



Social and Environmental Enhancement for Non-primate Research Animals

371.1 **Prologue**

371.1.1 In order to enhance animal wellbeing, minimize animal stress, promote consistency and fulfill regulatory obligations, the IACUC has a standing policy for minimum (or “required”) enrichment standards, specifically defining housing conditions and socialization opportunities, for all species used in research at Emory University with the exception of nonhuman primates (addressed separately, see: http://www.iacuc.emory.edu/documents/ee_nhp.pdf).

371.2 **Introduction**

371.2.1 The environment may influence the validity, reliability and replicability of experiments by introducing abnormal animals into studies, increasing variability within the population, and altering the number and type of individual animals between laboratories, respectively.¹ In the context of the research animal, the environment consists of both physical attributes (e.g., lighting, temperature, cage design and complexity) as well as the nature of social interactions. In the proper care and use of research animals, the availability or suitability of enrichment must be considered in the provision of the environment and specifically with opportunities to exhibit species-typical behaviors and activity.²

371.2.2 When animals are unable to perform species typical behaviors and control their environment, unintended stress results and may proceed to adversely affect physiology and distress manifested as abnormal behaviors, both maladaptive and malfunctional.¹ Altered physiology and abnormal behaviors in a population are similarly potentially confounding to science because they are usually expressed inconsistently across the spectrum of the group.¹ Their expression varies by genetic background and developmental experience and may be difficult to mitigate with aging.¹ As such, successful enrichments reduce or prevent the occurrence of physiological dysfunction and malfunctional and maladaptive behaviors through appropriately lifelong (e.g., from development onward) social and environmental enrichment.^{1,3}

371.2.3 An important enrichment caveat is that social, environmental, dietary and other supplementations intended for improvement of animal well-being may alter important aspects of an animal’s physiology and development in ways not easily predictable based on what is already known.^{4,5} Enrichment is a research variable that must be sensibly managed and must be biologically relevant.^{1,6} In essence, enrichment enables “good welfare” to equal “good science”.

371.2.4 In most cases, principles of training (e.g., operant conditioning or classical conditioning) may be employed to elicit voluntary cooperation with procedures. Habituating animals to routine husbandry, veterinary or experimental procedures is encouraged as it may assist the animal to better cope with a

captive environment by reducing stress associated with those procedures . The type and duration of habituation or training needed will be determined by the individual species as well as by the complexity or frequency of the procedure.²

371.2.5 The social and environmental enrichments prescribed in this document have been demonstrated to promote animal wellbeing while enabling valid research. The IACUC assumes that investigators have sufficient knowledge of the species used and their model systems to take into account their associated needs and to scientifically justify any exceptions or enhancements from the minimum.

371.3 Abbreviations and Definitions

371.3.1 “Animal” – for purposes of the default enrichment program, “animal” is defined as to comprise all vertebrate species used in research at Emory University with the exception of nonhuman primates covered by a separate policy and program.

371.3.2 AWAR – Animal Welfare Act Regulations. Detailed regulations and standards for implementing the federal Animal Welfare Act of 1966 and subsequent revisions. Found in Title 9 of the Code of Federal Regulations (9CFR), Chapter 1, Subchapter A, Parts 1, 2 and 3.

371.3.3 Social Animals – Animals are considered to be social if during the adult stages of ontogeny they are found in groups of two or more individuals under natural ecological conditions. All plans for socialization should take into account the needs and natural history of the species at hand.

371.3.4 Enrichment – Animal management principles that attempt to enhance the quality of care by identifying and providing the environmental stimuli necessary for psychological and physiological wellbeing meets the definition of “enrichment”.⁷ Effective enrichment is based on the species’ natural history and activity budgets, encourage beneficial species-specific behaviors, and are driven by specific goals (e.g., increase foraging behavior, decrease aggression, etc.).⁸

371.4 General Principles

371.4.1 Social animals will be housed in compatible pairs or groups, rather than individually, provided such housing is not contraindicated by the protocol in question and does not pose undue risk to the animals in question.² When individuals of social species are housed in a solitary arrangement, auditory, visual and/or olfactory contact to compatible individuals must be provided.

371.4.2 The structural habitat will include objects that increase opportunities for the expression of species-typical postures and activities that enhance the animals’ well-being.²

371.4.3 When social animals must be housed alone, other forms of enrichment must be provided to compensate for the absence of other animals unless scientifically contraindicated.²

371.4.4 Exemptions from some or all of the requirements of the enrichment program for scientific reasons must be documented in the protocol and specifically approved by the IACUC.⁹

371.4.5 Qualified institutional veterinarians have the authority to exempt specific animals from inclusion in the enrichment program for reasons related to health, condition or well-being. The exemption and rationale must be documented in a medical record. For Act Species, veterinarians are obligated to review the status of the exemption at least every 30 days and renew it or void it accordingly (AWAR §3.8(d), §3.81(e)).

371.4.6 This program will be revised with the addition of new species to the census or in the case where significant new information emerges or approaches to enrichment come to be the norm.

371.5 Default Enrichment Program Description by Species

371.5.1 Aquatics (Hagfish, Lamprey, Zebrafish)

- **Minimum Requirements:** **Zebrafish** must be housed at densities that promote normal feeding and other behaviors and minimize aggression. For **Hagfish** a retreat space, either a darkened tank or sand in which to burrow, must be provided. The **lamprey** larval form requires sand in which to burrow and sustenance to filter feed. The pre-spawning adult form is parasitic and requires fish to feed. Post-spawning lampreys do not feed.
- **Additional Recommendations:** **Sea lamprey and hagfish** may be found as individuals or in groups in the wild – wherever a suitable habitat is found. Group housing is recommended, but not required. In the wild, **zebrafish** are found amid dense plant foliage, and also have been show to prefer structure in captivity.¹⁰ The provision of structure is recommended, in low-density housing and breeding tanks, but not required.¹¹

371.5.2 Birds (Passeriformes):

- **Minimum Requirements:** Individuals of social species must be housed in appropriate group sizes with compatible individuals.^{12, 13} A shelter (e.g., shelves or nest/roost boxes) must be provided to allow birds to nest and roost (Association of Avian Veterinarians 1999) and obtain refuge from aggression. Additional perches that allow for proper footing and minimization of foot trauma must be provided to allow Passeriformes the option to stay above the ground. Space within the enclosure must allow for exercise (i.e. flapping of wings) and the ability to express a range of natural behaviors.¹³
- **Additional Recommendations:** Housing birds in pens or aviaries versus cages is suggested as it provides more space for flight.¹³ Nesting material in the form of hay, shredded paper or other appropriate material should be provided for species that construct nests. A water (or sand) bath should be available at least weekly to promote bathing activity. As foraging and feeding are two of the most common behaviors of birds, the complexity of food acquisition should be manipulated (scattering seed on floor, placing produce between mesh, hanging feeders from ceiling, providing feed in nature form such as millet sprays) and selections of food varied to satisfy these needs.¹³ For birds in social housing, multiple food portions should be presented to reduce hording by dominant individuals. Grit should be provided when appropriate.^{14,15} Human interaction is encouraged and training birds to perform tasks by hand-feeding improves habituation to people.¹³

371.5.3 Galliforme Chicks:

- **Minimum Requirements:** Recently-hatched chicks and those up to 250 grams body weight (ca. 2-3

weeks of age) must be housed in brooders with a space requirement of 0.25 square feet per chick.² Substrate must be used to help the chicks maintain body temperature. Food and water must be provided in low profile linear troughs for ease of access and also to encourage foraging behavior. Any chicks remaining past 1.5 kg must be transferred to cages or pens with perches, litter and dust bath with a minimum of 1 square foot per bird.

371.5.4 Guinea Pigs:

- **Minimum Requirements:** Group-housing of compatible individuals is the standard housing option.¹⁶⁻¹⁸ Shelter must be provided and must provide sufficient canopy to accommodate each individual in the enclosure.¹⁹⁻²¹ PVC tubes, transparent red huts or other approved structures can be used to meet this requirement. Hay and approved produce must be placed in the enclosure or present in devices approved for guinea pigs to promote foraging behaviors and increase diversity of food items. Hay and/or produce must be given on a daily basis as a nutritional supplement to the regular diet to decrease risk of alopecia.²²
- **Additional Recommendations:** If permissible, human contact with guinea pigs (social- and single-housing) is recommended and contributes to positive social interactions.²³

371.5.5 Hamster:

- **Minimum Requirements:** Social housing is not required. Hamsters may be cohabitated if a stable group or pairing is established at a young age (The Laboratory Rabbit, Guinea Pig, Hamster, and Other Rodents).⁶ Nesting female hamsters, together with her litter, must be housed without other hamsters (The UFAW Handbook on the Care and Management of Laboratory and Other Research Animals, Eighth edition). Enrichment must include nesting material(s) and at least one other enrichment option.⁶
- **Additional Recommendations:** Other enrichment options include: shelters, tubes, lofts/platforms; gnawing devices (nylon chewing blocks/bones, aspen blocks, manzanita wood sticks); novel food and foraging opportunities (seeds, seed hulls, cereal, treats, vegetables); feed on the cage floor to allow normal caching behavior; positive human-animal interaction and training.²⁴

371.5.6 Mice:

- **Minimum Requirements:** Mice must be group or pair housed unless otherwise approved by the IACUC. However, the following exceptions may apply; (1) Adult male mice which are either unfamiliar or have been separated from stable social housing must be housed individually or with female mice for breeding; a male mouse, used as a stud for a few days, may be returned safely to the group if the cage has not been changed; (2) Mice may be held in cages as single pregnant females to prevent cage mate trauma or overcrowding in the case of harem or trio breeding;²⁵ and (3) the occasional finding of singly-housed mice because of the death of all others in the cohort or removal of cage mates at scheduled experimental time points. Minimum enrichment for socially housed mice: nesting materials in addition to the regular bedding.²⁶ Minimum enrichment for individually housed mice: extra nesting materials or shelter in addition to regular bedding and regular nesting materials. Options for nesting materials include nestlet pads, shredded paper or other approved nesting materials.^{5,27}

- Additional Requirements: Other enrichment options for mice include: shelters, tubes, lofts/platforms; gnawing devices (nylon chewing blocks/bones, aspen blocks, manzanita wood sticks), foraging opportunities with laboratory grade diets and running wheels.²⁶

-

371.5.7 Rabbits:

- Minimal Requirements: Rabbits that are compatible must be socially housed in pairs or groups. Singly housed rabbits must be provided with the ability for visual, auditory and olfactory association with conspecifics. Manipulanda such as toys must be provided. Food enrichment in addition to pelleted diet is required.
- Additional Recommendations: Enrichment devices should be rotated to ensure novelty, and elevated shelves should be provided to provide an area for resting.² Huts or boxes should be provided as a means for visual retreat in social housing situations. Handling and positive social interaction with animal care staff is encouraged. Rabbits housed in isolation should be provided mirrors, additional enrichment devices and additional positive human interaction.

371.5.8 Rats:

Minimal Requirements: Rats must be socially housed unless otherwise approved by the IACUC.^{3, 26, 28-30} However, the following exceptions may apply; (1) socially incompatible animals, such as in the case of sexually-mature, unfamiliar males (2) pregnant females (3) the occasional finding of singly- housed rats because of the death of all others in the cohort or removal of cage mates at scheduled experimental time points. The minimum enrichment for an individually housed rat is to provide shelter and/or nesting material^{5,27, 31-36} Tunnels, sections of PVC pipe, some type of nesting material³⁴ or shelters best serve this purpose. The quantity of the nesting material must be enough to cover the entire individual. When supplemented with nesting material, rats prefer long-fiber materials such as crinkled paper over nesting materials such as compressed cotton square.³²

Additional Recommendations: As rats are highly adaptable and readily acclimate to human handling and research procedures, acclimation and handling programs may be beneficial and should be considered.³⁷ Some research procedures may qualify as positive human animal interaction. Shelter and nesting material as described above can also be used for socially housed animals, provided it still allows for animals to move normally. Other enrichment options for rats that scientists may elect and that must be disclosed in the protocol include increasing cage complexity by using lofts/platforms gnawing devices (nylon chewing blocks/bones, aspen blocks, manzanita wood sticks), foraging opportunities with laboratory grade diets,³⁸ and positive human-animal interaction and training.³⁷

371.5.9 Sheep:

- Minimum Requirements: Sheep must be socially housed in stable, compatible pairs or small groups. If sheep are individually housed for approved research purposes, position them in such a way that they can see at least one other conspecific, because visual isolation is stressful for sheep. If other sheep are unavailable, a mirror may alleviate isolation stress. However, because sheep appear to treat their own reflection as a strange individual, a mirror may cause social stress.^{39, 40} Careful monitoring and adjustments of mirror placement are necessary. Where there is likelihood of a single sheep remaining on census at a single site, experimental plans must account for the timely use of the remaining animal. Sheep are particularly susceptible to isolation stress and those not coping with social isolation

will be subject to IACUC endpoints including veterinary interventions (e.g., tranquilization) or euthanasia.

- **Additional Recommendations:** Species-appropriate bedding such as straw or wood shavings is recommended and should be provided to enclosures when possible. Sheep should be provided a diet high in roughage, to allow species-typical feeding and rumination, and to reduce the likelihood of abnormal behaviors. An undesirable behavior called wool biting may develop in sheep confined indoors for prolonged periods due to a paucity of roughage or other environmental stimulation. Strategies used to prevent or decrease this behavior include access to outdoor pastures, hanging chains from above the surface of the pen or adding objects to the pen (e.g., basketballs, plastic bottles, or chewing bars), playing music and altering the diet.⁴¹ Stressful research manipulations (e.g., venipuncture, drug application) should be accomplished within the presence of a familiar conspecific. Care personnel should habituate animals that are subjected to experimentation or any new, stressful or fear-inducing situations.⁴⁰ Emphasizing positive reinforcement training techniques to encourage voluntary cooperation during common procedures such as blood collection and injection have been described in other ungulates and are recommended techniques for sheep whenever possible.

371.5.10 Swine:

- **Minimum Requirements:** Animals must be housed socially with compatible cage mates in suitable size runs or pens that allow them to turn around and move freely (unless justified, clinical, or in the case of a single animal which would receive special considerations). Within each enclosure, a toy or device must be provided to stimulate foraging.²
- **Additional Recommendations:** The use of visual barriers and separate feeding stations may help ameliorate aggression should that arise, as well as opportunities that encourage rooting, scratching and wallowing could be provided through the use of substrates (i.e. wood chips, wheat straw, or hay) and/or a scratching post or brush. Acclimation and training to any research equipment is encouraged and can be readily achieved by using food rewards.

371.5.11 Voles:

- **Minimal Requirements:** Voles must be housed in social groups^{42,43} with males closely monitored for fighting. However, retired male breeders can be housed individually since they may be incompatible with other males. To maintain pheromone cues, part of the old nesting material must be transferred to the new cage at cage change.⁴⁴ The housing requirement for space should minimally meet the “Guide” space requirements for hamsters. Minimum enrichment for socially housed voles: nesting material in the form of hay, straw, paper products such as crinkled paper or nestlets must be provided to fulfill burrowing needs in addition to the regular bedding.⁴⁵ For voles that are individually housed, chewing devices (nylon chewing blocks/bones, aspen blocks, manzanita wood sticks) must be provided in addition to regular enrichment.
- **Additional Recommendations:** As additional shelter, tunnels, such as a PVC pipe section, can be used. Other enrichment options for voles: foraging opportunities with laboratory grade diets or hay (Timothy cubes).

371.5.12 *Xenopus laevis*:

- **Minimum Requirements:** Adult *Xenopus laevis* must be housed in tanks with a population density not exceeding one per 2 liters tank water volume and as otherwise stipulated by facility SOP. With respect to the latter, water treatment, circulation and quality may stipulate that greater volumes be accorded per head. For frogs housed with direct exposure to room light, refuges or retreats must also be provided in the form of pipes, flower pots, floating lily pads, or submerged plastic boxes unless the environment is already sufficiently dark. For tanks with young froglets who are typically weaker swimmers, small, floating balls must be placed in the tanks to provide structure to which froglets can cling to so that they can “hang” and rest at the surface.⁴⁶
- **Additional Recommendations:** Although typically found solitary in the wild, African clawed frogs are often found socially housed in captivity. Maintaining *Xenopus* with familiar frogs in established, long-term housing cohorts is an advisable practice whenever possible.⁴⁶ An increase in aggression may be observed if the stocking density is too high or there is no refuge cover available for lower ranking animals.⁴⁷ Other enrichment may be used as a form of refuge, which may include: rocks, foam pieces, larger rocks, tiles, cups, and other plants.⁴⁶

371.6 REFERENCES

1. Garner J. P. 2005. Stereotypes and other abnormal repetitive behaviors: Potential impact on validity, reliability, and replicability of scientific outcomes. *ILAR J* 46(2): 106-17.
2. Institute for Laboratory Animal Research (2011). The Guide for the Care and Use of Laboratory Animals, 8th edition. National Research Council, Washington, DC.
3. Baumans V. 2005. Environmental enrichment for laboratory rodents and rabbits: Requirements of rodents, rabbits and research. *ILAR J* 46(2): 162-70.
4. Benefiel A. C., Dong W. K., and W. T. Greenough. 2005. Mandatory “enriched” housing of laboratory animals: The need for evidence-based evaluation. *ILAR J* 46(2): 95-105.
5. Hutchinson E., Avery A. and S. VandeWoude. 2005. Environmental enrichment for laboratory rodents. *ILAR J* 46(2): 148-61.
6. Weed J. L., and J. M. Raber. 2005. Balancing animal research with animal well-being: Establishment of goals and harmonization of approaches *ILAR J* 46(2): 118-28.
7. Sheperdson, D.J., Mellen, J.D., and Hutchins M. 1998. Second Nature, Environmental Enrichment for Captive Animals, Smithsonian Institute Press, Washington and London.
8. Mellen, J. and Sevenich Macphee, M. 2001, Philosophy of environmental enrichment: Past, present and future. *Zoo Biol.*, 20: 211-226.
9. National Institute of Health, Office of Laboratory Animal Welfare, Institutional Animal Care and Use Committee Guidebook, 2nd ed., MD, 2002, p.50.
10. Kistler, C., Hegglin, D., Wurbel, H., and Konig B., 2011, Preference for structured environment in zebrafish (*Danio rerio*) and checker barbs (*Puntius oligolepis*). *Applied Animal Behavior Science*, 135 (4): 318.
11. Collymore, C., Lawrence, C., and Lieggi, C. 2014. Enrichment for Laboratory Zebrafish (*Danio rerio*). *Laboratory Animal Science*, vol 2(3): 51-54.

12. Lickliter R, Dyer AB, McBride T (1993) Perceptual consequences of early social experience in precocial birds. *Behavioral Processes* 30: 185-200.
13. Hawkins, P., Morton, D.B., Cameron, D., Cuthill, I., Freire, R., Gosler, A., Healy, S., Hudson, A., Inglis, I., Jones, A., Kirkwood, J., Lawton, M., Monaghan, P., Sherwin, C. and Townsend, P. 2001. Laboratory birds: refinements in husbandry and procedures. Fifth report of BVA/AFW/FRAME/RSCPA/UFWA [British Veterinary Association Animal Welfare Foundation/Fund for the Replacement of Animals in Medical Research/Royal Society for the Prevention of Cruelty to Animals/Universities Federation for Animal Welfare] Joint Working Group on Refinement. *Laboratory Animals* 35 (Supplement): 1-163.
14. Gionfriddo, J.P. and Best, L.B. 1996. Grit color selection by house sparrows and northern bobwhites. *Journal of Wildlife Management* 60:836-842.
15. López-Calleja, M.V., Soto-Camboa, M. and Rezende, E.L. 2000. The role of gastrolites on feeding behavior and digestive efficiency in the Rufous-collared Sparrow. *Condor* 102:465-469.
16. Berryman, J. 1978. Social behaviour in a colony of domestic guinea pigs: Aggression and dominance. *Zeitschrift fur Tierpsychol* 46:200-214.
17. Kaiser, S., Nübold, T., Rohlmann, I. and Sachser, N. (2003) Pregnant female guinea pigs adapt easily to a new social environment irrespective of their rearing conditions. *Physiological Behavior* 80: 147-153.
18. Donnelly, T. and Brown, C. 2004. Guinea pig and chinchilla care and husbandry. *Veterinary Clinics of North America: Exotic Animal Practice* 7: 351-373.
19. King, J. 1956. Social relations of the domestic guinea pig living under semi-natural conditions. *Ecology* 37: 221-228.
20. Scharmann, W. 1991. Improved housing of mice, rats and guinea pigs: A contribution to the refinement of animal experiments. *Alternatives to Laboratory Animals* 19: 108-114.
21. Banjanin, S., Barley, J., Bell, L., Cunneen, M., Johnston, H., Quintero, I., Weilemann and Reinhardt, V. (2004). Environmental enrichment for guinea pigs: a discussion by the laboratory animal refinement and enrichment forum. *Animal Technology and Welfare* 3:161-163.
22. Gerold, S., Huisinga, E., Iglauer, F., Kurzawa, A., Morankic, A. and Reimers, S. 1997. Influence of feeding hay on the alopecia of breeding guinea pigs. *Journal of Veterinary Medicine Series A* 44: 341-348.
23. Anderson, L. 1987. Guinea pig husbandry and medicine. *Veterinary Clinics of North America: Small Animal Practice* 17: 1045-1060.
24. (Pawlowicz *et al.*, 2010)
25. (Coviello-McLaughlin *et al.*, 1997)
26. Smith A. L., and D. J. Corrow (2005) Modifications to husbandry and housing conditions of laboratory rodents for improved well-being. *ILAR J* 46(2): 140-47.
27. Belz, E.E., J.S. Kennell, R. K. Czambel, R.T. Rubin and M.E. Rhodes. 2003. Environmental enrichment lowers stress-responsive hormones in singly housed male and female rats. *Pharmacology, Biochemistry and Behavior* 76: 481-486.
28. Hurst, J.L., Barnard, C. J., Nevison, C. M. and West, C.D.1997. Housing and welfare in laboratory rats: Welfare implications of isolation and social contact among caged males. *Animal Welfare* 6, 329-347.
29. Hurst, J.L., Barnard, C. J., Nevison, C. M. and West, C.D.1998. Housing and welfare in laboratory rats: The welfare implications of social isolation and social contact among females. *Animal Welfare* 7, 121-136.

30. Winnicker, C., B. Gaskill, J. Garner, and K. Pritchett-Corning. 2012. *A Guide to the Behavior and Enrichment of Laboratory Rodents*. Published by Charles River Laboratories.
31. Manser, C. E., Broom, D. M., Overend, P. and Morris, T. H. 1998. Operant studies to determine the strength of preference in laboratory rats for nest-boxes and nesting materials. *Lab. Anim.*, 36-41.
32. Manser, C. E., Broom, D. M., Overend, P. and Morris, T. H. 1998. Investigations into the preferences of laboratory rats for nest-boxes and nesting materials. *Lab. Anim.*, 32, 23-35.
33. Patterson-Kane, E. G. 2004. Enrichment of laboratory caging for rat: a review. *Animal Welfare*, 13, S209-S214.
34. Van Loo P.L. and V. Baumans. 2004. The importance of learning young: The use of nesting material in laboratory rats. *Lab Animal* 38: 17-24.
35. Blom, H. et al. 1996. Preferences of mice and rats for types of bedding material. *Laboratory Animals*, 30, 234-244.
36. Jegstrup, I. M., Vestergaard, R., Vach, W. and Ritskes-Hoitinga, M. 2005. Nest-building behavior in male rats from three inbred strains: BN/HsdCpb, BDIX/Orlco and LEW/Mol. *Animal Welfare*, 14, 149-156.
37. Davis, H. and Perusse, R. 1988. Human-based social interaction can reward a rat's behavior. *Learning and Behavior*, 16, 89-92.
38. Johnson, S. R., Patterson-Kane, E. G. and Niel, L. 2004. Foraging enrichment for laboratory rats. *Animal Welfare*, 13, 305-312.
39. Parrott, R.F., Misson, B.H., and de la Riva, C.F. 1994. Differential stressor effects on the concentrations of cortisol, prolactin and catecholamines in the blood of sheep. *Res. Vet Sci.*, 56(2): 234-239.
40. Hinch, G. N., and J. J. Lynch. "Comfortable quarters for sheep and goats." *Comfortable Quarters for Laboratory Animals Reinhardt V (ed)* (1997): 94-100.
41. McGlone, J., Swanson, J., et al. 2010. Guide for the Care and Use of Agricultural Animals in Research and Teaching, 3rd edition. Federation of Animal Science Societies, Champaign, IL.
42. Clarke, J. 1999. Voles. *In: The UFAW Handbook on The Care and Management of Laboratory Animals*, seventh edition, volume 1, chapter 20, pp. 331-344, 1999.
43. Donnelly, T.M. and Quimby F.W. 2002. Biology and Diseases of Other Rodents. *In: Laboratory Animal Medicine*, 2nd edition, chapter 7, pp. 279-281.
44. Solomon, N.G. and Vanderbergh, J.G. 1994. Management, Breeding, and Reproductive Performance of Pine Voles. *Laboratory Animal Science*. 44(6): 613-617, 1994.
45. Odberg, F. O. 1987. The influence of cage size and environmental enrichment on the development of stereotypies in bank voles (*Clethrionomys glareolus*). *Behavioral Processes*. 14 (2):155-173, 1987.
46. Chum, H., Felt, S., Garner, J. and Green, S. 2013. Biology, behavior, and environmental enrichment for the captive African clawed frog (*Xenopus spp*). *Applied Animal Behaviour Science*, 143: 150-156.
47. Torreilles, S.L and Green, S.L. 2007, Refuge Cover Decreases the Incidence of Bite Wounds in Laboratory South African Clawed Frogs (*Xenopus laevis*). *JAALAS* 46(5): 33-36.

371.6.2 Additional References

- Archard, G.A. 2012. Effects of enrichment on the behavior and growth of juvenile *Xenopus laevis*. *Applied Animal Behaviour Science*, 139: 264-270.
- Association of Avian Veterinarians (1999) Basic Pet Bird Care. www.aav.org/basic_care.htm
- Baxter M.R. 1994. The welfare problems of laying hens in battery cages. *Vet Rec* 134(24):614-9.
- Bayne K.A. Environmental enrichment of nonhuman primates, dogs and rabbit used in toxicology studies. *Toxicologic Pathology*. 31(Suppl.): 132-137, 2003.
- Bayne K.A. 2005. Potential for unintended consequences of environmental enrichment for laboratory animals and research results. *ILAR J* 46(2): 129-39.
- Beattie, V.E., 1995. Effect of rearing environment and change of environment on the behavior of gilts. *Applied Animal Behavior Science*. 46: 57-65.
- Benefiel A. C., Dong W. K., and W. T. Greenough. 2005. Mandatory “enriched” housing of laboratory animals: The need for evidence-based evaluation. *ILAR J* 46(2): 95-105.
- Bingham, W.E., and W.J. Griffiths, Jr. 1952. The effect of different environments during infancy on adult behavior in the rat. *J Comp Physiol Psychol* 45: 307-312.
- Brown, M.J. and Nixon, R.M. 2004. Enrichment for the captive environment-The *Xenopus laevis*. *Animal Technology and Welfare*, 3(2): 87-95.
- Cowan D.P. Group living in the European rabbit: mutual benefit or resource localization? *Journal of Animal Ecology*. 56:779-795, 1987.
- Craig JV. Swanson J.C. 1994. Review: welfare perspectives on hens kept for egg production. *Poultry Science*. 73(7):921-38.
- Cravener T.L. Roush W.B. Mashaly M.M. 1992. Broiler production under varying population densities. *Poultry Science*. 71(3):427-33.
- Crockram, M.S., Ranson, M., Imlah, P., Goddard, P.J., Burells, C., and Harkiss, G.D. 1994. The behavioural, endocrine and immune responses of sheep to isolation. *Animal Production*, 58: 389-400.
- Dawkins M.S. Donnelly C.A. Jones T.A. 2004. Chicken welfare is influenced more by housing conditions than by stocking density. *Nature*. 427(6972):342-4.
- de Groot, J., de Jong, I.C., Prelle, I.T., and Koolhaas, J.M.. 2000. Immunity in barren and enriched housed pigs differing in baseline cortisol concentration. *Physiol Behav* 71(3-4): 217-23.
- de Jong, I.C., Prelle, I.T., van de Burgwal, J.A., Lambooi, E., Korte, S.M., Blokhuis, H.J., and Koolhaas, J.M. 2000. Effects of environmental enrichment on behavioral responses to novelty, learning, and memory, and the circadian rhythm in cortisol in growing pigs. *Physiol Behav*. 68(4): 571-8.
- de Jong, I.C., Ekkel, E.D., van de Burgwal, J.A., Lambooi, E., Korte, S.M., Ruis, M.A., Koolhaas, J.M., Blokhuis, H.J. 1998. Effects of strawbedding on physiological responses to stressors and behavior in growing pigs. *Physiol. Behav*. 64(3): 303-10.
- Dwyer, C.M. and Bornett, H.L.I. 2004. Chronic stress in sheep: assessment tools and their use in different management conditions. *Animal Welfare*, 13: 293-304.
- Forgays, D.G. and J.M. Read. 1962. Crucial Periods for free-environmental experience in the rat. *J Comp Physiol Psychol*

55: 816-818.

Fraser, A.F. and Broom, D.M. 1997. Farm animal behaviour and welfare. CAB International: New York, New York.

Gaunt A.S. and L.W. Oring, eds. 2010. Guidelines to the Use of Wild Birds in Research. 3d ed. North American Ornithological Council, Washington, D.C.

Grandin, T., 1983. The effects of rearing environment on the behavior of young pigs. *Journal of Animal Science*, 57 (supplement 1): 137.

Grandin, T. 1987. Toys, mingling and driving reduce excitability in pigs. *Journal of Animal Science*, 65(1): 230-231.

Grandin, T. 1988. Environmental enrichment for confinement pigs. *Livestock Conservation Institute Proceedings*.

Greenough, W.E. and A. Benefiel. 2003. Enriching the housing of the laboratory rodent: How might it affect research outcomes? "The Development of Science-based Guidelines for Laboratory Animal Care" National Academy of Sciences. Proceedings of the November 2003 International Meeting.

Halliday, T.R. 1999. Amphibians In: *The UFAW Handbook on The Care and Management of Laboratory Animals*, seventh edition, volume 2, chapter 6, pp. 90-102.

Hargreaves, A.L. and Hutson, G.D. 1990. Some effects of repeated handling on stress responses in sheep. *Applied Animal Behaviour Science*, 26: 253-256.

Harper, C., & Lawrence, C. (2010). *The Laboratory Zebrafish*. Boca Raton: CRC Press.

Harris, LD, Custer, LB, Soranaka, ET, Burge, J, Ruble, GR. 2001. "Evaluation of Objects and Food for Environmental Enrichment of NZW Rabbits". *JAALAS* 40 (1), pp27-30.

Hayes, M.P., Jennings, M.R. and Mellen, J.D. 1998. Enrichment for amphibians and reptiles. In: *Second Nature- Environmental enrichment for captive animals*, Smithsonian Institute, Washington, pp. 205-235.

Hebb, D.O. 1949. *The Organization of Behavior*. New York: John Wiley & Sons.

Hilken, G., Dimigen, J., and Iglauer, F. 1995. Growth of *Xenopus laevis* under different laboratory rearing conditions. *Laboratory Animals*, 29: 152-162.

Hill, J.D. 1998. Environmental enrichment influences on pig behavior, performance and meat quality. *Applied Animal Behavior Science*, 57: 51-68.

Hinch, G.N. and Lynch, J.J. (1995). Comfortable quarters for sheep and goats. Department of animal science, University of New England, Armidale NSW 2350, Australia.

Johnson, CA, Pallozzi, WA, Geiger, L, Szumiloski, JL, Castiglia, L, Dahl, NP, Destefano, JA, Pratt, SJ, Hall, SJ, Beare, CM, Gallagher, M, Klein, HJ. 2003. "The Effect of an Environmental Enrichment Device on Individually Caged Rabbits in a Safety Assessment Facility". *JAALAS* 42 (5), pp27-30.

Jones R.B., Carmichael N.L., and E. Rayner. 2000. Pecking preferences and pre-dispositions in domestic chicks: implications for the development of environmental enrichment devices. *Appl Anim Behav Sci* 69(4): 291-312.

Kreger, M.D. 2002. Comfortable Quarters for Amphibians and Reptiles in Research Institutions. In: *Comfortable Quarters for Laboratory Animals*, Reinhardt, V. and Reinhardt A. (eds). Animal Welfare Institute, Washington DC, pp. 109-114.

Kulpa-Eddy, J.A, Taylor, S, and K.M. Adams. 2005. USDA perspective on environmental enrichment for animals. *ILAR*. 46(2): 83-94.

Laboratory Animal Medicine Edited by James G. Fox, Lynn C. Anderson, Franklin M. Loew, Fred W. Quimby. Page 1245

Lawrence, C. (2007). The husbandry of zebrafish (*Danio rerio*): A review. [Review]. *Aquaculture*, 269(1-4), 1-20. doi: 10.1016/j.aquaculture.2007.04.077

Lawrence, C. (2011). Advances in zebrafish husbandry and management. *Methods Cell Biol*, 104, 429-451. doi: B978-0-12-374814-0.00023-9 [pii]10.1016/B978-0-12-374814-0.00023-9

Lynch, J.J., Hinch, G.N., and Adams, D.B. 1992. *The behaviour of sheep: Biological principles and implications for production*. CAB International & Commonwealth Scientific and Industrial Organization (CSIRO): Wallingford.

Major, N. and Wassersurg, R.J. 1998. Survey of Current Techniques in the Care and Maintenance of the African Clawed Frogs (*Xenopus laevis*). *Contemporary Topics*, 37(5), pp. 57-60.

Mateo, J.M., Walker, R.I., Cullis, B.R., and Luff, M.F. 1991. Effects of differential handling on the behaviour of domestic ewes (*Ovis aries*). *Applied Animal Behaviour Science*, 32: 45-54.

Moncek, F., R. Duncko, B.B. Johansson, and D. Jezova. 2004. Effect of environmental enrichment on stress related systems in rats. *J Neuroendocrinology* 16: 423-431.

Morgan, C.A. 1998. The effects of straw bedding on the feeding and social behavior of growing pigs fed by means of single-space feeders. *Applied Animal Behavior Science*, 58: 23-33.

Nepote, K. 1999. Pigeon housing: practical considerations and welfare implications. *Lab Animal* 28: 34-37.

Ramsay, J. M., Feist, G. W., Varga, Z. M., Westerfield, M., Kent, M. L., & Schreck, C. B. (2006). Whole-body cortisol is an indicator of crowding stress in adult zebrafish, *Danio rerio*. *Aquaculture*, 258(1-4), 565-574. doi: 10.1016/j.aquaculture.2006.04.020

Reed, B.T. Guidance on the housing and care of the African clawed frog-*Xenopus laevis*. Research Animals Department-RSPCA. 2005.

Rodarte, L.F., et al. 2004. The effect of environmental manipulation on behavior, salivary cortisol, and growth of piglets weaned at 14 days of age. *J Appl Anim Welf Sci*, 7(3): 171-9.

Sanotra G.S., Lawson L.G., and K.S. Vestergaard. 2001. The Influence of Stocking Density on Tonic Immobility, Lameness and Tibial Dyschondroplasia in Broilers. *J Appl Anim Wel Sci* 4(1): 71-87.

Schmorrow DD, Ulrich RE (1991) Improving the housing and care of laboratory pigeons and rats. *Humane Innovations and Alternatives* 5: 299-304

Schultz, T.W. and Dawson, D.A. 2003. Housing and Husbandry of *Xenopus* for oocyte production. *Lab Animal*, 32(2): 34-39.

Second report of the BVAAWF/FRAME/RSPCA/UFAW joint working group on refinement. 1993. *Laboratory Animals*. 27:301-329

Taylor R.E., Field T.G. 2004. *Scientific Farm Animal Production: An Introduction to Animal Science*, 8th ed., Pearson Prentice Hall, Upper Saddle River, N.J., pp. 644-47.

The Laboratory Rabbit, Guinea Pig, Hamster, and Other Rodents Edited by Mark A. Suckow, Karla A. Stevens, Ronald P. Wilson. Pages 765-766

The UFAW Handbook on the Care and Management of Laboratory and Other Research Animals, Eighth Edition Edited by Robert C. Hubrecht, James Kirkwood .Page 349

Virginia Cooperative Extension Service: <http://www.ext.vt.edu/pubs/poultry/factsheets/5.html>

371.7 Document Properties

Authored by: IACUC

Administering Division/Department: IACUC Office

Original Approval Date: 12/03/2008

Last Review/Revision: 05/04/16

Effective:05/04/16

Version: v. 20160504