running and wing flapping. Ponds should be large enough for swimming and diving.
- Do not wing clip or pinion waterfowl unless there is a good welfare reason to do so.
- Minimize the risk of aspergillosis, but not by keeping birds in barren conditions.

17.2.1 Physical environmental conditions

The optimal temperature range for domestic ducks and geese housed indoors lies between 18 and 21°C, although the thermoneutral zone of cold-adapted individuals or species may vary considerably. Waterfowl are extremely well insulated, so published literature should be consulted before housing non-domesticated birds to ensure that they will not suffer from heat stress. This especially applies to species native to temperate or polar regions. For domestic ducks, relative humidity should be maintained at 50–70%. Air quality parameters should be monitored at bird head height and ammonia levels should not be permitted to rise above 25 ppm. Carbon dioxide levels should not rise above 5000 ppm. Averaged over 8 h, dust should not exceed 10 mg/m^3 and carbon monoxide should not exceed 50 ppm (RSPCA 1999).

Day length for waterfowl, especially growing chicks, should correspond to that at the latitude of their usual habitat each season, and this information can be obtained from bird books. Incorrect day lengths will disrupt annual cycles, including moulting. In general, tropical species do well with a 13 h light to 11 h dark regime, whereas polar species can have 24 h light during the summer/growing period (Kear 1976). Temperate species will need intermediate lighting periods depending on the season. Domestic birds should have at least 8 h daylight (either by providing artificial light or allowing them outside) and a minimum of 6 h of continuous darkness in every 24 h cycle. A minimum of 20 lux light intensity must be provided to allow birds to see and be seen without difficulty. Lights should not be suddenly turned

Table 2 Pond sizes and depths for ducks and geese

	Minimum (Home Office 1989)		Common practice		Good practice	
	Area (m^2)	Depth (m)	Area (m^2)	Depth (m)	Area (m^2)	Depth (m)
Geese	N/A	N/A	0.5	0.1 to 0.3	1.5	0.1 to 0.3
Dabbling ducks	N/A	N/A	0.5	0.1 to 0.3	2	0.1 to 0.5
Diving ducks	N/A	N/A	0.75	0.5	3	1

N/A = not available

on or off and there should be a 'twilight' period to simulate dawn and dusk.

Recommendation:

- Research and maintain appropriate environmental conditions and day length for each species.

17.3 Breeding and rearing

Breeding vs rearing: It is generally easier to buy in fertilized eggs and incubate them using an artificial incubator or broody hen than to breed waterfowl for research use (see Section 8). Expert advice on the behaviour and requirements of each species will be needed before setting up a breeding programme. It is especially important to ensure that there are sufficient nesting sites and materials to prevent competition, and that the ratio of males to females is such that females will not be harrassed. Breeding waterfowl exhibit varying degrees of territoriality during the breeding season, which may lead to aggression if insufficient space is provided.

Rearing ducklings and goslings: For guidance on incubating and hatching eggs, see Sections 8.2 and 8.3. When fluffed up and alert, chicks should be group-housed in an indoor brooder pen with a brooder lamp. Ducklings appear to thrive best if they can choose where they want to be along a temperature gradient (Forbes 1996). Hatchlings should never become seriously chilled or they may suffer from septicaemia or gastrointestinal disease, even after they have been warmed. The brooder temperature should be 32–34°C and be decreased by 3°C weekly until the birds are around 5 weeks old (Forbes 1996). Plastic or rubber matting (UFAW 1993) or Astroturf is suitable bedding for juvenile birds—hay, straw, shavings and newspaper can tangle around the feet, be eaten and cause impaction, or harbour *Aspergillus*.

Ducklings and goslings are precocial and covered in down, and can walk, eat, swim and dive almost immediately after hatching. Broods hatch synchronously and have a strong instinct to become imprinted on and follow their parent(s). It is very important to provide the hatchlings with an appropriate item or person for imprinting immediately or at least within the first 16 h after hatching (see Section 8.4). Waterfowl will accept a wide range of 'parent' objects but they do not appear to become sexually imprinted on them if they are reared in a brood rather than singly (Matthews 1973).

Feeding ducklings and goslings: Ducks and geese feed by a variety of methods including pecking, sieving, grazing, diving and digging, so appropriate food should be given that is easy to handle and will encourage correct feeding behaviour. Chick crumbs are suitable for species that peck at discrete food items (e.g. dabbling ducks and some diving ducks), but are too dry to be eaten on their own so a bowl of water should always be available nearby. Floating food such as duckweed (*Lemna* spp.) and small seeds including millet, canary seed and rape can be added to the water for species that sieve their food, and goslings can be given turf or specially grown grass (Kear 1976).

The appearance of food is very important when encouraging young ducks and geese to feed. Waterfowl have good colour vision and hatchlings will preferentially peck at green and yellow items (Kear 1964). Ducklings who peck at items also prefer curved 'worm' shapes to round, triangular or long, thin shapes, so sieved egg yolk is useful for inducing them to feed (but note that an excess of boiled egg in the diet can cause constipation). Movement of small items, e.g. mealworms, attracts carnivorous and omnivorous chicks who take live food. However, great care must be taken when giving items of natural food to birds, as they may contain parasites to which captive birds have a lowered resistance. Tapeworm and nematode eggs or larvae may be present among duckweed obtained from areas where wild ducks or fish live and gapeworm eggs overwinter on grass. Adequate hygiene standards must always be observed and vegetation should be grown especially for the birds if possible.

Providing water for swimming: Newly hatched ducklings and goslings are very active and can be introduced to water for bathing in a shallow pebble filled bowl within 24 h of hatching (Forbes 1996). Great care must be taken when allowing very young hand-reared ducklings or goslings access to a pond for swimming. Natal down is poorly structured for waterproofing, but naturally-reared chicks are brooded by their parents, which keeps them clean and dry (Robinson 1996). Hand-reared chicks can become soaked and chilled if they spend too long in a pool and may also have difficulty in getting out of the water. They must be supervised and called out if they get too wet, then dried off on someone's lap or under a brooder lamp. Short swims two or three times a day will provide ducklings and goslings with supplementary exercise and help to encourage preening. A shallow pond with large stones on the bottom will also give them extra interest (food or grit can be scattered among the stones) and help to exercise their legs. The pond should be emptied or closed to the birds when unsupervised until they are larger and have begun to 'feather up', which will occur at some 3–6 weeks of age, depending on the species. Birds should also be moved to outside housing at the same time but must be provided with a shelter as the juvenile feathers of many species are not water resistant (Forbes 1996).

Growth: Waterfowl grow rapidly compared with other precocial birds of similar size (Sedinger 1992). All ducklings and goslings grow according to a similar pattern, where the legs develop quickly so that the birds can walk, swim and dive and the flight muscles and wings develop more slowly (Lack 1968, Kear 1970, Sedinger 1986). The rate of growth and feeding of each species will depend on its feeding habits and habitat in the wild. Dabbling ducks gain body mass and fledge earlier than diving species (Kear 1970, Lightbody & Ankney 1984) and Arctic ducks and geese grow faster than temperate or tropical species (Kear 1973). It is important not to force rapid growth by overfeeding temperate or tropical chicks on an excess of high protein food, or deformities and disorders such as 'slipped wing', where the wing appears to be too heavy for its joints and supporting musculature, may result (Kear 1973). Waterfowl, especially those from low latitudes reared at higher latitudes where there are more daylight hours for feeding, are prone to twisting and bending deformities of the long bones (of the legs and wings) if fed *ad libitum* on high energy or high protein diets. The aetiology of these conditions is not entirely clear but unusually rapid rates of weight gain are an important factor (Kirkwood *et al.* 1989, Kirkwood 1996). Growth rates should be carefully monitored and regularly compared with published growth rates for the same sex and race.

Recommendations:

- Anticipate and plan for increased aggression if you intend to breed birds.
- Supply a brooder lamp for all species to prevent chilling.
- Choose food that will encourage appropriate feeding behaviour and supply it immediately after hatching.
- Provide natural food items and make sure that they are safe.
- Allow supervised access to water within 24 h after hatching but never allow birds to become chilled.

- Check that dietary content is correct and that young birds are growing at an appropriate rate.

17.4 Diet

A variety of commercially produced diets are available for waterfowl, but these are often bland and their nutritional content may be inappropriate (see Section 9). Diets that will meet a species' nutritional requirements and promote natural foraging behaviour should be researched and formulated before any animals are obtained (Section 17.5.2).

17.5 Environmental stimulation

Although sufficient space to exercise is of primary importance for waterfowl, a stimulating environment is also necessary to encourage them to forage, play and use all three dimensions of their pond. Features of their natural environment can be reproduced to an extent in the laboratory, and a variety of natural and synthetic objects can be used to provide environmental stimulation in pens and ponds.

17.5.1 Good quality environment

Grazing geese will need sufficient space to forage and exercise by walking but may benefit from either natural plant cover (either outdoors or potted shrubs indoors) or artificial refuges such as boxes and straw bales. Freshwater ducks may also need cover or a refuge, but this is less likely to be important for sea ducks, who are more dependent on water as a refuge. Many waterfowl will become interested in items securely fixed to the walls of their pens that they can pull, such as lengths of metal chain (which should be replaced if they rust) or large plastic cable ties. These items should be too large to swallow or be very securely fixed. A further advantage of this type of environmental stimulation is that it can be left in place and hosed down when pens are cleaned.

Birds should be encouraged to use all three dimensions of their ponds or tanks. Stones and bricks at the bottom of ponds encourage dabbling and diving, as does supplying food or grit for the birds' gizzards on the bottom only. This is vital for diving birds even if the water is relatively shallow, as air within the respiratory system and plumage becomes more compressed with depth (Lovvorn & Jones 1994); hence the birds work hard against their own buoyancy at the top of the water column and so gain natural exercise. Cable ties for pulling can also be stuck on the side of smooth-walled ponds or tanks. Supplying treats in submerged pipes will encourage longer dives, but care must be taken not to supply anything in which birds could become trapped and drown. Other suitable items for the bottom of deep or shallow ponds include shells, vacuum cleaner fan belts (used for snatching games) and new, clean rubber bungs (Hawkins 1998).

Everything given to birds should be clean and non-toxic and either too large to swallow or safe when swallowed. Aggression may be associated with the provision of environmental stimulation if animals are competing for an insufficient number of objects or the space allowance is inadequate, but this can be reduced or prevented by allowing sufficient objects and space and by observing the birds. Occasional competition for items accompanied by single pecks, rather than sustained attacks, should be regarded as normal social interaction and is no reason to stop providing environmental stimulation.

Recommendations:

- Provide natural or synthetic cover for grazing and freshwater birds.
- Encourage birds to use all three dimensions of their pond by placing objects or food on the bottom.
- Experiment with a variety of enrichment objects; observe the birds' behaviour and use it to invent new toys.
- Make sure that there are sufficient items and space to prevent serious disputes over objects.

17.5.2 Foraging behaviour

Waterfowl in the field often spend more time feeding than doing anything else (Goudie & Ankney 1986, Paulus 1988, Sedinger 1992) so it is very important to encourage appropriate foraging behaviour. A simple way of doing this is by scattering food instead of providing it in bowls. Wild ducks and geese eat a variety of food items and employ a range of different feeding methods but are highly social and generally feed together, so their diet should ideally always be available for them at times when they would normally forage so as to avoid disrupting natural behaviour patterns. Many diving ducks feed nocturnally, but dabbling ducks tend to feed diurnally on water and nocturnally on land. Not all ducks and geese have crops, but in general carnivorous ducks have relatively small crops and may need to feed almost continuously. Grazing geese and ducks eat food with a high fibrous content and a relatively low energetic value, so may also need to fill their crops many times during the day (Kear 1976). However, food selection, feeding times and durations ultimately depend on a bird's species, age, the season and which food is currently available (Paulus 1988).

Grazing species: Wild geese 'farm' vegetation by not returning to grazed areas until the plants have had time to regrow (Owen & Black 1990), but grazing species housed outdoors will rapidly eat and trample all their grass unless it is carefully managed. Areas will need to be periodically rested to prevent overgrazing and to discourage parasites that may be present, such as gizzard worm (*Amidostomum* sp.) and gapeworm (*Syngamus* spp. or *Cyathostoma* spp.). These parasites overwinter on grass and so juvenile birds should have fresh grazing every year (Forbes & Richardson 1996). Short billed species such as the barnacle goose graze most efficiently on short grass, whereas those with longer bills have a slower pecking rate and require longer grass (Owen 1976).

Grazing species housed indoors should be given turf as environmental stimulation and to supplement the diet. If pathogens in collected turf could present problems, 'clean' grass can be grown for them by growing cereal seeds on absorbent paper in clean seed trays with drainage holes. Dietary enrichment for geese includes lettuce, celery, hydroponically grown grass, lucerne (alfalfa) and grass clippings. Suitable grains are wheat, barley, oats and corn. Whole cabbages can be either fixed to the ground outdoors or suspended at bird head height indoors. Goslings can be given hydroponic grasses, comfrey, kale and other 'greens', shredded or cut finely (Lint & Lint 1981).

Diving and dabbling ducks: For freshwater birds, duckweed (*Lemna* spp.) can be added to the pond to supplement the diet and encourage foraging and can also be frozen in the summer for consumption later in the year. Tubs of hydroponically grown grass or pieces of turf and duckweed can also be given to herbivorous or omnivorous waterfowl for grazing. Wheat and dry dog food are suitable for shelducks, diving ducks and dabbling ducks, with the addition of corn for dabbling ducks (Lint & Lint 1981). Feeding diving or dabbling ducks their regular food or treats on the surface or at the bottom of the water will make them work harder and longer for their food, which is especially important for specialized diving birds.

Exclusively carnivorous diving ducks such as eiders and scoters will need a diet containing animal protein that sinks when thrown into water but does not disintegrate too quickly. A good supply of grit is also essential to compensate for animal shells that would normally be ingested. It can be difficult to obtain the natural food of sea ducks (e.g. very small blue mussel spat) but dietary enrichment can be provided in the form of small fish such as sand eels *Amodytes* spp. Birds fed on the bottom of the pond can be weighed weekly to ensure that they are getting enough to eat. If the pond cannot be emptied regularly for cleaning, any residue of uneaten food and faeces can be siphoned out using a tube with a vacuum cleaner attachment on the end, and the water level can be topped up.

Recommendations:

- Encourage birds to spend time foraging, e.g. by scattering food, not giving it in bowls.
- Ensure that food is available at times when birds prefer to eat as a group.
- Manage outdoor grass carefully for grazing species to prevent parasitic infections and trampling.
- Provide suitable vegetable food indoors, growing it hydroponically if necessary.

- Feed dabbling birds in the water and diving birds on the bottom of the pond.

17.5.3 Group size and composition

Waterfowl are extremely gregarious and form strong attachments to one another. Living in large groups confers two main benefits: reduced individual risk of predation and enhanced location and exploitation of food. Geese in particular form long-term, stable bonds, especially within family groups (Ely 1993). Some ducks such as the European teal (*Anas crecca*) and common eider (*Somateria mollissima*) do especially well in groups and display behaviour that may not be observed in single pairs, but others should be kept in single pairs only, e.g. shelducks, *Tadorna tadorna* (Forbes & Richardson 1996). Group housing ducks and geese is vital for an acceptable standard of welfare in the majority of cases and the amount of time when any individual is left alone should be minimized. Ducks and geese generally become distressed if they cannot see conspecifics, so it may be necessary to provide a bird undergoing procedures with a companion who they can see (e.g. Stephenson 1994) or an object on which they are imprinted. Similarly, injured birds should generally be hospitalized with another compatible bird, unless there is a risk of infection. The minimum group size should therefore be four, as this ensures that two other birds remain when one is removed for procedures or weighing and that a bird on procedures can be provided with a companion if this is feasible. It is preferable to keep larger groups than this, with equal numbers of males and females wherever possible.

Breeding groups: Many species of waterfowl become territorial during the breeding season. Male ducks and geese will defend females against other males until incubation has begun, and geese will defend their mate and her feeding resources throughout incubation. Some geese drive other families of geese away while rearing young. In most dabbling ducks, stifftails and some diving ducks, lone males will attempt to forcibly mate with other females. Many broods of mallards have mixed parentage as a result (Owen & Black 1990) but this extra-pair forced copulation can also result in the death of the female. It may be necessary to reduce group sizes and ensure that there is sufficient space to allow escape and reduce the risk of injury.

Recommendations:
- Avoid housing waterfowl singly.
- Maintain groups of at least four birds, preferably with equal numbers of males and females.
- Make sure that you are aware of behavioural changes during the breeding season and that you can cater for them.

17.5.4 'Natural' conditions

The opportunity to replicate natural wildfowl habitats is limited in the laboratory, but consideration should be given to supplying features of the habitat that are likely to be important to the birds, for example shallow water with vegetation for dabbling ducks, turf for geese and deeper water with large stones for species that live along rocky coasts (Forbes & Richardson 1996). All waterfowl should have some sort of pond with a mixture of stones and grit on the bottom, both to increase the birds' behavioural repertoire and to encourage adequate maintenance of the feathers. The very minimum that waterfowl should be able to do is immerse their heads under water and shake water over the body. Many species may be nocturnal and rest during the day but still make good use of the pond during the night, especially if they are fed in or under the water.

Solid plastic paddling pools or sandpits can be used as ponds if nothing else is available. Some have lids that can be filled with water to make a very shallow pool for ducklings and goslings, and the deeper pool or sandpit can be filled with water and stones for older birds. Even if a pool is too shallow for birds to swim in, they can still use it for drinking, bathing and play, and food or treats can be scattered among the stones. Most waterfowl enjoy a shower and this can be set up using a hose and sprinkler over the pond to facilitate bathing and play.

Whatever the size of the pond or pool, birds must be able to get into and out of it easily, especially juveniles who may not be fully waterproof. Regular access to water is also important for the integrity of the feet and helps to prevent 'vent gleet', cloacal infections (usually *Pseudomonas* spp.) caused by the birds being unable to defecate naturally into water while swimming (Redig 1996). Ponds will need to be drained and cleaned out periodically, and the water in small indoor ponds should be continually replaced with clean water from a slowly running hose submerged at the bottom.

If birds are to be kept outdoors, a pond should be constructed for them or an existing pond should be adapted if necessary. Ponds should ideally include a range of depths and substrates, including clean gravel and sand with silt and mud in deeper hollows. Diving ducks will require deeper ponds than dabbling ducks and geese (see Table 2). Stones and boulders in a range of sizes should be placed on the bottom of the pond, and large boulders can be used as roosts if they break the surface.

From the birds' point of view, an ideal pond will have an island to allow privacy and feelings of safety, but this requirement must be offset against increased difficulty with catching birds and the disruption that this may cause. Artificial islands can be constructed outdoors from concrete pipe rings placed vertically in the water if the cores are filled with rubble and earth. 'Raft' islands that can be towed to the side of the pond when the birds need to be caught are suitable for indoor or outdoor ponds and can be made from a framework of treated wooden boards and expanded polystyrene. The upper surfaces should be dry and the birds will need boarding ramps (Street 1989).

Marine waterfowl often drink fresh water in the wild (Nyström & Pehrsson 1988) and may be kept on fresh water, but if so will have atrophied salt glands and may be susceptible to *Candida* spp. infections in the mouth, conjunctiva and nicitating membrane (Waine 1996). Such birds will need an acclimatization period if they are released or rehomed to a collection with salt-water ponds.

Recommendations:

- Provide all ducks and geese with a pond—even a child's plastic paddling pool is better than nothing.
- Consider constructing islands if the pond is large enough.
- Keep marine birds on salt water if possible, or they will need to be acclimatized to it before release.

17.6 Training and rewards

If ducks or geese are hand-reared, they can be habituated to experimental apparatus from hatch by encouraging them to follow their 'parent' into the laboratory and being fed there or given extra rewards. Noisy equipment should also be turned on to further accustom them to experimental conditions, which will reduce stress when they come to be used. Rewarding them after handling and procedures, if possible, may also help to reduce stress. Waterfowl enjoy being showered and this can be done (using a shower head or by placing the thumb over the end of a hose) before their pens have been cleaned and new bedding has been provided.

Sea ducks generally eat very small invertebrates and may benefit from the addition of dried shrimp to their diet, but also enjoy fish such as sprats (cut up) and sandeels (whole). Fish can also be used to reward sawbills. All omnivorous and carnivorous ducks can be given live mealworms, which are also a useful supplement to the diet although they have a high fat content. Geese and grazing ducks like whole cabbages, maize and other fresh vegetables.

Recommendations:

- Use imprinting and rewards to habituate young birds to the laboratory and equipment.
- Give birds a shower before they have been cleaned out.
- Try a variety of treats to reward birds after cleaning, handling and procedures.

17.7 Potential health and welfare problems

- Leg abnormalities—always ensure that the nutrient content of the diet is correct,

food quality is good and feeding regimes are appropriate (see 17.3).
- Abraded feet and feathers—flooring should not be too rough (see 17.2).
- Eye and/or nostril problems, cloacal infection—waterfowl must be able to immerse the head in water to prevent feed and dust clogging the eyes and nostrils, and regular access to water helps to prevent infection of the cloaca (see 17.5.4).
- Aspergillosis—minimize contact with mouldy feed and bedding, ensure that appropriate bedding is provided and avoid stressing birds wherever possible (see 17.2). Note that the prevention of aspergillosis does not justify keeping waterfowl in a barren environment.
- Aggression during the breeding season—obtain advice and plan for this before any birds are obtained (see 17.3, 17.5.3).
- Abnormal behaviour, e.g. stereotypies—provide ducks and geese with a good quality and quantity of space and conspecifics as appropriate (see 17.3, 17.5). See also WILD*Pro* Multimedia (2001) Waterfowl: Health and Management CD-ROM (Appendix 1).

18 Birds of prey (Falconiformes and Strigiformes)

Birds of prey have been kept for a number of scientific purposes; mainly studies of raptor biology and husbandry aimed at contributing to basic knowledge on avian biology and especially on aspects relevant to the conservation of endangered species. Raptors feed on vertebrate prey and are at the top of their ‘food chains’, so have been found to be at risk from environmental pollutants. Populations of many species underwent dramatic declines worldwide associated with the widespread use of persistent hydrocarbon pesticides in the latter half of the twentieth century. Raptors are therefore used occasionally for studies aimed at elucidating the toxicity of environmental contaminants.

18.1 Biology

‘Birds of prey’ or ‘raptors’ are the collective terms given to the many species in the orders Falconiformes (eagles, hawks and falcons) and Strigiformes (owls). These birds are adapted to carnivorous diets. Many take live vertebrate or invertebrate prey but some Falconiformes are scavengers. Most, but not all, owls are nocturnal. The Falconiformes are diurnal or crepuscular. Both groups have an altricial development pattern: chicks are born at an immature stage of development, are reared by their parents, and show very rapid rates of growth. Both orders have worldwide distributions with representatives in wide ranges of ecosystems from the tropical to the arctic. Many species are threatened, some are critically endangered, and there has been considerable interest in captive management and breeding as conservation tools. For example, the Mauritius kestrel (*Falco punctatus*) and the Californian condor (*Gymnogyps californiacus*) (Ensley 1999) owe their continued existence to this technology. The biology of some species has received considerable study but there are many, especially forest species, about which little is known (Brown & Amadon 1968, del Hoyo *et al.* 1992). Many species are monomorphic—the sexes are indistinguishable externally—although there is a tendency in both owls and diurnal birds of prey for females to be larger than males. Monomorphic birds can in many cases be sexed by genetic fingerprinting methods or, if this technique is not available, by laparoscopy under anaesthesia (see Section 12).

18.2 Housing and space requirements

Although the management of birds for research purposes differs from that of birds kept for falconry, study of the literature on falconry and hawking (e.g. Woodford 1966, Glasier 1978) can provide valuable background information for modern raptor husbandry, especially on aspects of taming and training. Management guidelines on the captive care of birds of prey have been developed by the Federation of Zoological Gardens of Ireland, Falconiformes Taxon Advisory Group (Parry-Jones 1997, 2000). Another valuable source of information on husbandry and care is the literature on the treatment and rehabilitation of wild raptor casualties (e.g. McKeever 1979, van de Water

1996). For guidance on housing and rearing barn owls (*Tyto alba*) in the laboratory, see Rich and Carr (1999).

Aviary design: Birds of prey kept for scientific purposes should be housed in aviaries. There are merits (e.g. ventilation, sunlight, interest for the birds) in these being outdoor, providing the extremes of the local climate are within those encountered by the species in its normal range. Generally the larger the aviary the better, but aviaries should at the least be large enough to allow some flight. For small species (less than 500 g body weight) a sensible minimum might be 2 m × 4 m and 2 m in height. There should be a double door system to prevent accidental escapes during staff entry or exit. Aviaries can be roofed with solid material or with nylon netting which has some 'give' if hit by a flying bird but the mesh must be fixed taut enough to prevent it from becoming tangled around a leg or foot. Forbes and Parry-Jones (1996) recommend that roof mesh is supported by wooden battens to reduce the chances of scalp injuries caused by birds hitting the mesh in flight. If a mesh roof is used some internally-roofed areas must be provided to give shelter from rain or intense sunlight. Mesh roofs have some advantage in providing a view of the sky for the birds and in facilitating self-cleaning of the aviary by rain. To provide security two or three sides of the aviary should be solid, but leaving one or two sides open and meshed provides the birds with an opportunity to see out and watch the world.

Substrate: The substrate should be well-draining and hygienic. Gravel over a concrete base is easy to keep clean. Aviary furnishings should include a variety of perches and ledges, thoughtfully sited so as to provide a selection of perching and roosting places (many raptors like to perch high up at the side of aviaries) without cluttering the potential flying space, and to allow the birds to perch in the sun, wind or rain, or out of these, according to their preferences. Perches should be of various diameters, appropriate for the size of the bird, to provide choice. Birds like to dust-bathe, and a tray of dry sand will allow them to do so. Food can be provided on a feeding platform.

Many species of birds of prey are largely solitary outside the breeding season and some are strictly territorial. Birds should be kept singly, in pairs or in groups depending on their biology in the wild. For breeding, a nest box, platform, or ledge should be provided according to the preference of the species.

Attendants should always approach aviaries from the same direction and should go about their work quietly and avoiding sudden movements. Birds will become accustomed to people and routines that they are familiar with but may be stressed by any changes.

Recommendations:
- Always base management systems on knowledge of the species biology.
- Keep birds of prey in outdoor aviaries whenever possible, with some form of shelter.
- Site perches thoughtfully to provide a variety of options without cluttering flying space.

18.3 Obtaining raptors

Birds of prey have been maintained in captivity for centuries, and many species have been used for falconry purposes. However, it is only since about 1970 that species have consistently been bred in captivity and that some self-sustaining captive populations have been established. Because there are now captive populations of a number of species of diurnal and nocturnal raptors, it is unlikely to be necessary to take birds from the wild. Raptors are protected species and cannot be taken from the wild in the UK, or in most other countries, except under licence (see Section 6.1).

Recommendation:
- Only obtain raptors from captive, self-sustaining populations.

18.4 Feeding and nutrition

In deciding diets for birds of prey, note should be taken of their usual diet in the wild. Many raptors eat vertebrate prey and, because the body and nutrient composition of vertebrate animals tends to be similar across species of fish, reptiles, birds and mammals, readily available whole animals such as surplus laboratory rodents, quail or day-old chicks appear to be suitable foods for a wide range of species. Although some species may tend to become fat when fed *ad libitum*, this is usually the preferred feeding method for aviary-housed birds as it avoids the risk that loss of body condition might pass unnoticed if food is restricted, unless the birds are weighed regularly.

The estimation of the daily food requirements of captive raptors has been described by Kirkwood (1996). For most species, feeding once daily is adequate, but in very warm environments twice daily may be necessary in order to ensure fresh food is available. Some species 'cache' (hide) uneaten items in corners for retrieval to eat later in the day (Vander Wall 1990). Whole food animals such as euthanased rats or quail provide well-balanced meals for many species and it is unlikely when these form a major part of the diet that mineral or vitamin supplements will be necessary. Euthanased day-old chicks are also widely used as food because of their ready-availability. These also appear to support good health but have a lower calcium density (1% of dry matter *cf* 2.5% of dry matter in mature vertebrates) which may only just suffice for normal skeletal development. The use of quail or day-old chicks can carry a risk of infectious disease introduction and the health status of supplier flocks should be checked. Because of its low calcium content, lean meat is emphatically not a suitable diet.

Falconiformes have crops (in which food accumulates prior to passing on down to the stomach); Strigiformes do not. Both species regurgitate pellets of indigestible elements of their diets (bone, feather and fur) and this typically occurs one or more times a day, often in the morning. Birds of prey do not need grit for the digestion of their food, but some falcons ingest and later regurgitate small 'wrangle' stones (for unknown reasons) and a supply of suitably rounded small gravel stones should be made available.

Raptors generally derive their daily water requirements from their food. However, water should always be made available for drinking should the birds need to do so, and also for bathing. A large, flat dish containing an inch or two of water is ideal.

Recommendations:
- Ensure adequate dietary calcium intake. Whole-animal diets are suitable for most species.
- Feed to appetite.
- Supply small, rounded gravel stones if necessary.
- Provide large shallow water bowls for drinking and bathing.

18.5 Environmental stimulation

There is very little literature on specific environmental enrichment techniques for raptors (but see Field 1998). The key elements of enrichment are that birds (at least the diurnal species) should have as much of a view, at least in one direction, as possible, they should have a selection of thoughtfully-placed perching sites, they should have water and dust baths, and should be kept in pairs or groups if appropriate, in the light of their biology in the wild and previous experience with captive birds.

Recommendations:
- Design and site aviaries so as to provide diurnal birds with a view, including a view of the sky above.
- Provide a sand tray for dust-bathing.
- Site perches to provide variously for shelter, sunning, and exposure to wind and rain, with regard to the birds natural habitat.

18.6 Catching, handling and restraint

Raptors, or at least individuals of some species, can become very tame to the extent that they will step backwards onto a hand gently raised behind their legs or allow themselves to be picked up. Birds can be caught in aviaries using appropriately sized nets or by throwing a towel over them on the ground, and birds can then be 'cast' (caught and wrapped) in clean towels (Forbes 1996, Fowler 1995). Restraint of the feet is important when handling raptors as these can inflict painful injuries. Small raptors (up to about 250 g) can be safely held in one hand with the lower legs and tail gently clamped by the thumb extended to the base of the index finger, with the bird lying on its back with its head extending over the medial aspect of the palm and with wings folded and gently restrained by the fingers. For examination, birds can be held on their backs by one person whilst another restrains the feet (this can often be facilitated by placing a piece of cloth in the bird's grasp). Individuals of some species may lie quietly in this position with gentle restraint. In other cases it may be useful to cover the head with a light cloth to help calm the bird and reduce the risk of bites. Training and expert advice will be necessary before attempting to handle and restrain raptors. For detailed examinations or if immobilization is necessary (for example for radiography), a variety of combinations of injectable agents such as ketamine/xylazine or ketamine/medetomidine mixtures have been found to be safe and effective (see Section 10.6) as is inhalation anaesthesia using isoflurane (see Section 12.4.2; Lawton 1996, Fitzgerald & Blais 1993). A veterinarian should always be consulted before birds are immobilized or anaesthetized.

Recommendations:

- Do not allow fear of talon or beak wounds to compromise a calm, gentle but firm approach in catching and handling raptors.
- Do not attempt to anaesthetize birds without first obtaining veterinary advice.

18.7 Routine veterinary procedures

Birds of prey in captivity can develop overgrown beaks and it may be necessary to 'cope' (carefully trim) the beak using clippers and files. Talons can also become abnormally long and may need clipping. Taking the points of talons also reduces the chances of self-inflicted injuries when nervous birds are handled—punctures of the sole of the foot may also lead to infections ('bumblefoot', see Section 18.8 below).

Blood samples can be collected from the brachial vein where it runs across the ventral surface of the elbow joint. Use of a fine (e.g. 25 gauge) needle reduces the chance of haematoma formation (leakage of blood into the subcutaneous tissues) (see also Section 12.1).

Recommendations:

- Trim the beaks of some birds occasionally, if this is necessary to prevent them from becoming overgrown and splitting.
- Clip the tips from talons to reduce the chance of self-inflicted punctures of the sole when birds are caught regularly.

18.8 Diseases and medicine

Although birds of prey are susceptible to a wide range of avian infectious and non-infectious diseases (e.g. see Redig *et al.* 1993, Ritchie *et al.* 1994, Altman *et al.* 1997), when kept to high standards of management the incidence of diseases and injuries is typically low and the average lifespans of birds in captive populations can be much greater than those in the wild. Common minor problems include damage to the plumage or cere through flying into mesh. If neglected, overgrowth of beaks can lead to splits in the mandibles which can be difficult to deal with (however, beak trimming is not something that is routinely needed in most birds). 'Bumblefoot', which is the traditional name for infections of the foot, also occurs quite commonly in captive birds and its incidence can be related to perch hygiene. Mild infections may respond to antibiotic therapy if treatment is started promptly but chronic forms may require surgery. It is hard to wholly eliminate the threat of aspergillosis, a fungal infection usually of the air sacs and lungs. Stressed birds are particularly susceptible but cases can occur sporadically in well-managed birds. The first signs may be loss of appetite and body condition, and by the time the disease is diagnosed it can be very difficult to treat (Bauck 1994).

Severe nutritional bone disease can develop rapidly in young chicks reared on calcium-deficient diets (Butterworth & Harcourt-Brown 1996, Kirkwood 1996). It is most important that nestlings are provided with whole vertebrate-animal diets to ensure an adequate intake of bone to meet their calcium requirements. Hand-reared chicks, especially if reared in isolation, imprint on humans and can show severe behavioural abnormalities (Butterworth & Harcourt-Brown 1996).

Recommendations:

- Ensure that you are familiar with the birds and spend time observing them closely each day—this facilitates the early detection of diseases.
- Perform routine observations from a hidden position (e.g. through peep-holes) wherever possible, unless birds are very tame.
- Always consult a veterinarian experienced in the treatment of each species.

19 The domestic fowl, Gallus gallus domesticus

The majority of birds used in research are domestic fowl (see Section 2). Most are used in fundamental or applied research into disease, nutrition and genetics, or for the production of biological materials such as antibodies and infectious agents, which may require the creation of genetically modified birds. Within toxicology, domestic fowl are principally used to evaluate the safety of veterinary drugs or other animal health products, and also in pharmacokinetic and controlled efficacy studies (e.g. anticoccidial efficacy which involves experimental infection with *Eimeria* spp.).

19.1 Natural habitat and behaviour

The domestic fowl is derived from the Burmese Red Jungle fowl (*Gallus gallus*). Domestication, probably for cockfighting and as a sacrificial bird, began more than 5000 years ago. Despite the lengthy domestication period, domestic fowl retain much of the biology and behaviour of Jungle fowl, and modern breeds have been successfully re-established in the wild (McBride *et al.* 1969). Consideration of the ecology and behaviour of Jungle fowl is therefore a useful starting point for predicting the requirements of the domesticated bird.

Jungle fowl are predominantly ground-living in tropical and temperate scrub, forest or jungle habitats with ample overhead cover. The most common social organization is of one male with up to four females, though they form larger groups of around 20 birds in more open environments. Other males are either solitary or form unisexual groups of two or three birds. Mixed groups have a well-defined home range with a regular roosting location. Flocks spend the majority of the time (up to 75% of the day) foraging for seeds, fruits and insects. Maintaining the condition of the plumage through preening and dust-bathing is also a time-consuming daily activity. The breeding season varies according to the position within the species range, but is generally in the spring in temperate zones and all year round in tropical areas. Courtship is complex and includes a chain of stimulus–response patterns, initiated by the male, which ensures that the female is receptive. Five to eight eggs are laid in a well-disguised hollow, sometimes lined with grass or leaves. Soon after hatching, chicks imprint on the mother and all leave the nest site. Hens cease to be broody and drive the chicks away when they are 6–8 weeks old.

19.2 Housing and space requirements

Behavioural considerations: Behaviours that are most important to domestic fowl appear to be nesting, perching and using litter for scratching, pecking and dust-bathing (FAWC 1997), so birds should be housed in floor pens large enough to permit all of these behaviours whenever possible. Laying hens have a very high demand for a litter substrate (Gunnarsson *et al.* 2000) so they should always have access to a solid floor or resting area with substrate. Minimum space allowance will depend on which activities are considered important for the birds to be able to express. Domestic fowl are highly motivated to perform 'comfort behaviours' such as wing flapping, feather ruffling and leg stretching, which help to ensure strong leg bones (Knowles & Broom 1990).

Space requirements: The European Convention and Directive guidelines for caging domestic fowl (Council of Europe 1986, European Community 1986) allow 650 cm^2 per bird for groups of three birds or more with body mass 1800–2400 g. Six large fowl could therefore legally be kept in an area 45 cm high and approximately 50 cm × 80 cm. This would not be sufficient to permit a range of normal behaviours or the provision of a good quality environment (see Section 19.5.2). UK Home Office minimum guidelines allow a slightly larger area, but in practice birds are often allowed more floor space, especially when group-housed in large pens (see Table 3).

If birds must be caged, e.g. where a study requires the collection of faeces, they should be housed in modified cages designed to address behavioural requirements (Sherwin 1994) rather than in 'battery' cages. Standard cages with a height of 40 cm prevent many comfort behaviours, and so cage heights that prevent full extension of the head and wings should be avoided. Adult birds will require at least 2000 cm^2 for the expression of comfort behaviours (Dawkins & Hardie 1989). Clearly, small birds and chicks would be able to express all comfort behaviours in smaller areas.

The requirement for an extensive area appears to be important in two contexts. First, in the early stages of pre-laying behaviour, hens with access to a suitable nest site show increased walking and exploration in larger areas rather than smaller ones. If access to the nest is denied, hens develop stereotypic pacing, suggesting that locomotory motivation is thwarted (Duncan & Wood-Gush 1972). These findings suggest that hens may be motivated to walk and explore the environment during the early stages of pre-laying behaviour. If so, then a confined area such as a cage is unlikely to meet these requirements and may account for the unusually high number of nest entries sometimes observed in cages with nest sites. Secondly, studies on spacing suggest that there are social attraction and repulsion forces (e.g. Keeling & Duncan 1989). In small pens, birds may be motivated to achieve appropriate spacing, but be physically prevented from doing so. It is likely that the failure to express this motivation gives rise to social stress. As there is an incomplete understanding of the minimum space requirements of group-housed birds, the Working Party suggests that a minimum pen

Table 3 Space allowances for domestic fowl

	Minimum (Home Office 1989)				Common practice				Good practice			
Mass (g)	Area per bird: singly housed (m^2)	Area per bird: group housed (m^2)	Minimum height (m)	Minimum length of feed trough per bird (cm)	Area per bird: singly housed (m^2)	Area per bird: group housed[a] (m^2)	Minimum height (m)	Minimum length of feed trough per bird (cm)	Area per bird: singly housed (m^2)	Area per bird: group housed[a] (m^2)	Minimum height (m)	Minimum length of feed trough per bird (cm)
Up to 300	0.035	0.025	0.3	3	0.4	0.15	0.3	3	N/A	0.6	2	3
300–600	0.070	0.047	0.4	7	0.5	0.2	0.4	7	N/A	0.7	2	7
600–1200	0.125	0.083	0.5	10	1.0	0.3	0.5	15	N/A	0.8	2	15
1200–1800	0.145	0.095	0.5	12	1.0	0.4	0.5	15	N/A	0.8	2	15
1800–2400	0.170	0.120	0.55	12	1.5	0.5	0.55	15	N/A	0.9	2	15
Over 2400	0.280	0.190	0.75	15	1.5	0.6	0.75	15	N/A	1.0	2	15
Male birds	–	–	–	–	1.5	0.6	0.75	15	N/A	1.0	2	15

[a]The minimum pen size for group-housed domestic fowl is 2 m^2. Domestic fowl should not be housed singly; groups of between 5 and 20 birds are preferable (if groups are mixed, there should be a maximum of three males). Group size, density and the quality of the environment have complex effects on behaviour and the occurrence of deleterious behaviour patterns. As a general rule, aggression should be rare and all birds should move around the entire pen and display a wide range of activities. N/A = not available

size of 2 m^2 should be provided for all group-housed domestic fowl.

Feeding behaviour and perching space: Domestic fowl show diurnal rhythms in feeding behaviour, with peaks in feeding usually at the beginning and end of the light period. Additionally, the sight and sound of a feeding bird triggers feeding behaviour in others, and so it is likely that at certain times of the day all birds are motivated to feed. The provision of insufficient feeder space for all birds to feed synchronously is likely to be deleterious to the well-being of displaced birds. A minimum of 15 cm of feeder length per bird should be provided to allow birds to feed synchronously. Similarly, the minimum perch space required per bird will depend on bird size, but most adult birds require at least 15 cm of perch per bird.

Recommendations:

- Provide sufficient space to allow expression of all comfort behaviour—generally, at least 2 m^2 of floor area for group-housed birds and a height that allows complete extension of the head.
- House birds in pens wherever possible; if cages must be used then ensure that modified cages are used as opposed to 'battery' cages.
- Provide at least 15 cm of perch and feeder space per bird to allow them to perch and feed synchronously.

19.2.1 Physical environmental conditions

Hygiene: It is important for the animal house to have high levels of hygiene prior to the introduction of fowl (see Section 11.2.1). Once it is populated, regular removal of droppings is essential to reduce the risk of disease and the build-up of noxious gases such as ammonia. The frequency of cleaning out will depend on many factors such as the type of housing and stocking density. Droppings that accumulate in trays away from the birds should be cleaned once or twice a week and certainly before ammonia levels rise to undesirable high levels. In large-scale facilities, levels of gases should be monitored once a week or more frequently. Floor litter should be kept at least 10 cm deep and replaced at intervals that ensure it is always dry and friable—preferably once weekly.

Temperature: Domestic fowl can maintain body temperature over an ambient temperature range of around −1 to 37°C (Esmay 1978). However, the optimum ambient temperature for keeping adult birds is 16–24°C. Variations greater than 5°C from the optimum temperature are generally avoided in a commercial environment as there is greater food consumption at low temperatures and lower egg production and growth at high temperatures. Domestic fowl fed *ad libitum* can withstand a wide range of temperatures (FAWC 1997), but rapid changes in ambient temperature throughout the pen should be avoided as fowl are unable to adapt to them.

Ventilation and relative humidity: Although the rate of accumulation of dust and ammonia in the air will depend on many factors, including the housing system and stocking density, effective ventilation is required to maintain low dust and ammonia levels for the well-being of both birds and staff. A range of about 40–80% humidity is recommended (Sainsbury 1992). Outside this range the risk of respiratory infections is increased, and high humidity should be avoided at high ambient temperatures as body heat is dispersed less efficiently.

Light:dark cycles: Day-length is the main factor controlling seasonal changes in physiology and behaviour. During rearing, a constant but short cycle, such as 8 h light :16 h dark, ensures that domestic fowl reach sexual maturity at an appropriate age. For laying hens, gradually increasing the light period to about 14 h light:10 h dark is recommended. Additionally, the lighting regime for layers and broiler breeders needs to be carefully considered in experiments that aim to simulate production conditions. Sudden drops in day-length should be avoided as this can stop laying and induce moulting. Domestic fowl can be kept in a wide range of light intensity, though no lower than 20 lux. It is unlikely that there is an optimum light intensity for fowl, as the best practice is likely to be dependent on many other factors, such as the source of the light, its wavelength and the birds' experience. In cases where feather pecking becomes a problem, temporarily or periodically lowering the level of light intensity can alleviate this, although husbandry and care should be critically evaluated and modified if necessary first.

Recommendations:

- Ensure that high levels of hygiene are maintained at all times.
- Aim to keep adult domestic fowl at around 16–24°C, and provide a choice of temperatures where possible.
- Control perceived day-length carefully to ensure an appropriate rate of development and minimize physiological stress.
- Maintain dust, ammonia and humidity levels within acceptable limits for birds and humans.

19.3 Rearing

Environmental conditions: The environment provided soon after hatching is extremely important to ensure survival of the precocial chicks. Room temperature for one-day-old chicks should be 25–30°C, with a temperature of 35°C under the brooder lamps. Both the ambient temperature and temperature under the lamps should be decreased by 3°C weekly until chicks are 3 weeks old (Sainsbury 1992). Alternatively, air heaters that provide a temperature of 31°C at one day old, decreasing by 0.5°C a day until a temperature of 18–21°C is reached, are also suitable. Monitoring of movement and activity throughout this period should be undertaken as it can provide an early indication of problems. For example, reluctance of chicks to move away from under the lamps may indicate that the house temperature is too low, and if not corrected can lead to deaths from starvation. Also, chicks who cannot move away from excessive heat will suffer from overheating (hyperthermia) and may dehydrate and die.

Feeding and parental care: Chicks are sustained by yolk reserves until 3 days of age, and much of the exploratory pecking during this time is essential for the development of eating and drinking and the ability to identify suitable food and water sources. Providing the appropriate stimuli for the development of these responses is thus vital for the chicks' survival. One way to ensure chicks learn to feed and drink is to imprint a small number of them to the mother or a broody hen. To achieve filial imprinting, chicks should be exposed to the hen between 12 and 24 h post-hatching (Rogers 1992). Monitoring is essential during the early post-hatching period to determine that the hen is indeed broody, as non-broody hens may kill chicks. If a mother is not provided, it is important to ensure that chicks can readily obtain access to food and water. Water should be provided in chick drinkers or other small drinkers that allow chicks to see the water but not fall into it. Additionally, allowing chicks to feed and drink in view of each other encourages feeding and drinking in all chicks through social facilitation. If chicks are reared in isolation, or if it appears that a group is not feeding, it is necessary to stimulate pecking by tapping a stick or pencil on food grains in front of the chick. Increasing the contrast between the food grains and the background, such as by placing food on white paper, increases the effectiveness of this action.

Recommendations:

- Regulate ambient temperature carefully in the first 3 weeks of life. Observe chicks regularly for signs of inactivity that may indicate an incorrect room or brooder lamp temperature.
- Try to rear chicks with their mother or another broody hen if possible, but monitor closely during the early post-hatching period as non-broody hens may kill chicks.
- Take great care to ensure that chicks reared without a hen start feeding and drinking before 3 days of age.

19.4 Diet

Domestic fowl should be fed on appropriate commercial diets, taking care to monitor their growth and development. Nutrient content, food quality and feeding regimes must be carefully controlled to prevent leg abnormalities and other health and welfare problems associated with rapid growth rates

(RSPCA 1999). For guidance on diet specifications for each life stage, see Duncan (1999). Allowing birds to forage in an appropriate substrate is especially important (see Section 19.5.1).

19.5 Environmental stimulation

Domestic fowl in commercial flocks are often housed in extremely barren environments that seriously limit their ability to exercise and to express a range of natural behaviours. The Working Party believes that this does not justify inadequate housing and husbandry in the laboratory and that fowl should be provided with a good quality and quantity of space wherever they are kept (Höfner *et al.* 1997). For guidance on appropriate environmental stimulation for fowl, see Höfner *et al.* (1997), Animal Welfare Information Center (1995).

19.5.1 Foraging behaviour and flooring substrate

When kept on loose substrate, domestic fowl spend about one-third of the day performing foraging behaviour, i.e. pecking and scratching the ground. Motivation for this behaviour appears to be high, as fowl will forage for feed rather than eat identical feed that is freely available (Duncan & Hughes 1972) and, when given the choice, strongly prefer litter to a wire floor (FAWC 1997). Fowl kept on a wire floor may express their motivation to forage through food manipulation with the beak and through feather pecking, which represent severe welfare problems. The incidence of feather pecking is significantly lower when litter is provided (Blokhuis 1989), so fowl should preferably be kept in pens with a loose substrate such as sand, soft wood shavings or straw. In these conditions it is important to replace the litter frequently to remove droppings and reduce the risk of disease. Activities such as dust-bathing require a considerable amount of space as birds tend to roam some distance when foraging and bathing.

If birds must be kept in cages, it is advisable to provide a solid area with loose substrate covering at least one-third of the floor area to allow some expression of foraging behaviour. Several cage designs have been developed that incorporate such an area (see Sherwin 1994). Many modified cages also provide a perch and nest box that allow much of the natural behavioural diversity of the domestic fowl and provide an alternative method of housing if very hygienic conditions are required. However, measures that reduce feather pecking may be necessary, such as providing objects for pecking (e.g. Pecka-Blocks, Breckland International Ltd, UK) and temporarily or periodically lowering the light intensity. It is advisable to use systems that have been extensively developed and tested, as deaths due to trapping are common in many early designs. If there are sound scientific reasons for not providing a solid area with loose substrate, toys or other items such as rope, turf or straw should be provided for pecking.

Recommendations:

- Provide a loose substrate such as sand, wood shavings or straw for the expression of foraging and dust-bathing behaviour.
- Use modified cages if very hygienic conditions are required, with at least one-third of the floor as a solid resting area with substrate.
- Always supply items for pecking if solid areas and substrate cannot be provided.

19.5.2 Good quality environment

Perches: Fowl have feet that are anatomically adapted to close around a perch when they sit, and feral and wild birds spend a large amount of time perching on branches. In captive environments with limited perch space, fowl struggle vigorously to obtain and keep perching space despite severe crowding, which indicates a high motivation to do so. Perching also provides welfare benefits such as increased leg bone strength, reduced aggression and improved foot and plumage condition. Any deleterious effects of perching, such as bumblefoot or keel deformation, are due to poor perch design or positioning (Baxter 1994).

Domestic fowl should therefore always be provided with the opportunity to perch, so at least 15 cm should be available to each bird. Perches should have a flat top about 3–4 cm wide, as round perches can increase the incidence of keel deformation (Duncan *et al.* 1992). The optimum height above the floor varies for different breeds and housing conditions (see also Lambe & Scott 1998), although layers can generally reach higher perches than broilers. One way to determine if perch height is suitable is to briefly observe birds during lights-off. Generally, all birds will roost on perches unless they are too high.

Nest boxes: Pre-laying behaviour occurs between 20 and 120 min before oviposition and starts with searching behaviour that leads to selection of a nest site and nest building. Domestic hens are strongly motivated to obtain a suitable nest site (Cooper & Appleby 1994) and become frustrated and develop stereotypic pacing if deprived of access to one (Duncan & Wood-Gush 1972). Physiological stress arising from the failure to find a suitable nest site can lead to the egg being retained and 'dropped' later in the day without pre-laying behaviour. These eggs have a dusted or banded appearance, arising from extended calcification, and are a good indicator of stress during the pre-laying period. Laying hens should therefore have access to nest boxes from at least 16 weeks of age. Although the exact nest site requirements of individual hens vary considerably, an enclosed individual nest box is satisfactory and highly preferable to most hens. Nest boxes should preferably be littered, enclosed and allow one bird to turn around. Hens are motivated to examine nest sites in the weeks before they come in to lay and allowing them to do so increases later use of the nest box (Sherwin & Nicol 1993). A loose substrate such as wood shavings or straw is also important and allows complete expression of nest building activities. An astroturf floor is also suitable though less preferable to the birds.

Recommendations:

- Provide sufficient flat perches for all the birds to roost at the same time and at an appropriate height.
- Encourage nest building by providing nest boxes and suitable substrate.
- Examine eggs for a dusted or banded appearance, which reveals that the hen was stressed during pre-laying behaviour.

19.5.3 Group size and composition

The domestic fowl is a highly social species and forms groups with stable hierarchies under appropriate conditions. Although there is currently no evidence to suggest that fowl suffer in isolation, they prefer familiar birds to an empty cage and it is perhaps preferable not to house birds in isolation if possible. There is probably no optimum group size, though generally small groups of around 5–20 birds are favourable as there is less aggression and stress than in larger sized groups. Keeping birds in large groups should be avoided as they are usually unable to form a hierarchy in groups of larger than 60 birds. Mixed sex groups should contain few males (e.g. a ratio of 1:5) to avoid excessive competition between them. In the wild, fowl form groups of mixed sex. It appears that the males are motivated to be with females, rather than the reverse. Female groups with a small number of males may have lower aggression than groups of females only. However, the addition of males to a group of females may increase social stress if there is insufficient space.

Get-away cages provide birds with sites for avoiding aggressive persecution but generally do not lower aggressive interactions. Repeated aggression towards subordinate hens showing pre-laying behaviour is often observed in environments without nest sites, suggesting that such persecution is triggered by restlessness. At present, it appears that the best method to eliminate aggressive persecution is through provision of an appropriate environment and careful consideration of group size and composition.

Recommendations:

- Keep fowl in small groups, with relatively few mature males in mixed sex groups.
- Provide a complex and interesting environment and consider group size and composition carefully to reduce the risk of aggression.

19.5.4 'Natural' conditions

Both Jungle and feral fowl maintain plumage condition by dust-bathing daily. Dust-bathing removes excess and stale lipids and has clear benefits for feather condition. Besides the obvious physical benefits, motivational studies have also indicated that dust-bathing is pleasurable to fowl (Widowski & Duncan 2000). Domestic fowl have a preference to dust-bathe on sand, though wood shavings and other floor litter are also suitable—particle size is of greater importance than substance.

Recommendation:

- Provide sand or another suitable substrate (e.g. wood shavings) for dust-bathing.

19.6 Training and rewards

Domestic fowl can be trained to perform various tasks for food rewards, but training should be devised with care as excessive repetition can lead to species-specific behaviour that will interfere with the task being learned. For example, after repeatedly receiving food rewards birds will start pecking and scratching the ground rather than doing the task. Mealworms can be given as rewards (although naïve birds may reject them) and fowl also enjoy drops of water in their food.

Recommendations:

- Design training programmes carefully so that desired behaviours are reinforced.
- Reward birds with mealworms and/or water in their food.

19.7 Potential health and welfare problems

Feather pecking: This is a serious welfare problem that can lead to more severe injurious pecking and mortality. Although it is less likely in small groups with access to litter and other pecking substrates, it may still develop for seemingly inexplicable reasons. Lowering the light intensity or changing the light colour to blue, red or green, providing alternative pecking substrates and spraying birds with a noxious tasting (but non-toxic) substance may reduce the incidence of feather pecking once it has developed. If, for experimental reasons, domestic fowl are to be kept in an environment where severe feather pecking is likely to occur, it is advisable to use strains that have been selected to show little feather pecking (Kjaer & Sorensen 1997). It is therefore important to research each strain thoroughly when planning projects.

Beak trimming or tipping are commonly used, or 'spectacles' fitted, if feather pecking or cannibalism become a problem in commercial situations. These procedures can cause both acute and chronic pain and should never be undertaken without strong justification. Appropriate anaesthesia and analgesia must also be administered (see Section 11.2.3).

Recommendations:

- Choose strains that are known to exhibit a low incidence of feather pecking.
- Keep birds in small groups with access to litter and pecking substrates.
- Try lowering light intensity or spraying birds with a noxious tasting substance.
- Only beak trim as a last resort (do not debeak) and use appropriate anaesthetics and analgesics.

Behavioural frustration: Severe frustration, usually expressed as pacing and aggression, is widespread in some environments and is indicative of compromised welfare. Frustration commonly arises from the failure of laying hens to find a suitable nest site in the pre-laying period. To prevent behavioural frustration, the necessary stimuli for the full expression of behaviour patterns should be provided (such as a nest box for pre-laying behaviour and/or litter for foraging behaviour).

Recommendation:

- Provide a nest box and litter for laying hens.

Restricted feeding: Although food intake varies across different housing systems, it is generally not necessary to restrict the food intake of fowl. One exception is for broiler breeders who, because of the selection for large appetites, will develop severe health problems if food is freely available. However, the common practice of restricting the food intake of broiler breeders leads to chronic hunger and stereotyped pecking (Savory 1979, FAWC 1998). Lameness is also prevalent in broilers (FAWC 1992) and studies involving the self-selection of analgesics have shown that lame broilers are likely to be in pain (Danbury *et al.* 2000). It is therefore advisable to avoid the use of broiler breeders in research wherever possible unless the study is directly applicable to their welfare.

Recommendation:

- Do not use broiler breeders unless the project aims to improve their welfare.

Bone and foot problems: Skeletal weakness in domestic fowl is exacerbated by lack of opportunity to exercise and by high levels of egg production (FAWC 1997). Good quality housing with sufficient perching space improves foot condition and increases bone strength, although care must be taken when designing facilities to minimize the risk of injury as a result of birds flying into perches. Bone strength varies between strains and rearing systems (FAWC 1997), so both these factors should be considered when choosing experimental animals.

Recommendations:

- Provide housing with a good quality and quantity of space.
- Research bone strength in different strains when choosing experimental animals.

19.8 Recommended reading

- Farm Animal Welfare Council (FAWC) (1997) *Report on the Welfare of Laying Hens.* Tolworth, UK: FAWC
- Farm Animal Welfare Council (FAWC) (1998) *Report on the Welfare of Broiler Breeders.* Tolworth, UK: FAWC
- RSPCA (1999) *Welfare Standards for Chickens*. Horsham, UK: RSPCA
- RSPCA (1999) *Welfare Standards for Laying Hens and Pullets*. Horsham: RSPCA
- Sainsbury D (1992) *Poultry Health and Management.* London, UK: Blackwell Scientific Publications
- Sherwin CM, ed. (1994) *Modified Cages for Laying Hens.* Potters Bar, UK: UFAW
- UFAW (1999) *Management and Welfare of Farm Animals: The UFAW Handbook*, 4th edn. Potters Bar, UK: UFAW. Wells RG: Laying hens, pp 193–233; Sainsbury DWB: Broiler chickens, pp 235–47
- UFAW (1999) *The UFAW Handbook on the Care and Management of Laboratory Animals*, 7th edn. Potters Bar, UK: UFAW. Duncan IJH: The domestic fowl, pp 677–96

20 The domestic turkey, Meleagris gallopavo

Turkeys are not used widely for scientific procedures other than applied studies that aim to improve the efficiency of their commercial production, e.g. studies relating to the diagnosis and prevention of disease, manipulation of diet and nutrition to increase food conversion efficiency, genetics for increased growth rate and reproduction, and the effects of lighting and environmental factors in addressing problems with feather pecking and aggression. Some of this research is conducted to evaluate the welfare of turkeys in commercial situations.

20.1 Natural habitat and behaviour

The domestic turkey is derived from the native wild turkey of North America. Birds taken to Europe during the 1500s were descendants of the Mexican turkey (*Meleagris gallopavo*) but since these original transportations occurred, subspecies from south-western North America and breeding from feralized early domesticated strains have all contributed to the genotype of the modern bird. Perhaps the most plausible derivation of the popular name is that when these birds were first introduced to Europe, anything foreign was said to be from Turkey and this word eventually became associated with the species (Bent 1963, Schorger 1966, Crawford 1984).

Habitat: The natural habitat used by wild turkeys varies considerably according to the season, climatic conditions and behaviour being performed. Turkeys regularly utilize environments as diverse as open plains, dense woodland, thick scrub, and treetops, and can sometimes even be seen wading in lakes. The walking speed of the wild turkey is approximately 5 km/h but birds can run with great manoeuvrability at speeds of up to 30 km/h. Although their endurance is not great, wild turkeys are capable of flight—in stark contrast to the domesticated strains. Wild turkeys are not true migrants but will move up to 80 km between winter and summer sites. Typically, daily movement is 2–3 km and the home range covers from 200 to 1000 acres (Bent 1963, Schorger 1966, Williams 1981).

Social behaviour: The social behaviour of the wild turkey is complex. During the breeding season, males congregate in large groups to display to each other. This involves the males fanning their tail feathers, drooping the wings and erecting all the body feathers, including a tuft of black modified hair-like feathers on the centre of the breast, commonly termed a 'beard'. The skin of the head, neck and caruncles becomes bright blue and red, and the snood elongates. The birds 'sneeze' at regular intervals, followed by a rapid vibration of their tail feathers. Throughout, the birds strut slowly about with the neck arched backward and their breasts thrust forward. The birds also emit their characteristic 'gobbling' call. In domestic birds this display is readily elicited by the presence of humans. After hatching, the family is a basic social unit with the young firmly imprinted on the hen. The mother apparently teaches the young about the suitability of various foods with a series of displays and distinctive 'clucks'. Several broods usually join together in the spring to form a larger flock with the males leaving in the winter, such that during this season there are four types of flock: (i) old hens without broods, (ii) brood hens with female offspring, (iii) young males recently separated from mothers and (iv) older males (Schorger 1966, Watts & Stokes 1971).

Wild turkeys perform a wide variety of other behaviours such as dust-bathing, anting, foraging, hunting (they are omnivores) and fighting (which may sometimes last for hours). They are a highly vocal animal with a wide diversity of calls; eight are recognized and used routinely during hunting (Williams 1981).

Domestication: During the short time of their domestication, modern strains of turkeys have been selected for rapid growth rate and increased body size. Fertilization is therefore performed by artificial insemination (AI) to protect the welfare of the female bird. Therefore, although domestic birds retain many of the characteristics of their wild cousins, there are other fundamental differences. The vast majority of domestic turkeys are from only a very small number of strains, most of which have completely white plumage, though some have retained the wild type mottled appearance.

Commercially, domestic male turkeys are routinely grown to approximately 20 weeks of age when they can weigh over 20 kg (a 3-year-old male wild turkey weighs 9 kg (Williams 1981)). Perhaps the most obvious difference in behaviour between the wild and domestic turkey is the inability of the latter to fly—although this does not always stop them attempting to! Domestic turkeys have retained the ability to run quickly, especially at younger ages.

20.2 Housing and space requirements

Space allowance: Turkeys are the largest domesticated gallinaceous bird. They show a variety of 'comfort' behaviours such as wing-flapping, feather ruffling and leg stretching. In addition, they show spontaneous vigorous locomotion ('frolicking') which has all the appearance of 'play' and which decreases in frequency as the birds get older (Sherwin & Kelland 1998). All these activities, particularly locomotion, require a considerable amount of space. The UK Farm Animal Welfare Council noted that a maximum stocking density of 38.5 kg/m^2 had been recommended, but provided their own formula which suggested a maximum permis-

Table 4 Space allowances for turkeys

	Common practice				Good practice			
Mass (kg)	Area per bird: singly housed (m^2)	Area per bird: group housed (m^2)[a]	Minimum height (m)	Minimum length of feed trough per bird (cm)	Area per bird: singly housed (m^2)	Area per bird: group housed (m^2)[a]	Minimum height (m)	Minimum length of feed trough per bird (cm)
1	0.9	0.3	2	15	N/A	0.35	2	20
4	1.0	0.35	2	15	N/A	0.7	2	20
8	1.2	0.4	2	15	N/A	1.0	2	20
12	1.5	0.5	2	20	N/A	1.1	2	30
16	1.6	0.55	2	20	N/A	1.1	2	30
20	1.8	0.6	2	20	N/A	1.2	2	30
Over 20	2.0	1.0	2	20	N/A	2.0	2	30

[a]The minimum pen size for group-housed turkeys is 2 m^2. For birds over 20 kg, the minimum size is 4 m^2 and all pen sides should be at least 2 m. N/A = not available

sible stocking density of 59.1 kg/m^2 (FAWC 1995). This higher density approximates to three adult birds each weighing 20 kg being provided with 1 m^2, which is clearly limiting for birds wishing to perform behaviours that require considerable space, such as dust-bathing and wing-flapping. Good practice would suggest a considerably lower density is maintained (see Table 4 for recommended space allowances).

Feeders and drinkers: Social facilitation plays a major role in turkey behaviour in that feeding, drinking, running and investigation of novel objects by one bird encourages this activity in other individuals. Similarly, all members of a group will be highly motivated to feed and drink when the lights come on immediately after the dark phase. Under commercial conditions, turkeys are normally provided with 7.5 cm feeding trough space per adult bird and one 'bell' type drinker for 50–100 birds or 3.25 cm for each bird. In addition, it has been suggested that no bird should have to walk more than 3 m to feed or drink, although some walking is desirable to help maintain good leg health. Best-practice would suggest a considerably greater amount of trough space to allow several birds to feed or drink next to each other, i.e. approximately 30 cm of feeding trough per adult bird and two drinkers for every 10–20 birds. It is inadvisable to use feeders and drinkers designed for domestic fowl. Although these look similar in design, the larger heads of turkeys means it becomes difficult for them to use fowl feeders and drinkers when older. Care should also be taken to avoid chicks drowning themselves in adult drinkers; a section of flexible pipe (for bell drinkers) can be placed in the trough section to prevent this. In addition, recently hatched chicks can sometimes suffocate if pushed by others against or under immovable objects such as drinkers or feeders.

Substrate: Turkeys are normally housed in indoor rooms on a deep-litter substrate, e.g. wood shavings. The suitability of this substrate depends on stocking density, and a controlled build-up of a microbial flora is essential. There must be sufficient substrate to ensure adequate dilution of faeces. Litter must be added where necessary and maintained at a minimum depth of 5 cm. Those areas which become overly wet—often a circular area underneath the drinker—should be removed and fresh substrate added as required.

Recommendations:

- House turkeys on a clean, wood-shavings, deep-litter system.
- Provide sufficient space to allow expression of all comfort behaviours.
- Provide 30 cm of feeder space for each bird and two drinkers per 10–20 birds to

allow them to feed and drink synchronously.
- Place food on the floor to encourage foraging behaviour and reduce injurious pecking.

20.2.1 Physical environmental conditions

Requirements for most physical conditions, e.g. dust, ammonia and humidity, are similar to those for domestic fowl when housed on deep-litter systems. Levels of CO_2 and ammonia should not exceed 5000 ppm and 5 ppm, respectively and relative humidity should be maintained at 50–70% (RSPCA 1997). Ammonia, CO_2, dust and humidity must be maintained regularly (see Section 19.2.1), but under commercial conditions ambient temperatures for adult turkeys are usually maintained at between 18 and 21°C. Once fully feathered, turkeys can easily tolerate wide temperature ranges. High temperatures in particular should be avoided because the large mass and high metabolic rate of turkeys makes them susceptible to heat stress. Turkeys rely on panting and postural changes for losing excess body heat, but their ability to avoid overheating is limited. Hyperthermia is exacerbated by high stocking densities. Vigorous handling (picking up and moving) of larger birds during warm conditions should be avoided.

Light and photoperiods: Commercially, turkeys are usually housed under very low light intensities to reduce feather pecking, sometimes in conjunction with long (23 h) or continuous photoperiods. However, such lighting conditions might cause great concern for welfare as they can result in retinal detachment, buphthalmia (distortions of the eye morphology) and subsequent blindness (Ashton *et al.* 1973, Siopes *et al.* 1984, Davis *et al.* 1986, Manser 1996). Behavioural studies have shown that turkeys prefer light intensities (e.g. 20 lux, RSPCA 1997) which are higher than those generally provided under commercial conditions (Sherwin 1998). In addition, very low intensities make it difficult for humans to detect colours, thus making it almost impossible adequately to inspect the birds.

Long photoperiods are used commercially to optimize production but can result in distortion of the behavioural time budget (Newberry 1991) and eye abnormalities (see above). Comparatively short photoperiods (8 h) can influence performance, such as causing retarded sexual development in males (Davis & Siopes 1985, Classen *et al.* 1994, Lewis *et al.* 1998), and will also cause turkeys to eat in total darkness (Sherwin *et al.* 1999a). This may indicate an abnormally high motivation to feed (possibly resulting from artificial selection for production characteristics), and during nocturnal feeding turkeys are at a greater risk of injury from colliding with feeders, drinkers, etc. A photoperiod of 12–16 h appears adequate for turkeys to consume their daily feed requirement without any obvious adverse physiological or behavioural consequences (Sherwin *et al.* 1999b). There should be a minimum light period of 8 h and of at least 20 lux, and a minimum 'night' of 6 h.

Recommendations:
- Maintain dust, ammonia and humidity levels within limits acceptable for the birds and experimenters.
- Maintain ambient temperatures for adult turkeys between 15 and 21°C.
- Use photoperiods of 12–16 h, with a minimum 8 h 'day' and 6 h 'night'.
- Do not keep at very low light levels—20 lux should be the minimum.

20.3 Rearing

Environmental conditions: Early post-hatching conditions are critical to ensure the survival of turkey chicks. Ambient temperature should be maintained at 35°C for 3 days and then lowered gradually by approximately 3°C every 2 days to 18°C at 37 days of age. Supplementary brooder heaters should be provided initially to aid thermoregulation. The need for these heaters and the most suitable position and height can be judged by the chicks' tendency to aggregate under the heaters or to disperse.

Feeding and parental care: As with layer hen chicks, turkey chicks are naturally precocial and are sustained by yolk reserves until 3 days of age. Learning during this time is essential for the development of eating and drinking. Without intervention, it is common for a significant proportion of turkey chicks to die from failing to learn to feed or drink (commonly termed 'starve-out'). This can be reduced by using small, circular brooding pens approximately 2 m in diameter (to house 100 chicks) and 40 cm high for the first week of life. These pens keep the chicks in close proximity to feed, water and heat, but in addition, staff should attract the chicks' attention by tapping repeatedly on the feeders and drinkers, thus simulating the feeding behaviour of the mother hen. It is usual to give continuous illumination for the first 24–48 h to aid this learning process.

Pecking: Injurious feather pecking can occur from the first day of life. Recent evidence (Sherwin *et al.* 2001) indicates that, at least in relatively small groups (of between 50 and 100 birds), this can be considerably reduced by providing supplementary UV radiation (turkeys can see in the UV spectrum), pecking substrates (e.g. straw), and visual barriers to reduce social transmission of this behaviour. Other pecking substrates which might be used are chains or twine (both placed at head height to ensure the birds do not become entangled), vegetable matter such as cabbages, or food scattered in the substrate.

Recommendations:

- Regulate environmental conditions closely, especially during the first few days of life.
- Ensure that newly-hatched turkey chicks learn to peck at food and water, otherwise deaths from starvation and thirst are likely.
- Provide environmental enrichment, particularly pecking substrates such as straw, from the day of hatching to avoid injurious feather pecking becoming prevalent.

20.4 Diet

Domestic turkeys should be fed commercially available diets that have been developed to meet their nutritional requirements, although they will also benefit from fresh food as dietary enrichment. Nutrient content, food quality and feeding regimes must be carefully controlled to prevent leg abnormalities and other health and welfare problems associated with rapid growth rates (RSPCA 1997).

20.5 Environmental stimulation

Like the domestic fowl, the turkey is often housed in extremely barren conditions when kept in a commercial flock. Less has been published on environmental stimulation for turkeys than fowl, but it is equally important to provide sufficient quality space to allow turkeys to express a range of natural behaviours.

20.5.1 Good quality environment

Young turkey poults will readily perch and roost; at 10 days of age they will fly to land on a perch 30 cm high. Perches should be placed at a height where birds on the ground are not able to easily peck and tug at the feathers of perching birds. The best perch shape and material is probably similar to that for domestic fowl, i.e. ovoid or rectangular with smoothed corners and made of wood or plastic which can be cleaned effectively. The strong motivation to perch and fly becomes less obvious as the birds become older, but they will readily climb on objects such as bales of straw if these are placed in the pen. To prevent older, less agile birds from injuring themselves whilst trying to perch, these perches should be placed at a low height (e.g. 5 cm). The shape and size of the perch should be in accordance with the rapidly growing claws of the birds.

Recommendations:

- Provide young turkeys with perches.
- Consider using hanging objects and straw, and encourage foraging.
- Place perches at a lower height for older birds of heavier strains, or avoid them altogether.

20.5.2 Foraging behaviour

As noted above, scattering food such as grain in pecking substrates such as straw promotes foraging behaviour, and other vegetable matter, such as brassicas (e.g. cabbage leaves), can also be provided on the floor of the pen. Straw bales also make the birds' environment more interesting and can provide a refuge from dominant birds, but will need to be frequently replaced.

Recommendations:

- Provide a pecking substrate and scatter the birds' food in it.
- Regularly give extra vegetables such as cabbages.

20.5.3 Group size and composition

Domestic turkeys are highly social and become very distressed when isolated. Handling or housing birds as individuals should be avoided as this generally makes the birds considerably less tractable.

However, turkeys easily recognize 'strangers'. Placing any strange turkey into an established group will almost certainly result in that individual being attacked by several others and possibly killed. Social 'tension' within the group can be detected by listening to the birds' vocalizations. Experience of calls will reveal that a rather high-pitched trill indicates birds have been fighting (check for head injuries!) or are about to fight.

Group-housed turkeys can be highly aggressive to one another. Intense sparring fights can occur as the birds mature. During such fights, the opponents become almost oblivious of extraneous stimuli—handlers must be cautious if trying to intervene in a fight. The most extreme form of injurious pecking is head pecking, in which one individual is incessantly targeted and pecked, sometimes with great force, by several other birds. It tends to become more frequent when the turkeys reach sexual maturity, especially if there is a significant difference in size between birds.

When head pecking occurs under standard laboratory housing conditions, i.e. relatively small enclosures with few opportunities to escape, the outcome is almost always fatal. Head pecking often occurs after a single, relatively minor injury has been received during a fight or if the bird has been trampled upon by another. Birds with fresh injuries larger than 1 cm should be constantly monitored and, if targeted by other individuals, separated immediately. Attempts to re-introduce individuals who have been isolated because of being head-pecked usually result in immediate attack, even when re-introduced as long as 48 h after the original attack—it may be impossible to re-introduce head-pecked individuals. Turkeys should therefore only be isolated if there is a good chance that they will recover. Victims should be separated and a decision should be made after 24 h whether to attempt re-introduction or humanely kill the bird. Fatal head pecking can occur spontaneously even in small groups (of fewer than 10 birds) which have been housed together since hatching. Death may occur rapidly; healthy birds known to be unscathed can be found dead 3 h later—therefore frequent monitoring of turkey groups during the light phase is essential, particularly for males approaching maturity.

Commercial turkeys are normally reared in single-sex flocks. If a male is inadvertently placed in a female flock, he may be aggressively victimized (hence the term 'hen-pecked'). Females in a group of males will be repeatedly mated during which injury from being trodden upon is very likely.

Recommendations:

- Avoid housing turkeys singly.
- Do not mix groups or place newcomers into established groups.
- Pay attention to the birds' vocalizations—these can indicate the degree of social 'disharmony' within the group.
- Monitor group-housed turkeys frequently, e.g. every 2 to 3 h during the light phase.
- Remove birds with bleeding head wounds immediately, even if these are only small.
- Rear birds in small, single-sex flocks.

20.5.4 'Natural' conditions

Turkeys dust-bathe regularly when conditions are appropriate and this appears to be socially facilitated. Providing fresh sawdust often results in many birds immediately performing vigorous dust-bathing which can cause a very dusty environment! Alternatives such as sand will help to prevent this.

Recommendation:
- Provide fresh substrate on a regular basis to promote dust-bathing.

20.6 Training and rewards

Turkeys are difficult to train in isolation and so should be trained where they can see at least one other bird. Mealworms are suitable rewards that can be given following procedures or as treats.

Recommendation:
- Train turkeys in the presence of other birds and reward with mealworms.

20.7 Potential health and welfare problems

As with broiler fowl, commercial strains of domestic turkeys become less agile and often experience difficulty in walking as they become older (approximately 17 weeks of age) (Sherwin *et al.* 1999a). This is due to a variety of diseases and anatomical changes resulting from intensive selection for production traits (Nestor *et al.* 1985, Hester *et al.* 1983, 1987, Duncan *et al.* 1991, Noble *et al.* 1996a,b). Sometimes, the difficulty in locomotion can become so severe that birds utterly refuse to walk and will die of starvation or thirst unless intervention occurs. The tendency to spend long periods of time sitting on the substrate can lead to breast blisters and hock burns due to the high nitrogen content of the litter, particularly if the substrate is not adequately maintained. A policy for dealing with lameness should be agreed with the attending veterinarian, i.e. it should be set out when and whether pain relief should be administered, or when birds should be culled.

Turkeys are prone to heart-related problems, therefore any physical exertion for them can be quite traumatic and result in sudden cardiovascular failure or breathlessness. Since turkeys appear to target and repeatedly peck any individual who behaves in an obviously different fashion, individuals who become exhausted, unable to walk, or sit for prolonged periods should be closely monitored or protected.

Recommendations:
- Regularly monitor all birds for walking ability. Consider culling those who show signs of difficulty.
- Agree a policy on dealing with lame birds with the attending veterinarian.
- Minimize stress to older, larger turkeys and avoid over-exercising them.

20.8 Transport

When young, turkey poults should be transported in a similar fashion to the chicks of domestic fowl. When larger and less agile, the birds readily and vigorously extend their wings to maintain balance, thus risking bone breakages if placed in confined conditions or if they fall over due to a bumpy section of road. Again due to the generally reduced cardiovascular function, catching, handling and transport of mature turkeys appears to cause distress and should be considered carefully before being attempted. It may be safer for the birds to be transported in very high stocking densities (i.e. touching) so they can lean on each other without extending their wings to balance, but ensure that legal limits are not exceeded. Trailers are ideal for transporting small numbers of birds short distances. The turkeys can be walked up and down a straw-covered ramp.

Recommendations:
- Avoid transporting mature turkeys whenever possible.
- If transport is unavoidable, use high (but legal) stocking densities and allow birds to walk in and out of the trailer.

20.9 Recommended reading

- Farm Animal Welfare Council (FAWC) (1995) *Report on the Welfare of Turkeys.* Tolworth, UK: FAWC
- Hale EB, Schleidt WM, Schein MW (1969) The behaviour of turkeys. In: *The Behaviour of Domestic Animals*, 2nd edn (Hafez ESE, ed). London, UK: Baillere Tindall and Cassell

- Lister SA (1999) Turkeys. In: *Management and Welfare of Farm Animals: The UFAW Handbook*, 4th edn (Ewbank R, Kim-Madslein F, Hart CB, eds). Potters Bar, UK: UFAW
- RSPCA (1997) *Welfare Standards for Turkeys*. Horsham, UK: RSPCA

21 The quail, including Coturnix spp.

Quail belong to the family Phasianidae, order Galliformes. Species most frequently used in research and testing include the Japanese quail (*Coturnix japonica*), the European quail (*Coturnix coturnix*), the bobwhite (*Colinus virginianus*), the California (*Lophortyx californica*), and the Chinese painted (*Excalfactoria chinensis*). This section focuses mainly on the Japanese quail, as it is a commonly used species in both research and especially farming, and so there is consequently more information available about its behaviour and physiology.

In the laboratory, quail are used in studies of behaviour and development, pharmacology, toxicology (especially with respect to pollutants and agricultural substances), studies on genetics, growth, nutrition and physiology. Within the EU, Convention ETS123 and Directive 86/609 stipulate that *C. coturnix* must be obtained from designated suppliers (Council of Europe 1986, European Community 1986).

21.1 Natural habitat and behaviour

Wild quail live in small social groups and devote much of their time to scratching and foraging for seeds and invertebrates on the ground. The Japanese quail is indigenous to South-East Asia, where its preferred habitat is dense vegetation such as grasslands, bushes alongside rivers, and cereal fields. Wild Japanese quail live in pairs during winter and the breeding season (Taka-Tsukasa 1967), forming large groups during migration (Raethel 1988).

Although European and Japanese quail are migratory, quail generally only perform short flights to escape predators during winter and the breeding season. Most have short, rounded wings and are capable of extremely rapid, upward flight that enables them to escape from danger.

Domestication does not appear to have substantially altered quail behaviour, so it is essential to design housing systems that respect this. Substrate for scratching, pecking and dust-bathing, nest boxes and cover are all important for quail welfare (Johnson & Guthery 1988, Schmid & Wechsler 1997).

Recommendation:
- Recognize that the behaviour of domestic quail is very similar to that of wild-type birds, and design housing that permits the expression of a range of behaviours, especially upward flight and the ability to hide or escape.

21.2 Housing and space requirements

Quail are generally housed in outdoor aviaries, floor pens with deep litter or smaller battery-type caging. Outdoor aviaries are to be preferred, but where birds must be housed indoors, serious consideration should be given to housing in pens as opposed to cages.

21.2.1 Outdoor aviaries

Groups of eight Japanese quail housed in semi-natural outdoor aviaries of 19 m^2 containing a substrate of soil and wood chips, herbs, shrubs and artificial shelters have been reported to display a range of natural behaviours including exercise, foraging, flight and dust-bathing. These birds had been reared in battery cages up to 5 weeks of age (Schmid & Wechsler 1997).

Outdoor housing is therefore likely to benefit quail, but birds must have access to shelter from rain and extremes of temperature. There may also be an increased risk of disease due to contact with faeces and damp earth, and this should be taken into account during health monitoring (see Sections 11.2 and 21.7). Rotating groups of quail between different pens within their lifetimes or between cohorts so that enclosures can 'rest' and dry out may also help (K Miller, personal communication).

Quail can be difficult birds to catch, especially when housed in enriched aviaries or pens. It may be necessary to adapt equipment, for example by mounting fishing nets on poles (Robbins 1992). Quail require confident but gentle handling, and should be carried so that the wings are pinned against the body but the legs are able to hang freely (Gerken & Mills 1993). It is therefore essential that staff are well trained and competent in capture techniques that are efficient and minimize stress.

Recommendations:

- House quail in enriched outdoor pens wherever possible, but ensure that they always have access to shelter, and heating if necessary.
- Make sure that any increased risk of disease in birds housed in outdoor pens is offset by adequate health monitoring.
- Ensure that anyone attempting to catch quail housed in pens or aviaries has been fully trained in appropriate capture techniques.

21.2.2 Floor pens

These are an adaptation of agricultural practice and commonly suggested stocking densities range between 40–200 birds/m^2; UFAW recommends 55 birds/m^2 for farm production (Hodgetts 1999) and no more than 50 adult birds/m^2 in the laboratory (Mills *et al.* 1999). The UK Home Office Code of Practice (Home Office 1989, Table 5) allows 250 cm^2 per individual for birds weighing between 150 and 250 g, which equals 40 birds/m^2. Table 5 also sets out recommended sizes for pens and cages with lower stocking densities. Suitable substrates include sand, wood shavings or straw.

The highest levels of fertility and hatchability are achieved at lower stocking densities (Ernst & Coleman 1966). Some welfare problems may still occur when birds are housed in floor pens, however. Care must be taken to ensure that adequate food and water stations are provided to prevent excessive competition resulting in emaciation of subordinate birds. Quail housed in floor pens are often found to have hardened balls of food, litter and faeces adhering to their feet (Gerken & Mills 1993), which can lead to increased pecking at the toes, injuries and

Table 5 Space allowances for quail

	Minimum (Home Office 1989)				Common practice				Good practice			
Mass (g)	Area per bird: singly housed (m^2)	Area per bird: group housed (m^2)	Minimum height (m)	Minimum length of feed trough per bird (cm)	Area per bird: singly housed (m^2)	Area per bird: group housed (m^2)[a]	Minimum height (m)	Minimum length of feed trough per bird (cm)	Area per bird: singly housed (m^2)	Area per bird: group housed (m^2)[a]	Minimum height (m)	Minimum length of feed trough per bird (cm)
Up to 150	0.035	0.025	0.20	4	0.5	0.10	0.3	4	N/A	0.6	2	3
150–250	0.040	0.025	0.25	4	0.6	0.15	0.3	4	N/A	0.7	2	7

[a]The minimum pen size for group-housed quail is 2 m^2. N/A = not available

possibly cannibalism. Good husbandry and regular monitoring of floor-penned birds' feet are therefore essential.

Aviary-housed female Japanese quail have been found to have a strong preference for artificial cover, especially while egg laying, and also to show flight behaviour in response to a frightening stimulus significantly less when under cover (Buchwalder & Wechsler 1997). Cover (either natural or artificial) should therefore be provided to encourage natural behaviour and reduce stress.

Recommendations:

- Maintain quail in floor pens at low stocking densities for good welfare and breeding success.
- Ensure that all birds have adequate access to food and water.
- Monitor feet carefully for adherent food and faeces.
- Always provide cover for quail housed in aviaries or pens.

21.2.3 Battery cages

This type of cage is frequently used in both farming and research. Standard laboratory battery cages are extremely small (Table 5) and in no way allow birds to exercise adequately or permit the provision of environmental stimulation. For example, quail housed in semi-natural aviaries (with cover) were found to spend 24% of their time walking, running or flying and 8% pecking and scratching away from their feeder, despite having *ad libitum* access to food (Schmid & Wechsler 1997); neither of these activities are possible in battery cages. Breeding female quail housed in cages also exhibit pre-laying restlessness (Gerken & Mills 1993). The justification for housing quail in standard size battery cages should therefore always be questioned, and birds should be housed in aviaries or pens wherever possible.

Modifying cages: If there are compelling scientific or veterinary reasons for keeping quail in cages, serious consideration should be given to modifying them to provide a better quality and quantity of space and thereby improving welfare (see also Section 19.2). The typical quail flight response is vertical (see Section 21.1) and serious injuries can result when birds are housed in battery cages, and so the cages quail are typically kept in have insufficient headroom to permit high jumps. However, the welfare of caged quail can be significantly improved by combining cages to give birds more space for exercise, by adding enrichment items (see Section 21.5) and by providing a minimum cage height of 30 cm. Although it has been suggested that injuries will be worse if cage height exceeds 20 cm (Gerken & Mills 1993, Mills *et al.* 1999), it is the experience of Working Party members that cages of 30 cm in height significantly reduce or even eliminate the problem. Consideration could also be given to providing solid cage roofs, as this may make birds feel safer, although this could result in unacceptably low light levels in lower cages if birds are housed in racks. Alternatively, flexible plastic grid roofs (mesh size 12 mm × 12 mm) do not cause head injuries and permit better air circulation without blocking as much light as solid roofs (I Schmid, personal communication).

Laying hens will benefit from nest boxes, which can be clipped on to the sides of their cages, and nesting materials; nest boxes filled with chaff or hay were preferred over those containing artificial turf in a study using Japanese quail (Schmid & Wechsler 1998). If wire floors are deemed to be necessary, e.g. for some toxicology studies, a solid resting area should be provided and the wire should be coated with soft plastic to reduce damage to the feet of the birds.

Reducing aggression: Aggression may also be a problem where birds are housed in cages. This may be reduced by establishing breeding pairs or trios at about 4 weeks of age, but close monitoring will still be required to reduce the incidence and severity of fighting. Female quail are often larger than males and there are occasions when the males are injured (Gerken & Mills 1993). Repeated mating attempts by males can also result in head-pecking injuries to females, and this may be exacerbated by the close contact inevitable in battery cages.

Studies should always be carefully planned in advance so that birds are housed in cages for the minimum possible period, not only to reduce the duration of stress but also because many welfare problems become more severe with age, especially if birds are kept for one year or more (Gerken & Mills 1993).

Recommendations:

- Seriously question whether cages are really necessary to achieve your aims.
- If cages must be used, modify them to allow more space, supply enrichment and provide a solid resting area if possible. Laying hens should have access to nest boxes and materials.
- Minimize the risk of birds damaging themselves in cages by providing cage heights of 30 cm, using wire coated with soft plastic and possibly solid roofs.
- Establish stable groups carefully and reduce the duration of studies as far as possible, as many welfare problems worsen with age.

21.2.4 Physical environmental conditions

For guidance on environmental conditions, see Home Office (1995), Hodgetts (1999) and Mills *et al.* (1999).

21.3 Breeding and rearing

Breeding: Most quail are sexually dimorphic and can be sexed from about 3 weeks of age (9 weeks in the case of bobwhites) using feather colour or pattern. Japanese and European quail both share the same colour patterns, where males have breast feathers with brown and white streaks and females have breast feathers with dark brown to black speckles. Quail become sexually mature at 5–6 weeks of age (16 weeks for bobwhites) when kept on day lengths of 12 h or more (Ottinger & Rattner 1997, Mills *et al.* 1999). Breeding is most successful where the ratio of females to males is 2 or 3 to 1 (Hodgett 1999). See Ottinger & Rattner (1999), Mills *et al.* (1999) for further guidance on reproduction and breeding in Japanese quail.

In the wild, quail nests are scrapes in the ground with a lining of dry grass. Nesting materials such as chaff or hay should always be provided in the laboratory unless there is genuine scientific justification not to do so. Japanese quail hens in aviaries have been shown significantly to prefer laying their eggs under plants or artificial cover (Buchwalder & Wechsler 1997, Schmid & Wechsler 1997, 1998), so cover and/or nest boxes should also be provided as appropriate (see Schmid & Wechsler 1998 for nest box preferences in Japanese quail).

Quail are prolific egg layers and lay on three out of four days on average. The eggs vary in colour from being heavily pigmented with dark brown blotches to almost fawn all over. Many strains of quail will not incubate their own clutch, so the eggs may need to be incubated by broody bantams or pigeons, or artificially incubated (see Section 8.2). Eggs taken for incubation should be used as soon as possible; if they have to be stored they should be held in cooled incubators at 12–15°C and 75–80% relative humidity for up to 7 days, turning daily. Any type of egg incubator can be used for the 16–17 days of incubation at a temperature of 37.5°C, but forced air incubators produce the best results. See Hodgetts (1999) for further guidance on incubation.

Rearing: Newly-hatched quail chicks are precocial but need special attention and must be kept at a temperature of 35–36°C for the first couple of days after hatching. The temperature can then be reduced by 0.5°C per day until they are housed in a temperature of 20°C by 3 weeks (Hodgetts 1999). Note that these temperatures are approximate and attention should be paid to the chicks' behaviour for further guidance; if they are all at the perimeter of the heated area they are likely to be too hot, but if they are crowded together immediately below the heat source they are probably too cold. Particular care must be taken with food and water for hatchlings. Water can be offered in cylinder drinkers or small containers in which glass marbles or rings of plastic tubing have been placed to prevent the chicks from drowning, whereas food can be scattered over the floor area or placed in shallow trays. Food and water should be placed so that the chicks do not have to move far from the heat source to find it. It is also important to ensure that chicks can grip the substrate to prevent their legs from becoming splayed, so it may be necessary to place a layer of textured paper over the litter for the first few days, replacing it regularly.

Recommendations:

- Provide nest boxes and nesting materials for all laying hens, even those housed in cages, where this will not compromise the study.
- Transfer eggs to the incubator as soon as possible; do not store them for more than 7 days.
- Use a forced air incubator to minimize egg wastage.
- Keep quail chicks warm and reduce temperature slowly; use chick behaviour as an indicator of suitable temperature conditions.
- Position food and water near to the brooder lamp, ensuring that young chicks cannot drown in the water.
- Scatter food on the floor to encourage foraging.

21.4 Diet

Japanese quail are generally provided with 'starter' diets for either game birds or turkeys until they are 21 days old, 'grower' diets between 21 days and 6 weeks, and 'breeder' diets thereafter (see Mills *et al.* 1999 for details of nutritional requirements). Water should be provided *ad libitum*. All quail will take a variety of fruit, grains, small seeds and invertebrates, and a choice of different foods should be offered as dietary enrichment where possible. Food can also be presented in more interesting ways, e.g. by coring fruit or vegetables and stuffing them with seeds or grain. Limestone or oyster shell grit should always be available.

Recommendations:

- Feed quail on diets that are formulated for their nutritional needs at each life stage.
- Provide a choice of different foods in a range of ways where possible.

21.5 Environmental stimulation

Laboratory quail are rarely supplied with enrichment objects or given the opportunity to forage or dust-bathe. There is a pressing need to question this, as it has been shown that quail will use pen or cage additions. It is important to give the birds the benefit of the doubt and provide environmental stimulation that elicits a range of behaviours including foraging, dust-bathing and social behaviours.

21.5.1 Good quality environment

Providing environmental stimulation for chicks in the form of coloured objects (balls, tubing, cylinders and cubes) alleviates fear of both human beings and novel stimuli in adult birds, perhaps by reducing underlying fearfulness (Jones *et al.* 1991). Toys in the form of stones and pine cones may reduce aggression in groups of adult birds (Ottinger & Rattner 1999). Other commonly provided items are balls, tubes, mirrors and branches of vegetation (K Miller, personal communication).

A study involving continuous observation of Japanese quail in a semi-natural aviary at twilight found that the birds did not roost on perches at night, unlike domestic fowl. They also spent very little time (0.5%) on elevated structures, e.g. on top of shelters (Schmid & Wechsler 1997). It is not currently considered to be necessary to provide perches.

Dust-bathing is important to quail (Schmid & Wechsler 1997); Japanese quail use litter for dust-bathing (Mills *et al.* 1999) and exhibit vacuum dust-bathing behaviour in its absence (Gerken 1983). Dust baths should therefore always be provided if possible, with suitable substrates such as sand or sawdust (see also Section 19.5.4).

Recommendations:

- Provide toys and other stimulation.
- Supply dust baths with appropriate substrate.

21.5.2 Foraging behaviour

Quail are usually fed commercial pelleted or powdered diets from food hoppers, which does not encourage natural time budgets or behaviour. Birds can be encouraged to forage by supplying alfalfa cubes for pecking, scattering food or treats in substrate on the aviary or pen floor, or hiding them among shredded paper in a trough (Nicol 1995), or among soil in a tray. Hanging fresh vegetation from the pen roof also provides extra stimulation.

Recommendation:

- Encourage birds housed in pens and cages to forage for at least some of their food.

21.5.3 *Group size and composition*

Japanese quail form 'pecking order' type dominance hierarchies under artificial husbandry conditions. Male birds are likely to attack if new birds are introduced to well-established groups, so individuals should not be added to groups and groups should not be mixed (Mills *et al.* 1999). If the sexes are mixed, the ratio of males to females should never be greater than 1:4, or males may repeatedly attempt to mount females which could lead to injury (Mills *et al.* 1999). Females can be kept successfully in single-sex groups, which is probably beneficial to their welfare, but males housed in single-sex groups may become aggressive and attempt to mount one another (Gerken & Mills 1993). In the experience of the Working Party, males and females can be housed in single-sex groups of up to five birds, and aggression can be dealt with by identifying and removing the aggressor. Singly housing birds in cages is not desirable and should only be done with incompatible birds and if there is no other suitable husbandry system.

Aggression is sometimes countered by debeaking birds, which is likely to cause both acute and chronic pain (see Section 11.2.3), or by fitting metal rings which pass through the nasal septum and between the mandibles so that birds cannot fully close their beaks. The latter inhibits normal behaviour more than debeaking, and neither method is desirable. Housing males and females together in appropriately composed groups before sexual maturity should render debeaking unnecessary (Gerken & Mills 1993), and providing sufficient space and environmental stimulation for the birds is also likely to reduce aggression. If aggression problems persist, beak trimming is preferable to debeaking (see Section 11.2.3).

There is strong individual variation in birds' underlying sociality, or motivation to be with other quail, and birds have been found to prefer those with similar levels of sociality to their own in two-choice behavioural tests (Carmichael *et al.* 1998, Jones & Mills 1999). This means that individual quail may be suited to particular social environments and careful monitoring may therefore be necessary to minimize social stress.

Recommendations:

- Ensure that groups are compatible and formed before sexual maturity to prevent aggression.
- Do not house birds singly without strong scientific or veterinary justification.
- Do not routinely beak trim birds or fit rings to reduce injury without trying to minimize aggressive behaviour using good housing and husbandry practices first.
- Monitor groups carefully for signs of social stress.

21.5.4 *'Natural' conditions*

Japanese quail are usually found in dense vegetation (Buchwalder & Wechsler 1997), and breeding females in semi-natural aviaries choose to nest among rough grasses and shrubs (Schmid & Wechsler 1997). Natural or artificial cover is therefore likely to enhance quail well-being (Johnson & Guthery 1988), besides helping to prevent injuries caused by the vertical flight response (Buchwalder & Wechsler 1997). Ground cover should be provided using horizontal screens, artificial plants, old Christmas trees, potted grass or by stacking up hay or straw around the walls of pens; constructing 'L' shaped barriers from bales may provide refuge for subordinate birds. Shrubs should be planted and maintained in outdoor aviaries. It is not possible to provide cover in cages, so their use should be restricted as far as possible.

Recommendation:

- Provide cover for quail wherever possible—this is a fundamental requirement for welfare.

21.6 Training and rewards

Quail have been trained to perform tasks for food rewards in behavioural research (e.g. Stattelman *et al.* 1975). Mealworms are suitable rewards, provided that the birds have been accustomed to them as chicks. Handling quail chicks regularly has been found to reduce their fear of humans through habituation, although it does not seem to reduce underlying fearfulness in the same way that novel objects do (Jones *et al.* 1991).

Recommendations:
- If quail are to be used in procedures that involve handling by humans, habituate them to handling beforehand, preferably as chicks.
- Reward quail with mealworms.

21.7 Potential health and welfare problems

Quail are susceptible to most diseases that occur in gallinaceous birds, including bacterial infection with organisms such as *Salmonella*, *Clostridium* spp., *Escherichia coli* and *Staphylococcus* spp. Secondary bacterial infections often also occur if birds contract fungal diseases, e.g. aspergillosis or *Mycoplasma* infections. Common parasitic diseases of quail include coccidiosis, blackhead and enteric nematodes (Hodgetts 1999); coccidiosis can occur in floor-housed quail, so coccidiostats are often included in the diet (Mills *et al.* 1999, Ottinger & Rattner 1999). Diseases of the Japanese quail are listed in Mills *et al.* (1999).

- Agonistic behaviour—aggressive pecking leading to skin lesions and feather loss is often associated with intensive husbandry conditions (Gerken & Mills 1993) but has also been reported in semi-natural aviaries (Schmid & Wechsler 1997). The reasons for this are not always clear (Wechsler & Schmid 1998), but agonistic behaviour may be reduced if quail are not kept under intensive conditions and established groups are not mixed (see 21.5.3).
- Injury through repeated attempts at mating—establish stable social groups with appropriate sex ratios before sexual maturity (see 21.5.3).
- Head injuries—these are due to escape attempts in response to frightening stimuli, and injuries may be fatal. Provide birds with more cover and environmental enrichment, especially early in life, in order to reduce fear (Jones *et al.* 1991). If birds must be caged, provide at least 30 cm of headroom (see 21.2.3). Ensure that everyone approaches birds sympathetically and wears the same colour clothing if possible.
- Foot problems—birds kept in cages are prone to foot swelling of unknown cause, whereas quail housed in floor pens are often found to have hardened balls of food, litter and faeces adhering to their feet (Gerken & Mills 1993). Provide solid resting areas for caged birds and ensure that husbandry standards for floor-housed birds are high; monitor feet regularly (see 21.2.2, 21.2.3).
- Feather-pecking and cannibalism—these do not appear to be common in Japanese quail (head injuries may be mistaken for cannibalism) but have been reported in association with a shortage of food (Gerken & Mills 1993).
- High post-hatch mortality—ensure that temperature and hatchling nutrition are both carefully monitored and controlled (see 21.3).
- Infections of reproductive organs in females—use photoperiod to delay the onset of sexual maturity (Mills *et al.* 1999).
- Behavioural frustration in breeding females—provide nest boxes in cages, or nesting materials and cover in pens or aviaries (see 21.2).

22 The pigeon, Columba livia

The 313 species within the family Columbiformes range in size from the sparrow-sized dwarf fruit dove (*Ptilinopus naina*) to the domestic fowl-sized crowned pigeons (*Goura* spp.) of New Guinea. In general, 'pigeon' is the name given to larger species and 'doves' to smaller species. The most commonly used Columbiform in the laboratory is the domestic pigeon, which is believed to derive from the rock dove (*Columbia livia*) (Hawes 1984). Domestic pigeons are kept in a variety of forms and over 200 fancy breeds now exist, including strains that have been developed for appearance, endurance flying, racing and for meat production. Care must be taken when choosing a breed for laboratory use, as some strains may show abnormal or undesirable behaviours and should be avoided (Hutchison 1999).

Pigeons possess well-developed powers of navigation and orientation, so are often used in fundamental studies to evaluate the cues used by animals during migration. Their ability to learn to perform tasks in the laboratory has led to their extensive use in behavioural and psychology studies, especially with respect to vision and learning. Pigeons are also used in toxicology, physiology and pathology and in the development of avian medicines.

22.1 Natural habitat and behaviour

Rock doves nest and roost on cliffs or gorges or within potholes and caves, and so feral pigeons will utilize sheltered ledges on man-made structures in the same way. In their natural habitat pigeons usually occur in pairs to large flocks, feeding and roosting together, but they remain very territorial and will defend roosting spaces and nesting areas. Pairs are generally monogamous, with males 'driving' females away from the rest of the flock during the breeding season, but a female will mate with another male if her original male fails to mate or dies (Hutchison 1999). Pigeons are primarily seed eaters but will take a very wide range of grains, fruits, berries and vegetation and also small snails and other molluscs.

22.2 Housing and space requirements

Outdoor housing: Pigeons should be housed in large, outdoor flights wherever possible, but will need access to covered, well-ventilated, draught-proof shelters at all times, with supplementary heating if necessary. If space and resources permit, pigeons do well in pens (e.g. 7 m long by 3 m wide by 3 m high) or tunnel aviaries (e.g. 20 m long by 7 m wide by 3.5 m high) with appropriate environmental stimulation and provision for perching. Such large aviaries can be tidied daily and hosed and scrubbed twice a week (J Archer, personal communication).

Indoor housing: If birds must be housed indoors, consideration must be given to providing sufficient quality and quantity space to allow a range of behaviours, including flight wherever possible. Laboratory pigeons are often housed singly in small cages that do not permit them to extend their wings (Table 6). This does not permit exercise or the provision of environmental stimulation and, in the UK, contravenes the Wildlife and Countryside Act 1981. Small cages are therefore not appropriate for long-term housing, and pigeons have been demonstrated to express a strong preference for aviaries that are large enough for them to fly (Schmorrow & Ulrich 1991). If pigeons must be housed in cages for scientific or veterinary reasons, consider using modified rabbit cages (e.g. plastic-based caging 790 mm by 695 mm and 500–600 mm high) with shelving, perches and toys (Nepote 1999a) rather than 'standard' pigeon cages. However, pigeons should be housed in pens or aviaries large enough to permit flight wherever possible (Table 6). If this is not feasible, access to 'flight rooms' with perches for exercise and social interaction (e.g. a modified animal room) is an alternative, provided that birds are carefully monitored to ensure that subordinate birds are not bullied (Nepote 1999a).

Catching birds: If pigeons must be handled frequently, 'nesting areas', as described in Section 22.3 below, should be provided so that birds can be trained to retreat to the nest area for capture. It is possible to house pigeons in outdoor aviaries with conspecifics even where they are required for training in small test chambers (e.g. Skinner boxes), by constructing connecting channels directly from the aviary and training the birds to enter the chambers for food. Following a habituation period of several days, a sliding door can be used to shut the pigeons in the experimental chamber, eliminating the need for stressful manual capture (see Huber 1994). Birds can become tame with training to the

Table 6 Space allowances for pigeons

Number of birds	Minimum (Home Office 1989): Area per bird: singly housed (m^2)	Area per bird: group housed (m^2)	Minimum height (m)	Minimum length of feed trough per bird (cm)	Common practice: Pen area (m^2)[a]	Minimum height (m)	Minimum length of feed trough per bird (cm)	Minimum length of perch per bird (cm)	Good practice: Pen area (m^2)[a]	Minimum height (m)	Minimum length of feed trough per bird (cm)[b]	Minimum length of perch per bird (cm)
N/A	0.1225	0.080	0.35	5								
Up to 6					2	2	5	30	3.5	2.5	10	30
Up to 12					3	2	5	30	5	2.5	10	30
Each additional bird					0.15		5	30	0.25		10	30

[a]Long, narrow pens (e.g. 2 m × 1 m) permit short flights and are to be preferred
[b]Consider scattering at least some of the diet or treats among substrate on the floor or in trays

extent that they will jump onto the hand, although it will be necessary to handle birds on at least 5 days of every week to achieve this (D O'Connor, personal communication).

Perching: Flights and aviaries should allow a separate perching area for each bird, as sufficient box perches at a range of levels will allow birds to establish their own territories, reducing fighting and facilitating easy capture. Box perches approximately 30 cm square and 15 cm deep located in blocks on one wall simulate a 'natural' type of environment and also help to deposit faeces in one area. Each flight should have covered food, grit and water hoppers, with additional water for bathing. It may be necessary to supply large waterproof trays in which smaller baths can be placed, as pigeons splash considerably when they bathe and will soak the surrounding area.

Flooring and substrate: Pigeons should not be housed on grid floors, as this prevents foraging. Birds housed on solid floors should be cleaned out regularly, the frequency depending on the degree of confinement. Smaller cages will require daily cleaning, but in larger flights it will only be necessary to clean heavily soiled areas beneath perching areas daily.

Pigeons create considerable amounts of faeces, feather dust (keratinized scales) and debris, but daily cleaning and the use of minimal substrate can reduce the levels of dust and contamination. If deep litter is used this should be removed and replaced weekly. Whatever substrate is used will quickly be dispersed by the flapping of the birds. Baths can be offered to the birds on the day before cleaning, which serves two purposes: it allows the birds the opportunity to bathe, and the bathing will damp down the substrate, so reducing the dust when the birds are cleaned out. Frequent air changes are also essential to reduce dust levels.

Recommendations:

- House pigeons in outdoor aviaries wherever possible, with access to a sheltered area.
- House indoor birds in large aviaries or pens that permit flight wherever possible.

- Provide sufficient perches for each bird, dust baths and water baths.
- If pigeons must be caged, consider using rabbit cages with enrichment and try to provide access to 'flight rooms'.

22.2.1 Physical environmental conditions

For guidance on environmental conditions, see Home Office (1989), Hutchison (1999) and Nepote (1999).

22.3 Breeding and rearing

Sexing birds: Pigeons are generally sexually monomorphic, although males of some strains have distinctive colouring (e.g. red chequers, mealies and silvers that show black flecking), and cock birds may be built more heavily than females and have rounded heads and larger ceres and wattles. Pigeons are usually sexed by their behaviour: males strut, bob up and down and have a double 'coo', whereas hens are lighter in build and tend to have flatter heads and a single 'coo'. Males will also turn 360 degree circles, fan their tails out and drag them along the floor when chasing or driving hens.

Breeding birds: Breeding pigeons appear to be both opportunist and promiscuous, but pairs often mate for life. Splitting up breeding pairs is therefore likely to cause stress and, if this is necessary, can only be achieved by the total removal of one of the pair. Whatever breeding method is used, it is best to place the cock birds in the flight first, then introduce the hens once the cocks have established perching and nesting areas. If breeding from specific pairs is required, the hen can be shut into the selected cock bird's nest box for about 2 days before the male is introduced. This will reduce aggression and the risk of injury, but the nest box must be large enough for the hen to eat, drink, preen and exercise.

Where parentage is of no consequence the cocks can be allowed to select their own nest boxes and become established before the hens are introduced and the birds left to select their own mates. Fighting will occur until pairs are established, but this can be reduced by allowing the cocks to establish their territory without the hens present. If seasonal breeding is practised, the cocks can be left in the breeding area at the end of the season and the hens can be removed. If both sexes are removed from the breeding area the cocks will normally return to 'their' box when returned in the following breeding season. Pigeons should be rested and not allowed to breed all the year round; they should be allowed to moult normally during the autumn.

Housing breeding stock: Breeding birds can be housed in several ways. Pedigree stocks are often maintained in single flights to ensure desired parentage of chicks (squabs), but racing stock are usually housed in communal areas with a nesting area for each pair that is large enough for them to be shut in until the clutch is laid. Communal flights with large numbers of small nest areas are provided where the aim is to produce as many offspring as possible. Nest pans, nesting materials and perches are fundamental requirements: courtship in male ring doves (*Streptopelia risoria*) is more aggressive and laying is delayed if these are not provided (Hutchison *et al.* 1996).

A suitable breeding flight would be a cube with sides of 2 m and nesting areas on one wall. Each nesting area should measure approximately 65 cm long by 60 cm high and 60 cm deep and have a nest pan area that can be closed off. A flight of this size can house six breeding pairs and will allow the production of offspring with known parentage. If this is not necessary, then boxes approximately 35 cm^2 may be used, in which case alternative perching should be provided so that non-incubating birds have roosting areas.

Nesting and incubation: Earthenware nest pans or disposable *papier mâché* nest pans should be provided for pigeons. The earthenware pans should be cleaned and disinfected with sodium hypochlorite bleach (e.g. Chloros) between each brood, and all types of nest pan should be dusted with insecticide powder effective against ectoparasites before use. Female wild and feral pigeons construct nests of twigs, grass and hay collected by the male birds (Hutchison 1999). Breeding birds should therefore be supplied with straw as a substrate, which will encourage natural nesting behaviour. Two white eggs are usually laid about 48 h apart and 10–12 days after pairing. Incubation lasts for 17 or 18 days and the squabs should be close-ringed at 5–6 days old (see Section 10.7).

Rearing: Squabs are fed 'pigeon milk', a secretion from the crop lining of both parents, for approximately 10–12 days after hatching. The adults then feed the chicks with whole grain until fledging occurs at around 21–24 days. Chicks will remain on the flight floor after fledging and should be removed from the flight at about 28 days. At this stage they are known as 'squeakers', due to the noise they make. Young birds will start to show signs of sexual development and behaviour from about 20 weeks but they should not be allowed to breed until they are at least 36 weeks old, or during the next breeding season (whichever is later).

It is essential that squabs can grip the substrate well with their feet to prevent 'pinwheel' or 'splayleg', where the legs become splayed and cannot support the bird. Any squabs who hatch with or develop splayed legs will never be able to walk and will have to be humanely killed (Hutchison 1999), so pinwheel must be prevented.

For further guidance on breeding and rearing, see Hutchison (1999) and Nepote (1999b).

Recommendations:

- House breeding birds in large flights.
- Place cock birds in the flight before females to reduce aggression.
- Always provide adequate perching space, nest pans and material for nest building.
- Make sure that nest pans are disinfected, clean and treated with insecticide.
- Ensure that squabs can grip the substrate well.
- Remove squeakers from the flight at 28 days but do not allow them to breed until they are at least 36 weeks old.

22.4 Diet

Wild pigeons are omnivorous, so a vegetable diet alone does not provide adequate nutrients and amino acids. Pigeons should therefore be offered a wide range of grains and green food, supplemented with pelleted diets containing animal protein such as turkey starter crumbs or chick rearing meal (Hutchison 1999). Each adult bird requires approximately 28 g of food per day, and pigeons should not be fed *ad libitum*. Birds who are fed *ad libitum* and/or only allowed limited exercise tend to become fat, which can cause problems with breeding stock. Birds can be monitored by regular weighing to ensure that they are getting enough to eat and maintaining good body condition but not becoming too fat.

Foraging should be encouraged by feeding part of the daily diet as small seeds such as millet, rape or linseed. The seed ration can be scattered on the floor, but feeding also provides the opportunity to habituate the birds to human attention, and birds will quickly become tame if fed from the hand. Oyster shell and mineral grit must be available at all times and fresh water should be offered daily. Both the grit and water should be provided in covered containers to prevent the birds from fouling them.

Recommendations:

- Do not allow birds to become fat; do not feed *ad libitum* but ensure that food intake and body condition are monitored regularly.
- Encourage foraging by scattering seeds on the floor.
- Hand feed regularly and give treats and rewards.
- Make sure that grit and water are always available in covered containers.

22.5 Environmental stimulation

Pigeons are often housed in barren conditions in the laboratory, but they will benefit from and make good use of large pens or aviaries supplied with enrichment items. Any requirement to house pigeons in cages or without enrichment should therefore always be questioned (see below).

22.5.1 Good quality environment

Pigeons require an area sufficient for flight, with adequate perching space along at least one wall of the aviary or pen (see Section

22.5.4). Birds housed in the laboratory have been found to benefit from toys such as bird bells, mirrors and rubber toys designed for cats, hung from chains. Foliage can be attached to the sides of aviaries using thick gardening wire to provide additional perching and shelter. Branches hung from the roof and scaffolding can also be used for perching (J Archer, personal communication) Pigeons also enjoy showers, which can be constructed using water sprinkler systems and turned on for e.g. 45–60 min weekly, although birds must be monitored to ensure that they do not become chilled. Sufficient water baths should also be provided for all birds, but these should not be too deep.

Recommendation:

- Encourage a range of behaviours by providing both items that simulate natural conditions and commercially available toys.

22.5.2 Foraging behaviour

Food should always be available in the morning, as that is when pigeons tend to feed most by choice. Part of the normal diet or additional treats should be scattered among the substrate on the floor, turf or in separate trays to encourage foraging behaviour (N.B. birds can use turf for nesting in the breeding season as it dries). Food should always be scattered away from areas where birds defecate.

Recommendation:

- Feed at least part of the diet (or treats) by scattering among foraging substrate, avoiding areas where birds defecate.

22.5.3 Group size and composition

Wild and feral birds usually occur in large, mixed flocks and are usually housed in mixed groups in the laboratory, which helps to prevent aggression during the breeding season (Hutchison 1999). Groups should be closely observed when first acquired to ensure that aggressive birds do not bully or injure others. An 'escape area' for more timid animals should be provided wherever possible. Breeding can be prevented by not providing nesting places, as females may lay eggs but will not incubate them without a nesting site.

Recommendation:

- House birds in mixed groups but do not provide nest sites unless breeding is required.

22.5.4 'Natural' conditions

All domestic and feral pigeons are descended from the rock dove (*Columba livia*), which roosts on rocky outcrops. Providing shelves, nest boxes and perches on vertical walls is therefore likely to encourage a range of natural behaviours.

Recommendation:

- Always provide a range of shelves, nest boxes and perches to facilitate natural behaviour.

22.6 Training and rewards

Food rewards can also be used to train birds to perform simple or more complex tasks, either for experimental purposes or to provide extra stimulation and interaction with humans. Favourite rewards include seeds such as pinhead oats, hemp with peanuts, popcorn and mealworms.

Recommendation:

- Encourage habituation to humans by hand feeding rewards.

22.7 Potential health and welfare problems

Effective ecto- and endoparasite control is essential and should be discussed with the attending veterinarian. The transmission of endoparasites can be greatly reduced by good husbandry and care, especially by removing faeces regularly (Hutchison 1999). Flocks should also be regularly checked for parasites, but it is important to be aware that certain ectoparasites (e.g. red mites, *Dermanyssus gallinae*) may not live on the host but in the structure of the housing, coming out at night to feed on the blood of the birds. Both birds and housing should be treated at regular intervals for these parasites, which is especially important when carrying out health checks immediately before the breeding season.

The following references provide useful overviews of pigeon diseases and pathologies: Tudor (1991), Keymer (1991), Pennycott (1994), Beynon *et al.* (1996), Rupiper & Ehrenberg (1997), Rupiper (1998 a and b), Hutchison (1999), Nepote (1999b). Veterinary advice must always be sought at any time when birds are thought to be unwell and before administering any drugs or vaccines.

Recommendations:

- Obtain veterinary advice on parasite management.
- Regularly check both housing and birds for parasites; remove faeces regularly.
- *Always* consult a veterinarian if in any doubt as to birds' well-being and before administering any drugs.

23 Psittacines

The order Psittaciformes comprises over 330 species including Amazon parrots, African grey parrots, lovebirds, budgerigars, cockatiels, cockatoos and macaws. As a group, Psittacines are renowned for their cognitive abilities, mimetic skills and social nature. Although there are a large number of Psittacine species, many are endangered and several are close to extinction, with all but two common species now being covered by CITES (see Section 6.1.1).

With the exception of the domestic budgerigar (*Melopsittacus undulatus*), Psittacines are not widely used in UK laboratories. Studies involving other species are reported mainly from North America, often relating to the aviculture industry or research into avian cognition. Budgerigars are often used in behavioural studies, for example those investigating social and sexual behaviour. Although the numbers involved are not thought to be large, the complexity of providing for Psittacines in captivity demands that they are given consideration in a laboratory context.

Current husbandry knowledge derives mainly from conservation breeding programmes or committed aviculturists. Although evidence is often anecdotal, some serious welfare issues have been recognized. Furthermore, both commercial aviculture and conservation may take different approaches and have objectives that are not always applicable to the laboratory situation.

23.1 Natural habitat and behaviour

Psittacines are widely distributed in the wild, occurring primarily in Australia and the Neotropics and to a lesser extent in Africa and Asia (Forshaw 1989). Although the majority of species are found in lowland tropical rainforests, Psittacines occupy a diverse range of habitats from high mountains, grasslands or coastal areas to tiny Pacific islands.

Many species are highly specialized and extremely sensitive to environmental change. For example, some *Calyptorhynchus* spp. (black cockatoos) feed on larvae that are only found on the bark of certain *Eucalyptus* trees. Other species are very adaptable and escapees of *Psittacula* spp. (ring-necked parakeets) and *Amazona* spp. (Amazons) have successfully settled in European and North American cities.

Overall the behavioural ecology of Psittacines remains poorly known. Studies to date have tended to concentrate on species from Australia or from dry or open habitats in the Neotropics. In contrast, the majority of species that occur in dense closed canopy forests remain largely unstudied due to the difficulties of observing birds in these environments. It is therefore not possible to make any assumptions about the ecology, behaviour or husbandry and care requirements of any species without conducting thorough research and seeking expert advice.

Foraging behaviour: Psittacines are generally seed- and fruit-eating birds and the natural diet of many species is very varied. For example, the Puerto Rican parrot (*Amazona vittata*) has been found to ingest the fruit, leaves, bark and stems of at least 58 species of plant. Complex food processing skills are required for dealing with such varied food, and when foraging Psittacines make full use of their characteristic hooked bill, tongue and zygodactyl feet (i.e. two toes point forward and two back). The bill is often used in climbing and the foot in manipulating food. Unusually for a bird, many species use one of their feet to lift food up to the bill (Smith 1971). The Lories (Fam. Loriidae) show a different specialization, using their tongues to extract nectar.

Where food resources are spatially or temporally separated, a great amount of time must be spent foraging. Even in species with a uniform diet, feeding may take up a large part of the day. The thick-billed parrot (*Rhynchopsittacus pachyrhyncha*), for example, spends hours extracting seeds from pine cones. Many Psittacines have a marked diurnal pattern of behaviour and are particularly active in the morning and late afternoon. In tropical forests with abundant food supply, it is suggested that Psittacines feed to satiety in the morning and then rest before commencing foraging activity again (Gilardi & Munn 1998).

Social behaviour: Psittacines are very social, gregarious birds, with only rare exceptions such as the solitary kakapo (*Strigops habroptilus*). In the wild the breeding birds form flocks which vary considerably in size and composition between different species. Some species gather in their thousands, whereas in others, such as the large Amazons, the primary social unit appears to be the pair together with any offspring. Behavioural studies within flocks have reported complex social behaviours such as cooperative alarm signalling, individual recognition and play interactions. Communal roosting is also thought to be widespread among Psittacines. African grey parrots (*Psittacus erithacus*), for instance, are known to form traditional roosts numbering in the hundreds (Forshaw 1989).

Breeding behaviour: The majority of parrots are thought to have a socially monogamous mating system, forming strong lifelong pair bonds. Other systems are known to exist, such as the polyandrous vasa parrot (*Coracopsis vasa*) (Wilkinson & Birkhead 1995), but they are the exception. Most Psittacines are hole nesters, enlarging natural hollows in trees or old nesting holes of other birds. In some species successful nesting may be preceded by many days or weeks of excavation activity. However, few species are known to excavate fresh hollows in trees and the low reproductive rate of most Psittacines is thought to be due at least partly to limited availability of nest sites (Forshaw 1989).

Longevity: Reliable records of the life span of Psittacines in the wild are hard to obtain. Evidence from captive birds suggests that the larger Psittacines have the potential to live to 60–70 years or more. It is therefore essential to consider the fate of birds following research projects (see Section 13). Great care must be taken when finding homes for Psittacines, as in practice companion birds live on average for just 5 years due to impoverished conditions. Even the generally more hardy domesticated budgerigar often reaches only 5 or 6 years of age before succumbing to breed-related diseases when kept as a companion bird (Beynon 1996).

Recommendations:

- Thoroughly research the behaviour, husbandry and housing requirements of each species and seek expert advice where appropriate.
- Make plans for the long-term care of Psittacines before projects begin, especially for the larger, long-lived species.

23.1.1 *Physical environmental conditions*

Psittacines inhabit a wide range of environmental conditions. At the extremes, the kea (*Nestor notabilis*) is found at high altitudes in snow-covered mountains, while cockatoos (*Cacatua* spp.) in Australia have to seek shade during the middle of the day to escape high temperatures. The most typical environment of the Psittacines is tropical forest with high temperatures, humidity and frequent rainfall. In the tropics, Psittacines experience equal lengths of daylight and darkness. The temperature, humidity and day length that each species would encounter in the wild should be researched and provided as closely as is practicable in the laboratory, allowing birds a degree of choice wherever possible (see Section 11.1.1). For guidance on Amazon parrots and cockatiels, see Millam (1991).

23.2 Rearing

There is much debate over suitable rearing methods for Psittacines. Conservation-based breeding programmes promote parental rearing in an attempt to retain natural behaviour patterns. Conversely, aviculturists breeding for the pet trade argue that hand-reared chicks socialize more easily to human companions.

Conditions in which young birds are reared can affect their later behaviour in many ways (ten Cate 1995). Although studies are limited, abnormal behaviours have been reported for hand-reared Psittacines (e.g. Preiss & Franck 1974, Lantermann 1994). It is important to know the rearing history of all birds brought into the laboratory as this may have implications for future studies and breeding success.

Parent rearing: It is strongly recommended that pairs be allowed to rear their own offspring wherever possible, especially if the species is conservation-sensitive. Most Psittacines will use artificial nest boxes, the optimum size and position of which depend on the species. Only lovebirds (*Agapornis* spp.) and hanging parrots (*Loriculus* spp.) use nesting material, but other species will enlarge the nest cavity by chewing.

Initiating the first occurrence of egg laying is an important factor limiting reproductive efficiency in captive Psittacines. Compatibility between birds is often hard to predict and it may take some time for a pair to become established. Optimal conditions for each species vary; for example, African grey parrots do not breed well if they can see their neighbours, whereas this may not matter for other species. Incubation generally commences after the second egg has been laid and is usually performed by the female alone, who is fed by the male. During this time it is important to disturb the pair as little as possible.

Newly-hatched nestlings are closely brooded and fed by the male. The nesting phase depends on the species, and varies from 30–90 days until the chicks are ready to leave the nest box. On fledging, young birds are fed by their parents until they have learnt to fend for themselves. In the wild young birds usually remain with their parents until the next breeding season, thus forming the family parties which are often observed. In captivity, a careful watch should be kept in case parents become aggressive to their offspring in the confined space; for example, cock crimson rosellas (*Platycercus elegans*) will attack and occasionally kill the hen as well as the chicks. Some larger species, e.g. macaws and cockatoos, will also become aggressive to humans during the breeding season.

Hand rearing: Where hand rearing is necessary, methods are now well reported for many of the species likely to be kept in the laboratory (see Low 1987, Stoodley *et al.* 1992). If the correct procedures are followed success can be high in terms of chick survival, although hand-reared parrots may not go on to breed with great success.

Eggs are hatched using artificial incubators that maintain them at the correct temperature (37.2°C) and turn them regularly at least 12 times per day. An initial relative humidity of 50% should be increased to 70–80% after the chick has broken through the membranes and just prior to hatching. Newly-hatched chicks should be transferred to a brooder at 37°C for the first couple of days. The temperature must then be gradually decreased until it reaches 30°C when the chick is about 3 weeks old.

Chicks rely on the yolk sac for a period immediately after hatching. Initial feeds are then given every 1–2 h, depending on the species. As the chick grows, a greater quantity of food can be administered and the period between feeds lengthened. Specially formulated rearing mixtures are available for Psittacine chicks and are administered using a spoon or syringe. The food should always be warmed first to 38–40°C. Chicks should be hand-reared in conspecific groups wherever possible.

Fostering: A second method that can be used where parent rearing has failed is to transfer eggs or chicks to another breeding pair. This technique is uncommon in Psittacines as they are usually kept in small numbers, which reduces the chances of suitable foster parents being available. It may be useful in the laboratory for rearing small species, such as the budgerigar and cockatiel.

Fostering is less labour intensive than hand rearing and frequently results in more normal growth rates. Transferring eggs to closely related species can be successful, although the young will imprint on their foster parents and may develop non-conspecific behaviour patterns (Rowley & Chapman 1985).

Recommendations:

- Allow pairs to rear their own offspring wherever possible, especially if the species is conservation sensitive.
- Follow established hand-rearing procedures for the species in question carefully, if hand rearing is appropriate.
- Remember that some species become aggressive to humans during the breeding season, so handle them with care.

23.3 Diet

Specialist advice should be sought on appropriate diets for Psittacines, although budgerigars can be easily provided for in the laboratory using one of the readily available commercial seed mixes that contain a variety of small seeds including hemp, canary seed and millet. The seed diet should be supplemented with small amounts of greenfood such as dandelion, chickweed or groundsel and with the provision of cuttlefish and grit. Cockatiels (*Nymphicus* spp.) also do well on a seed mixture with larger seeds and where fresh fruit and vegetables such as apples, oranges, grapes, grated carrot and cabbage are included. Lories and lorikeets require specialized nectar drinks.

Commercial seed mixes are available for larger species, but these tend to be based on a sunflower and peanut mix with a typical fat constitution of 40%. The correct diet should be approximately 18% vegetable protein with only 5–8% fat and the remainder composed of carbohydrates and roughage. In addition to possible obesity problems, commercial diets may also result in the bird becoming a 'seed junkie'. This term is used to describe a bird who has become fixated on a particular dietary component, normally the sunflower seed, which it eats to the exclusion of all others. The resulting unbalanced feeding habit is hard to break and pet owners have been known inadvertently to starve birds to death in an attempt to change the diet (Beynon 1996).

Complete pelleted diets are commercially available and most are well researched products which appear to be nutritionally adequate. The major disadvantages are the cost and the fact that these diets appear not to perform as well as more natural balanced diets. Pelleted food is also eaten very quickly and does not encourage natural foraging behaviour. Aviculturists often employ a diet consisting of fresh fruit and vegetables, boiled or soaked pulses and some seed and nuts, with precise composition varying between species. Beynon (1996), Low (1992) and Stoodley *et al.* (1992) contain good sections on nutrition and it is worth consulting experienced aviculturists for advice on a particular species (see also Burgmann 1993).

The value of vitamin and mineral additives is the subject of debate (Beynon 1996) and a balanced diet will greatly reduce the need for such supplements. However even when provided with a suitable range of food types, birds may not eat all of it and so develop a deficiency in one or more essential nutrients. Birds kept indoors may also suffer a shortage of vitamin D3, without which they cannot metabolize the calcium in their food. Water is an important requirement for most Psittacine species and should be provided daily in a clean container.

Recommendations:

- Supply a varied and balanced diet that provides for the birds' nutritional and behavioural requirements.
- Seek the advice of experienced specialists when devising diets for less common or unfamiliar species of Psittacine.
- Always provide clean drinking water.

23.4 Minimum space allowance

In the absence of any systematic studies on space requirements in Psittacines, the following recommendations depend heavily on known physical characteristics and natural behaviours of the group.

Size in Psittacines ranges from the small pygmy parrots (*Micropsitta* spp.) of New Guinea, measuring less than 9 cm, to the giant macaws (e.g. *Ara* spp.) of South America. These include the largest of all Psittacines, the hyacinth macaw (*Anodorhynchus hyacinthinus*) with a total body length of over 100 cm and a wing length of 40 cm. Many species also have long tail feathers that may be damaged by cramped conditions.

Physical activity is a more important consideration than body size, as enclosures must be large enough to allow the birds sufficient room for exercise. There are no true migratory species within the Psittacines and so great flight distances are not a feature of the group. However, some species may cover large areas within a given day when following patchily distributed food resources. Other species are reported to travel daily distances of more than 30 km between feeding and roosting sites.

Observational evidence from aviculturists can help identify the needs of individual species. African greys are reported to be more secure in a smaller cage, while long-winged parakeet species, such as *Alisterus* spp., need ample flying space (Sweeney 1997). Cage specifications are often given for pet birds, but these may assume they will have some flying time outside the cage, a scenario uncommon in the laboratory.

Although it is impossible to give precise recommendations for all Psittacines likely to be kept in the laboratory. Table 7 gives guidelines for some common species, across a range of sizes. It is important to consider not only the overall size, but also the dimensions of space allocation. Further guidance on housing Psittacines can be found in Stoodley *et al.* (1992). The number of individuals to be housed in the aviary will clearly have an impact, as overcrowding can cause aggression, yet the presence of too few birds in a group can lead to territorial disputes.

Recommendations:

- Give the natural activity levels, the behaviour of the species and its optimum group size in captivity prime consideration when setting space allowances.
- Do not employ cage specifications recommended for pet birds as they often assume flying time outside of the cage.

23.5 Environmental stimulation

The social nature, cognitive abilities and foraging skills of the Psittacines all suggest that they are likely to suffer in an impoverished captive environment (King 1993). Abnormal behaviour patterns commonly reported in companion birds support this view (Davies 1991). Every effort should therefore be made to provide a stimulating environment, appropriate to the species in question.

23.5.1 Good quality environment

Perching and climbing: In the wild, Psittacines spend much time clambering among trees whilst foraging in the foliage. They are adept climbers, and even species that inhabit open country show a strong attachment to trees (Forshaw 1989). Opportunities to perch and climb within the enclosure are therefore important, and the inclusion of a variety of natural branches is recommended. Such perching should be positioned at different heights and measure different diameters. Branches that are flexible enough that they bend when the bird lands help to promote wing exercise through balancing. Horizontal or mesh bars rather than vertical ones are recommended for the enclosure itself, to encourage climbing.

Running and foraging: A few species are terrestrial, and cockatiels in particular have a very distinctive running behaviour. Hanging cages, sometimes used for Psittacines to increase hygiene, are not recommended for those species that require floor space for exercise. Solid floors covered with a suitable substrate such as planted soil, pebbles, sand or wood chips in which food or treats can be scattered are also useful in encouraging foraging activities. Water baths and dust baths should always be provided.

Toys: Unlike many other birds, Psittacines will also make use of manipulable, chewable,

Table 7 Space allowance for Psittacines

	Example species with body mass (g) and length (cm)	Minimum pen size: Pen length per pair (m)	Minimum pen size: Each additional pair (m)	Good practice: Pen length per pair (m)	Good practice: Each additional pair (m)
Budgerigar	*Melopsittacus undulatus* (29 g, 18 cm)	0.5	0.5	1	1
Lories and lorikeets	Green-naped lorikeet *Trichoglossus haematodus* (130 g, 27 cm)	1.2	0.6	2	1
Cockatoos	White-crested cockatoo *Cacatua alba* (440 g, 46 cm)	7	Keep as single birds or pairs	7	–
Parakeets	Indian ringneck parakeet *Psittacula krameri* (115 g, 40 cm)	3	1.5	4.5	1.5
Lovebirds	Peach-faced lovebird *Agapornis roseicollis* (55 g, 15 cm)	1.2	1	2	1
Macaws	Scarlet macaw *Ara macao* (1000 g, 90 cm)	4 (15 when not breeding)	Keep as pairs except when not breeding	8	–
African grey	*Psittacus erithacus* (400 g, 33 cm)	3	Keep as pairs	6	–
Conures	Red-bellied conure *Pyrrhua frontalis* (70 g, 26 cm)	2 (3 for larger species)	1	4	1
Amazons	Orange-winged Amazon *Amazona amazonica* (360 g, 33 cm)	3	Keep as pairs	6	1

non-food items in a manner similar to primates. The best way to provide such items depends upon the species, but twigs, bark, cardboard tubes, chewing wood, knotted ropes, rotting logs and large rawhide dog chews have all been found to be effective. Wood and rope items may need frequent changing as they become chewed. Chains are resistant to chewing as well as being highly manipulable and are useful to hang perches on.

There is also a large market in artificial enrichment devices produced mainly for the companion bird trade. Such devices include bells, swings, gyms, mirrors, models, 'jukeboxes' and even running wheels. These products can be considered if they promote natural (or desirable) behaviour but some seem designed primarily to appeal to the owners and should be regarded with scepticism. All objects should therefore be selected with care and the birds' use of them closely monitored to ensure that they are stimulating appropriate behaviours.

Many of the techniques mentioned above are based on a 'trial and error' approach and success will depend on the needs of each particular species. Natural materials have been shown to be preferred by some species (e.g. the crimson-bellied conure (*Pyrrhura perlata*), van Hoek & King 1997) and many aviculturists report a preference for objects that can be destroyed. However, note that too much change in the bird's environment can also be stressful for some individuals. A study on the response of species to a novel object (a wooden ring) found some individuals to exhibit neophobia (Mettke 1995).

Recommendations:

- Provide natural branches so that birds can perch and climb (fruit trees are safest).
- Allow sufficient ground space for terrestrial species to exercise.
- Give Psittacines manipulable, chewable non-food items for play, but evaluate commercially available toys carefully.
- Supply water baths and dust baths.
- Always research species-specific preferences for enrichment devices.
- Remember that some individuals may exhibit neophobia to certain novel objects, which could be detrimental to their welfare.

23.5.2 Foraging behaviour

Providing opportunities for natural foraging is a key component in the effective environmental enrichment of Psittacines. Smaller species such as the budgerigar require a constant food supply. For larger species, food is best presented in the morning and sometimes again in the afternoon to correspond to natural activity patterns.

Natural foraging behaviour should be encouraged by presenting the diet and/or treats in different ways. Providing food in an unprocessed state, for example as branches of whole fruit, millet sprays, unshelled nuts or whole pieces of fruit will increase the amount of time spent in food handling. Alternatively food can be hidden or scattered in the enclosure so that the bird has to search before feeding. Ensure that none of the forage is left to rot in the aviary.

'Work to feed' methods or devices like puzzle feeders are becoming more widely used with captive Psittacines (Bauck 1998). Several basic designs have been employed with success in zoological institutions and may be useful in a laboratory environment. Feeder balls are artificial multi-chambered devices that allow the slow release of food items. The ball must be turned many times within an enclosure before all the food is released. Hanging tube puzzle feeders, of the type used with primates, can also be adapted for Psittacines. Another approach is to hang a whole food item such as a pomegranate or corn on the cob on a piece of string hanging from a perch. The bird must learn to pull up and secure the string before the food can be obtained. Mendoza (1996) described a 'Flintstone wheel', which is a section of a log with a large hole drilled in the middle for the perch to pass through and smaller holes into which food or sticks with pieces of fruit and vegetable speared onto them can be pushed. This was originally made for an Amazon parrot but has also been used for corvids and finches. Numerous other commercial products are available, mostly from the US aviculture industry. Relatively little work has been done in investigating the welfare impact of these feeding devices, but see Coulton *et al.* (1997). These types of devices encourage the birds' cognitive and manipulative skills and increase time spent in foraging. The most appropriate method differs between species. For example red fronted macaws (*Ara rubrogenys*) failed to forage for seeds hidden in holes in a piece of wood, whereas other species emptied the device in preference to taking freely available food (Coulton *et al.* 1997). It is therefore very important to monitor birds' dietary intake, body mass and condition when using foraging devices.

Recommendations:

- Provide a constant food supply for small species of Psittacine such as the budgerigar.
- Present food to larger Psittacines in accordance with natural activity patterns.
- Encourage birds to spend time foraging by hiding or scattering food, or presenting it in an unprocessed state.
- Consider 'work to feed' methods of food presentation for some species.

23.5.3 *Group size and composition*

In such a social order of birds, group size and composition are important aspects of behavioural enrichment. The optimal group size for Psittacines varies greatly depending on the species, but where possible it should reflect natural behaviour. Housing highly gregarious species such as the budgerigar in isolation is likely to cause distress and can have a negative effect on subsequent social behaviour (Nicol & Pope 1993). Access to group mates is particularly important for the socialization of young birds (e.g. spectacled parrotlet (*Forpus conspicillatus*) Garnetzke-Stollmann & Franck 1991) and for establishing future pairs. Composition of the group is also important. In general, the primary social unit within a flock of Psittacines is the pair. Unfortunately, it is impossible to sex many species of Psittacine from external physical appearance, in which case surgical examination or genetic analysis of feathers will need to be conducted to ensure a balance of sexes. If surgical sexing is deemed to be necessary, appropriate anaesthesia, analgesia and post-operative care must be provided (see Sections 8.1, 12.4).

Introduction of an unfamiliar bird to an existing group must be done carefully. Reports from re-introduction schemes have shown that in the wild it may take many months for an unfamiliar individual to be accepted by an established group (French 1996). Ease of integration depends on the species. For example, new birds can be introduced to a budgerigar colony with few problems, reflecting the lack of a strong hierarchy in wild flocks (Wyndam 1980). For more aggressive species a gradual introduction is recommended, initially allowing birds to see and hear each other through double-meshed walls.

Mixed-species flocks sometimes occur in the wild, usually where there is a shared food resource. There is no particular advantage to this in captivity, and for some species such as the Amazons, it is not recommended (Pilgrim & Perry 1995). Some Psittacines are also disturbed by visual or vocal disturbance from other species in neighbouring cages.

Recommendations:

- Do not house Psittacines in isolation—most are very social.
- Try to group house in numbers that reflect the natural situation for the species, as far as is practical in the laboratory.
- Consider group composition and how birds can be sexed to ensure a balance appropriate to the species.
- Introduce new individuals to an existing group with care.
- Avoid mixed-species flocks.
- Avoid disturbance from birds in neighbouring cages.
- Always ensure that young birds have access to group mates for socialization.

23.5.4 *'Natural' conditions*

Again, Psittacine diversity makes it difficult to generalize about the important features of the birds' natural environment that should be provided in the laboratory. Species-specific information should be sought on optimal environmental conditions. In general, however, most species of Psittacine can adapt to a temperate climate and do better in outdoor avaries, with natural sunlight, provided that adequate cover is available. Additional heat may be needed during the winter months for some of the smaller or more sensitive species.

Many species of Psittacine, particularly those that originate from a tropical habitat, suffer if the environment is too dry. Lack of humidity is thought to be a contributing factor in feather plucking behaviour (Blanchard 1996). Non-poisonous foliage can help maintain humidity levels, although plants are liable to be destroyed and may need to be replaced regularly or planted outside the aviary. Daily misting with a low-pressure sprinkler or spray bottle is beneficial for many species, particularly those caged indoors. Other species such as the conures should be given access to daily bathing water.

Indoor aviaries that are artificially lit should be on a light:dark cycle that reflects the natural day length of the species. Most species come from the tropics or sub-tropics and will suffer without a minimum of 10 or preferably 12 h of undisturbed darkness each night. Birds kept in outdoor aviaries may benefit from an artificial extension of natural daylight hours during winter, and an opportunity to roost under cover during summer.

In Psittacines, perching height has an effect on dominance behaviour. Suspended cages that are hung too high can cause a bird to show heightened levels of aggression, whereas very low cages or perching may be stressful. Cover is also important for many species, not just as protection from the elements, but also to provide security. Nest boxes with deep substrate (e.g. of coir and wood shavings) provide opportunities for natural nesting behaviours. A rotting log with a nest cavity started can promote excavation. In a controlled breeding programme, restricting the nest hole size of a regular box using a plywood cover has been used effectively in allowing birds to modify their own nest box (Millam *et al.* 1995).

Recommendations:

- Keep Psittacines in outdoor aviaries with appropriate cover, heating and daylight extension where possible.
- Ensure that relative humidity is carefully controlled and monitored when housing birds indoors.
- Always provide appropriate baths, showers and/or misting.
- Time inside lighting to reflect natural day length for each species.
- Ensure that perches are placed at appropriate heights to reflect each species' natural behaviour.
- Provide opportunities for natural nest excavation behaviour during breeding.

23.6 Training and rewards

Psittacines are renowned for their cognitive abilities and also for the close associations they form with human caretakers in the absence of conspecific flock mates. They are extremely amenable to training and, indeed, interaction with humans can be crucial for the welfare of isolated birds, particularly those who have been hand-reared. Information on training pet Psittacines is available in the form of books and videos (e.g. Martin 1983).

The most extensively reported training techniques in the laboratory are those involved in the study of cognition in an African grey parrot, Alex (e.g. Pepperberg 1981, 1990; see also http://www.alexfoundation.org/). Here the use of intrinsic rewards has been very successful. For example, Alex verbally requests a particular object such as a piece of banana, or favourite toy and receives it as a reward. A type of training called the model/rival technique has also been used to great effect where he learns by observing interactions between two human demonstrators.

A key feature of the above training techniques is the amount of interaction, up to 8 h a day, allowed with human trainers. Simpler techniques, such as operant conditioning, have been used successfully with the budgerigar (e.g. Trillmich 1976). Where training has reached advanced levels, behaviours suggesting boredom and frustration are reported. In addition, birds who have been highly stimulated during training will require a consistency of human attention regardless of whether a particular study has finished. It is essential that, when studies are completed, arrangements are made for such birds to be rehomed with people who will be able to provide appropriate levels of interaction and stimulation, especially as it may never be possible to house them with other birds. This should be considered at the project planning stage, before any birds are acquired.

Recommendations:

- Always use positive reinforcement techniques when training Psittacines.
- Maintain the level of human interaction to which a Psittacine has become accustomed after the study, particularly for isolate birds.
- Never impose boredom or frustration on birds during training.

23.7 Potential health and welfare problems

The source of Psittacines acquired for research must be considered as part of the welfare 'costs' of a project. Although a large proportion of commercially available Psittacines are captive-bred, many birds are still wild-caught. The capture and long distance transportation of wild birds raises many serious welfare and conservation concerns and may even be lethal for some birds. It is therefore important to make sure that the source of all birds is fully established before purchase, and never to buy wild-caught birds without extremely strong scientific justification.

Behavioural problems are common in Psittacines (Lawton 1992). They can be severe and include unbalanced aggressive behaviour (all species), feather plucking (mainly African greys and cockatoos), restlessness and screaming (mainly Amazons), stereotypies (mainly cockatoos) and apathy (van Hoek 1995). Current knowledge about the causes and maintenance of these behaviours and the factors that may prevent them is still very limited. Environmental enrichment has been shown to have some success in stabilizing plumage problems in conures (van Hoek & King 1997), and in improving initial breeding success in captive orange-winged Amazons (*Amazona amazonica*) (Millam *et al.* 1995). There has been an increasing trend to treat behavioural problems with anti-depressant drugs. However these drugs, not developed specifically for Psittacines, treat the symptoms rather than the underlying cause and so their use should be discouraged, although their temporary use may be necessary until the cause of the symptoms is removed.

It has been suggested that daily cage cleaning is stressful, especially for recently acquired or poorly habituated birds (Millam 1999), so a balance may need to be struck between the need to maintain hygiene standards and the psychological well-being of the birds. Poor environmental conditions and nutrition are the major factors behind many of the health problems encountered in Psittacines. A useful manual on Psittacine health care is Price (1992), but where health problems are encountered a specialist bird veterinarian should always be consulted. Even the domesticated and generally hardy budgerigar is prone to breed-related diseases and epileptic fits, due to inbreeding and artificial selection.

Recommendations:

- Never buy wild-caught birds without compelling scientific justification. Ensure that the source of all birds has been thoroughly researched.
- Always provide a stimulating environment and an appropriate diet for each individual.
- Avoid using anti-depressant drugs long term to treat behavioural problems.
- Seek specialist advice immediately should any bird appear to become ill, depressed or show behavioural problems.

24 Tits and chickadees, Parus and Poecile spp.

Tits and chickadees are usually used for non-invasive behavioural research in the laboratory, for example, to investigate learning and memory (e.g. Healy & Krebs 1992) or the use of visual cues in foraging (Church *et al.* 1998). A much greater body of work has accumulated on the ecology and behaviour of non-captive tits and chickadees, particularly in Europe. Some recent work has also addressed the sites of learning and memory in the brain of these birds. This work has involved neural lesions, neural implants and examinations of neuroanatomy (e.g. Barnea & Nottebohm 1994, Patel *et al.* 1997). Other studies have involved taking blood for relatedness studies or investigating parasite load, from which no long-term deleterious effects have been shown (Lubjuhn *et al.* 1998).

24.1 Natural habitat and behaviour

Tits are found across much of the world, except South America, Antarctica, Australasia and the Pacific Islands, in both deciduous and coniferous woodland and a variety of scrubland habitats. All species are typically socially monogamous and territorial during the breeding season (the spring). During the late summer they tend to form larger groups, perhaps as families holding an enlarged territory, sometimes as more mobile mixed-species flocks (Perrins 1979).

All species of tit are both insectivorous and seed eating, and all but *Parus caeruleus* and *P. major* are thought to store food, particularly during the autumn and winter. In Britain, they are commonly found visiting garden feeders, especially blue and great tits.

24.2 Housing and space requirements

Tits can be housed in either cages or aviaries. Outdoor aviaries are likely to be better for the birds' well-being than indoor cages. Birds may be group housed in large aviaries but need to be kept individually if housed in small cages to avoid aggression. Requirements to house tits in such cages should therefore be questioned and their use avoided. Cage floors should be covered with absorbent paper, which must be changed at least twice a week. The minimum acceptable cage size is 70 cm × 40 cm × 40 cm high, but such small cages are only suitable for keeping birds in for short periods of time, e.g. 2–3 days (see Table 8 and Section 24.5.1 for further cage specifications).

If housed in aviaries, species should not be mixed. Close observation should be kept over the first 2 days if birds are to be kept in aviaries with conspecifics, especially if there is more than one male in the group. The upper group size depends on the size of the aviary and the cover provided in it by plants or artificial structures, but groups of more than 12 birds are not recommended. Indoor aviaries should also have the floor covered with absorbent paper, changed twice a week.

If birds are group housed, a food and a water bowl should be provided for each bird and placed at least 10 cm apart in order to prevent dominant birds restricting access to these by subordinates. If housed in outdoor aviaries, birds must be provided with shade, windbreaks and appropriately positioned perches. An alternative would be to link the outdoor aviary to an indoor flight to provide shelter and for ease of capture.

Recommendations:

- Keep wild-caught adults in outdoor aviaries whenever possible.
- Do not keep more than 12 birds in a single aviary.
- Do not mix species.
- Avoid housing birds in small cages; if there is no alternative then house them individually.
- Provide a food and a water bowl for each bird.

Table 8 Space allowances for tits

Number of birds	Cage dimensions (m)	Minimum height (m)	Minimum number of feeders
1	0.4 × 0.7	0.4	1
Breeding pair	2 × 2	2	2
Up to 6	3 × 3	2	1 per bird
Up to 12	4 × 4	2	1 per bird
Over 12	Not advised	–	–

24.2.1 *Physical environmental conditions*

Tits are able to deal with a wide range of temperatures in the wild but in the laboratory the variation in temperature should be kept within a reduced range. This range should be between 10 and 20°C, although birds would be able to cope with short periods both above and below this.

There is no good evidence as to either the effect of humidity on the birds' health or normal behaviour or to what is an adequate level of ventilation. Dust from droppings and feathers is far less in these birds than other species more usually maintained in captivity, so the recommendations for both humidity and ventilation levels for these other species will be more than adequate for maintaining tits in a healthy condition.

Tits in the wild are exposed to a wide, although slow changing, range of day lengths and this range can safely be used in the laboratory. A long-term constant light:dark cycle under fluorescent lighting is likely to adversely affect the timing and success of the birds' moult. Use of natural daylight or of natural daylight light bulbs is recommended.

Recommendations:

- Do not allow laboratory temperatures to get too low (<10°C) or too high (>20°C) for extended periods of time (more than a few hours).
- Use daylight light bulbs in the laboratory holding area.
- Research and maintain the appropriate environmental conditions and day lengths for each species.

24.3 Rearing and capture from the wild

Rearing: In the wild, *Parus* spp. chicks are raised largely on caterpillars. Young tits can be taken from the nest and hand reared in the laboratory. This requires nearly constant feeding, especially during the early nesting period. Hand-raised birds cannot be released to the wild.

Capture from the wild: Relevant legislation must always be researched and complied with before planning to take birds from the wild (see Section 6.1). Catching of tits in the UK can only be carried out under English Nature and BTO licensing. An English Nature licence can be acquired to permit the taking of a specified number of birds from a specified location(s). Birds are caught by mist netting and in the UK this must be done by someone who holds the appropriate BTO licence.

Handling: Like most wild animals, tits are adversely affected by handling (Haftorn 1999). This should be kept to a minimum. A bird is held in the handler's non-dominant hand (e.g. right-handed people should use the left hand to hold the bird) with the head gently but firmly held between the index and third fingers. The rest of the hand should be gently curled around the rest of the bird's body, but there should be no need to restrain the legs when birds are held passively. Birds will be relatively calm if kept in this position for a short time and both body and plumage condition can be examined while holding the bird in this way.

Transport: Birds should be transported in dark, quite closely confined conditions. If for a short period of time (up to one hour), a cloth bag at least 15 cm × 15 cm suspended by ties is sufficient. For longer periods of time, small bird carrying boxes can be bought from pet shops. Food and water should be provided. In both cases, birds should be confined singly.

Care after capture: The first few days after capture are the most crucial for the birds' long-term survival. During this time the birds should be oversupplied with a range of food items and several live invertebrates. If a bird is seen to be fluffed up as if roosting but during the day, a special eye should be kept on it. If in this position for more than 30 min, remove the bird to a small heated hospital cage, provide lots of live food and seek veterinary advice promptly. If these actions are taken soon enough, most birds survive.

Once in captivity for a few weeks, many birds will remain calm provided that nearby human activity is limited.

Recommendations:

- Ensure that only those with catching and handling experience mist net can take wild birds.

- Transport birds in dark, quiet, closely confined conditions.
- Do not return hand-raised tits to the wild.
- Try to avoid taking birds during the breeding season.
- Be aware that catching and handling the birds may be very stressful to them, so attempt to keep this to a minimum.

24.4 Diet

A bowl of food (a commercial insectivorous food mixture, plus 2–6 of the following: peanuts, sunflower seeds, pine nuts, hemp seeds and at least one live food item e.g. mealworm or wax moth larvae, dried egg, fresh grated carrot) must be provided daily in the morning. The smaller tits invariably refuse to eat mealworms, and avoidance of some types of nut or seed may also develop. A bowl of fresh water must be provided to allow the birds to drink and to bathe. As with other species, careful diet analysis should be undertaken to ensure an appropriately balanced nutrient profile and any deficiencies or imbalances should be corrected; blue tits, in particular, are susceptible to vitamin A deficiency.

Recommendations:
- Provide fresh food and water daily.
- Monitor diet content and provide vitamin supplements if necessary.

24.5 Environmental stimulation

There are no current data on whether or not tits would make use of 'toys' or whether the provision of such toys would enhance the birds' living conditions. However, cage or aviary additions should be provided that will encourage the birds to spend time exercising and foraging for their food.

24.5.1 Good quality environment

Tits spend most of their resting time sitting on a perch. Perches can be branches or pieces of dowel varying in thickness from 1–2 cm and at least two per cage should be provided. Roosting boxes can be provided for birds in cages but birds will roost on a perch, often in preference to using a roosting box. Field work has shown that habitat quality is increased by the provision of roosting boxes (Dhondt & Adriaensen 1999), so these should be provided for birds in outdoor aviaries (one box per bird), particularly if the birds are to be housed outdoors during the winter. Suspended balls of straw can also be provided for enrichment and additional roosting.

Recommendations:
- Provide birds with several perches.
- Provide birds in outdoor aviaries with individual roosting boxes and suspended balls of straw.

24.5.2 Foraging behaviour

Tits will forage throughout the day but the highest intensity of foraging is in the morning. They will eat the live food first and then the nuts and seeds. These items are usually carried to a perch for eating, the food gripped between the bird's feet.

It is reasonably straightforward to provide tits with 'puzzle feeders'. Such feeders can be built to take advantage of the birds' ability to manipulate objects with the bills as well as with their feet. Thus feeders may consist of reservoirs of food from which one item (e.g. a peanut) is released at a time by pulling or tapping at another element of the feeder. This system could be made gradually more elaborate with several tasks being required before a single item becomes available. Birds will pull string, lift cloth flaps and pull at small pieces of wood, so food can also be hidden behind any of these. Birds will readily learn to search for such hidden food items, even when the items are small.

Recommendations:
- Supply fresh food in the morning.
- Consider providing 'puzzle feeders' to extend foraging time.

24.5.3 Group size and composition

Although tits can be found in mixed-species flocks in the wild, it is preferable not to mix them in captivity. Dominance hierarchies will be established within intraspecific groups, and food and water containers must be provided for each bird so that they can gain access even if subordinate. Group-housed birds should be closely observed for aggressive interactions during the breeding period. Removal of males from groups during this time may be necessary. Birds should not be maintained in groups of more than 12 birds in a single aviary.

Recommendations:

- Keep different species separately.
- Do not maintain groups of more than 12 birds and observe groups closely for aggressive encounters.

24.5.4 'Natural' conditions

To maintain tits under 'natural' conditions, birds should be housed in outdoor aviaries exposed to the weather, but with shade and windbreaks. Small trees and undergrowth should also be provided. Indoor pens could also be used and provided with these features. Feeding in both situations should be as it is described for birds kept in cages in the laboratory.

Recommendations:

- Keep wild-caught birds in outdoor aviaries where conditions permit, and provide small trees and undergrowth, shade and windbreaks.
- Feed birds kept in outdoor aviaries the same diet as those housed in laboratory cages.

24.6 Training and rewards

Tits have been trained in the laboratory to perform a variety of different tasks, mostly those that have tested their abilities to learn and remember different kinds of information. Invariably the birds are rewarded with small food items (rather than other kinds of reward such as water or an opportunity to see or hear a conspecific); typically a small piece of peanut or sunflower seed. Some degree of food deprivation is usually involved to increase motivation, but any requirement to do so should be questioned and food should never be withheld for more than 3.5 h. If there is a delay to onset of training or testing, birds should be given a small number of nuts, seeds or wax moth larvae in the intervening period.

Recommendations:

- Question any requirement to deprive birds of food during training programmes.
- Provide birds with small amounts of food if there is a delay to the onset of experimental training or testing and the birds are food deprived.
- Do not withhold food for more than 3.5 h.

24.7 Potential health and welfare problems

- Claws growing too long—claws should be shortened by clipping, not sandpaper.
- Vitamin A deficiency—correct this with carefully calculated and measured supplements of vitamin A (see 24.4).
- Moulting problems—house birds outside or inside with daylight light bulbs. Use appropriate day lengths, if birds are housed indoors (see 24.2.1, also 9.3).
- Stereotypies—some flight stereotypies may develop, e.g. somersaulting backwards off the perch. These can be prevented by providing larger caging, environmental stimulation and the opportunity for flight, e.g. at least access to a larger area for restricted periods (see 24.2, 24.5).
- Abraded feathers—decrease human activity around cages or aviaries. Provide more perches and larger caging (see 24.2, 24.5.1).

24.8 Additional information

The online user group TitNet is a discussion forum for the biology and behaviour of the Paridae. To obtain further information, send a message to listserver@relay.doit.wisc.edu containing only the line info TitNet, leaving the subject line blank.

25 Corvids

Corvids are considered to be among the most intelligent of birds. They have a much higher brain weight to body weight ratio than average for vertebrates, as well as a larger than expected brain-cell density. Their skill at hiding and subsequently recovering large quantities of stored food indicates exceptional spatial memory and learning abilities.

Shell-dropping is one example of intelligent opportunistic behaviour being used to obtain food, and many species have been observed to use tools, e.g. long twigs, when foraging. Imitation learning is also commonly observed, which enables new foraging techniques to spread rapidly throughout the local corvid population. Play is frequently seen; for example aerobatics, the dropping and catching of twigs, and hanging upside-down from perches. It is not surprising, therefore, that corvids have often been used in laboratory experiments designed to evaluate cognitive abilities such as spatial memory, number sense and concept formation.

25.1 Natural habitat and behaviour

The 115 species that comprise the family Corvidae are among the most adaptable and successful members of the order Passeriformes. Corvids have a worldwide distribution; being absent from only the Arctic, Antarctic and some oceanic islands. They are found in a range of habitats, from forest and woodland to steppe, tundra, and even desert (Cramp & Perrins 1994). The corvids encountered in the UK include the jay (*Garrulus glandarius*), magpie (*Pica pica*), chough (*Pyrrhocorax pyrrhocorax*), jackdaw (*Corvus monedula*), rook (*Corvus frugilegus*), carrion crow (*Corvus corone*) and raven (*Corvus corax*). Most have a generalized diet including a wide variety of animal and plant food often obtained by scavenging. The concealment of surplus food for later use is a characteristic behaviour pattern of the whole family.

Corvids nest in trees, on rock ledges or in holes. Most species construct nests composed mainly of twigs and muddy earth. The eggs are mostly blue or green with olive green and blackish markings. Neonatal young are downy or naked and are fed regurgitated food by their parents. The pair-bond is strong in corvids, being sustained throughout the whole year and probably until the death of the partner in the majority of the species. Family bonds are also strong, with post-fledgling care and associations between both adults and young and between siblings lasting for several months.

Flight is characteristically strong with steady wing-beats, although some (e.g. the carrion crow) perform aerial displays and others (e.g. the raven) glide, soar and tumble. The gait is often a hop or 'gallop' but most species can also walk and run. The feet are used to hold down food items to be torn apart by the bill, which is typically stout and strong with a slight hook. Most species drink by dipping the bill into the water and then raising the head. Dust-bathing has not been recorded, even in the desert species. 'Anting' behaviour has been noted for several species, which may involve both direct application of ants to the plumage using the bill, and indirect application involving the stirring up of an ants nest with vigorous movements of forward posturing wings and/or a fanned tail.

25.2 Housing and space requirements

Corvids usually adapt well to captivity as long as they are subjected to minimal disturbance and are maintained by the same animal care staff. The ideal aviary is a long tunnel measuring about 20 m long by 6 m wide and 3 m high at the apex of the tunnel. The floor should be grass and the frame covered in strong flexible netting with the first metre from the floor having an additional layer of protective wire netting. A sheltered end should be provided with a range of natural branches serving as perches. An area of bark fragments that can be raked over and replaced should be situated under these perches and foliage provided at the other end of the aviary for additional shelter (see Inglis & Hudson 1999).

Smaller aviaries can be used to house individual birds. These should be timber framed with wire netting and at least 6 m long with shelter at one end. Natural branches serving as perching areas should be provided at both ends of the aviary and the floor under these areas should be either concrete that can be hosed down, or large pebbles, to a depth of 30 cm, that can be raked over; corvids also like to turn stones over.

Corvids should not be housed indoors or in cages unless there is a strong scientific or veterinary justification for doing so. If it is considered to be necessary to maintain birds indoors, rooms should be dry and well-ventilated with a temperature range of 21–24°C and relative humidity at 55±10%. Cages should be at least 1 m by 2 m by 1 m high so that environmental stimulation can be provided (see Section 25.5) and birds can hop between perches and perform short flights.

Recommendations:

- House corvids outdoors in large, timber framed aviaries wherever possible.
- If corvids must be housed indoors, ensure that cages are large enough to permit short flights and the addition of enrichment items.

25.3 Breeding and rearing

Corvids are difficult to breed in captivity and it is generally easier to obtain adults or large young direct from the wild as required (see Section 6.1). If birds are taken as adults and a veterinarian considers them to be in good health, it may be possible to release them at the site where they were caught (N.B. it is essential to read Section 13 before planning this).

If captive breeding is to be attempted it is necessary to provide a box about 60 cm square and 15 cm deep in the shelter of the aviary. This box should be about 0.5 m below the shelter roof (Meaden 1979). The floor of the box should be covered with thin beech or birch twigs, and more twigs should be provided in the unsheltered part of the aviary, where the rain can keep them supple. Once nest building has started moss, animal hair, wool and feathers should be provided. The birds will also require a supply of damp mud that will be used to bind the nest structure together. If birds are reluctant to nest, artificial nests can be constructed using 16 gauge mesh and thick conifer cuttings. Once the eggs have hatched the animal protein content of the diet should be increased; day-old chicks, mice, minced offal and bits of fish will be readily taken. In addition, calcium lactate, Casilan and Complan are valuable supplements (Meaden 1979). Basic information on breeding seasons in some species of corvid are set out in Table 9 below, but further research and expert advice will always be necessary when planning breeding programmes.

Recommendations:

- Obtain adult corvids from the wild rather than breeding, if possible.
- Always thoroughly research breeding seasons, behaviour and basic requirements when planning to breed corvids.
- Ensure that appropriate nesting materials, food and supplements are supplied as required.

25.4 Diet

Wild corvids eat mainly insects and larvae such as ground dwelling beetles and moth caterpillars. However, they are opportunistic foragers and the range of food items taken can include small mammals, bird eggs and nestlings, frogs, slugs, snails, worms, fruit, berries, nuts, cereal grains and household waste. As already mentioned, food storing is a common behaviour when there is an abundance of food. The bird holds the food

Table 9 Breeding seasons in corvids (Harrison 1975)

Species	Breeding season	Eggs in clutch	Incubation period (days)	Chicks tended by	Fledging age (days)
Jay *Garrulus glandarius*	Late April–early May	5–7	16–17	Both parents	19–20
Magpie *Pica pica*	Early April	5–8	17–18	Both parents	22–28
Rook *Corvus fructilegus*	Late March–early April	3–4	29–30	Both parents	29–30
Crow *Corvus corone*	Late March	4–6	18–20	Both parents	28–35
Jackdaw *Corvus monedula*	Late April	4–6	17–18	Both parents	28–32
Chough *Pyrrhocorax pyrrhocorax*	Late April–early May	3–4 (lost clutch may be replaced)	17–23	Both parents	Around 38

item in the bill or throat, pushes the bill into a suitable hiding place, ejects the food with the aid of the tongue and withdraws the bill. The cached food provides a reserve that can be recovered during periods when food is less abundant, and some species (e.g. jays) are thought to rely largely on stored food such as acorns throughout the winter.

In the laboratory the main diet for corvids is usually composed of 50% dog food and 50% dog biscuit. However, this should be frequently supplemented with a range of other items. For example a favoured food supplement is a mixture of turkey crumbs moistened with milk and added to grated raw root crops such as swede, turnip, carrot and parsnip. Cereal grains, invertebrates such as maggots and mealworms and dead mice or chicks should also be provided on a regular basis. Fruits and nuts (e.g. apple, banana, grapes, sultanas, acorns, beech mast) can also be offered. Corvids tend to drink often and should be supplied with ample sources of water from shallow troughs.

Recommendation:

- Provide a varied diet in a manner that allows the birds to search for at least part of their food.

25.5 Environmental stimulation

The highly developed spatial memory and learning abilities observed in corvids, together with the many instances in which spontaneous play has been observed, suggest that it is especially important to provide environmental stimulation for these species.

25.5.1 Good quality environment

Corvids respond well to a varying environment in terms of the range of objects that can be investigated and manipulated. Perches at a range of different levels should be provided and toys, including tennis balls, toys designed for Psittacines, and shiny objects.

Corvids like to bathe in water rather than dust baths and normally perform this behaviour standing in shallow water. The bird initially places the head and breast towards the water and then shakes the bill and wings from side to side, transferring water on to the head and breast. In addition the tail is lowered into the water and the wings are beaten strongly, showering water onto the back. After bathing, birds will retreat to a spot where they can dry themselves. In captivity a water trough, grit bowl and water bath are required to allow natural drinking and bathing behaviour. Some individuals will bathe until they become waterlogged, so careful monitoring may be necessary.

Recommendations:

- Supply and continually change a range of objects that can be investigated and manipulated.
- Provide sufficient perches for each bird, within a sheltered area if birds are housed outdoors.
- Make sure that there is a water bath shallow enough for the birds to stand in.

25.5.2 Foraging and caching behaviour

At least part of the diet should be hidden and scattered in the substrate to encourage foraging, and a grass area can be kept for the purpose in outdoor aviaries. Food can also be hidden in rotten branches and tree stumps. Indoors or outdoors, birds can be provided with a 'play box', i.e. a deep plastic box filled with chipped bark or coca mulch to hide live invertebrate food such as mealworms. A number of static objects that can be used to cache food should be provided, such as short lengths of plastic pipe or half-broken flower pots.

Recommendations:

- Encourage foraging by hiding part of the diet and provide objects suitable for caching food.
- In outdoor aviaries, leave a grass area for foraging.

25.5.3 Group size and composition

Corvid flocking behaviour varies between species. Rooks and jackdaws can be highly social, nesting within a few metres of each other, having small territories and foraging in flocks. Ravens and magpies, however, are far less social and tend to forage alone, although they will share a territory with a breeding mate. It is thus essential to research the social behaviour of each species to avoid causing social stress and possibly aggression.

When kept in captivity corvids display dominance and form a social hierarchy. This is most apparent during feeding, where subordinates have to wait their turn at the feeding dish. Females are generally lower in the hierarchy than males, although during the breeding season a female can increase in rank, particularly if she is paired with a dominant male. The extent to which these social behaviours occur in the wild is unclear for several species. Flocking species can be kept in groups of 5–10 individuals.

Recommendations:
- Thoroughly research the social behaviour of each species.
- Always keep social, flocking species in groups.

25.6 Health care

See Section 11.2 for general guidance on health care and disease prevention. Most captive corvids are caught in the wild and brought into the laboratory rather than having been bred in captivity. During the initial 3 weeks following capture, all new birds should be placed as far away from other birds as possible to minimize the risk of infection. Established stock should always be cleaned out before new birds are introduced. When the birds first arrive they should be checked for parasites (e.g. worms, ticks and fleas). Each bird should be weighed and individually identified by, for example, a numbered leg ring.

It should also be remembered that corvids, like other wild birds, can carry a number of diseases transmissible to humans such as erysipelothrix, salmonella and chlamydia (Inglis & Hudson 1999). Scrupulous personal hygiene and adherence to the following safety codes is essential.

(i) Adequate protective clothing should be worn at all times; in particular, face masks and gloves should be worn when cleaning aviaries.
(ii) All cuts, scratches and abrasions should be covered with waterproof dressings before entering aviaries.
(iii) Hands and forearms must be thoroughly washed with antiseptic soap after handling corvids and cleaning aviaries.
(iv) Staff should undergo a course of anti-tetanus injections and regularly receive booster injections.

Recommendations:
- Quarantine new birds for 3 weeks.
- Clean out established birds before new ones are introduced.
- Check and treat all new birds for parasites.
- Carry out regular health checks.
- Ensure that staff take adequate safety precautions when working with corvids.

25.7 Recommended reading

- Goodwin D (1976) *Crows of the World*. London: British Museum (Natural History)

26 The starling, Sturnus vulgaris

The starling has been used as a model species in a diversity of behavioural investigations apart from, and often because of its popularity in, field studies. Because it can subsist on pelletted livestock feed, and is both inquisitive and a rapid learner, it has been used in many laboratory studies of foraging behaviour, learning and perception. Amongst birds, it is second only to the pigeon (albeit a distant second) in use in experiments involving operant (or instrumental) conditioning, where the bird works for food rewards in a 'Skinner box'. On account of its large vocal repertoire and capacity to learn new songs throughout its life, the starling is a model species in studies of learning and neural plasticity. Its vivid coloration and the fact that its visual system is well understood have led to its use in behavioural studies of visual perception, signalling and mate choice. Again, because its natural breeding ecology is well understood, it has been extensively used in investigations of photoperiodic control of reproduction and the field of behavioural endocrinology in general.

In all cases, the starling has been favoured because of its robustness in captivity and because of its size, being neither too large to require large amounts of space and food, nor so small as to make handling or experimental procedures tricky. Against these advantages, and a major consideration in housing and husbandry, is the mess the birds create. The same faecal production that creates urban problems through fouling of buildings, also makes cleanliness a far greater problem than for, say, small granivorous species like the zebra finch. The starling also seems to have a remarkable capacity for ballistic defaecation: droppings are rarely confined to the aviary or cage floor. The extra maintenance required for hygiene and cleanliness is somewhat offset by its simple dietary requirements.

26.1 Natural habitat and behaviour

The European starling is a medium sized (70–90 g) songbird, widespread across the Palaearctic and also, thanks to human introduction, North America, Australia and New Zealand. In common with many bird species reliant on grassland, numbers have been declining in Europe in the last few decades, probably through changes in land-use practices. The starling is varied in both its diet and habitat, but several features are universal requirements. Whilst it eats high quantities of vegetable matter in autumn and winter (fruit and grain seedlings), it is reliant on soil invertebrates (leatherjackets, beetle larvae and earthworms) when raising young in spring (Feare 1984). It is mainly a ground-feeder but, on a seasonal basis, will take fruit from orchards and insects from trees. The gut too changes morphology seasonally, increasing in length during winter by almost one-third to facilitate processing of the less digestible fibrous food (Al-Joborae 1979).

As it is a hole-nester, as well as needing to breed near pasture or gardens for food, it relies on mature woodland or buildings for a nesting site. Males do not defend a territory as such, only the area immediately around the nest cavity, and prefer to breed near other starlings. They thus readily take to nest boxes even when spaced only a few metres apart. This has made them a popular species for the study of breeding ecology, parental care and mating systems (e.g. Wright & Cuthill 1989, Pinxten *et al.* 1993a, Smith 1995). Successful males can attract more than one female so, whilst monogamy is the most frequent breeding pattern, polygyny is common in many populations (Pinxten *et al.* 1989, Wright & Cuthill 1992). The typical pattern here is that the male attempts to attract a second female to another nest while his mate is incubating the eggs. If successful, the male nevertheless will usually devote most of his paternal care to his first mate's brood (Pinxten *et al.* 1993b, Sandell *et al.* 1996). The best general reference for starling behaviour and ecology is Feare (1984).

26.2 Housing and space requirements

Housing: Starlings are gregarious so can be housed together, providing there is adequate perch space for roosting (see Section 26.5.1) and feeders cannot be monopolized by one or a few individuals. Adults are generally dominant over juveniles, and males over females (Feare 1984), but there is no strong social structure as such. For this reason, it is feasible to house birds individually, if necessary for an experimental protocol, but communal housing is closer to the starling's natural lifestyle. In the wild, starlings often roost at very high densities, with a clear pecking order of dominant birds getting the favoured perch sites on the interior of, and high off the ground in, the roost (Feare 1984). Such sites are both safer from predators and have a more sheltered microclimate. Even though captive housing may remove such natural vicissitudes, the birds will still be motivated to compete for what would be the best sites in nature. For this reason, although starlings can be housed at moderately high densities, it is important that there are adequate roosting perches for all birds.

Space requirements: A minimum space requirement for a singly-housed bird would be about 1 m^3, but it is preferable to keep several birds together in a larger cage, even if this is at a reduced space per bird. A $2 \times 1 \times 1$ m cage with four birds may well provide better conditions than two $1 \times 1 \times 1$ m cages with one bird in each, as starlings will naturally perch close to each other and the larger space gives scope for free flight. Stocking density in a communal aviary is determined more by the difficulty of maintaining cleanliness and hygiene, due to the high fouling rate of the birds, than any adverse interactions between the birds. The greater the space for flight the better, so a long narrow aviary is preferable to a cubic aviary of equivalent volume. See Table 10 for recommended space allowances for starlings.

Recommendations:

- House birds communally with plentiful perching space and feeders which allow multiple access.
- Do not exceed the maximum recommended stocking density of 10 birds in a $4 \times 3 \times 2$ m aviary.
- Provide outdoor aviaries with clear flyways wherever possible.
- Do not provide nest boxes for mixed-sex groups, as this promotes aggressive nest defence.

26.3 Diet and basic requirements

Diet: Starlings can be kept indefinitely on a diet of commercial turkey or 'game' bird starter crumbs, provided that a small supplement of live invertebrate prey is supplied (about 3–5 mealworms per day). There can be some loss of colour in the bill, which in the summer would normally be yellow, but this can be countered by adding a vitamin A supplement to the drinking water (veterinary advice should be sought beforehand). Turkey crumbs, being dry, demand that plentiful water is provided. Both the crumbs and the water are best supplied in gravity-feed dispensers, so that they cannot be soiled by faeces. Apart from mealworms, another 'treat' that can be provided occasionally is fresh fruit. However, the starling's physiology is such that it cannot readily digest high-sucrose fruits; a peculiarity of the starling family as a whole (Avery *et al.* 1995). Cherries and grapes, however, are fine, a fact most fruit growers are well aware of (Feare 1984).

Bathing: Bathing water is essential, not just for feather maintenance but as a basic behavioural need of the species. Starlings love water, and will compete strongly for access to a fresh bath, so shallow water baths should be provided. If a flow-through system is feasible, birds can be provided with *ad libitum* fresh water; otherwise an absolute minimum would be to provide baths once a week. It is advisable to fill them only an inch or so deep, so that the feathers do not become waterlogged and the bird can get out easily.

Bill and claw trimming: As the bill and claws' natural growth is geared to a lifestyle of walking and probing in the soil, both can become overgrown in captivity. Bill-wiping on rough wooden perches can counter this to some degree (Cuthill *et al.* 1992), but normally the birds must be manually trimmed with nail-clippers every few months. Overgrowth of one mandible by the other is a common problem with bills that are not trimmed regularly, and this can cause feeding and grooming problems. Overgrown bills can also interfere with preening.

Table 10 Space allowances for starlings

	Common practice			Good practice		
No. of birds	Pen area (m^2)	Minimum height (m)	Minimum No. of feeders	Pen area (m^2)	Minimum height (m)	Minimum No. of feeders
1	0.5	0.3	1	N/A	N/A	N/A
Up to 6	1.5	0.5	1	2	2	1
Up to 12	2	1	2	3.5	2	2
Over 12	3+	1.75	3+	5+	2	3+

Recommendations:

- Supplement turkey starter crumbs with mealworms and occasional low-sucrose fruit (e.g. cherries, blackberries, grapes).
- Provide large shallow water baths and replenish water regularly; starlings love water.
- Provide rough natural perches for bill-wiping, but check bills and claws regularly and trim as necessary.

26.4 Rearing and capture from the wild

Rearing: It is impractical, and extremely difficult, to breed starlings in captivity, due to the chicks' dependence on live invertebrate prey. Birds will attempt to breed if kept in aviaries with nest boxes and enough space for free flight and social interaction between pairs (pairs housed in isolation seem to be less successful). However, the breeding attempt often fails soon after the chicks hatch. Those breeders who have been successful rearing starlings have used large mobile aviaries erected over natural pasture and moved, on a daily basis, to undepleted areas. Chicks can be hand-reared but, as this is extremely labour intensive, with chicks needing fed every 15 min or so, this will rarely be practicable.

Capture: Capture from the wild is easiest, and causes least disturbance to the species' ecology if carried out during the post-fledging period in summer (N.B. see Section 6.1.1 on laws regarding trapping). Juveniles, particularly, can be caught in large numbers with a large baited funnel or walk-in trap, the most profitable sites often being near pig farms, where the birds not only congregate but are used to entering agricultural-type buildings. Once a few birds have been caught, they act as decoys for further individuals. Unless only a few are being caught and the capture site is near to where they are to be housed, birds are best transported in cages rather than bird-bags. In transporting the birds, and on first housing them in captivity, it is sensible to provide live prey, such as mealworms (*Tenebrio* spp. larvae), as these are more likely to stimulate feeding than dry food. Likewise, if being housed in an outdoor aviary, it is unwise to release the birds into the cage near to dusk. In an unfamiliar space, the birds may not find a suitable roosting perch and so, particularly in a hungry and stressed state, are at risk of developing hypothermia overnight.

Recommendations:

- Catch starlings during the post-fledging period in summer, when parents have ceased breeding and juveniles are easier to catch.
- Use walk-in or funnel traps to catch starlings; these cause least distress to the birds, catch large numbers most efficiently and are easiest to operate.
- On capture, provide with water, familiar food and live mealworms. If housing outdoors, transfer them to the new conditions well before dusk.

26.5 Environmental stimulation

Starlings are inquisitive birds and require a complex environment that will stimulate foraging behaviour. Group housing birds in outdoor aviaries will promote a range of natural behaviours and optimize welfare, but it should still be possible to provide good quality and quantity space for those housed indoors.

26.5.1 Good quality environment

The ideal starling housing would be a large outdoor aviary with a natural substrate, such as bark chips, on the floor. This flies in the face of most guidelines for laboratory animal housing, as the temperature cannot be controlled and the substrate cannot be cleaned as easily as a steel cage. However, as long as roosting perches, sheltered from the elements, are provided, starlings will have no problems surviving sub-zero conditions, and their plumage and general condition appear to be much better when they are kept in ambient light and temperature. Starlings naturally spend a lot of time walking and searching on the ground, so a bare wire cage floor is a poor substitute. Furthermore, in carrying out their natural 'probing' behaviour (see below) through wire mesh, starlings can injure the base of their bills. Although a substrate such as bark chips cannot be cleaned as easily as metal, it can be hosed down on a regular basis and periodically replaced. As already mentioned, provision of numerous perches is important. Doweling of 1–1.5 cm diameter is suitable, placed both high (within 20 cm of the aviary roof, for roosting) and low (but >1 m from the ground), so that the birds can move between a range of perch sites. To avoid fouling, perches should not be placed over food or water containers. There is some evidence that provision of protective cover, such as shrubs or natural, leafed, branches can reduce stress, measured both behaviourally and through both fat reserves and reduced abnormalities in plumage development (Witter & Lee 1995). This is presumably related to their natural anti-predator behaviour.

Recommendations:

- Provide a diversity of natural and/or doweling perches at different heights, ensuring there are high perches for roosting.
- Use bark chips as a substrate, as this is better for the feet of these birds which are often ground-feeding, and which promotes natural searching and foraging behaviour.
- Provide branches with foliage or shrubs for protective cover, which seems to reduce stress.

26.5.2 Foraging behaviour

As anyone who has watched starlings foraging knows, their characteristic feeding behaviour is to probe into the soil with their bill, then open the mandibles once inserted. In fact, their eyes are so located, and swivel in their sockets, such that they can look between the mandibles and see any prey in the hole they have created (Martin 1986). This behaviour, and their apparent natural inquisitiveness, are what make provision of a natural, complex substrate, such as bark chips, so beneficial for the species in captivity. Even with a bare cage, lining the base with newspaper for ease of cleaning will provide the starlings with the opportunity for poking, probing, tearing and searching underneath. If feasible, the ideal environmental enrichment is to provide birds with cut pieces of turf (Gill 1994, Gill *et al.* 1995); this allows both the natural foraging behaviour and the possibility of finding live prey e.g. mini mealworms or crickets as a diet supplement. Several turves should be provided at once, to reduce aggression, as starlings have been seen to defend these valued resources (Gill 1994, Gill *et al.* 1995). An alternative to providing turves is to place the daily mealworm ration in a sand box so that the birds have to probe to find them.

Recommendation:

- Place cut pieces of fresh turf or sand boxes with live prey supplements in the aviary to enrich the environment and promote natural foraging behaviour.

26.5.3 Group size and composition

Starlings are social animals and ideally should be housed in a group, the size of which is only limited by aviary and roosting space, and access to food. Adult males are dominant over other classes of individuals, so if large numbers of birds are competing for one feeder, the juveniles and females will suffer. Otherwise, there are no special restrictions on the composition of the group. Whilst provision of roosting boxes may seem to be beneficial, in the breeding season this will only promote male–male competition for these as nest sites (Gwinner & Gwinner 1994). Without suitable nest sites, females appear not to be fully stimulated into breeding condition (A R Goldsmith, unpublished data). For this reason, and their lack of territorial behaviour, mixed-sex groups can be kept together even in the breeding season, provided there are no nest sites to compete over.

Recommendation:

- Group-house starlings wherever possible but do not provide nest boxes in the breeding season.

26.5.4 'Natural' conditions

Once provision of suitable space, shelter, perching, foraging substrates, diet and bathing facilities have been provided, one less obvious aspect of the environment needs to be considered, namely lighting. Outdoor housing has not only ambient temperature, humidity and air flow, but it also has natural photoperiod. Starlings, like most birds breeding at temperate latitudes, have a reproductive cycle strongly controlled by photoperiod. The short days of winter stimulate gonadal maturation and, ultimately, all other aspects of reproductive physiology and behaviour (Nicholls *et al.* 1988). After breeding, the long days of summer have the reverse effect, the gonads regressing, behaviour related to breeding being suppressed and moult being stimulated. Long days are also necessary for the subsequent breeding season, as the stimulatory effect of short days is only effective if the bird has experienced long days first, the latter being necessary for 'photosensitivity'. Without long days, the post-breeding bird would remain 'photorefractory' and remain in a non-breeding state indefinitely. In hormonal terms starlings, like many temperate breeding birds, effectively undergo puberty every year (Nicholls *et al.* 1988). Consequently, with artificial lighting, starlings can be maintained permanently in a non-breeding state, or their annual cycle accelerated, slowed, or otherwise manipulated—facts that have been important in research on photoperiodism and avian endocrinology. The welfare effects, if any, of suppressing or altering the annual cycle in this way are unknown. However, close attention must be paid to these profound effects of the light:dark regime when keeping captive birds under artificial lighting. Either the photoperiod should be advanced approximately in step with ambient conditions (e.g. on a weekly basis) or, if this is impractical, birds should at least be taken through a sequence of short, then long, days to stimulate an annual moult and maintain feather condition (see e.g. Nicholls *et al.* 1988).

Recommendations:

- Keep starlings in outdoor aviaries with a natural photoperiod, light intensity and climatic variation wherever possible.
- If keeping birds indoors, track changes in natural photoperiod over the year by altering the light:dark cycle regularly.

26.6 Training and rewards

Their ease of training, and the fact they will work for the same dry turkey crumbs as they are routinely fed in captivity, have made starlings popular in 'Skinner box' type experiments. Starlings rapidly learn to hop on perches, peck at panels, follow cueing lights, discriminate between shapes, colours, time intervals, sounds and complex patterns of food distribution (e.g. Cuthill *et al.* 1990, Bateson & Kacelnik 1995). Training can either be by 'autoshaping', whereby the bird will spontaneously peck at a light which is illuminated in conjunction with delivery of a food reward (Reboreda & Kacelnik 1993), or by slowly building up the complexity of the task from simpler elements (e.g. Cuthill *et al.* 1990, Dall *et al.* 1997). If additional encouragement is required (which is rarely the case, as the starling is a naturally curious bird), live mealworms or small pieces of low sucrose fruit (e.g. grapes, cherries) are favoured. Note that pigeon pellets are not suitable rewards because they are too hard for starlings to eat. It is possible to have softer foods such as turkey starter crumbs and mynah bird food pelletted for starlings.

Recommendations:

- Reward starlings regularly with mealworms and fruit.
- Do not use pigeon pellets as rewards—they are too hard for starlings.

26.7 Potential health and welfare problems

- Beak and claw overgrowth—check beaks and claws regularly and trim if necessary (Section 26.3).
- Feather damage—this is generally due to keeping birds in small cages with inadequate perching, so house birds in aviaries with plentiful perches (Section 26.5.1).
- Stereotypies, particularly somersaulting—house birds socially and provide substrate

for foraging and branches (Sections 26.2 and 26.5.3).

- 'Canary pox' (*Avipox* spp.) in young birds—the risk of infection is exacerbated by stress, so keep at low densities on a high-quality diet and check for clinical signs (wart-like neoplasms around the eyes). If birds are housed appropriately, canary pox should either not appear or should resolve itself quickly (see Sections 26.2 and 26.3).
- Feather mites—place an insecticidal strip in the room.

27 Finches, including the zebra finch, Taeniopygia guttata

Grassfinches of the tribe Poephilini, along with the mannikins and waxbills, belong to the subfamily Estrildinae. They come from tropical and subtropical Australasia, South-East Asia, India and Africa, and include many of the most popular small aviary songbirds. Zebra finches are the finches by far the most commonly used in scientific research, as well as being perhaps the easiest to keep. This section relates largely to zebra finches, similar concerns being applicable to other Estrildines, with the caveat that many of the other species are more delicate and require greater care and attention in captivity, particularly if it is desired to breed them.

As well as being one of the most popular and readily bred aviary birds, zebra finches are a model species in studies of both sexual selection and of the development of sexual preferences (references in Collins & ten Cate 1996, Zann 1996). This is because the bird adapts readily to, and is easy to breed in, captivity, and both colour and song are important cues in mate choice. The latter are readily quantified and manipulated (*via* use of different colour morphs, or direct painting or dyeing) and the species seems to show similar patterns of choice in both artificial 'mate choice chambers' and free-choice aviary situations (see e.g. Zann 1996).

Zebra finches are inexpensive to buy, but it is worth noting that many of the individuals bought from pet shops can be a haphazard genetic mix, with unexpected colour morphs appearing in the second generation. Such variation is usually undesirable for scientific reasons, so it is best to buy birds directly from a breeder who knows the genetic background of the stock. This Section should be read in conjunction with Jones and Slater (1999).

27.1 Natural habitat and behaviour

Zebra finches are monogamous and sexually dimorphic. They are found across most of Australia, as well as neighbouring islands (Zann 1996). The male's plumage is more ornate than that of the female. Females are greyish in colour, with a buff-to-white underside and white cheek patches bordered by a black stripe; males have an additional reddish brown cheek patch, similarly-coloured flanks with white spots, and black-and-grey striped throat and chest. Both sexes have orange legs, whilst the bills differ in that the female's bill is usually orange while the male's is deeper red. From this basic wild-type stock, a variety of domesticated colour mutants have been bred (see e.g. Bates & Busenbark 1970).

Flocking and breeding: Zebra finches usually live in flocks, from a few dozen to a few hundred, often mixed with other species of small birds. They range over a wide area in search of food and local populations can be highly mobile, deserting an area if conditions are unfavourable. Perhaps as an adaptation for the need to be able to fly large distances at short notice, there is no synchronous moult, the feathers being shed gradually throughout the year (Zann 1996). The birds will use nests as roost sites even outside the breeding season, a habit which allows them to survive in areas where the temperature is low at night. Roosting nests are either old breeding nests, or purpose-built (Zann 1996). The breeding season is not fixed, but is triggered by the arrival of rains. In a long-term population study, Zann *et al.* (1995) showed that there was a time-lag of one or 2 months between the start of the rains and breeding, such that hatching of the eggs coincided with the first availability of ripening grass seeds. Dry seed alone, however abundant, did not stimulate breeding, a fact that aviculturalists use to control reproductive output in captive birds.

27.2 Housing and space requirements

The zebra finches is a sociable species, so it is best not to house birds in isolation. The one exception would be when individuals need to be temporarily separated because they are ill or have been the object, or cause of, aggression between conspecifics. A typical 'hospital cage' for a sick bird is enclosed on all sides but one, and heated by a tungsten bulb of about 25 W, which can maintain a temperature of around 24°C and also enables birds to move towards or away from the heat source. Heat, provided day and night, and access to plentiful 'favourite' foods, such as mealworms and soaked seeds, are essential first aid prior to veterinary treatment.

Cages: Keeping birds in cages rather than a large aviary may sometimes be necessary for scientific reasons, and may be preferable if the birds need to be captured and handled on a very regular basis. Specific individuals are more easily and rapidly captured from a small cage than an aviary, and this reduces stress to both the target bird and the others in the group. A standard canary cage (about 50 cm × 30 cm × 30 cm), with solid sides on all but the front, is suitable for a pair of birds; a double canary cage, which allows greater movement, is better still and can house up to six birds (see Table 11). However, we stress that aviary housing is preferable under most conditions.

Aviaries: Communal housing of several birds in an aviary is preferable to many small cages. Provided sufficient perch space is available for all individuals, 20 birds could be adequately housed in a 2 × 3 × 2 m aviary. Zebra finches feed regularly on the ground as well as flocking in trees, so if space is limited, width can be compromised to maintain vertical height and length, for free flight. With a frame of steel or treated wood, plastic-coated wire mesh, of no greater than 1 cm width, is preferable to plastic aviary netting, as it is easier to clean and longer lasting. Suitable flooring includes bark chips, wood shavings or sand.

Recommendations:

- House birds communally; even breeding birds fare better in groups than as isolated pairs.
- If sick birds are housed singly, provide a heat source that they are able to move away from.
- Keep birds in outdoor aviaries wherever possible, with shelter and an indoor area with supplemental heating in winter. Otherwise, large, indoor aviaries are best.

27.3 Breeding and rearing

Breeding behaviour: Presumably so that they can take advantage of unpredictable breeding conditions without the delay imposed by courtship, zebra finches form long-term monogamous pair bonds in the wild. Once paired, much of the social behaviour of the male and female is directed towards maintaining this bond. The surest sign of pair-bonding is allopreening, where the male and female sit close to and preen each other. Young birds are capable of breeding at quite an early age, probably another adaptation for

Table 11 Space allowances for finches

	Common practice			Good practice		
No. of birds	Pen area (m^2)	Minimum height (m)	Minimum No. of feeders	Pen area (m^2)	Minimum height (m)	Minimum No. of feeders
1	0.3	0.3	1	0.5	0.3	1
Breeding pair	0.3	0.3	1	0.5	0.3	1
Up to 6	0.6	0.3	1	1	1	2
Up to 12	1	1.5	2	1.5	2	2
Over 12	1.5	2	3	2+	2	3+

opportunistic breeding when conditions are unpredictable. In a study of wild birds, one female laid her first egg at 62 days old, the median age of first breeding being about 90 days in both sexes (Zann 1996). In aviary conditions birds can breed even earlier. The modal clutch size is five, both sexes incubating during the day and the female at night (Zann 1996). The average length of incubation is 14 days.

The zebra finch is amongst the easiest of birds to breed in captivity; it is the first bird of most aspiring aviculturalists. This relates to its natural opportunistic pattern of breeding in response to the arrival of rains (Zann *et al.* 1995). If breeding is desired, it is important to stock birds at a lower density than for standard housing, provide an excess of nest sites, and maintain an equal sex ratio. This reduces sexual conflict and aggression between pairs. Zebra finches seem to breed better when a small number of pairs are housed together in a medium-sized aviary with sufficient breeding sites, than when pairs are isolated in individual cages. Whenever pairs of birds are provided with a nesting site and with a supply of greens, live insects, and softened seeds, they are liable to attempt breeding. More often the problem is overproduction of young, or unhatched eggs, under the 'ideal' conditions of captive housing (Bates & Busenbark 1970).

Nesting materials: Dried grass and/or coconut fibre should be provided for nest-lining, although not in great excess, as under the 'cost free' conditions of captivity some birds may overfill their nests with lining, constricting the space available to the nestlings. Suitable commercially produced nests are either a completely enclosed pear-drop-shaped wicker basket (or its more easily cleaned plastic equivalent), or a cubic wooden box of side about 12 cm and with either an entrance hole of about 4 cm or the top half of the front cut away. Dried grass for nest-lining can be hung in a basket of wide-mesh chicken-wire within the aviary; this keeps it unsoiled by faeces and the aviary tidy. Some birds continue to add nesting material over clutches and then lay another clutch on top—this is known as 'sandwich nesting'. Nesting material should therefore be removed after clutches have been laid.

Recommendations:

- Keep breeding birds at an equal sex ratio, at lower densities, and with an excess of suitable nest sites and nesting materials.
- Supplement the diet with greens, live insects and softened seeds.
- Remove nesting material after clutches have been laid.

27.4 Diet

Seeds: In the wild, zebra finches can, and do, subsist on an almost exclusive diet of dry grass seeds. Although, as a species, the range of seed types taken is large, in any one population the diet is fairly narrow (Zann 1996). However, in captivity, and perhaps as a result of over 100 years of captive breeding with little or no input from wild stock, the birds do best with a mixed diet. A balanced diet for the zebra finch consists of foreign finch seed mix (largely millet and canary seed), a few live insects, grit to assist in the breakdown of seeds in the gizzard, and cuttlebone for calcium.

Additional foods: In addition to dry seeds, finches also seem to like both soaked and sprouted seeds; these, and provision of greens, are essential for birds to breed. In the former case, the normal finch mix is soaked for a day and the hydrated seeds are rinsed and given to the birds. If such seeds are stored in a warm dark place and kept moist, they will sprout and, again should be rinsed before being given to the birds. The rinsing, and use of fresh seeds, are essential to avoid health risks from fungal spores or mould. Suitable greens for zebra finches include the darker outer leaves of lettuce, or dandelion, watercress, and spinach; pet shops also sell dehydrated greens which often have vitamin supplements added. Breeders sometimes also provide bran and mashed egg, as a protein supplement, to breeding birds. It is best to give the birds a small amount of greens and protein-rich foods regularly, because an infrequent supply encourages them to overeat, which can result in diarrhoea. Live insect prey, most conveniently mealworms or cricket nymphs, provide essential protein, but these should be limited to two or three a day, in order to prevent overeating. If birds are in a communal aviary where there is a risk of subordinate individuals having reduced access to these preferred foods, they are best supplied in several small, separated dishes, so that no one bird can monopolize the resource. Millet (e.g. *Panicum*) in spray form, fruit such as apple, and the yolk of hard-boiled eggs, are all recommended additions to the diet (Bates & Busenbark 1970).

Other requirements: Attempts should be made to carefully assess the nutrient balance of the diet and to correct any potential deficits with supplements (Kirkwood 1996). Supplements can be added to the birds' water in liquid form or to the food or grit as powder. Grit is best provided in a small dish separate from the seed mix, so that the bird can control its intake as necessary. Finally, cuttlebone is the most convenient means of providing finches with calcium. Whole cuttlebone should be attached to the side of the bird's cage with the softer side outermost; alternatively, crushed cuttlebone can be added to the grit mix.

Recommendation:

- Provide foreign finch seed mix, sprays of millet, greens, a few live insects, grit and cuttlebone. Breeding birds need these plus soaked and sprouted seeds, bran and mashed eggs.

27.5 Environmental stimulation

Toys, perches and swings designed for finches are commercially available and birds are likely to benefit from these, provided that care is taken to ensure that all cage additions are used by the birds and promote a range of behaviours.

27.5.1 Good quality environment

Zebra finches feed extensively on the ground, but are essentially perching birds, so they are likely to feel most secure in the trees. The most convenient perching materials are 0.5 cm doweling rods which should be easy to remove and be cleaned periodically. However, natural branches are a seemingly welcome supplement, recommended by most breeders. Swings may help birds exercise as their movement necessitates use of the wings for balance. Plentiful perching space, at several different levels with some high up (within 15 cm of the roof) for roosting, provides the birds with alternative perching heights. Like most birds, zebra finches feel safest on branches near the roof of the aviary, but prefer to approach feeders, or the ground, by moving to progressively closer perches. The aviary should not, however, be so crowded with perches as to make free flight difficult. Furthermore, a crowded aviary makes capture, when necessary, more difficult, and hence increases the time and stress to which the bird is exposed. Perches should not be placed over food or water containers, so as to avoid fouling.

Recommendations:

- Provide many perches at a variety of heights, plus several feeding stations so that dominant birds cannot monopolize preferred foods.
- Do not place perches over food or water containers.

27.5.2 Foraging behaviour

The most obvious means of stimulating captive birds is to provide part of the seed diet as sprays of *Panicum* millet, rather than simply as mixed seed in a bowl. Zebra finches seem to take such active interest in food presented this way that many breeders recommend this as an essential provision. Otherwise, the inevitable spillage of seeds on the floor of the cage or aviary will promote the active search on the ground which is part of their natural foraging behaviour. In addition, spillage of seed ensures that subordinate birds in a communal aviary can gain adequate food. As mentioned above, additional supplements to the diet which are important for bringing birds into breeding condition, as well as promoting good health and satisfying behavioural needs, are live insect prey and pieces of fruit.

Recommendation:

- Provide sprays of *Panicum* millet, live insect prey and pieces of fruit to encourage foraging behaviour.

27.5.3 Group size and composition

Zebra finches naturally live in large flocks, often of mixed species, during the non-breeding season. Even whilst breeding, they live in sometimes large aggregations, so it is perfectly feasible, indeed desirable, to house birds communally. The only caution in this respect is that if nesting sites are provided, by way of wicker or plastic baskets, birds will actively and aggressively defend these. Consequently, if the desire is to breed birds, it is better to: (i) provide an excess of nest sites; and (ii) divide birds into several smaller aviaries rather than keeping all of them together in one large aviary. As mentioned previously, being a sociable species, it is best not to house birds in isolation.

Coloured leg rings: An aspect of husbandry which may be unexpected and is of welfare significance, is that banding the birds with colour rings for identification can have profound effects on their social behaviour. The colour of rings which a bird wears can affect their attractiveness to mates, their breeding success, longevity and even the sex ratio of their broods (Burley 1985, 1986 a,b,c, 1988, Zann 1994). Females appear to prefer males with red leg rings, perhaps a redirected preference for the redness of the male's bill, and dislike green rings; females also find black-ringed males attractive and blue-ringed males unattractive (Burley *et al.* 1982). More recently, this pattern has been shown to be mirrored in intrasexual dominance interactions, with red-ringed males being dominant over green-ringed males (Cuthill *et al.* 1997). The important lesson for keeping zebra finches in captivity, is that colour-banding for identification is far from neutral in its effect on behaviour. Even banding a male with asymmetrical arrangements of multiple colours (e.g. orange over green on the left leg, green over orange on the right) will reduce his attractiveness to potential sexual partners (Swaddle & Cuthill 1994). If birds have to be banded for identification, it is best to use colours which have less impact on social interactions (see Burley *et al.* 1982, Burley 1986a) and/or to provide multiple food sources so that dominant birds cannot monopolize the resource (see Cuthill *et al.* 1997).

Recommendations:

- Keep finches in flocks, taking care to provide sufficient nesting sites if breeding is required.
- If using colour rings/bands to aid individual identification, pay special attention to the birds' condition, as ring colour can affect dominance in non-breeding birds and mating success during the breeding season.

27.5.4 'Natural' conditions

As the zebra finch is Australian, it is easy to envisage it as a bird of semi-desert tropical conditions. However, the range of the species is widespread within Australia, and it can sometimes be exposed to sub-zero temperatures over winter (Meijer *et al.* 1996). This makes it less surprising that many commercial breeders in the UK keep their birds in outdoor aviaries, where the breeding pattern becomes somewhat seasonal. Certainly zebra finches seem to thrive in outdoor accommodation, provided that some indoor shelter and/or heating is provided for particularly harsh conditions (Bates & Busenbark 1970). The benefits of varied ambient conditions, natural lighting, and access to live insect prey in summer, can outweigh what appears, to the human, to be a more taxing environment.

As one might expect for a species that can persist in arid conditions, zebra finches can do without water for long periods, their needs being met by metabolic water from carbohydrate breakdown. However, in captivity it is essential to provide them with drinking water and also bathing water at least once a week.

Recommendations:

- Consider keeping zebra finches in outdoor aviaries, with shelter and heating, if possible.
- Provide water for drinking continually and for bathing at least once a week.

27.6 Training and rewards

Zebra finches have been successfully trained to operant responses for the discrimination of different songs and sounds (Weisman *et al.* 1994). However, they are placid and relatively uninquisitive species compared to, say, the starling (see Section 26). Probably for this reason, they have not been much used in experiments involving instrumental learning or any active training. They will work for seeds and can be autoshaped to light cues (Biondolillo *et al.* 1997, see also Section 26), but small pieces of fruit and live mealworms are suitable 'special' rewards.

Recommendation:

- Reward finches regularly with fruit and mealworms.

27.7 Potential health and welfare problems

Zebra finches can suffer from a range of diseases (see Jones & Slater 1999) and, because of the stress of captivity and their physiology, veterinary attention should be promptly sought when signs of illness are first observed.

- Feather pecking—this may be caused by a lack of nesting material for breeding birds or overcrowding. Ensure that nesting material is available and that space allowances and group sizes are appropriate (see 27.2, 27.3, 27.5.3); it may be necessary to remove a persistent feather-pecker from a group.
- Feather infestations with mites or lice—constantly monitor birds and treat at an early stage.
- Hypothermia—finches are sensitive to low temperatures, so maintain indoor temperatures between 20 and 25°C and ensure that birds housed outdoors have adequate shelter and heating.

Acknowledgments The authors would like to thank David Anderson who attended as a Home Office observer. They would also like to thank Peter Budd, Ian Duncan, Jason Finney, Alan Gardner, Rosemary Hutchison, Maggy Jennings, Bryan Jones, Caroline Le Sueur, Cheryl Meehan, Katherine Miller, Trevor Poole, Ian Robinson, Amanda Sandos, Imelda Schmid and Debbie Zombeck for their comments on the text, and Gilly Griffin, Robert Baker, Richard Crawford and Jerry Depoyster for information on national legislation and guidelines.

References

Advisory Committee on Dangerous Pathogens (1997) *Working Safely with Research Animals: Management of Infection Risks*. London: HSE Books

Åhlund M, Götmark F (1989) Gull predation on eider ducklings *Somateria mollissima*: effects of human disturbance. *Biological Conservation* 48, 115–27

Al-Joborae FF (1979) The influence of diet on the gut morphology of the Starling (*Sturnus vulgaris*) L1758 (unpublished DPhil thesis). Oxford: University of Oxford

Altman RB, Clubb SL, Dorrestein GM, Quesenberry K (1997) *Avian Medicine and Surgery*. Philadelphia: WB Saunders

Animal Welfare Advisory Committee (1994) *Code of Recommendations and Minimum Standards for the Welfare of Animals Transported in New Zealand (amended 1996)*. New Zealand: AWAC

Animal Welfare Advisory Committee (1995) *Code of Recommendations and Minimum Standards for the Care and Use of Animals for Scientific Purposes*. New Zealand: AWAC

Animal Welfare Information Center (1995) *Environmental Enrichment Resources for Laboratory Animals 1965–1995*. Maryland: AWIC, pp 5–25

Ar A (1991) Egg water movements during incubation. In: *Avian Incubation: Poultry Science Symposium*, No. 22. Chap. 10 (Tullett SG, ed). London: Butterworth-Heinemann

Ashmole NP (1971) Seabird ecology and the marine environment. In: *Avian Biology*, Vol. 1. Chap. 6 (Farner DS, King JR, Parkes KC, eds). London: Academic Press

Ashton WLG, Pattison M, Barnett KC (1973) Light-induced eye abnormalities in turkeys and the turkey blindness syndrome. *Research in Veterinary Science* 14, 42–6

Association of Avian Veterinarians (1999) *Basic Pet Bird Care*. www.aav.org/basic_care.htm

Avery ML, Decker DG, Humphrey JS, Hayes AA, Laukert CC (1995) Color, size, and location of artificial fruits affect sucrose avoidance by Cedar Waxwings and European Starlings. *Auk* 112, 436–44

Barnea A, Nottebohm F (1994) Seasonal recruitment of hippocampal-neurons in adult free-ranging black-capped chickadees. *Proceedings of the National Academy of Sciences of the United States of America* 91, 11217–21

Bates HJ, Busenbark RL (1970) *Finches and Soft-Billed Birds*. Neptune City, New Jersey: TFH Publications Inc

Bateson M, Kacelnik A (1995) Accuracy of memory for amount in the foraging starling, *Sturnus vulgaris*. *Animal Behaviour* 50, 431–43

Batty J (1997) *Artificial Incubation and Rearing*. Midhurst, UK: Beech Publishing House

Bauck L (1994) Mycoses. In: *Avian Medicine* (Ritchie BW, Harrison GJ, Harrison LR, eds). Lake Worth, Florida: Wingers Publishing Inc, pp 947–83

Bauck L (1998) Psittacine diets and behavioural enrichment. *Seminars in Avian and Exotic Pet Medicine* 7, 135–40

Baudinette RV, Norman FI, Roberts J (1982) Salt gland secretion in saline-acclimated chestnut teal, and its relevance to release programs. *Australian Journal of Zoology* 30, 407–15

Baxter MR (1994) The welfare problems of laying hens in battery cages. *Veterinary Record* 134, 614–19

Bell DD, Adams CJ (1998) Environmental enrichment devices for caged laying hens. *Journal of Applied Poultry Research* 7, 19–26

Bennett ATD, Cuthill IC (1994) Ultraviolet vision in birds: what is its function? *Vision Research* 34, 1471–8

Bennett ATD, Cuthill IC, Partridge JC, Lunau K (1997) Ultraviolet plumage colors predict mate preferences in starlings. *Proceedings of the National Academy of Science USA* 94, 8618–21

Bennett EL, Diamond MC, Krech D, Rosenzweig MR (1964) Chemical and anatomical plasticity of brain. *Science* 146, 610–19

Bent AC (1963) *Life Histories of North American Gallinaceous Birds*. New York: Dover Publications, Inc

Beynon PH (1996) *Manual of Psittacine Birds*. Iowa: Iowa State University Press

Beynon PH, Cooper JE (1991) *Manual of Exotic Pets*. Cheltenham, UK: British Small Animal Veterinary Association

Beynon PH, Forbes NA, Harcourt-Brown NH (1996) *Manual of Raptors, Pigeons and Waterfowl*. Cheltenham, UK: British Small Animal Veterinary Association

Bhatt RS, Wasserman EA (1989) Secondary generalization and categorization in pigeons. *Journal of the Experimental Analysis of Behaviour* 52, 213–24

Bilcik B, Keeling LJ, Newberry RC (1998) Effect of group size on tonic immobility in laying hens. *Behavioural Processes* 43, 53–9

Bingman VP, Benvenuti S, Budzynski C, Strasser R, Alyan S (1997) Effects of zinc sulfate anosmia on the homing performance of pigeons in different climatic regions of the United States: evidence for global use of atmospheric cues for navigation. In: *Orientation and Navigation—Birds, Humans and Other Animals*. Oxford: Royal Society of Navigation

Biondolillo K, Stamp C, Woods J, Smith R (1997) Working and scrounging by zebra finches in an operant task. *Behavioural Processes* 39, 263–9

Blanchard S (1996) The complexities of feather picking. *Psittascene* 8, 11–12

Blogg SL, Townsend PP, Butler PJ, Woakes AJ (1998) A method of anaesthesia and post-operative care for experimental procedures in avian species. *Animal Technology* 49, 101–9

Blokhuis HJ (1989) The effect of a sudden change in floor type on pecking behaviour in chicks. *Applied Animal Behaviour Science* 22, 65–76

Bowmaker JK, Heath LA, Wilkie SE, Hunt DM (1997) Visual pigments and oil droplets from six classes of photoreceptor in the retinas of birds. *Vision Research* 37, 2183–94

Broom DM, Knight PG, Stansfield SC (1986) Hen behaviour and hypothalamic-pituitary-adrenal responses to handling and transport. *Applied Animal Behaviour Science* 16, 98

Brown L, Amadon D (1968) *Eagles, Hawks and Falcons of the World*. London: Country Life Books

Brown MJ, Forbes NA (1996) Waterfowl: respiratory diseases. In: *Manual of Raptors, Pigeons and Waterfowl* (Beynon PH, Forbes NA, Harcourt-Brown NH, eds). Cheltenham: British Small Animal Veterinary Association, pp 315–16

Brown PW, Fredrickson LH (1986) Food habits of breeding white-winged scoters. *Canadian Journal of Zoology* 64, 1652–4

Buchwalder T, Wechsler B (1997) The effect of cover on the behaviour of Japanese quail (*Coturnix japonica*). *Applied Animal Behaviour Science* 54, 335–43

Burgmann PM (1993) *Feeding Your Pet Bird*. New York: Barron's

Burley N (1985) Leg-band color and mortality patterns in captive breeding populations of zebra finches. *Auk* 102, 647–51

Burley N (1986a) Comparison of the band-colour preferences of two species of estrildid finches. *Animal Behaviour* 34, 1732–41

Burley N (1986b) Sex-ratio manipulation in color-banded populations of zebra finches. *Evolution* 40, 1191–206

Burley N (1986c) Sexual selection for aesthetic traits in species with biparental care. *American Naturalist* 127, 415–45

Burley N (1988) The differential-allocation hypothesis: an experimental test. *American Naturalist* 132, 611–28

Burley N, Krantzberg G, Radman P (1982) Influence of colour-banding on the conspecific preferences of zebra finches. *Animal Behaviour* 30, 444–55

Burtnick NL, Degernes LA (1993) Electrocardiography on fifty-nine anaesthetized convalescing raptors. In: *Raptor Biomedicine* (Redig PT, Cooper JE, Remple JD, Hunter DB, Hahn T, eds). Keighley: Chiron Publications, pp 111–21

Butler DE (1991) Egg handling and storage at the farm and hatchery. In: *Avian Incubation: Poultry Science Symposium*, No. 22, Chap. 12 (Tullett SG, ed). London: Butterworth-Heinemann

Butterworth G, Harcourt-Brown NH (1996) Neonate husbandry and related diseases. In: *Manual of Raptors, Pigeons and Waterfowl* (Beynon PH, Forbes NA, Harcourt-Brown NH, eds). Cheltenham, UK: British Small Animal Veterinary Association, pp 216–23

British Wildlife Rehabilitation Council (1989) *Ethics and Legal Aspects of Treatment and Rehabilitation of Wild Animal Casualties*. UK: BWRC

Canadian Council for Animal Care (1996) *CCAC Animal Utilisation Survey 1996*. Ottawa: CCAC

Cantin M, Bédard J, Milne J (1974) The food and feeding of common eiders in the St Lawrence estuary in summer. *Canadian Journal of Zoology* 52, 319–44

Carmichael NL, Jones RB, Mills AD (1998) Social preferences in Japanese quail chicks from lines selected for low or high social reinstatement motivation: effects of number and line identity of the stimulus birds. *Applied Animal Behaviour Science* 58, 353–63

Carter-Storm A (1988) Special considerations for general anaesthesia of birds. *Clinical Insight* 2, 61–2

Choudhury S, Black JM (1994) Barnacle geese preferentially pair with familiar associates from early life. *Animal Behaviour* 48, 81–8

Church SC, Bennett ATD, Cuthill IC, Partridge JC (1998) Ultraviolet cues affect the foraging behaviour of blue tits. *Proceedings of the Royal Society of London* B265, 1509–14

Clark L, Avilova KV, Bean NJ (1993) Odor thresholds in passerines. *Comparative Biochemistry & Physiology* A104, 305–12

Classen HL, Riddell C, Robinson FE, Shand SJ, McCurdy AR (1994) Effect of lighting treatment on the productivity health behaviour and sexual maturity of heavy male turkeys. *British Poultry Science* 35, 215–25

Clayton NS, Krebs JR (1994) Hippocampal growth and attrition in birds affected by experience. *Proceedings of the National Academy of Sciences of the United States of America* 16, 7410–14

Close B, Banister K, Baumans V, Bernoth E-M, Bromage N, Bunyan J, Erhardt W, Flecknell P, Gregory N, Hackbarth H, Morton D, Warwick C (1996) Recommendations for euthanasia of laboratory animals: Part 1. *Laboratory Animals* 30, 293–316

Close B, Banister K, Baumans V, Bernoth E-M, Bromage N, Bunyan J, Erhardt W, Flecknell P, Gregory N, Hackbarth H, Morton D, Warwick C (1997) Recommendations for euthanasia of laboratory animals: Part 2. *Laboratory Animals* 31, 1–32

Clutton RE (1986) Prolonged isoflurane anaesthesia in the Golden Eagle. *Zoo Animal Medicine* 17, 103–5

Clyde VL, Paul-Murphy J (1999) Avian analgesia. In: *Zoo and Wild Animal Medicine: Current Therapy 4*. Philadelphia: WB Saunders, pp 309–14

Coles BH (1985) *Avian Medicine and Surgery*. Oxford: Blackwell Scientific Publications, pp 102–22

Coles BH (1991) Cage and aviary birds. In: *Manual of Exotic Pets* (Beynon PH, Cooper JE, eds). Cheltenham, UK: British Small Animal Veterinary Association, pp 150–79

Coles BH (1997) *Avian Medicine and Surgery*, 2nd edn. Cambridge: Blackwell Science, pp 125–47

Collins SA, ten Cate C (1996) Does beak colour affect female preference in zebra finches? *Animal Behaviour* 52, 105–12

Commission of the European Communities (1999) *Second Report from the Commission to the Council and the European Parliament on the Statistics on the Number of Animals Used for Experimental and Other Scientific Purposes*. Office for Official Publications of the European Communities, Luxembourg

Cooper JE (1989) Anaesthesia of exotic species. In: *Manual of Anaesthesia for Small Animal Practice*, 3rd edn (Hilbery ADR, Waterman AE, Brouwer GJ, eds). Cheltenham, UK: BSAVA

Cooper JJ, Appleby MC (1994) The use of aversive barriers to quantify nesting motivation in domestic hens. In: *Modified Cages for Laying Hens* (Sherwin CM, ed). Potters Bar: UFAW, pp 11–26

Coulton LE, Waran NK, Young RJ (1997) Effects of foraging enrichment on the behaviour of Parrots. *Animal Welfare* 6, 357–63

Council of Europe (1986) *European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes, ETS123*. Strasbourg: Council of Europe

Cramp S, Perrins CM, eds (1994) *The Birds of the Western Palearctic*, Vol. VIII. Oxford: Oxford University Press

Crawford RD (1984) Turkey. In: *Evolution of Domesticated Animals* (Mason IL, ed). London: Longman, pp 325–33

Culik BM, Wilson RP (1995) Penguins disturbed by tourists. *Nature* 376, 301–2

Cuthill I (1991) Field experiments in animal behaviour: methods and ethics. *Animal Behaviour* 42, 1007–14

Cuthill I, Witter M, Clarke L (1992) The function of bill-wiping. *Animal Behaviour* 43, 103–15

Cuthill IC, Hunt S, Cleary C, Clark C (1997) Colour bands, dominance, and body mass regulation in male zebra finches (*Taeniopygia guttata*). *Proceedings of the Royal Society of London Series B, Biological Sciences* 264, 1093–9

Cuthill IC, Kacelnik A, Krebs JR, Haccou P, Iwasa Y (1990) Starlings exploiting patches: the effect of recent experience on foraging decisions. *Animal Behaviour* 40, 625–40

Dall SRX, Cuthill IC, Cook N, Morphet M (1997) Learning about food: Starlings, Skinner Boxes and earthworms. *Journal of the Experimental Analysis of Behaviour* 67, 181–92
Danbury TC, Weeks CA, Chambers JP, Waterman-Pearson AE, Kestin SC (2000) Self-selection of the analgesic drug carprofen by lame broiler chickens. *Veterinary Record* 146, 307–11
Davies CS (1991) Parrot psychology and behavior problems. *Veterinary Clinics of North America—Small Animal Practice* 21, 1281–8
Davis DS, Allen HA (1989) An improved waterfowl enclosure: considering animal welfare as a research priority. *Journal of Field Ornithology* 60, 162–7
Davis GS, Siopes TD (1985) The effect of light duration on turkey poult performance and adrenal function. *Poultry Science* 64, 995–1001
Davis GS, Siopes TD, Peiffer RL, Cook C (1986) Morphologic changes induced by photoperiod in eyes of turkey poults. *American Journal of Veterinary Research* 47, 953–5
Dawkins MS, Hardie S (1989) Space needs of laying hens. *British Poultry Science* 30, 418–16
D'Eath RB (1998) Can video images imitate real stimuli in animal behaviour experiments? *Biological Reviews of the Cambridge Philosophical Society* 73, 267–92
del Hoyo J, Elliott A, Sargatal J, Cabot J (1992) *Handbook of the Birds of the World*. Barcelona: Lynx Edicions
Dhondt AA, Adriaensen F (1999) Experiments on competition between Great and Blue Tit: effects on Blue Tit reproductive success and population processes. *Ostrich* 70, 39–48
Doolen MD, Jackson L (1991) Anaesthesia in caged birds. *Iowa State University Veterinarian* 53, 76–80
Dooling RJ (1992) Hearing in birds. In: *The Evolutionary Biology of Hearing*, Chap. 26 (Webster DB, Fay RR, Popper AN, eds). New York: Springer-Verlag
Dorrestein GM (1997) Bacteriology. In: *Avian Medicine and Surgery* (Altman RB, Clubb SL, Dorrestein GM, Quesenberry K, eds). Philadelphia: WB Saunders, pp 255–80
Duncan ET, Appleby MC, Hughes BO (1992) Effect of perches in laying cages on welfare and production of hens. *British Poultry Science* 33, 25–35
Duncan IJH, Beatty ER, Hocking PM, Duff SRI (1991) Assessment of pain associated with degenerative hip disorders in adult male turkeys. *Research in Veterinary Science* 50, 200–3
Duncan IJH, Hughes BO (1972) Free and operant feeding domestic fowls. *Animal Behaviour* 20, 775–7
Duncan IJH, Savory CJ, Wood-Gush DGM (1978) Observations on the reproductive behaviour of domestic fowl in the wild. *Applied Animal Ethology* 4, 29–42
Duncan IJH, Wood-Gush DGM (1972) Thwarting of feeding behaviour in the fowl. *Animal Behaviour* 20, 444–51
Ely CR (1993) Family stability in greater white-fronted geese. *Auk* 110, 425–35
Elzanowski A (1991) Motivation and subjective experience in birds. In: *Acta XX Congressus Internationalis Ornithologici*. New Zealand Ornithological Congress Trust Board, pp 1921–9
Ensley PK (1999) Medical management of the California Condor. In: *Zoo and Wild Animal Medicine: Current Therapy 4* (Fowler ME, Miller RE, eds). Philadelphia: WB Saunders, pp 277–92
Ernst RA, Coleman TH (1966) The influence of floor space on growth, egg production, fertility and hatchability of *Coturnix japonica*. *Poultry Science* 45, 437–40
Esmay ML (1978) *Principles of Animal Environment*. Westport: AVI
European Community (1979) *Council Directive 79/409 on the Conservation of Wild Birds*, OJ L.103. Luxembourg: Official Journal of the European Communities
European Community (1986) *Council Directive 86/609 on the Approximation of Laws, Regulations and Administrative Provisions of the Member States Regarding the Protection of Animals Used for Experimental and Other Scientific Purposes*, OJ L.358. Luxembourg: Official Journal of the European Communities
Farm Animal Welfare Council (1992) *Report on the Welfare of Broiler Chickens*. Tolworth: Ministry of Agriculture, Fisheries and Food
Farm Animal Welfare Council (1993) *Second Report on Priorities for Research and Development in Farm Animal Welfare*. Tolworth: Ministry of Agriculture, Fisheries and Food PB1310, pp 3–4
Farm Animal Welfare Council (1995) *Report on the Welfare of Turkeys*. Tolworth: FAWC
Farm Animal Welfare Council (1997) *Report on the Welfare of Laying Hens*. Tolworth: FAWC
Farm Animal Welfare Council (1998) *Report on the Welfare of Broiler Breeders*. Tolworth: FAWC
Feare C (1984) *The Starling*. Oxford: Oxford University Press
Fedde MR (1986) *Avian Physiology*, 4th edn (Sturkie PD, ed). New York: Springer-Verlag, pp 191–220
Field D (1999) Environmental enrichment of birds. In: *Guidelines for Environmental Enrichment* (Field DA, ed). Chester, UK: The Association of British Wild Animal Keepers
Finney JK (2000) The care and the maintanance of the captive cormorant *Phalacrocorax carbo*. *Animal Technology* 51, 37–46
Fisher J, Hinde RA (1949) The opening of milk bottles by birds. *British Birds* 42, 347–57
Fitzgerald G, Blais D (1993) Inhalation anaesthesia in birds of prey. In: *Raptor Biomedicine* (Redig PT, Cooper JE, Remple JD, Hunter DB, Hahn

T, eds). Keighley, UK: Chiron Publications, pp 128–35
Fitzgerald M (1994) Neurobiology of fetal and neonatal pain. In: *Textbook of Pain*, 3rd edn (Wall PD, Melzack R, eds). London: Churchill Livingstone, pp 153–63
Flammer K (1989) Update on avian anaesthesia. In: *Current Veterinary Therapy X* (Kirk RW, Banoguara JD, eds). Philadelphia: WB Saunders, pp 776–80
Flammer K (1997) Chlamydia. In: *Avian Medicine and Surgery* (Altman RB, Clubb SL, Dorrestein GM, Quesenberry K, eds). Philadelphia: WB Saunders, pp 364–79
Flecknell P (1996) *Laboratory Animal Anaesthesia*, 2nd edn. London: Academic Press
Flecknell P A, Waterman-Pearson A, eds (2000) *Pain Management in Animals*. London: Harcourt Pub
Follett BK (1984) Birds. In: *Marshall's Physiology of Reproduction, Volume 1: Reproductive Cycles of Vertebrates*. London: Churchill Livingstone
Forbes NA (1996) Examination, basic investigation and handling. In: *Manual of Raptors, Pigeons and Waterfowl* (Beynon PH, Forbes NA, Harcourt-Brown NH, eds). Cheltenham: British Small Animal Veterinary Association, pp 17–29
Forbes NA (1996) Waterfowl: neonatal diseases. In: *Manual of Raptors, Pigeons and Waterfowl* (Beynon PH, Forbes NA, Harcourt-Brown NH, eds). Cheltenham: British Small Animal Veterinary Association, pp 330–3
Forbes NA, Glendell G (1989) Wing clipping in psittacine birds. *Veterinary Record* 144, 299
Forbes NA, Richardson T (1996) Waterfowl: husbandry and nutrition. In: *Manual of Raptors, Pigeons and Waterfowl* (Beynon PH, Forbes NA, Harcourt-Brown NH, eds). Cheltenham: British Small Animal Veterinary Association, pp 116–28
Forshaw JM (1989) *Parrots of the World*, 3rd edn. London: Blandford Press
Fowler ME (1995) *Restraint and Handling of Wild and Domestic Animals*, 2nd edn. Iowa: Iowa State University Press
Fowler ME, Miller RE (1999) *Zoo and Wild Animal Medicine: Current therapy 4*. Philadelphia: WB Saunders
Freed D, Baker B (1989) Antagonism of xylazine hydrochloride sedation in raptors by yohimbine hydrochloride. *Journal of Wildlife Disease* 25, 136–8
Freire R, Mendl M, Nicol CJ (1997) Object permanence in domestic hens: visible displacements. *Proceedings of the 31st International Congress of the International Society for Applied Ethology* (Hemsworth PH, Spinka M, Kostal L, eds), Slovakia: Polygrafia SAV, p 146
French H (1996) Breeding the thick-billed parrot *Rhynchopsitta pachyrhyncha* at Jersey Wildlife Preservation Trust. *Dodo–Journal of the Wildlife Preservation Trusts* 32, 126–32
Fritz J, Kotrschal K (1999) Social learning in common ravens, *Corvus corax*. *Animal Behaviour* 57, 785–93
Furness RW, Monaghan P (1987) *Seabird Ecology*. Glasgow: Blackie
Gammonley JH, Kelley JR (1994) Effects of back-mounted radio packages on breeding wood ducks. *Journal of Field Ornithology* 65, 530–3
Garnetzke-Stollmann K, Franck D (1991) Socialisation tactics of the spectacled parrotlet (*Forpus conspicillatus*). *Behaviour* 119, 1–29
Gaunt AS, Oring LW (1999) *Guidelines to the Use of Wild Birds in Research*, 2nd edn. Winfield, Kansas: American Ornithologists, Union www.nmnh.si.edu/BIRDNET/GuideToUse/
Gentle MJ (1971) Taste and its importance to the domestic chicken. *British Poultry Science* 12, 77–86
Gentle MJ (1991) Behavioural and physiological responses to pain in the chicken. In: *Acta XX Congressus Internationalis Ornithologici*. New Zealand Ornithological Congress Trust Board, pp 1915–20
Gentle MJ (1992) Pain in birds. *Animal Welfare* 1, 235–47
Gentle MJ (2001) Attentional shifts alter pain perception in the chicken. *Animal Welfare* 10, S187–94
Gentle MJ, Corr SA (1995) Endogenous analgesia in the chicken. *Neuroscience Letters* 201, 211–14
Gentle MJ, Tilston VL (1999) Reduction in peripheral inflammation by changes in attention. *Physiology and Behaviour* 66, 289–92
Gerken M (1983) *Untersuchungen zur gnetischen Fundierung und Beeinflubarkeit von Verhaltensmerkmalen des Geflügels, durchgeführt in einem Selektionexperiment auf Staubbadedeverhalten bei der japenischen Wachtel (*Coturnix coturnix japonica*)* (unpublished PhD thesis). Rheinsche Freidrich Wilhelms Universität, Bonn. *Op. cit.* Gerken (1993)
Gerken M, Mills AD (1993) Welfare of domestic quail. In: *Proceedings of the 4th European Symposium on Poultry Welfare* (Savory CJ, Hughes BO, eds). Potters Bar: UFAW
Gerlach H (1994) Bacteria. In: *Avian Medicine: Principles and Application* (Ritchie BW, Harrison GJ, Harrison LR, eds). Lake Worth, Florida: Wingers Publishing Inc, pp 949–83
Gessaman JA, Nagy KA (1988) Transmitter loads affect the flight speed and metabolism of homing pigeons. *The Condor* 90, 662–8
Gilhardi JD, Munn CA (1998) Patterns of activity, flocking, and habitat use in parrots of the Peruvian Amazon. *The Condor* 100, 641–53
Gill EL (1994) Environmental enrichment for captive starlings. *Animal Technology* 45, 89–93
Gill EL, Chivers RE, Ellis SC, Field SA, Haddon TE, Oliver DP, Richardson SA, West PJ (1995) Turf as a

means of enriching the environment of captive starlings (*Sturnus vulgaris*). *Animal Technology* 46, 97–102

Glasier P (1978) *Falconry and Hawking*. London: Batsford

Goudie RI, Ankney CD (1986) Body size, activity budgets, and diets of sea ducks wintering in Newfoundland. *Ecology* 67, 1475–82

Greiner EC (1997) Parasitology. In: *Avian Medicine and Surgery* (Altman RB, Clubb SL, Dorrestein GM, Quesenberry K, eds). Philadelphia: WB Saunders, pp 332–49

Gunnarsson S, Matthews LR, Foster TM, Temple W (2000) The demand for straw and feathers as litter substrates by laying hens. *Applied Animal Behaviour Science* 65, 321–30

GV–SOLAS Working Committee for the Biological Characterisation of Laboratory Animals (1985) Guidelines for specification of animals and husbandry methods when reporting the results of animal experiments. *Laboratory Animals* 19, 106–8

Gwinner H, Gwinner E (1994) Effects of testosterone on nest-box occupation and associated behaviours by male European starlings (*Sturnus vulgaris*). *Behaviour* 129, 141–8

Haftorn S (1999) Calls by Willow Tits (*Parus montanus*) during ringing and after release. *Journal fur Ornithologie* 140, 51–6

Hagstrum JT (2000) Infrasound and the avian navigational map. *Journal of Experimental Biology* 203, 1103–11

Harcourt-Brown NH (1978) Avian anaesthesia in general practice. *Journal of Small Animal Practice* 19, 573–82

Harrison C (1975) *A Field Guide to the Nests, Eggs and Nestlings of British and European birds*. Glasgow: William Collins & Sons

Harrison GJ, Harrison L (1986) *Clinical Avian Medicine and Surgery*. Philadelphia: WB Saunders

Hatch KK, Lefebvre L (1997) Does father know best? Social learning from kin and non-kin in juvenile ringdoves. *Behavioural Processes* 41, 1–10

Hawes RO (1984) Pigeons. In: *Evolution of Domesticated Animals* (Mason IL, ed). London: Longman

Hawkins P (1998) Environmental stimulation for waterfowl: the common eider duck. *Animal Technology* 49, 91–9

Hawkins P, Butler P, Woakes A (1995) Hatching and rearing the common guillemot, *Uria aalge*. *Animal Technology* 46, 75–88

Health and Safety Executive (1997) *Working Safely with Research Animals: Management of Infection Risks*. London: HSE Books

Healy SD, Gwinner E, Krebs JR (1996) Hippocampal volume in migrating and non-migrating warblers: effects of age and experience. *Behaviour & Brain Research* 81, 61–8

Healy SD, Krebs JR (1992) Comparing spatial memory in two species of tit—recalling a single positive location. *Animal Learning & Behavior* 20, 121–6

Heard DJ (1997) Anesthesia and analgesia. In: *Avian Medicine and Surgery* (Altman RB, Clubb SL, Dorrestein GM, Quesenberry K, eds). Philadelphia: WB Saunders, pp 807–27

Heffner HE (1998) Auditory awareness. *Applied Animal Behaviour Science* 57, 259–68

Hester PY, Elkin RG, Klingensmith PM (1983) Effects of high intensity step-up and low intensity step-down lighting programs on the incidence of leg abnormalities in turkeys. *Poultry Science* 62, 887–96

Hester PY, Sutton AL, Elkin RG (1987) Effect of light intensity litter source and litter management on the incidence of leg abnormalities and performance of male turkeys. *Poultry Science* 66, 666–75

Hockin D, Ounsted M, Gorman M, Hill D, Keller V, Barker MA (1992) Examination of the effects of disturbance on birds with reference to its importance in ecological assessments. *Journal of Environmental Management* 36, 253–86

Hodgetts B (1999) Quail production. In: *Management and Welfare of Farm Animals: The UFAW Farm Handbook*, 4th edn (Ewbank R, Kim-Madslien F, Hart CB, eds). Wheathampstead: UFAW, pp 269–71

Höfner M, Staack M, Fölsch DW (1997) Comfortable quarters for chickens. In: *Comfortable Quarters for Laboratory Animals*, 8th edn (Reinhardt V, ed). Washington: Animal Welfare Institute

Home Office (1989) *Code of Practice for the Housing and Care of Animals Used in Scientific Procedures*. London: HMSO

Home Office (1993) *Animals (Scientific Procedures) Act 1986 (Amendment) Regulations 1998 No. 2102*. London: HMSO

Home Office (1995) *Code of Practice for the Housing and Care of Animals in Designated Breeding and Supplying Establishments*. London: HMSO

Home Office (1997) *The Humane Killing of Animals Under Schedule 1 to the Animals (Scientific Procedures) Act 1986*. London: HMSO

Home Office (1998) *Animals (Scientific Procedures) Act 1986 (Amendment) Regulations 1998*. London: HMSO

Home Office (2001) *Statistics of Scientific Procedures on Living Animals: Great Britain 2000*. London: HMSO

Huber L (1994) Amelioration of laboratory conditions for pigeons (*Columba livia*). *Animal Welfare* 3, 321–4

Huber L, Volkl B, Rechberger S (1998) Understanding the emergence of novel forms in imitative learning. *Proceedings Napoli Social Learning Conference*. Italy: Istituto Italiano Studi Filosofici, p 31

Humane Slaughter Association (1999) *Code of Practice for the Disposal of Chicks in Hatcheries*. Wheathampstead: Humane Slaughter Association

Humphreys PN (1996) Waterfowl: wing and leg problems. In: *Manual of Raptors, Pigeons and Waterfowl* (Beynon PH, Forbes NA, Harcourt-Brown NH, eds). Cheltenham: British Small Animal Veterinary Association, pp 311–14

Hutchison RE (1999) Doves and pigeons. In: *The UFAW Handbook on the Care and Management of Laboratory Animals Volume 1: Terrestrial Vertebrates,* 7th edn (Poole T, ed). London: Blackwell Science, pp 714–21

Hutchison RE, Opromolla G, Hutchison JB (1996) Environmental stimuli influence oestrogen-dependent courtship transitions and brain aromatase activity in male ring doves. *Behaviour* 133, 199–219

International Air Travel Association (1999) *Live Animals Regulations,* 26th edn. Montreal: IATA

Inglis IR, Forkman B, Lazarus J (1997) Why do animals work for food in the presence of free food? A review, fuzzy model and functional explanation of contra-freeloading. *Animal Behaviour* 53, 1171–91

Inglis IR, Hudson A (1999) European wild birds. In: *UFAW Handbook on the Care and Management of Laboratory Animals Volume 1: Terrestrial Vertebrates,* 7th edn (Poole T, ed). London: Blackwell Science, pp 670–6

IUCN Veterinary Specialist Group (1999) *Quarantine and Disease Screening Protocols for Wildlife Prior to Translocations and Release into the Wild*. Switzerland: IUCN

Jaksch W (1981) Euthanasia of day-old male chicks in the poultry industry. *International Journal for the Study of Animal Problems* 2, 203–13

Jalanka HH (1989) Chemical restraint and reversal in captive markhors (*Capra falconeri megaceros*): a comparison of two methods. *Journal of Zoo and Wildlife Medicine* 20, 413–17

James AE, Hutchings G, Bush M, Natarajan TK, Burns B (1976) How birds breathe: correlation of radiographic with anatomical and pathological studies. *Journal of American Radiological Society* 17, 77–81

Jilbert A (1999) Ducks as a model for studies of human hepatitis. *ANZCCART News* 12, 4–6

Johnson DB, Guthery FS (1988) Loafing coverts used by northern bobwhites in subtropical environments. *Journal of Wildlife Management* 52, 464–9

Johnston ANB, Burne THJ, Rose SPR (1998) Observation learning in day-old chicks using a one-trial passive avoidance learning paradigm. *Animal Behaviour* 56, 1347–53

Jones RB (1994) Regular handling and the domestic chick's fear of human beings—generalisation of response. *Applied Animal Behaviour Science* 42, 129–43

Jones RB, Carmichael NL (1998) Pecking at string by individually caged, adult laying hens: colour preferences and their stability. *Applied Animal Behaviour Science* 60, 11–23

Jones RB, Hagedorn TK, Satterlee DG (1998) Adoption of immobility by shackled broiler chickens: effects of light intensity and diverse hooding devices. *Applied Animal Behaviour Science* 55, 327–35

Jones RB, Mills AD (1999) Divergent selection for social reinstatement behaviour in Japanese quail: effects on sociality and social discrimination. *Poultry and Avian Biology Reviews* 10, 213–23

Jones RB, Mills AD, Faure J-M (1991) Genetic and experimental manipulation of fear-related behavior in Japanese quail chicks (*Coturnix coturnix japonica*). *Journal of Comparative Psychology* 105, 15–24

Jones RB, Roper TJ (1997) Olfaction in the domestic fowl: a critical review. *Physiology and Behaviour* 62, 1009–18

Jones AE, Slater PJB (1999) The zebra finch. In: *The UFAW Handbook on the Care and Management of Laboratory Animals Volume 1: Terrestrial Vertebrates*, 7th edn (Poole T, ed). London: Blackwell Science, pp 722–30

Jordan FTW, Pattison M, eds (1996) *Poultry Diseases*, 4th edn. London: Baillière Tindall

Kahlert H, Fox AD, Ettrup H (1996) Nocturnal feeding in moulting greylag geese *Anser anser*—an anti-predator response? *Ardea* 84, 15–22

Kamphues J, Meyer H (1992) Basic data for factorial derivation of energy and nutrient requirements of growing canaries. *Journal of Nutrition* 121, S207–8

Kear J (1964) Colour preference in young Anatidae. *Ibis* 106, 361–9

Kear J (1970) Studies on the development of young tufted ducks. *Wildfowl* 21, 123–32

Kear J (1973) Notes on the nutrition of young waterfowl, with special reference to slipped-wing. *International Zoo Yearbook* 13, 97–100

Kear J (1976) The presentation of food to captive waterfowl in relation to their natural behaviour. *International Zoo Yearbook* 16, 25–32

Keeling LJ, Duncan IJH (1989) Interindividual distances and orientation in laying hens housed in groups of three in two differently sized enclosures. *Applied Animal Behaviour Science* 24, 325–42

Keiper RR (1969) Causal factors of stereotypies in caged birds. *Animal Behaviour* 17, 114–19

Keymer IF (1991) Pigeons. In: *Manual of Exotic Pets* (Beynon PH, Cooper JE, eds). Cheltenham: British Small Animal Veterinary Association, pp 180–202

King CE (1993) Environmental enrichment: is it for the birds? *Zoo Biology* 12, 509–12

Kirkwood JK (1996) Nutrition of captive and free-living wild animals. In: *Manual of Companion Animal Feeding and Nutrition* (Kelly J, Wills J, eds). Cheltenham: British Small Animal Veterinary Association, pp 235–43

Kirkwood JK (1999) Design of accommodation for wild animals: how do we know when we have got it right? In: *Fifth International Zoo Design Conference, Paignton Zoological and Botanical Gardens, 18–22 May 1998* (Plowman A, Stevens P, eds). Whitley Wildlife Protection Trust, Paignton, Devon, pp 51–61

Kirkwood JK (1999) Metabolic bone disease and twisting and bending deformities of the long bones in growing birds. In: *Avian Medicine* (Samour JH, ed). London: Mosby/Harcourt Publishers, pp 170–6

Kirkwood JK, Duignan P, Kember NF, Bennett PM, Price D (1989) The growth of the tarsometatarsus bone in birds. *Journal of Zoology, London* 217, 403–16

Kirkwood JK, Sainsbury AW (1996) Ethics of interventions for the welfare of free-living animals. *Animal Welfare* 5, 235–43

Kirkwood JK, Sainsbury AW (1997) Diseases and other considerations with wildlife translocations and releases. *Proceedings of the World Association of Wildlife Veterinarians Symposium on Veterinary Involvement with Wildlife Reintroduction and Rehabilitation*, September 1995, Yokohama, Japan, pp 12–16

Kjaer JB, Sorensen P (1997) Feather pecking behaviour in White Leghorns, a genetic study. *British Poultry Science* 38, 333–41

Klasing KC (1998) *Comparative Avian Nutrition*. Oxford, UK: CAB International

Knowles TG, Broom DM (1990) Limb bone strength and movement in laying hens from different housing systems. *Veterinary Record* 126, 354–6

Korbel R, Milovanovic A, Erhardt W, Burike J, Henke J (1993) Aerosaccular perfusion with isoflurane—an anesthetic procedure for head surgery in birds. In: *Proceedings of the European Conference of the Association of Avian Veterinarians*. Lake Worth: Association of Avian Veterinarians, pp 9–42

Kreeger TJ, Degernes LA, Kreeger JS, Redig PT (1993) Immobilization of raptors with tiletamine and zolazepam (Telazol). In: *Raptor Biomedicine* (Redig PT, Cooper JE, Remple JD, Hunter DB, Hahn T, eds). Keighley, UK: Chiron Publications, pp 141–4

Kreithen ML, Quine DB (1979) Infrasound detection by the homing pigeon: a behavioral audiogram. *Journal of Comparative Physiology* 129, 1–4

Kuehler C, Good J (1990) Artificial incubation of bird eggs at the Zoological Society of San Diego. *International Zoo Yearbook* 29, 118–36

Kummerfeld N (1998) Probleme bei der Kennzeichung von Vogeln und erst Erfahungen mit intraossar implantieren Transpondern. *Kleintierpraxis* 43, 411–92

Laboratory Animal Breeders Association/Laboratory Animal Science Association (1993) Guidelines for the care of laboratory animals in transit. *Laboratory Animals* 27, 93–107

Lack D (1968) *Ecological Adaptations for Breeding in Birds*. London: Methuen & Co

Lambe NR, Scott GB (1998) Perching behaviour and preferences for different perch designs among laying hens. *Animal Welfare* 7, 203–16

Lantermann W (1994) Social disturbances of a hand-reared noble parrot (*Eclectus-roratus*). *Kleintierpraxis* 39, 503–4

Laule G (1999) Training laboratory animals. In: *The UFAW Handbook on the Care and Management of Laboratory Animals Volume 1: Terrestrial Vertebrates*, 7th edn (Poole T, ed). Wheathampstead: UFAW, pp 21–7

Lawton M (1992) Behavioural problems. In: *Manual of Parrots, Budgerigars and other Psittacine Birds* (Price CJ, ed). Cheltenham, UK: British Small Animal Veterinary Association, pp 163–70

Lawton MPC (1993) Monitoring the anaesthetised bird. In: *Proceedings of the European Conference of the Association of Avian Veterinarians*. Lake Worth: Association of Avian Veterinarians, pp 1–8

Lawton MPC (1996a) Anaesthesia. In: *Manual of Psittacine Birds* (Beynon PH, Forbes NA, Mawton MPC, eds). Cheltenham, UK: BSAVA, pp 49–59

Lawton MPC (1996b) Anaesthesia. In: *Manual of Raptors, Pigeons and Waterfowl* (Beynon PH, Forbes NA, Harcourt-Brown NH, eds). Cheltenham, UK: British Small Animal Veterinary Association, pp 79–88

Lawton MPC (1997) Anaesthesia. In: *Proceedings of the European Association of Avian Veterinarians Conference, Core Session, London*. Lake Worth: Association of Avian Veterinarians, pp 10–24

Leach MC, Bowell VA, Allen TF, Morton DB (2001) The aversion to various concentrations of different inhalational general anaesthetics in rats and mice. *Veterinary Record* (in press)

Lewis PD, Perry GC, Sherwin CM (1998) Effect of photoperiod and light intensity on the performance of intact male turkeys. *Animal Science* 66, 759–67

Lickliter R, Dyer AB, McBride T (1993) Perceptual consequences of early social experience in precocial birds. *Behavioural Processes* 30, 185–200

Lierz M, Launay F (2000) Veterinary procedures for falcons re-entering the wild. *Veterinary Record* 147, 518–20

Lightbody JP, Ankney CD (1984) Seasonal influences on the strategies of growth and development of canvasback and lesser scaup ducklings. *Auk* 101, 121–33

Lint KC, Lint AM (1981) *Diets for Birds in Captivity*. Poole: Blandford Press

Lovvorn JR, Jones DR (1994) Biomechanical conflicts between adaptations for diving and aerial flight in estuarine birds. *Estuaries* 17, 62–75

Low R (1987) *Hand-Rearing Parrots and Other Birds*. Poole: Blandford Press

Low R (1992) *Parrots in Aviculture*. Poole: Blandford Press

Lubjuhn T, Brun J, Winkel W, Muth S (1998) Effects of blood sampling in Great Tits. *Journal of Field Ornithology* 69, 595–602
Mandelker L (1972) Ketamine hydrochloride as an anesthetic for parakeets. *Veterinary Medicine/Small Animal Clinician* 67, 55–6
Mandelker L (1987) Anesthesia and surgery. In: *Companion Bird Medicine* (Burr EW, ed). Ames: Iowa State University Press, pp 148–53
Manning A, Stamp Dawkins M (1998) *An Introduction to Animal Behaviour*, 5th edn. Cambridge: Cambridge University Press
Manser CE (1992) *The Assessment of Stress in Laboratory Animals*. Horsham: RSPCA
Manser CE (1996) Effects of lighting on the welfare of domestic poultry: a review. *Animal Welfare* 5, 341–60
Marler P (1996) Social cognition: are primates smarter than birds? In: *Current Ornithology*, Vol. 13 (Nolan V, Ketterson ED, eds). New York: Plenum Press
Martin GR (1986) The eye of a passeriform bird, the European starling (*Sturnus vulgaris*): eye movement amplitude, visual fields and schematic optics. *Journal of Comparative Physiology* A159, 545–57
Martin P, Bateson P (1993) *Measuring Behaviour: An Introductory Guide*, 2nd edn. Cambridge: Cambridge University Press
Martin RM, Nute JM, Nute G (1984) *First Aid and Care of Wildlife*. Newton Abbot: David and Charles
Martin S (1983) *Parrot Care and Training*. Escondido, California: Parrot Video
Matthews GVT (1973) Some problems facing captive breeding and restoration problems for waterfowl. *International Zoo Yearbook* 13, 8–10
McBride G, Parer IP, Foenander F (1969) The social organisation and behaviour of feral domestic fowl. *Animal Behaviour Monographs* 2, 127–81
McBride G, Parer IP, Foenander F (1969) The social organisation and behaviour of feral domestic fowl. *Animal Behaviour Monographs* 2, 127–81
McFarland D (1993) *Animal Behaviour*. Harlow: Longman Scientific and Technical
McFerran JB, McNulty MS (1993) Virus infections of birds. In: *Virus Infections of Vertebrates, 4*. Amsterdam: Elsevier Publishing
McKeever K (1979) *Care and Rehabilitation of Injured Owls*. Lincoln, Ontario: WF Rannie
Meaden F (1979) *A Manual of European Bird Keeping*. Poole: Blandford Press
Meijer T, Rozman J, Schulte M, Stach-Dreesmann C (1996) New findings in body mass regulation in zebra finches (*Taeniopygia guttata*) in response to photoperiod and temperature. *Journal of Zoology* 240, 717–34
Mendoza A (1996) A 'Flintstone wheel' for enrichment. *Shape of Enrichment* 5, 9–10
Mettke C (1995) Exploratory behaviour in parrots—environmental adaptation. *Journal fur Ornithologie* 136, 468–71
Millam JR (1999) Husbandry and care of research parrot colonies. *Poultry and Avian Biology Reviews* 10, 85–9
Millam JR, Kenton B (1995) Breeding orange-winged Amazon parrots in captivity. *Zoo Biology* 14, 275–84
Miller EH (1988) Description of bird behaviour for comparative purposes. In: *Current Ornithology*, Vol. 6. New York: Plenum Press, pp 67–121
Mills AD, Faure JM, Rault P (1999) The Japanese quail. In: *The UFAW Handbook on the Care and Management of Laboratory Animals Volume 1: Terrestrial Vertebrates*, 7th edn. London: Blackwell Science, pp 697–713
Mitchell MA, Sandercock DA, Hunter RR, Carlisle AJ (1999) Skeletal muscle damage following halothane anaesthesia in the domestic fowl: plasma biochemical responses. *Research in Veterinary Science* 67, 59–64
Moberg G (1985) *Animal Stress*. Bethesda, Maryland: American Physiological Society
Monachon G (1973) Sterilising goose shells with ultraviolet light. *International Zoo Yearbook* 13, 95–7
Morton DB (1990) Adverse effects in animals and their relevance to refining scientific procedures. *ATLA (Alternatives to Laboratory Animals)* 18, 29–39
Morton DB (1992) A fair press for animals. *New Scientist* 1816, 28–30
Morton DB (1997) A scheme for the recognition and assessment of adverse effects. In: *Animal Alternatives, Welfare and Ethics* (van Zutphen LMF, Balls M, eds). Amsterdam: Elsevier Science BV, pp 235–41
Morton DB (1998a) The use of score sheets in the implementation of humane endpoints. *Proceedings of the Joint ANZCCART/NAEAC Conference on Ethical Approaches to Animal-Based Science*, Auckland, New Zealand, 1997
Morton DB (1998b) Implementing assessment techniques for pain management and humane endpoints. *Proceedings of Conference on Pain Management and Humane Endpoints*, NAS, Washington USA, 1998
Morton DB, Abbot D, Barclay R, Close BS, Ewbank R, Gask D, Heath M, Mattic S, Poole T, Seamer J, Southee J, Thompson A, Trussell B, West C, Jennings M (1993) Removal of blood from laboratory animals and birds. *Laboratory Animals* 27, 1–22
Morton DB, Griffiths PHM (1985) Guidelines on the recognition of pain, distress and discomfort in experimental animals and an hypothesis for assessment. *Veterinary Record* 116, 431–6
Morton DB, Jennings M, Buckwell A, Ewbank R, Godfrey C, Holgate B, Inglis I, James R, Page C, Sharman I, Verschoyle R, Westall L, Wilson AB

(2001) Refining procedures for the administration of substances. *Laboratory Animals* 35, 1–41
National Health and Medical Research Council (1997) *Australian Code of Practice for the Care and Use of Animals for Scientific Purposes*, 6th edn. Canberra: Australian Government Publishing Service
National Research Council (1996) *Guide for the Care and Use of Laboratory Animals*. Oxford: National Academy Press
National Research Council (1997) *Occupational Health and Safety in the Care and Use of Research Animals*. Washington DC: National Academy of Sciences
Neistadt N, Alia C (1994) Seabird enrichment at the Oregon Coast Aquarium. *Shape of Enrichment* 3, 1–2
Neiworth JJ, Rilling ME (1987) A method for studying imagery in animals. *Journal of Experimental Psychology* 13, 203–14
Nepote K (1999a) Pigeon housing: practical considerations and welfare implications. *Lab Animal* 28, 34–7
Nepote K (1999b) Pigeons as laboratory animals. *Poultry and Avian Biology Reviews* 10, 109–15
Nestor KE, Bacon WL, Saif YM, Renner PA (1985) The influence of genetic increases in shank width on body weight, walking ability and reproduction of turkeys. *Poultry Science* 64, 2248–55
Nettleship DN, Birkhead TR (1985) *The Atlantic Alcidae: The Evolution, Distribution and Biology of the Alcids Inhabiting the Atlantic Ocean and Adjacent Water Areas*. London: Academic Press
New South Wales Agriculture (1998) *Animal Research Review Panel Annual Report, 1996–1997*. New South Wales: New South Wales Agriculture
New Zealand Government (1999) *Animal Welfare Act 1999, 142*. Auckland: New Zealand Government
New Zealand National Animal Ethics Advisory Committee (1998) *1997 Annual Report*. Wellington, New Zealand: New Zealand Ministry of Agriculture & Forestry
Newberry RC (1991) Increasing photo-period and toe clipping alter time budgets of heavy tom turkeys. In: *Applied Animal Behaviour: Past Present and Future* (Appleby MC, Horrell RI, Petherick JC, Rutter SM, eds). Potters Bar: UFAW, pp 91–2
Nicholls TJ, Goldsmith AR, Dawson A (1988) Photorefractoriness in birds and comparison with mammals. *Physiological Reviews* 68, 133–76
Nicol CJ (1995) Environmental enrichment for birds. In: *Environmental Enrichment Information Resources for Laboratory Animals 1965–1995*. Maryland: AWIC, pp 1–3
Nicol CJ, Pope SJ (1993) A comparison of the behaviour of solitary and group-housed budgerigars. *Animal Welfare* 2, 269–77
Nicol CJ, Pope SJ (1996) The maternal feeding display of domestic hens is sensitive to perceived chick error. *Animal Behaviour* 52, 767–74
Nicol CJ, Pope SJ (1999) The effects of demonstrator social status and prior foraging success on social learning in laying hens. *Animal Behaviour* 57, 163–71
Nind F (1999) *Identification microchip implantation sites*. www.angelfire.com/id/animal/WG3N233.html
Noble DO, Anderson JW, Nestor KE (1996b) Range and confinement rearing of four genetic lines of turkeys. 2. Effects on behaviour and tonic immobility. *Poultry Science* 75, 165–71
Noble DO, Nestor KE, Polley CR (1996a) Range and confinement effects of four genetic lines of turkeys. 1. Effects on growth mortality and walking ability. *Poultry Science* 75, 160–4
Nyström KGK, Pehrsson O (1988) Salinity as a constraint affecting food and habitat choice of mussel-feeding diving ducks. *Ibis* 130, 94–110
O'Connor RJ (1984) *The Growth and Development of Birds*. Chichester: John Wiley & Sons
Oppenheim RW (1972) Prehatching and hatching behaviour in birds: a comparative study of altricial and precocial species. *Animal Behaviour* 20, 644–55
Ottinger MA, Rattner BA (1999) Husbandry and care of quail. *Poultry and Avian Biology Reviews* 10, 117–20
Owen M (1976) The management of grass swards for captive waterfowl. *International Zoo Yearbook* 16, 135–8
Owen M, Black J (1990) *Waterfowl Ecology*. New York: Chapman & Hall
Papi F (1991) Olfactory navigation. In: *Orientation in Birds* (Berthold P, ed). Basel: Birkhauser, pp 52–85
Parry-Jones J (1997) *Guidelines for Using Birds of Prey in Flying Demonstrations*. London: Federation of Zoological Gardens of Great Britain and Ireland, Zoological Gardens, Regent's Park
Parry-Jones J (2000) *Management Guidelines for the Welfare of Falconiformes*. London: Federation of Zoological Gardens of Great Britain and Ireland, Zoological Gardens, Regent's Park
Patel SN, Clayton NS, Krebs JR (1997) Hippocampal tissue transplants reverse lesion-induced spatial memory deficits in Zebra Finches (*Taeniopygia guttata*). *Journal of Neuroscience* 17, 3861–9
Paul-Murphy J, Ludders JW (2001) Avian analgesia. *Veterinary Clinics of North America* 4, 35–46
Paulus SL (1988) Time-activity budgets of nonbreeding Anatidae: a review. In: *Waterfowl in Winter* (Weller MW, ed). Minneapolis: University of Minnesota Press
Pennycott TW (1994) Pigeon diseases—results from a Scottish diagnostic laboratory. *Proceedings of the Annual Conference of the Association of Avian Veterinarians*. Reno, Nevada: Association of Avian Veterinarians, pp 231–9

Pepperberg IM (1990) Referential mapping: a technique for attaching functional significance to the innovative utterances of an African Grey parrot *(Psittacus erithacus)*. *Applied Psycholinguistics* 11, 23–44

Pepperberg IM (1994) Evidence for numerical competence in an African Grey parrot. *Journal of Comparative Psychology* 108, 36–44

Pepperberg IM, Funk MS (1990) Object permanence in four species of psittacine birds. *Animal Learning and Behaviour* 18, 97–108

Pepperberg IM (1981) Functional vocalizations by an African Grey parrot *(Psittacus erithacus)*. *Zeitschrift für Tierpsychologie* 55, 139–60

Perrins CM (1979) *British Tits*. London: Collins

Perry MC (1981) Abnormal behaviour of canvasbacks equipped with radio transmitters. *Journal of Wildlife Management* 45, 786–9

Pilgrim M, Perry B (1995) *Husbandry Guidelines for Amazon parrots*. Federation of Zoological Gardens of Great Britain and Ireland: The Amazona Society UK

Pinxten R, Eens M, Verheyen RF (1989) Polygyny in the European starling. *Behaviour* 111, 234–56

Pinxten R, Eens M, Verheyen RF (1993b) Male and female nest attendance during incubation in the facultatively polygynous European starling. *Ardea* 81, 125–33

Pinxten R, Hanotte O, Eens M, Verheyen RF, Dhondt AA, Burke T (1993a) Extra-pair paternity and intraspecific brood parasitism in the European starling, *Sturnus vulgaris*: evidence from DNA fingerprinting. *Animal Behaviour* 45, 795–809

Poole T, ed (1999) *The UFAW Handbook on the Care and Management of Laboratory Animals Volume 1: Terrestrial Vertebrates,* 7th edn. Potters Bar: UFAW

Poole T, Stamp Dawkins MS (1999) Environmental enrichment for vertebrates. In: *The UFAW Handbook on the Care and Management of Laboratory Animals Volume 1: Terrestrial Vertebrates,* 7th edn (Poole T, ed). Potters Bar: UFAW, pp 13–20

Preiss HJ, Franck D (1974) Verhaltensentwicklung isoliert handaufgezogener Rosenkopfchen (*Agapornis roseicollis*). *Zeitschrift für Tierpsychologie* 34, 459–63

Price CJ, ed (1992) *Manual of Parrots, Budgerigars and Other Psittacine Birds*. Cheltenham: British Small Animal Veterinary Association

Raethel H-S (1988) *Hühnervögel der Welt*. Melsungen: J Neumann-Neudamm, pp 450–3

Raj M (1996) Aversive reaction of turkeys to argon, carbon dioxide and a mix of carbon dioxide and argon. *Veterinary Record* 138, 592–3

Reavill D (1996) Bacterial diseases. In: *Diseases of Cage and Aviary Birds,* 3rd edn (Rosskopf WJ, Woerpel RW, eds). Baltimore: Williams & Williams, pp 596–612

Reboreda JC, Kacelnik A (1993) The role of autoshaping in cooperative two-player games between starlings. *Journal of the Experimental Analysis of Behavior* 60, 67–83

Redfern C, Clark JA (2001) *Ringer's Manual,* 4th edn. Thetford: British Trust for Ornithology

Redig PE, Cooper JE, Remple JD, Hunter DB, eds (1993) *Raptor Biomedicine*. Minneapolis: University of Minnesota Press

Redig PT (1993) Avian aspergillosis. In: *Zoo and Wild Animal Medicine, Current Therapy 3* (Fowler ME, ed). Philadelphia: WB Saunders, pp 178–88

Redig PT (1996) Nursing avian patients. In: *Manual of Raptors, Pigeons and Waterfowl* (Beynon PH, Forbes NA, Harcourt-Brown NH, eds). Cheltenham: British Small Animal Veterinary Association, pp 42–6

Rich V, Carr C (1999) Husbandry and captive rearing of barn owls. *Poultry and Avian Biology Reviews* 10, 91–5

Ristau CA (1991) Aspects of the cognitive ethology of an injury-feigning bird, the piping plover. In: *Cognitive Ethology,* Chap. 5 (Ristau CA, ed). Mahwah, New Jersey: Lawrence Erlbaum Associates, pp 91–126

Ritchie BW (1995) *Avian Viruses: Function and Control*. Lake Worth, Florida: Wingers Publishing Inc

Ritchie BW, Harrison GJ, Harrison LR (1994) *Avian Medicine: Principles and Application*. Lake Worth, Florida: Wingers Publishing Inc

Robbins GES (1992) *Quail: Their Breeding and Management*. Reading, UK: World Pheasant Association International

Robinson I (1996) Waterfowl: feathers and skin. In: *Manual of Raptors, Pigeons and Waterfowl* (Beynon PH, Forbes NA, Harcourt-Brown NH, eds). Cheltenham: British Small Animal Veterinary Association, pp 305–10

Robinson I (2000) Seabirds. In: *Avian Medicine* (Tully T, Dorrestein GM, Lawton M, eds). Oxford: Butterworth-Heinemann, pp 339–63

Rogers LJ (1992) *The Development of Brain and Behaviour in the Chicken*. Wallingford: CAB International

Rosskopf WJ, Wierpel RW, Reed S, Snider K, Dispirito T (1992) Part 1: Anaesthetic agents: anaesthesia administration for pet birds. *Veterinary Practice Staff* 4, 34–7

Rotella JJ, Howerter DW, Sankowski TP, Devries JH (1993) Nesting effort by wild mallards with 3 types of radio transmitters. *Journal of Wildlife Management* 57, 690–5

Rowley I, Chapman G (1985) Cross-fostering, imprinting and learning in two sympatric species of cockatoo. *Behaviour* 126, 291–308

Royal Society for the Protection of Birds (1998) *Wild Birds and the Law: A Plain Guide to Bird Protection Today*. Bedfordshire: RSPB

Royal Society for the Prevention of Cruelty to Animals (1999) *Welfare Standards for Ducks*. Horsham: RSPCA

Rupiper DJ (1998a) Diseases that affect race performance of homing pigeons. Part I: Husbandry, diagnostic strategies, and viral diseases. *Journal of Avian Medicine and Surgery* 12, 70–7

Rupiper DJ (1998b) Diseases that affect race performance of homing pigeons. Part II: Bacterial, fungal, and parasitic diseases. *Journal of Avian Medicine and Surgery* 12, 138–48

Rupiper DJ, Ehrenberg M (1997) Practical pigeon medicine. *Proceedings of the Annual Conference of the Association of Avian Veterinarians*, Boca Raton, Florida: Association of Avian Veterinarians, pp 479–97

Sainsbury D (1992) *Poultry Health and Management*. London: Blackwell Scientific Publications

Samour J, ed (1999) *Avian Medicine*. London: Harcourt Brace & Co

Sandell MI, Smith HG, Bruun M (1996) Paternal care in the European starling, *Sturnus vulgaris*: nestling provisioning. *Behavioural Ecology and Sociobiology* 39, 301–9

Sandos A (1998) Enrichment for bird brains. *Shape of Enrichment* 7, 3–4

Saunders DK, Fedde MR (1994) Exercise performance of birds. *Advances in Veterinary Medicine and Comparative Medicine* 38B, 139–90

Savory CJ (1979) Feeding behaviour. In: *Food Intake Regulation in Poultry* (Boorman KN, Freeman BM, eds). Edinburgh: British Poultry Science Ltd, pp 277–323

Schmid I, Wechsler B (1997) Behaviour of Japanese quail kept in semi-natural aviary conditions. *Applied Animal Behaviour Science* 55, 103–12

Schmid I, Wechsler B (1998) Identification of key nest site stimuli for Japanese quail (*Coturnix japonica*). *Applied Animal Behaviour Science* 57, 145–56

Schmorrow DD, Ulrich RE (1991) Improving the housing and care of laboratory pigeons and rats. *Humane Innovations and Alternatives* 5, 299–304

Schorger AW (1966) *The Wild Turkey*. Norman: University of Oklahoma Press

Scott ML (1986) *Nutrition of Humans and Selected Animal Species*. New York: John Wiley & Sons

Scullion FT (1991) Wild birds. In: *Manual of Exotic Pets* (Beynon PH, Cooper JE, eds). Cheltenham: British Small Animal Veterinary Association, pp 203–11

Seastedt TR, Maclean SF Jr (1977) Calcium supplements in the diet of nestling Lapland longspurs (*Calcarius lapponicus*) near Barrow, Alaska. *Ibis* 119, 531–3

Sedinger JS (1986) Growth and development of Canada goose goslings. *Condor* 88, 169–80

Sedinger JS (1992) Ecology of prefledging waterfowl. In: *Ecology and Management of Breeding Waterfowl* (Batt BDJ, Afton AJ, Anderson MG, Ankney CD, Johnson DH, Kadlec JA, Krapu GL, eds). Minneapolis: University of Minnesota Press

Sherry DF (1977) Parental food-calling and the role of the young in the Burmese red junglefowl (*Gallus gallus spadiceus*). *Animal Behaviour* 25, 594–601

Sherry DF, Galef BG (1990) Social learning without imitation: more about milk bottle opening by birds. *Animal Behaviour* 40, 987–9

Sherwin CM, ed (1994) *Modified Cages for Laying Hens*. Potters Bar: UFAW

Sherwin CM (1998) Light intensity preferences of male domestic turkeys. *Applied Animal Behaviour Science* 58, 121–30

Sherwin CM, Nicol CJ (1993) Factors influencing floor-laying by hens in modified cages. *Applied Animal Behaviour Science* 36, 211–22

Sherwin CM, Kelland A (1998) Time-budgets, comfort behaviours and injurious pecking of turkeys housed in pairs. *British Poultry Science* 39, 325–32

Sherwin CM, Lewis PD, Perry GC (1999a) The effects of environmental enrichment and intermittent lighting on the behaviour and welfare of male domestic turkeys. *Applied Animal Behaviour Science* 62, 319–33

Sherwin CM, Lewis PD, Perry GC (1999b) Effects of environmental enrichment, fluorescent and intermittent lighting on injurious pecking amongst male turkey poults. *British Poultry Science* 40, 592–8

Sherwin CM, Lewis PD, Perry GC (2001) Injurious pecking amongst domestic turkeys. The effects of ultraviolet radiation, pecking substrates and visual barriers. *British Poultry Science* (in press)

Sibley CG, Monroe BL (1990) *Distribution and Taxonomy of Birds of the World*. New Haven: Yale University Press

Simon E (1982) The osmoregulatory system of birds with salt glands. *Comparative Biochemistry & Physiology* 71A, 547–56

Sinn LC (1994) Anesthesiology. In: *Avian Medicine: Principles and Applications* (Ritchie BW, Harrison GJ, Harrison LR, eds). Lake Worth: Wingers, pp 1066–80

Siopes TD, Timmons MB, Baughman GR, Parkhurst CR (1984) The effects of light intensity on turkey poult performance eye morphology and adrenal weight. *Poultry Science* 63, 904–9

Skutch AF (1996) *The Minds of Birds*. Texas: Texas A&M University Press

Smith GA (1971) The use of the foot in feeding, with especial reference to parrots. *Aviculture Magazine* 77, 93–100

Smith HG (1995) Experimental demonstration of a trade-off between mate attraction and paternal care. *Proceedings of the Royal Society of London Series B—Biological Sciences* 260, 45–51

Smith JA, Birke L, Sadler D (1997) Reporting animal use in scientific papers. *Laboratory Animals* 31, 312–17

Snow D, Perrins C, eds (1998) *The Birds of the Western Palaerctic. Volume 1: Non-passerines*. Oxford: Oxford University Press

Stattelman AJ, Talbot RT, Coulter DB (1975) Olfactory thresholds of pigeons (*Columba livia*), quail (*Colinus virginianus*) and chickens (*Gallus gallus*). *Comparative Biochemistry & Physiology* 50A, 807–9

Stattersfield AJ, Crosby MJ, Long AJ, Wege DC (1998) *Endemic Bird Areas of the World—Priorities for Biodiversity Conservation*, Birdlife Conservation Series No. 7. Cambridge: Birdlife International

Stephenson R (1994) Diving energetics in lesser scaup (*Aythya affinis*, Eyton). *Journal of Experimental Biology* 190, 155–78

Stokes AW (1971) Parental and courtship feeding in red jungle fowl. *Auk* 88, 21–9

Stoodley AAJ, Hadgkiss IM, Rance L (1992) Feeding, housing and breeding. In: *Manual of Parrots, Budgerigars and Other Psittacine Birds* (Price CJ, ed). Cheltenham: British Small Animal Veterinary Association, pp 189–202

Stoskopf MK (1993) Penguin and alcid medicine. In: *Zoo and Wild Animal Medicine, Current Therapy 3* (Fowler ME, ed). Philadelphia: WB Saunders, pp 189–94

Street M (1989) *Ponds and Lakes for Wildfowl*. Hampshire: Game Conservancy

Swaddle JP, Cuthill IC (1994) Preference for symmetrical males by female zebra finches. *Nature* 367, 165–6

Swayne DE (1999) Disease diagnosis and control in the laboratory. *Poultry and Avian Biology Reviews* 10, 65–77

Sweeney R (1997) *A Review of Modern Avicultural Techniques in the Captive Management and Breeding of Psittacines*. Association of Avian Veterinarians 4th European Conference, Aviculture Day. London: Vetark Professional

Swennen C (1989) Gull predation upon eider *Somateria mollissima* ducklings: destruction or elimination of the unfit? *Ardea* 77, 21–45

Swennen C (1997) *Laboratory Research on Sea-birds*. Texel: Netherlands Institute for Sea Research

Swennen C, Duiven P (1991) Diving speed and food-size selection in common guillemots, *Uria aalge*. *Netherlands Journal of Sea Research* 27, 191–6

Taka-Tsusaka N (1967) *The Birds of Nippon*. Tokyo: Maruzen

ten Cate C (1995) Behavioural development in birds and the implications of imprinting and song learning for captive propagation. In: *Research and Captive Propagation* (Ganslosser U, Hodges JK, Kaumanns W, eds). Fürth: Filander-Verlag

Tolman CW (1964) Social facilitation of feeding behaviour in the domestic chick. *Animal Behaviour* 12, 245–51

Tolman CW (1967) The feeding behaviour of domestic chicks as a function of rate of pecking by a surrogate companion. *Behaviour* 29, 57–62

Tolman CW, Wilson GF (1965) Social feeding in domestic chicks. *Animal Behaviour* 13, 134–42

Trillmich F (1976) Learning experiments on individual recognition in budgerigars (*Melopsittacus undulatus*). *Zeitschrift fur Tierpsychologie* 41, 372–95

Tudor DC (1991) *Pigeon Health and Disease*. Ames, Iowa: Iowa State University Press

Turner ERA (1964) Social feeding in birds. *Behaviour* 24, 1–46

Universities Federation for Animal Welfare (1999) Awards for innovation in zoo animal welfare. *Veterinary Record* 145, 567

Universities Federation for Animal Welfare (1993) Rubber brooder mats. *Annual Report 1992/3*, p 6

USDA Animal and Plant Health Inspection Service (APHIS) (1997) *Animal Welfare Enforcement: Fiscal Year 1996*, APHIS 41-35-049. Washington DC

Vallortigara G, Regolin L, Rigoni M, Zanforlin M (1998) Delayed search for a concealed imprinted object in the domestic chick. *Animal Cognition* 1, 17–24

Vander Wall SB (1990) *Food Handling in Animals*. Chicago: University of Chicago Press

van de Water D (1996) Raptor rehabilitation. In: *Diseases of Cage and Aviary Birds*, 3rd edn (Rosskopf WJ, Woerpel RW, eds). Baltimore: Lea & Febiger, pp 1007–27

van Hoek CS (1995) *Abnormal Behavior and Welfare of Caged Birds*. IEES Leiden University: Report for the Dutch Society for the Prevention of Cruelty to Animals

van Hoek CS, King CE (1997) Causation and influence of environmental enrichment on feather pecking of the crimson-bellied conure (*Pyrrhura perlata perlata*). *Zoo Biology* 16, 161–72

Waine JC (1996) Waterfowl: head and neck problems. In: *Manual of Raptors, Pigeons and Waterfowl* (Beynon PH, Forbes NA, Harcourt-Brown NH, eds). Cheltenham: British Small Animal Veterinary Association, pp 299–304

Waldvogel JA (1989) Olfactory orientation by birds. In: *Current Ornithology*, Vol. 6. New York: Plenum Press, pp 269–321

Walraff HG (1996) Seven theses on pigeon homing deduced from empirical findings. *Journal of Experimental Biology* 199, 105–11

Watanuki Y, Mori Y, Naito Y (1992) Adélie penguin parent activiities and reproduction: effects of device size and timing of its attachment during chick rearing period. *Polar Biology* 12, 539–44

Watts CR, Stokes AW (1971) The social order of turkeys. *Scientific American* 224, 112–18

Weathers WW (1983) Basal metabolism of the apapane: comparison of freshly-caught birds with long-term captives. *Auk* 100, 977–8
Wechsler B, Schmid I (1998) Aggressive pecking by males in breeding groups of Japanese quail (*Coturnix japonica*). *British Poultry Science* 39, 333–9
Weisman R, Njegovan M, Ito S (1994) Frequency ratio discrimination by zebra finches (*Taeniopygia guttata*) and humans (*Homo sapiens*). *Journal of Comparative Psychology* 108, 363–72
Welty JC, Baptista L (1988) *The Life of Birds*, 4th edn. New York: Saunders College Publishing
Wemelsfelder F, Birke L (1997) Environmental challenge. In: *Animal Welfare* (Appleby MC, Hughes BO, eds). Oxford: CAB International, pp 35–47
Widowski TM, Duncan IJH (2000) Working for a dustbath: are hens increasing pleasure rather than reducing suffering? *Applied Animal Behaviour Science* 68, 39–53
Wilkinson R, Birkhead TR (1995) Copulation behaviour in the Vasa parrots *Coracopsis vasa* and *Coracopsis nigra*. *Ibis* 137, 117–19
Williams LE (1981) *The Book of the Wild Turkey*. Tulsa, Oklahoma: Winchester Press
Wilson HR (1991) Avian incubation. In: *Avian Incubation: Poultry Science Symposium*, No. 22, Chap. 9 (Tullett SG, ed). London: Butterworth-Heinemann
Wilson RP, Grant WS, Duffy DC (1986) Recording devices on free-ranging marine animals: does measurement affect foraging performance? *Ecology* 67, 1091–3
Wiltschko W, Munro U, Wiltschko R (1997) Magnetoreception in migratory birds: light-mediated and magnetite-mediated processes? In: *Orientation and Navigation—Birds, Humans and Other Animals*. Oxford: Royal Institute of Navigation
Witter MS, Lee SJ (1995) Habitat structure, stress and plumage development. *Proceedings of the Royal Society of London Series B—Biological Sciences* 261, 303–8
Wobeser GA (1997) *Diseases of Wild Waterfowl*. New York: Plenum Press
Woodford M (1966) *A Manual of Falconry*. London: A & C Black
Wright J, Cuthill I (1989) Manipulation of sex differences in parental care. *Behavioral Ecology and Sociobiology* 25, 171–81
Wright J, Cuthill I (1992) Monogamy in the European starling. *Behaviour* 120, 262–85
Wyndham E (1980) Diurnal cycle, behaviour and social organization of the budgerigar *Melopsittacus undulatus*. *Emu* 86, 25–33
Zann R (1994) Effects of band color on survivorship, body condition and reproductive effort of free-living Australian zebra finches. *Auk* 111, 131–42
Zann R (1996) *The Zebra Finch: A Synthesis of Field and Laboratory Studies*. Oxford: Oxford University Press
Zann RA, Morton SR, Jones KR, Burley NT (1995) The timing of breeding by zebra finches in relation to rainfall in central Australia. *Emu* 95, 208–22
Zeigler HP (1975) Trigeminal differentiation and hunger in the pigeon. *Journal of Comparative Physiology & Psychology* 89, 827–44

Glossary

Air sacs: Thin-walled extensions of the rigid avian lung that act as 'bellows', so that air flows in one direction through the respiratory system (as opposed to the tidal system in mammals). There are usually nine air sacs located in the body cavities, some of which penetrate adjacent bones.

Altricial: Altricial hatchlings have little or no down, hatch with the eyes closed and are not capable of locomotion so must be fed by their parents (e.g. passerines).

Apnoea: Cessation of breathing.

Arrhythmia: Abnormal rhythm (beating) of the heart.

Beak tipping: The removal of the 'hook' at the end of the upper mandible to prevent or alleviate feather pecking or cannibalism. This is preferable to debeaking.

Blood gas partition coefficient: This reflects the solubility in blood, potential for tissue distribution and (more importantly) tissue retention of an anaesthetic agent. The lower the solubility, the more rapid the induction and recovery and the less tissue retention.

Bradycardia: Slowing of the heart rate.

Candling: The viability and stage of development of a bird embryo can be determined by shining a strong light through the egg (candling). Commercial candlers are available and to be preferred, although alternative light sources such as microscope lights may also be used.

Carotid bodies: Nodules close to the carotid arteries, which contain chemoreceptors that monitor O_2 and CO_2 levels in arterial blood.

Caruncle: A general term for integumentary structures such as combs and wattles.

Caudal thoracic air sac: Large air sac located in the thorax and towards the tail.

Cere: A soft, fleshy covering of the proximal part of the upper mandible (including the nostrils), which occurs in several orders including birds of prey, Psittacines and pigeons.

Cere reflex: Pain response obtained by gently pinching the cere, usually seen as a shaking of the head. This is reduced and eventually abolished with increased depth of anaesthesia.

Chemoreceptors: Sensory receptors that are sensitive to certain molecules, e.g. O_2 and CO_2.

Clavicular air sac: Air sac located beneath the clavicle.

Coelomic cavity: Body cavity that forms a lining to the body wall and a cover to the gut.

Comb: An unfeathered outgrowth derived from the skin of the crown, commonly seen in domestic fowl.

Conspecific: Another member of the same species.

Corneal reflex: Response obtained by gently touching the cornea with cotton wool which causes a protective blink. This is reduced and eventually abolished with increased depth of anaesthesia.

Crop: A thin-walled sac extending from the oesophagus in some species, used for food storage. All pigeons and some other species also produce an epithelial secretion known as 'crop milk' which is similar in composition to mammalian breast milk and is used to feed the young.

Debeaking: Removal of part of the beak to prevent or alleviate cannibalism or feather pecking in domestic poultry. Part of the upper mandible is usually removed using a hot iron, either at less than 10 days old or in adult birds if problems occur. Up to one-third of the upper mandible can legally be removed in the UK. Debeaking can cause acute pain and stress and also chronic pain due to the formation of neuromas (abnormal outgrowths of the severed nervous tissue). Beak tipping is a less severe practice which is to be preferred, although this should not be done routinely or without veterinary justification.

Dubbing: Removal of all or part of the comb of male domestic poultry, usually performed using scissors when birds are one day old. Dubbing was originally carried out to prevent damage or frostbite to the comb, but there are now no welfare advantages and the procedure is not justified (FAWC 1998).

Dyspnoea: Laboured breathing; breathlessness.

Endoscope: Flexible, tube-shaped instrument with lenses and a light source that can be inserted into body cavities to investigate and treat disorders.
Feathering up: Beginning to grow the first feathers, which displace the juvenile or neonatal down.
Glottis: Slit-like opening at the base of the tongue, opening into the larynx.
Haematoma: Swelling filled with blood, which may be due to injury or the rupture of a vein during blood sampling.
Hypercapnia: Elevated level of CO_2 in the blood.
Hypoglycaemia: Low level of glucose in the blood.
Hypotension: Fall in blood pressure.
Hypothermia: Fall in body temperature.
Imprinting: An extremely rapid form of learning that enables young birds to recognize their parents, suitable habitats, food items and (later) breeding partners. It has four key characteristics: (i) it is rapid and generally confined to a brief sensitive phase; (ii) it is stable and often irreversible; (iii) it involves the learning of species-specific characteristics; and (iv) it may be completed before adult behaviour is expressed (Bateson 1979, Bolhuis 1991). There are several forms of imprinting. *Filial* imprinting describes the 'following' response and *sexual* imprinting describes the tendency for precocial and altricial chicks to remember characteristics of their parents and use them to shape their subsequent mating preferences. Young birds also become imprinted on their *habitat* and on *food*, so it is especially important to provide them with appropriate surroundings and diet if they are to be released or rehomed.
Intrapulmonary chemoreceptors: Chemoreceptors within the lungs.
Keel: Bony process on the sternum in flying birds to which the pectoral (flight) muscles are attached.
Karyotyping: Inspection of chromosomes.
Nidicolous: Nidicolous hatchlings remain in the nest after hatching but may not be wholly altricial (e.g. gulls).
Nidifugous: Nidifugous hatchlings leave the nest immediately or soon after hatching, so are necessarily precocial (e.g. waterfowl).
Nociceptor: Nerve detecting and responding to painful stimuli.
Palpebral reflex: Blinking the eye when the edge of the eyelid is gently touched. This is reduced and eventually abolished with increased depth of anaesthesia.
Partial pressure: A measure of the amount of gas in a gaseous mixture or in solution.
Passerine: Member of the order Passeriformes, popularly referred to as the 'perching' or 'singing' birds. All passerines have feet with four toes (three facing forwards and one facing back) adapted to gripping perches. Passeriformes are all land birds and so the toes are never webbed. Passerines covered in this report are tits (family Paridae), crows (family Corvidae), starlings (family Sturnidae) and finches (family Fringillidae).
Patagium: The web of skin formed between the humerus and radius.
Pinioning: The removal of the second digit on a hatchling's wing to prevent flight in the adult bird. This may cause acute and chronic pain and should never be carried out routinely (see Section 11.2.3).
Pipping: A stage in hatching when the first, star-shaped cracks begin to appear in the egg shell.
Polygyny: Mating system in which a male regularly mates with two or more females during a breeding season.
Polypnoea: Panting; rapid breathing.
Precocial: Precocial species hatch with the eyes open, are largely independent and can walk and feed themselves soon after hatching (e.g. waterfowl). They may be completely independent of their parents, or follow them during development. Different species may either follow their parents but locate their own food, be shown suitable food by their parents or be fed by their parents.
Preen gland: See uropygial gland.
Safety margin: The numerical ratio of the lethal dose to anaesthetizing dose of an agent. The higher the value, the less possibility of causing an overdose.
Semi-altricial: Semi-altricial birds hatch covered in down but are unable to leave

the nest so are fed by their parents. They may hatch with their eyes open (e.g. herons) or closed (e.g. owls).

Semi-precocial: Semi-precocial birds hatch in a comparatively well-developed form but remain on or near the nest until they are fledged.

Snood: An erectile appendage found on the forehead of domestic turkeys. It elongates from a small bump to become several centimetres long during sexual and aggressive displaying (see desnooding).

Surgical sexing: Looking at the gonads using an endoscope under general anaesthetic.

Tenotomy: Cutting the extensor tendons on the anterior edge of the metacarpal bone to prevent flight, usually performed in young chicks. This is likely to cause acute and chronic pain and distress and should never be carried out without strong justification (see Section 11.2.3).

Time budget: The percentage of total time that each of an animal's activities occupies.

Uropygial gland: Also known as the preen gland; an oil secreting gland located dorsally on the rump. The secretion is spread over the plumage by the bird during preening and is thought to play a role in maintaining feather flexibility and plumage hygiene (but not waterproofing).

Volant: Species capable of flight.

Wattle: Unfeathered skin appendage, often hanging from the corners of the mouth, which may be moulted seasonally. Occur in many species, especially the turkey and domestic fowl.

Wing twitch reflex: This is seen in response to any painful stimulus in a lightly anaesthetized bird resulting in a flapping or twitching of the wings depending on the degree of painful stimulus felt.

Yolk sac: Embryonic chicks obtain nourishment from an external yolk sac. In precocial species, this is retained internally for up to 3 days after hatching, to sustain the chicks while they are learning how to feed.

Appendix 1 Recommended reading

General

del Hoyo J, Elliott A, Sargatal J, Cabot J (1992) *Handbook of the Birds of the World*. Barcelona: Lynx Edicions

Ethics and the law

Brooman S, Legge D (1997) *Law Relating to Animals*. London: Cavendish Publishing Ltd

Cooper NS, Carling RCJ (1996) *Ecologists and Ethical Judgements*. Dordrecht, Netherlands: Kluwer Academic Publishers

RSPB (1998) *Wild Birds and the Law: A Plain Guide to Bird Protection Today*. RSPB, The Lodge, Sandy, Bedfordshire, SG12 2DL, UK

Bird care and use

Animal Welfare Advisory Committee (1995) *Code of Recommendations and Minimum Standards for the Care and Use of Animals for Scientific Purposes*. Wellington, New Zealand: AWAC www.maf.govt.nz/animalwelfare/codes/scientif/httoc.htm

Association of Avian Veterinarians (1998) *Policy Statement for the Humane Care and Use of Birds*. Florida: AAV www.aav.org/careanduse.htm

Canadian Council on Animal Care (1993) *Guide to the Care and Use of Experimental Animals*, Vol. I, 2nd edn. Ontario: CCAC www.ccac.ca/guides/english/toc_v1.htm

Canadian Council on Animal Care (1984) *Guide to the Care and Use of Experimental Animals*, Vol. II. Ontario: CCAC www.ccac.ca/guides/english/toc_v2.htm

Ellis S, Branch S (1994) *Penguin Husbandry Manual*. Maryland: American Zoo and Aquarium Association

Ewbank R, ed (1999) *Management and Welfare of Farm Animals: The UFAW Handbook*. Wheathampstead, UK: UFAW

Farm Animal Welfare Council (FAWC) (1997) *Report on the Welfare of Laying Hens*. Tolworth, UK: FAWC

Farm Animal Welfare Council (FAWC) (1998) *Report on the Welfare of Broiler Breeders*. Tolworth, UK: FAWC

Gaunt AS, Oring LW (1999) *Guidelines to the Use of Wild Birds in Research*, 2nd edn. Washington DC: The Ornithological Council www.nmnh.si.edu/BIRDNET/GuideToUse/

International Zoo Yearbook, published annually by The Zoological Society of London, Regent's Park, London NW1 4RY, UK

National Health and Medical Research Council (1997) *Australian Code of Practice for the Care and Use of Animals for Scientific Purposes*, 6th edn. Australian Government Publishing Service www.health.gov.au/nhmrc/research/awc/code.htm

National Research Council, Institute of Laboratory Animal Resources, Committee on Birds (1977) *Laboratory Animal Management: Wild Birds*. Washington DC: National Academy of Sciences (out of print)

National Research Council (1997) *Occupational Health and Safety in the Care and Use of Research Animals*. Washington DC: National Academy of Sciences

Poole T, ed (1999) *The UFAW Handbook on the Care and Management of Laboratory Animals. Volume 1: Terrestrial Vertebrates*, 7th edn. London: Blackwell Science Ltd

Poultry and Avian Biology Reviews 10 (2) (1999) Ten papers from the Scientist's Center for Animal Welfare (SCAW) Symposium on 'Well being of birds in laboratory and field research', held at the 1995 Annual American Veterinary Medical Association Meeting

Redfern C, Clark JA (2001) *Ringer's Manual*, 4th edn. Thetford, UK: British Trust for Ornithology

Wolfensohn S, Lloyd M (1994) *Handbook of Laboratory Animal Management and Welfare*. Oxford, UK: Oxford University Press

Environmental stimulation

Animal Welfare Information Center (AWIC) (1995) *Environmental Enrichment*

Resources for Laboratory Animals 1965–1995. Maryland: AWIC
Field DA (Ed) (1999) *Guidelines for Environmental Enrichment.* Chester, UK: Association of British Wild Animal Keepers
Reinhardt V, ed (1997) *Comfortable Quarters for Laboratory Animals,* 8th edn. Washington DC: Animal Welfare Institute
The Shape of Enrichment—Quarterly journal published by The Shape of Enrichment, Inc. (see Appendix 2). Ideas for environmental stimulation for all captive animals, including birds.

Veterinary and nutrition

Altman RB, Clubb SL, Dorrestein GM, Quesenberry K (1997) *Avian Medicine and Surgery.* Philadelphia: WB Saunders
Beynon PH, Cooper JE (1991) *Manual of Exotic Pets.* Cheltenham, UK: British Small Animal Veterinary Association
Beynon PH, Forbes NA, Harcourt-Brown NH (1996) *Manual of Raptors, Pigeons and Waterfowl.* Cheltenham, UK: British Small Animal Veterinary Association
Coles BH (1997) *Avian Medicine and Surgery,* 2nd edn. Oxford, UK: Blackwell Scientific Ltd
Fowler ME, Miller RE (1999) *Zoo & Wild Animal Medicine: Current Therapy 4.* Philadelphia: WB Saunders
Harrison GJ, Harrison L (1986) *Clinical Avian Medicine and Surgery.* Philadelphia: WB Saunders
Kelly J, Wills J, eds *Manual of Companion Animal Feeding and Nutrition.* Gloucestershire, UK: British Small Animal Veterinary Association
Klasing KC (1998) *Comparative Avian Nutrition.* Oxford, UK: CAB International
Ritchie BW, Harrison GJ, Harrison LR (1994) *Avian Medicine: Principles and Application.* Lake Worth, Florida: Wingers Publishing Inc
Samour J, ed (1999) *Avian Medicine.* London: Harcourt Brace & Co
WILD*Pro* Multimedia (2001) Waterfowl: Health and Management CD-ROM. Wildlife Information Network, The Royal Veterinarian College, Royal College Street, London NW1 OTU, UK http://www.wildlifeinformation.org/

Appendix 2 Useful organizations

American Ornithologist's Union
http://www.aou.org/
Publication information:
http://birds.cornell.edu/AOU/pubs.html
Information office: aou@nmnh.si.edu

Animal and Plant Health Inspectorate Service (APHIS)
See US Department of Agriculture
APHIS.Web@usda.gov
http://www.aphis.usda.gov/

Association of Avian Veterinarians (AAV)
PO Box 811720
Boca Raton
FL 33481–1720, USA
Tel: (561) 393-8901
Fax: (561) 393-8902
AAVCTRLOFC@aol.com
http://www.aav.org

Association of British Wild Animal Keepers (ABWAK)
c/o Chester Zoo
Caughall Road
Upton, Chester
CH2 1LH, UK
http://www.abwak.co.uk/

Australia and New Zealand Council for the Care of Animals in Research and Teaching (ANZCCART)
Davies Building
Waite Campus
University of Adelaide
South Australia 5005
Tel: (61) 8 8303 7393
Fax: (61) 8 8303 7113
anzccart@waite.adelaide.edu.au
http://www.adelaide.edu.au/ANZCCART/

British Small Animal Veterinary Association (BSAVA)
Woodrow House
1, Telford Way
Waterwells Business Park
Quedgeley, Gloucestershire
GL2 4AB, UK
Tel: (44) 1452 726700
Fax: (44) 1452 726701
adminoff@bsava.com
http://www.bsava.ac.uk

Birds Australia
415, Riversdale Road
Hawthorn East
Victoria
Australia 3123
Tel: (61) 3 9882 2622
Fax: (61) 3 9882 2677
mail@birdsaustralia.com.au
http://home.vicnet.net.au/~birdsaus/

The Ornithological Council
This is a public information organization involving 10 US societies: American Ornithologists' Union, Association of Field Ornithologists, CIPAMEX (Sección Mexicana del Consejo Internacional para la Preservación de las Aves), Cooper Ornithological Society, Pacific Seabird Group, Raptor Research Foundation, Society of Canadian Ornithologists, Society of Caribbean Ornithology, The Waterbird Society and Wilson Ornithological Society.
http://www.nmnh.si.edu/BIRDNET/

British Ornithologist's Union
c/o The Natural History Museum
Tring
Hertfordshire, UK
Tel: (44) 1442 890080
Fax: (44) 1442 890693
bou@bou.org.uk
http://www.bou.org.uk/

British Trust for Ornithology
The Nunnery
Nunnery Place
Thetford, Norfolk
IP24 2PU, UK
Tel: (44) 1842 750050
Fax: (44) 1842 750030
ringing@bto.org
http://www.bto.org/

Canadian Council for Animal Care (CCAC)
315–350, Albert Street
Ottawa ON
Canada K1R 1B1
Tel: (613) 238 4031
Fax: (613) 238 2837
mbedard@bart.ccac.ca
http://www.ccac.ca

CITES
International Environment House
15, Chemin des Anémones
CH-1219 Châtelaine, Geneva
Switzerland
Tel: (41) 22 917 8139/40
Fax: (41) 22 797 3417
cites@unep.ch
http://www.cites.org/

Comparative Nutrition Society
Department of Biology
University of Central Florida
Orlando
FL 32816-2369, USA
Tel: (407) 823 2141
Fax: (407) 823 5769
http://www.cnsweb.org

Countryside Council for Wales
Plas Penrhos
Ffordd Penrhos
Bangor, Gwynedd
LL57 2LQ, UK
Tel: (44) 1248 385500
Fax: (44) 1248 355782
http://www.ccw.gov.uk

Department for Environment, Food and Rural Affairs (DEFRA)
Nobel House
17, Smith Square
London
SW1P 3JR, UK
Tel: 08459 335577
Outside UK: (44) 207 270 8961
Fax: (44) 207 270 8419
helpline@defra.gsi.gov.uk
http://www.defra.gov.uk

Department of the Environment Northern Ireland
Calvert House
23, Castle Place
Belfast
BT1 1SY, UK
Tel: (44) 2890 235000
Fax: (44) 2890 254865
ep@doeni.gov.uk
http://www.doeni.gov.uk

English Nature
Northminster House
Peterborough
PE1 1UA, UK
Tel: (44) 1733 455000
Fax: (44) 1733 568834
http://www.english-nature.gov.uk

Electronic Zoo
http://netvet.wustl.edu/ssi.htm

European Association of Zoos and Aquaria (EAZA)
http://eaza.net/

Farm Animal Welfare Council (FAWC)
FAWC Secretariat
1A, Page Street
London
SW1P 4PQ, UK
Tel: (44) 207 904 6534
Fax: (44) 207 904 6533

Game Conservancy Trust
Fordingbridge
Hampshire
SP6 1EF, UK
Tel: (44) 1425 652381
Fax: (44) 1425 651026
info@gct.org.uk
http://www.game-conservancy.org.uk/

Hawk and Owl Trust
41B, Dartmouth Road
London
NW2 4ET, UK
Tel: (44) 208 450 0662
http://www.hawkandowl.co.uk/

International Air Travel Association (IATA)
Route de l'Aeroport 33
PO Box 416
15 – Airport
CH-1215 Geneva
Switzerland
Tel: (41) 22 799 2525
Fax: (41) 22 798 3553
http://www.iata.org/

IUCN—The World Conservation Union
Rue Mauverney 28
1196 Gland
Switzerland
http://www.iucn.org/

National Wildlife Rehabilitators Association
14, North 7th Avenue
St Cloud
MN 56303-4766, USA
Tel: (320) 259 4086
nwra@nwrawildlife.org
http://www.nwrawildlife.org

New Zealand Department of Conservation (DOC)
PO Box 12416
Wellington
NZ
Tel: (64) 04 499 2300
Fax: (64) 04 499 2301
http://www.doc.govt.nz

Royal Society for the Protection of Birds (RSPB)
The Lodge
Sandy
Bedfordshire
SG19 2DL, UK
Tel: (44) 1767 680551
http://www.rspb.org.uk/

Scottish Natural Heritage (SNH)
12, Hope Terrace
Edinburgh
EH9 2AS, UK
Tel: (44) 131 447 4784
Fax: (44) 131 446 2277
http://www.snh.org.uk

The Shape of Enrichment, Inc.
1650, Minden Drive
San Diego
CA 92111-7124, USA
Fax: (858) 279 4208
shape@enrichment.org
http://www.enrichment.org

US Department of Agriculture (USDA)
14th & Independence Avenue SW
Washington DC 20250, USA
Tel: (202) 720 2791
Fax: (202) 720 2166
http://www.usda.gov/

US Fish and Wildlife Service (FWS)
US Department of the Interior
1849, C Street NW
Washington DC 20240, USA
contact@fws.gov
http://www.fws.gov/

Wildfowl and Wetlands Trust
Slimbridge
Gloucester
GL2 7BT, UK
Tel: (44) 1453 891900
Fax: (44) 1453 890827
enquiries@wwt.org.uk
http://www.greenchannel.com/wwt/

Wildlife Information Network
The Royal Veterinary College
Royal College Street
London
NW1 OTU, UK
Tel: (44) 207 388 7003
Fax: (44) 207 388 7110
win@wildlifeinformation.org
http://www.wildlifeinformation.org/

World Parrot Trust
info@worldparrottrust.org
http://www.worldparrottrust.org

Appendix 3 Example of assessment sheet with useful clinical signs when drawing up observation sheets for birds

IDENTIFICATION CODE:	ISSUE NUMBER:						
DATE OF OPERATION	PRE-OPERATION BODY MASS:						
DATE							
DAY	0	0	1	1	2	2	3
TIME							
FROM A DISTANCE							
Inactive							
Isolated							
Reduced communication							
Reduced interaction with others							
Huddled							
Wing drooping							
Tail down							
Hunched posture							
Not preening							
Fluffed feathers							
Panting/dyspnoea							
Slitty eyes							
Not inquisitive/alert							
Not eating/drinking*							
Vomiting							
Crusty eyes/nares							
Abnormal faeces							
Soiled vent							
ON HANDLING							
No righting reflex							
Body mass (g)							
% change from start							

Appendix 3 (continued)

Body temperature (°C)							
Dehydration							
Body mass lost**							
Problems with stitches							
Wound condition poor							
NAD***							
Comments							
Signature							

SPECIAL HUSBANDRY REQUIREMENTS:

SCORING DETAILS:

*Not interested during scatter feeding

**Pectoral muscle wastage

***Nothing abnormal detected

HUMANE ENDPOINTS AND ACTIONS:

SCIENTIFIC MEASURES:

Appendix 4 Summary of recommendations from General Sections 1–15

Cognition—The brain and senses

Avian intelligence and behavioural complexity have often been regarded as inferior to those of mammals, but there is a growing body of evidence that such assumptions are not justified. Birds have been shown to possess many different types of cognitive abilities which suggests that they have a higher mental capacity than has been previously thought and have considerable potential to experience suffering and distress. An appropriately stimulating environment is therefore likely to be a very important contributor to good bird welfare and should always be provided.

Avian physiological and behavioural responses to painful stimuli resemble those of mammals and so it should be assumed that if a stimulus would cause pain to a human or other mammal, it will also cause pain to a bird. Any potential pain in birds must be prevented or alleviated as appropriate.

Recommendations:

- Assume that avian cognitive skills are equivalent to those of mammals and that birds need an appropriately stimulating environment.
- Make sure that everyone wears the same colour laboratory coats and that the colour is not changed.
- Remember that birds can detect changes in sound direction, so make sure that your approach is audible to birds to avoid startling them.
- Assume that the hearing range of birds is similar to humans and protect them from noises that would adversely affect human welfare.
- Do not subject birds to infrasound (low frequency noise) unnecessarily.
- Assume that the ability of birds to smell and taste is at least similar to that of humans.
- When housing birds indoors, do not situate them where they will be able to smell mammalian or other avian predators.
- Try providing species that eat a diverse range of foods in the wild with a balanced diet including a choice of different foods; monitor individuals' preferences very carefully and adjust the diet accordingly.
- Assume that birds feel pain to the same degree as mammals.
- Consider how you would recognize when a bird is suffering discomfort or pain.
- Prevent or alleviate pain in birds wherever possible.

Staff training

Bird behaviour in general, environmental requirements and veterinary care are very different from those of mammals and insufficient knowledge or experience in dealing with these can cause serious welfare problems. Specialist training in catching and handling birds, recognition of pain and distress, avian nutrition and experimental techniques is vital, and it will be necessary to use expert trainers when planning projects with new species.

Recommendation:

- Ensure that everyone who will be caring for or using birds is adequately trained and competent before any projects begin.

Obtaining eggs or birds

Experimental birds can be either acquired as adults or reared from hatch. A decision must be made depending on the nature and duration of the project, the behavioural characteristics and conservation status of the study species and the intended fate of the birds when the project has ended. The taking of eggs or birds from the wild is regulated by national and international laws, so all necessary licences and permits must be obtained first.

It is preferable to buy birds from breeders wherever feasible, as they will then have had at least some contact with humans. It is important to obtain information on birds' hatching and rearing conditions, so that (i) any stress caused by removal to a new environment can be minimized by making changes gradually and (ii) you can ensure that husbandry and welfare standards in place at the breeder or supplier are good.

Recommendations:

- Assess the welfare costs and benefits associated with rearing birds from hatch versus obtaining adults for each project.
- Consider the birds' quality of life after procedures have ended and their eventual fate (i.e. rehoming, release or euthanasia) when making a decision.
- Buy birds from reputable breeders or suppliers wherever possible.
- Find out as much as possible about natural history, husbandry and care before obtaining birds and make sure that the breeder's welfare standards are good.
- Minimize stress by introducing changes to the birds' environment and/or husbandry gradually.
- Avoid taking eggs or birds from the wild unless it is impossible to obtain them from a breeder.
- When removing eggs or birds from the wild, consider carefully and minimize the potential for disrupting remaining individuals—this should be regarded as constituting part of the welfare 'cost' of the project.
- Pay full regard to the conservation cost of the project, where disturbance and removing individuals may have an impact on the population as a whole.
- In general, avoid using species that are rare or threatened.
- Make sure that you are fully aware of current national and international laws and codes of practice with respect to taking eggs or birds from the wild.
- Check published hatching and rearing failure rates when deciding how many eggs to collect—do not take too many (or unwanted birds may be hatched) or too few (or you may have to disrupt the colony again).
- Remember that you are a predator and your interference will be highly stressful and disruptive. Alter your behaviour to reduce stress.
- Observe nests carefully and try to take eggs that have not been incubated or that are very close to hatching, to avoid damaging embryos during vulnerable stages of development.
- Seek advice from appropriate organizations on the best collecting protocol with respect to the reproductive strategy of each species.
- Do not attempt to trap adult birds unless experience has been gained with an expert in attendance.
- Reduce stress by using passive walk- or fly-in traps wherever possible.
- Monitor traps and nets regularly and do not set out more than can be effectively checked.

Procedures in the field

For field procedures, it is essential to ensure that all appropriate licences have been granted before studies begin. All trapping and handling techniques and procedures should be refined so as to minimize the potential to cause physical or psychological harm or stress to experimental birds.

If surgical procedures or tissue sampling are to be conducted in the field, sterile instruments must always be used and anaesthesia and analgesia administered as appropriate. Careful consideration should also be given to the effects of procedures following release and no bird should be released unless it is certain that welfare or survival will not be compromised.

Recommendations:

- Minimize stress to birds taken from the field by allowing a period of acclimatization and quarantine before projects begin.
- Make sure that all necessary licences have been granted before conducting field procedures.
- Ensure that birds kept in bird bags for other than short periods are held in dark, well-ventilated areas and can preen and roost comfortably.
- Always use sterile instruments when sampling tissue.
- Never carry out surgical procedures in the field unless a sterile area can be set up and effective anaesthesia and analgesia administered.

- Do not use external devices unless there is evidence that (i) they will not adversely affect behaviour in the study species and (ii) external devices are the least harmful way to obtain the necessary data.
- Examine birds carefully for signs of shock or injury before releasing them.
- Make sure that appropriate transport containers and the means to euthanase birds humanely are always available when undertaking any study that involves catching birds.
- Allow birds to move away in their own time on release and observe them to ensure that they can walk or fly effectively.
- Give careful consideration to the impact of external and internal marking methods on birds in the field.

Transport

Anyone who wishes to transport birds must be aware of and understand all the relevant legislation that applies in each case. It is bad practice to waste eggs, so they should always be transported with extreme care, particularly throughout the first two-thirds of incubation.

'Bird bags' can be used to transport birds for short journeys, but there must be sufficient space to assume normal postures and engage in preening and feather maintenance during longer journeys. Routes and stopping places should always be planned well in advance, and at least one person who is trained in bird husbandry and care should be in attendance at all times.

Recommendations:

- Obtain advice from relevant authorities on all applicable legislation, guidelines and codes of practice before transporting or importing each species.
- Wasting eggs means wasting animals so take great care to minimize risks to them.
- Try to avoid transporting eggs during the first two-thirds of incubation—transport them before they have been incubated or wait until they are 'pipping'.
- Always insulate eggs or transport them in an incubator unless incubation has not yet begun.
- When transporting birds, ensure that containers are of an appropriate size and construction for the species and journey length.
- Take care to ensure appropriate physical and environmental conditions if transportation is unavoidable.
- Plan the journey thoroughly in advance, making contingency plans in case of delays.
- Ensure that trained personnel are always in attendance.

Breeding and hatching

If a species is relatively easy to breed and keep, and there is likely to be a sustained use, then it may be appropriate to breed them on-site. Breeding birds are likely to be especially nervous, and disturbance including handling and cleaning may need to be reduced, although it is important to maintain adequate health monitoring. Most fertile eggs allowed to incubate naturally will go on to hatch successfully, so it is generally best practice to allow the birds to hatch and rear the chicks themselves. If artificial incubators are to be used, advice on the temperature and humidity requirements and duration of incubation must be obtained for each species before obtaining incubators and eggs. Hatching eggs should be checked regularly and the growth rate of hatchlings should be carefully monitored.

Recommendations:

- Before making a decision to breed birds, consider whether there will be a sustained requirement for the species; whether appropriate conditions can be supplied and how the risk of overbreeding will be minimized.
- Eliminate all unnecessary disturbance to breeding birds, without compromising health monitoring.
- Allow birds to hatch and rear chicks themselves wherever possible.
- Obtain advice on the type of incubation systems and optimum conditions before

acquiring eggs. Buy new equipment if necessary.
- Ensure that egg shells, incubators and hatchers are all sterilized and wash your hands before handling eggs, both before incubation begins and routinely.
- If using broody birds to incubate eggs, make sure that their welfare is given equal importance to that of experimental birds.
- Always ensure that incubators are set for the correct temperature and humidity for each species, regardless of instructions (which are likely to be for domestic poultry).
- Check the temperature and humidity regularly and rectify any problems immediately.
- Make appropriate back-up provisions for incubator failure.
- Keep accurate records so that development can be monitored and egg wastage minimized.
- Label eggs clearly with a wax or graphite pencil and candle regularly to check for non-viable eggs or 'dead in shells'.
- Monitor deviations from expected mass throughout development, wherever possible, and adjust humidity accordingly.
- Do not incubate eggs from different species in the same machine unless it is known to be safe to do so.
- Ensure that temperature and humidity are maintained at appropriate levels for the species during hatching.
- Check hatchlings at least twice a day to ensure that they can leave the egg without obstruction.
- Provide suitable flooring in the hatcher that chicks can grip.

Imprinting, rearing and feeding chicks

Imprinting birds onto a human is a serious commitment, the consequences of which require planning in advance and a great deal of time and also have implications for rehoming or release. Hand-rearing young birds may be beneficial in terms of reducing stress during subsequent interactions with humans, but rearing chicks apart from conspecifics can have negative consequences for the birds' adult behaviour and welfare. Parent birds have a variety of strategies for feeding chicks and it is vital to research and be aware of the feeding behaviour of a species when hand-rearing birds. Young wild birds are generally fed on protein-rich diets, but commercial feeds may not be appropriate for all species. Great care must be taken to ensure adequate nutrient intake so that birds develop properly.

Recommendations:
- Check growth rates against published growth curves regularly, allowing for differences between wild and hand-reared birds.
- Plan imprinting on a human well in advance—the consequences require serious commitment.
- Research the behaviour of juvenile birds when considering rearing them as a group, in case there is a risk of fratricide.
- Rear chicks in broods or groups of conspecifics, never in isolation unless there is strong scientific or veterinary justification for doing so.
- Talk to birds in the eggs before hatch (where appropriate) to assist imprinting.
- If chicks are imprinted onto a model bird ensure that they are feeding.
- Teach hand-reared birds to forage or to feed soon after hatch if necessary.
- Research the feeding strategies of each species and provide appropriate food at each life stage, giving consideration to feeding times.
- Formulate diets carefully for growing birds to ensure appropriate dietary concentrations of nutrients, especially of calcium, phosphorus, vitamin D and protein.

Diets for juvenile and adult birds

Juvenile birds should be gradually introduced to their adult diet after the period of rapid growth is completed. Adult birds should be fed on the food that they would eat in the wild, as far as is possible. Supplements *may* be necessary but should not be given automatically or without consulting a veterinarian.

Recommendations:

- Feed birds on their 'natural' diet as far as possible, with supplements when necessary.
- Assume that taste and variety will be important to some species.
- Provide dietary enrichment where appropriate, but avoid abrupt changes in diet.
- Supply grit in a range of sizes for birds to choose from if this is a requirement for the species.
- Ensure that dietary calcium and phosphorus is provided in an appropriate form and at an appropriate level for each life stage.

Moulting

Moulting is necessary to maintain the basic functions of the plumage including efficient flight, insulation and waterproofing. The timing of moulting and amount and sequence of plumage lost should be researched for each species and their behavioural, environmental and nutritional requirements should be met. Efficient and empathetic monitoring will be necessary to ensure that good health is maintained but disturbance minimized.

Recommendations:

- Thoroughly research the moulting strategy for each species and ensure that you can provide appropriate temperatures, day lengths, housing and nutrition before obtaining any birds.
- Make sure that moulting birds are carefully monitored but are not subjected to unnecessary disturbance.
- Always seek veterinary advice if moulting patterns or feather growth are abnormal.
- Do not force-moult birds.

Catching and handling

Catching and handling should be carried out confidently, only when necessary, and only by those who are competent to do so. Training is essential and adequate equipment is also vital. All birds are liable to find restraint and handling extremely stressful and the bird's point of view must be considered at all times. Birds are liable to defend themselves in a variety of ways by a combination of pecking, kicking, scratching and beating with the wings. The correct way to catch and handle each species must be demonstrated to everyone who is likely to have to do so.

Many species of bird appear to 'freeze' when experiencing acute fear or distress. This is known as tonic immobility (TI) and is often used as an indicator of acute fear in birds. TI should never be deliberately induced or used in the place of chemical restraint—it is not a state of 'hypnosis'.

It may be possible to reduce handling stress by habituating birds to human contact and handling from hatch (if possible), using positive reinforcement and rewards, e.g. mealworms for species that eat invertebrates. Rewards can be given after procedures or cleaning out, and 'treats' should also be given regularly by humans to encourage birds to view humans positively.

Chemical restraint may be necessary when undertaking scientific or veterinary procedures that should not cause pain but appear to stress birds. A specialist should always be consulted on the best way to restrain each species, and many of the sedatives used will be prescription-only medicines (POMs) and so will have to be administered under the direction of a veterinarian. Skilled handling is probably preferable, as recovery from chemical restraint is nearly always stressful.

Recommendations:

- Ensure that everyone who will be handling birds is trained and competent, and that all equipment is well maintained.
- Remember that some birds will view humans as predators and may find handling extremely stressful.
- Never catch birds by the wings or carry them by the wings or legs alone.
- Hold birds securely so that they cannot damage their wings but never obstruct the movement of the sternum or allow the neck to kink.
- Catch small birds in dim light and approach from behind, obscuring the hand if necessary.
- Take great care not to let small birds escape, as it is especially easy to injure them.

- Ensure that the room has been made safe in case birds do escape.
- Obtain expert guidance before handling very small birds.
- Handle large birds firmly and empathetically to avoid injury to birds and handlers.
- Approach flocking birds slowly and deliberately.
- Do not catch birds by the wings or interlock the wings.
- Restrict the legs and prevent wing flapping when handling domestic fowl.
- Consider early and frequent, gentle handling of young birds as a way of minimizing stress if much handling is required at later ages.
- Do not carry birds upside down by their legs.
- Release large birds onto the floor.
- Make sure that correct handling techniques for each species have been demonstrated to everyone and that handlers are competent and empathetic.
- Remember that birds will defend themselves. Be prepared to restrain them firmly but do not risk obstructing their breathing or causing them physical damage.
- Do not induce tonic immobility (TI) deliberately—it imposes extra stress and is not 'hypnosis'. Birds are aware and capable of experiencing pain and fear while in a state of TI.
- If protocols require a lot of handling, begin habituating birds as early as possible and reward them regularly.
- Rewards should be positive additions over and above routine food, water and social interactions wherever possible.
- Do not use chemical restraint if competent and empathetic handling will have the same result and be less stressful.
- Always obtain veterinary advice when considering using chemical restraint.

Identifying individual birds

Birds may be identified (marked) by several methods including (from least to most invasive): noting physical differences, ringing, staining the feathers, electronic tagging and wing tagging. The least invasive method of marking should be chosen for each species and project.

Recommendations:

- Do not mark birds that are morphologically different or can be identified from their plumage markings unless there is a legal requirement to do so.
- Always use the least invasive identification method possible.
- Research the possible influence of leg ring colour and symmetry on behaviour in each species.
- Ensure that leg rings will not become too tight and cause injury.
- If using electronic tags, implant them subcutaneously or into the pectoral muscle, never bone.
- Consider the effects of external, visible markers on behaviour (and predation if the bird is to be released into the field).
- Do not toe-clip or web-punch birds—this is unacceptable.

Housing and husbandry—general considerations

A good standard of well-being and welfare cannot be achieved without appropriate housing, husbandry and care. Detailed species-specific recommendations on housing are set out in Sections 16–27, but it is essential to read Section 11 (Housing and husbandry) of the report before turning to these. Good housing should make birds feel safe, secure and able to express a range of behaviours. Poor quality and quantity of space is likely to lead to boredom and frustration, which may be expressed as stereotypic behaviour—this is unacceptable.

Recommendations:

- Provide a good quality and quantity of space—these are essential for good welfare.
- Choose flooring carefully to ensure good health and welfare.
- Supply birds with perches appropriate to the species.
- Position housing to minimize stress, blocking in one or more sides if necessary.
- Provide areas for activities such as dustbathing, bathing in water, play, etc.

- Do not house birds under intensive conditions.
- Research the range of temperature and humidity that each species would be subject to in the wild and match this as closely as possible, providing a degree of choice.
- Use gradual transitions from dawn to dusk for birds kept under artificial lighting, or dim 'night lights'.
- Seek expert advice before attempting to house nocturnal or crepuscular species.
- Consider using high frequency fluorescent light sources, preferably with a spectral composition mimicking daylight (i.e. with some UV component).

Routine husbandry and health care

Everyone who is involved in using or caring for laboratory birds should be fully aware of their normal behaviour and also of behavioural signs that could indicate a departure from a state of well-being. A veterinarian should always be consulted immediately if there is any doubt as to a bird's current or future health status. Stock birds should be routinely monitored at least twice a day, and those on studies should be monitored more frequently depending on the nature and severity of procedures.

A healthcare strategy should be drawn up in consultation with the attending veterinarian for each project while it is in the planning stages, setting out how health and adverse effects will be monitored, which diseases and pathologies the species is especially susceptible to and which preventive medicines, parasiticides and vaccinations may be necessary. See Section 11.2 of this report for detailed guidance on health care and disease prevention.

Recommendations:

- Monitor birds at least twice daily and make sure that everyone is aware of normal and abnormal behaviour and the clinical signs of disease in that species.
- Draw up a comprehensive healthcare plan with the attending veterinarian before any birds are acquired.
- Always consult a veterinarian at the earliest opportunity if there is any doubt as to health status.
- Obtain birds of a high health status.
- Where this is not possible, e.g. with wild birds, apply appropriate quarantine and hygiene procedures after consultation with the attending veterinarian.
- Use a structured and agreed approach to observation and, ideally, maintain objective measurements of animals (e.g. body mass).
- Quarantine new birds for 28 days where possible, monitoring health and treating for parasites.
- Ensure that everyone is familiar with the signs associated with ill-health in birds.
- Keep detailed health records and review them regularly.
- Always investigate the causes of morbidity or mortality, in consultation with veterinarians and animal technicians.

Physical modifications

Most bird behaviours that cause or indicate welfare problems can be reduced or eliminated by providing appropriate housing and care. Some behaviours such as feather pecking or panic leading to injury may persist even where every attempt has been made to optimize welfare and to choose strains with no or few behavioural problems. It may then be necessary to perform temporary or permanent physical modifications such as wing clipping, pinioning, tenotomy or beak tipping (*not* debeaking). These should only ever be done for veterinary reasons, and anaesthesia and analgesia must be given for all surgical procedures, including those performed on hatchlings.

Recommendations:

- Choose strains of birds that are less likely to develop behavioural problems such as aggression.
- *Always* administer appropriate anaesthetics and analgesics to all birds undergoing surgical procedures, regardless of their age.

- Pinioning and tenotomy are mutilations and should rarely be necessary unless fully justified on veterinary grounds.
- Do not beak tip birds without strong veterinary justification, as this can cause chronic pain that it is impossible to treat.
- Do not use domestic poultry strains with behavioural problems or pathologies unless the project is directly applicable to improving the welfare of that strain.

Routine scientific procedures

Birds are used in research for a variety of different purposes, but care should always be taken to ensure that experimental procedures are refined to reduce suffering as fully as possible. In this report, procedures have been broadly divided into blood sampling, administering substances and surgical procedures, but it is the responsibility of the investigator continually to obtain up-to-date knowledge on best practice for each procedure in each species.

Recommendations:

Blood sampling

- Select a site appropriate for the size of the bird and experimental protocol.
- Reduce the risk of haematoma formation by ensuring that the bird is carefully restrained, using a fine needle and applying pressure to stop bleeding effectively.
- Do not perform cardiac puncture unless the bird is under general anaesthesia and not allowed to recover, unless there is compelling scientific justification otherwise.

Administering substances

- Ensure that the least invasive method of administration is always used and only exceed the recommended doses with good scientific justification.
- Never pluck feathers.
- Avoid intramuscular injections wherever possible; if they are unavoidable then do not exceed the recommended total dose and split large doses between sites.

Surgical procedures

- Take the special needs of birds into account during anaesthesia, surgery and when providing postoperative care—do not assume that their physiology or requirements are the same as those of mammals.
- Give all birds postoperative pain relief, administering the first dose before the birds recover consciousness.
- Ensure that birds do not become dehydrated; fluids must be available and administered via a drip if necessary.
- Place birds in a heated incubator or cage for recovery, housed in a quiet area with subdued lighting.
- Monitor and maintain body temperature closely throughout recovery.
- Leave most birds alone to recover with minimum interference apart from necessary monitoring, but try speaking to and stroking hand-reared birds during recovery.
- Maintain adequate supervision after the birds have regained consciousness and been returned to their group.
- Consider how a stimulating postoperative environment could be provided to aid endogenous analgesia.

Monitoring for adverse effects

- Take pain in birds seriously: many species have evolved to conceal pain but this does not mean that they are not suffering or that there is no need to do anything about it.
- Make sure that everyone responsible for bird welfare can recognize pain and distress in order to alleviate suffering and employ humane endpoints.
- Devise and agree observation sheets for each species and type of procedure; also for general record keeping of well-being.
- Make sure that everyone is aware of indicators of acute distress such as tonic immobility and exaggerated 'comfort' behaviours.
- Regard all abnormal behaviour as an indicator that birds are unable to cope with their environment, and therefore unacceptable—ensure that strategies are in place for dealing with this.

Rehoming or release following procedures

The period when birds are housed in a laboratory and undergoing procedures should be regarded as one episode in their lives rather than their reason for existing, and so every attempt should be made to rehome or release them after experiments have finished unless there is a legal or compelling welfare or scientific reason not to do so. The potential for releasing birds to the wild or rehoming them to private care should be given serious thought when planning a research project, and decisions made on a case-by-case basis.

Recommendations:

- The welfare of individuals must be paramount when considering the fate of birds.
- The possibility of rehoming or releasing should be fully considered both at the project planning stage and when research has ended; birds should not routinely be killed.
- The probable quality of life that the birds can be expected to have after release or rehoming should be weighed against their likelihood of suffering, when making a decision.
- If rehoming to a collection, welfare standards must be as good as, or better than, those at the establishment where the birds have been housed previously.
- All legal, practical and ethical considerations (with respect to the bird as an individual and to the environment) must be fully considered before releasing birds to the wild.
- A stimulating environment should be provided to enable birds to adjust more rapidly when rehomed or released.

Euthanasia

Humane killing will be necessary if it would be unethical or illegal to release or rehome birds, if a study requires their tissues, if they are suffering unpredicted adverse effects during a study or if a determined humane endpoint is reached. It is essential that anyone who is required to kill animals is humane and competent, handling animals empathetically and ensuring that they lose consciousness as quickly as possible. Nobody should be asked to kill animals unless they are prepared to do so and are fully trained and competent.

Recommendations:

- Do not ask anyone to kill animals unless they are fully trained, competent, confident and willing to do so.
- Do not kill birds within the sight of others.
- Kill birds using an overdose of a suitable anaesthetic agent administered by intravenous injection or inhalation wherever possible.
- If a physical method must be used, dislocation of the neck is the most humane method. Ensure that persons carrying this out are fully competent and adequately trained.
- Avoid carbon dioxide euthanasia as this could cause distress; use injectable or inhalational anaesthetics instead or until consciousness is lost.

Reporting bird use

Good animal welfare is absolutely essential for good science, and so refinements to husbandry and procedures are both central to the experimental protocol and should always be reported in published papers.

Recommendation:

- Include information on refinements in housing, husbandry, scientific and veterinary procedures when publishing the results of studies using birds.