


Communication

Confronting Back-of-House Traditions: Primates as a Case Study [†]

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[†] Dedicated to the memory of Steve Ross.

Abstract: This review commentary focuses on traditional management practices and facility design with suggested improvements in non-public primate management areas, often called “back-of-house”, (henceforth BOH) in zoos, sanctuaries, and research facilities. Progress has been made toward improving animal quality of life in larger, more naturalistic, and enriched indoor and outdoor display areas. However, the quality of life in BOH areas has improved little in comparison. Basic management, regulatory, structural, and spatial BOH environments are lagging, especially in the developing world, and animals may be confined in less enriching spaces for substantial periods of the 24 h day. We reviewed traditional management policy and practice, as well as newer training, enrichment, and welfare policies and actions, and suggested alternatives for structural environments and spatial environments. The suggestions included using more animal-friendly construction materials and animal–computer interaction, providing greater control of the ambient environment and choice of access to multiple areas by the animals themselves, and designing for optimal animal wellbeing at all times, including when caregivers are no longer present. Case studies focused on primates were included. We concluded by suggesting a new, integrated design model based not upon rote standards and old models but building on empirical foundations while embracing empathy and innovation.

Keywords: back-of-house (BOH); animal welfare; primates; integrated zoo design model; zoo design; primate sanctuary; primate research laboratory; zoo; 24/7



Citation: Brando, S.; Coe, J. Confronting Back-of-House Traditions: Primates as a Case Study. *J. Zool. Bot. Gard.* **2022**, *3*, 366–397. <https://doi.org/10.3390/jzbg3030029>

Academic Editor: Lisa Lauderdale

Received: 10 February 2022

Accepted: 16 June 2022

Published: 26 July 2022

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1. Introduction

In this overview and commentary, we propose a new approach to the design and management of primate restricted, back-of-house (BOH) areas in zoos, sanctuaries, and research facilities. While these considerations could be applied to the management of a wide range of taxa, this paper focuses on primates. Our observations and ideas are based on considerable personal experience of prior evolutions, developments, and innovations of many of the publicly visible exhibits, as well as the continuing but more limiting evolution of BOH facilities. We find animal welfare data on BOH areas to be limited, but we do cite some useful examples [1–3]. Today, a plethora of studies are available proposing and illustrating the benefits of changes made in main exhibits, from older, barren cages and pits to complex, immersive environments including a widening variety of opportunities, choice, and control, including access to vegetation, views, shade, and more (for example, [3–6]). Our proposal is to extend these opportunities to all BOH areas.

This commentary is organized into six main areas: (1) defining back-of-house areas, (2) discussing management and operational environments (past, present, and future), (3) addressing structural or built environments, (4) considering spatial and ambient environments, (5) proposing a new synthesis, and (6) an appendix of brief exemplar case studies. We suggest an innovative blending of evidence-based and action-based design and management to improve the wellbeing of both animals and animal care staff in BOH

environments. We hope this paper is valuable for a wide international audience of animal managers, care givers, researchers, architects, and students.

1.1. Defining Back-of-House (BOH)

BOH areas in zoos have many names, e.g., off-exhibit area, holding area, retiring area, boma, bedroom, sleeping den, night house, etc. For the rest of this paper, we use BOH when referring to all animal areas that are not main public exhibit areas or large indoor or outdoor enclosures. While many animals in zoos and sanctuaries live day and night, 24/7 (e.g., twenty-four hours each day across their lifespan), in their public exhibit or primary enclosures, this paper focuses on conditions in which primates live in confined areas or are moved to confined areas overnight or for other extended times for management purposes. These areas are not normally open to the public.

In zoos and sanctuaries, BOH areas are used to safely confine primates during times when management staff are off work; when primary exhibit areas are being cleaned, provisioned, or repaired; during quarantine periods; and for individuals who become incompatible with the social group. In research laboratories using primates, small areas are used to house primates during certain research procedures. The restrictions placed on animals in BOH areas compared to primary display areas are summarized in the next section.

1.2. Types of BOH Structures

Animals can be kept in several types of BOH facilities, depending on climate and public access. The different areas we identified are:

1. Indoor group area. This is usually a cold-season public display area, sometimes called a 'day room', but can also be used as a BOH 'community room' overnight when neither guests nor staff is present.
2. Indoor isolation "shift" area. These small, off-display areas are used for moving animals from one area to another and should be used only for short terms, i.e., shifting animals, cleaning, feeding, training, medical examination, treatment, and recovery. These areas might also be designed as refuges in case of severe storms or fire emergencies.
3. Separate, off-display areas for individuals and groups, either outdoors with shelters in warm climates or indoors and outdoors in colder climates. Larger facilities may need additional areas. These include off-display "exercise areas" for individuals or small groups needing long-term separation from the main group, such as bachelor male groups or low-ranking individuals ejected by the main group. Additional areas may also be necessary for geriatric and quarantined animals.
4. Raceways (enclosed animal pathways, either overhead or on the ground) connecting enclosures can also become enrichment opportunities when they provide access to additional opportunities such as exercise or viewpoints of interest for primates.

1.3. Summary of BOH Issues

Our first concern is that many common management and design features of BOH facilities place limits on optimal animal welfare [7,8]. Common limiting features include a lack of choice, control, and occupation; limited viewing and locomotive opportunities; and unbiological [5,7], sterile, rigid, and unvaried environments. These are very different from the complex and changing habitats in which the species evolved. Thus, we are concerned about the use, size, and quality of BOH areas.

Our second overall concern is the amount of time many animals are confined in BOH enclosures with limited behavioral opportunities [9]. Commonly, primates with adequate activity opportunities on-exhibit are required to spend up to sixteen of twenty-four hours in small, choice- and opportunity-poor BOH enclosures. A quick calculation illustrates the time an animal could spend in BOH facilities: $365 \times 16/24 = 243$ days a year.

The time that an animal can potentially spend in the BOH is more days per year than out in the more opportunity-rich exhibit unless primates have continued access to such areas. While this time may vary depending on the management practices and local climate, it still is a lot of time in areas that we sometimes refer to as ‘temporary holding’. A revolution of the BOH areas is needed to promote optimal wellbeing, 24/7, across animal lifespans.

Figure 1 illustrates the staff time use observed by Brando and Buchanan-Smith [7] for a typical day at a zoo. These characteristic time budgets show the hours most caregivers are absent from primates (black) and all the activities they may be tasked with, reducing time for animal observations, environmental enrichment, and other activities promoting good welfare. While the staff arrives before the public and leaves after the zoo is closed, the animals are brought in earlier to facilitate closure. If a primate facility closes in winter at 4 o’clock, care staff could start bringing in the animals around 3 o’clock, depending on procedures and how well the animals are trained to shift between enclosures.

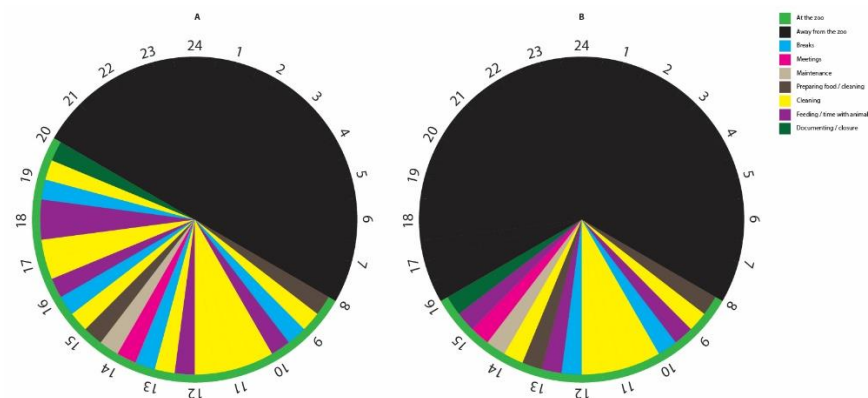


Figure 1. A 24/7 clock example simulating (A) summer and (B) winter working hours of care staff in a zoo that varies opening hours according to daylight hours [7].

Even accepting that wild primates may sleep twelve hours a day, it is not acceptable that animals can be confined to small areas for such extended periods because of caregiver work schedules, operating costs, and regulatory requirements. If policy dictates animals must be fully confined when staff are not present—apart from, for example, most species of waterfowl [10]—and, therefore, animal needs and preferences are not met, alternative strategies must be activated. A solution may be to provide large, all-weather, enriched, enclosed areas, on- or off-exhibit (see examples and case studies later in this paper) in which animals can spend the great majority of their lives. It may be necessary to have a number of these 24/7 facilities because in any social group there are usually some individuals ostracized or animals who need special care.

Our third concern is the lack of research concerning the suitability of BOH conditions. It is generally accepted and supported by management regulations that non-human primates in zoos should live in species-specific, custom-made environments considering individual needs and preferences, offering complexity, allowing for choice, and affording some control [7,9]. However, the BOH areas for many taxa seem similar, regardless of the species they were designed for. We have observed little positive evolution in BOH area design, and these areas are less frequently researched. While there have been recent studies of primate night activities, “... the majority of research on zoo animals has been conducted during daytime, therefore biasing the research evidence towards human working hours rather than following the animal’s life cycle and activity budget” S. Brando, animal welfare scientist [11]. There are also a few studies on sleep and rest, nest building, and the effects of open access to indoor and outdoor areas [5,7].

Our fourth concern is the slow pace of BOH improvements. The discussion on improving BOH areas is not new, and many of the topics discussed in this paper can be

found in earlier best-practice care manuals [12,13] and articles [5,14]. However, we fail to see many excellent recommendations acted upon or a broad, integrated list of alternative directions produced for BOH design. Therefore, we review the general policies and practices upon which the design and management of such facilities are based and suggest promising alternatives. Ultimately, BOH facilities must also support the organization's conservation and research objectives and, where BOH visitor tours are conducted, their public education objectives.

1.4. *Understanding the Past*

Modern architectural functionalism, the philosophy behind the design of most BOH facilities, celebrates simplicity, functionality, hygiene, and standardization and shares an anthropocentric perspective from earlier eras when animals were managed as objects for human use and enjoyment. The past lack of veterinary knowledge placed greater emphasis on sanitation than on psychological wellbeing [9,15]. Worker objectives were focused more on efficiency than on promoting optimal animal welfare. Animal management standards and regulations co-evolved with facility design but lagged in design innovations. Today, we still find this focus on efficiency, functionality, and standardization in BOH design requirements, ranging from government regulations to species care and best-practice manuals.

Standardization and regulation are slow, enduring processes, establishing minimum allowable practices that, for convenience or cost, tend to become customary practice. When designers begin planning new or renovated BOH areas, they use existing standards as models. Eventually, copies of copies are copied, perpetuating what we now see as inherent limitations. These considerations, together with normal risk aversion, tend to discourage innovation.

1.5. *Standards and Norms: Defining the Problem*

This is a complex topic since many countries have national and even state animal welfare codes, and zoos, sanctuaries, and animal laboratories each have their own governing organization management policies, with details often subdivided by separate primate species. While a full review of this broad subject is beyond the scope of this study, the review of a few typical policies over time shows progress toward seeking improved animal welfare. For example, the 1985 Guide for the Care and Use of Laboratory Animals (Bethesda, MD, USA) [16] emphasized standardized features optimizing hygiene and worker efficiency. The 2011 edition of this same publication [17] is more focused on animal welfare.

Here follow some positive statements for modern zoo animal management standards supporting improvements that we suggest later in Sections 3 and 4.

Housing and husbandry: non-human primates. NC3Rs UK [18] provides very up-to-date recommendations for the management of primates in lab conditions.

The Exhibited Animals—Australian Animal Welfare Standards and Guidelines [19] require temperature and humidity gradients (p. 17) and state that “Species-appropriate lighting should mimic the light cycles, levels and spectral distribution normally experienced by the species in its wild habitat” (p. 18).

The American Zoo and Aquarium Association (AZA) Gorilla Species Survival Plan (SSP) [20], Item 12, p.10, calls for “. . . ambient gradients to be provided, and the assessment and enforcement of such standards will be fundamental” (compare to item 4.4 in this study).

The Secretary of State's Standards of Modern Zoo Practice 2012 (UK), Ref. [10], www.defra.gov.uk (accessed on 17 June 2022), defines animal welfare in a zoo environment: Item 10 requires that “An environment consistent with species requirements must be provided” and that “A balance must be struck between hygiene and the species biological requirements”.

The Central Zoo Authority of India Standards and Norms, 1992 edition, Animal Enclosures: Item 16, states that “All animal enclosures in a zoo shall be so designed as to meet the full biological requirements of the animals housed therein. The enclosures shall be of such size as to ensure that the animals get space for their free movement and exercise.”

Item 17 requires that “The zoo operators shall endeavour to simulate the conditions of the natural habitat of the animal in the enclosures as closely as possible” [21].

These quotes from a variety of international governing authorities appear satisfactory. What could be wrong? When visiting international zoo BOH facilities controlled by these standards, we typically find that they rarely meet these zoo-wide requirements. For example, when visiting zoos in India, Coe learned that BOH enclosures are governed by Item 18: “The enclosures housing the endangered . . . species . . . shall be feeding and retiring cubicles/cells of minimum dimension given in the said appendix. Each cubicle/cell shall have resting, feeding, drinking water and exercising facilities, according to the biological needs of the species. Proper ventilation and lighting for the comfort and well-being of animals shall be provided in each cell/cubicle/enclosure. Monkeys and langurs. 2.0 m × 1.0 m × 1.5 m.” How can “exercising facilities, according to the biological needs of the species” be accommodated in so small a space? Clearly, the intent is for brief use, yet we observed many species occupying these restrictive spaces for 16 h of the day. In modern western zoos seemingly controlled by welfare-oriented standards, we often see and have even designed facilities in which great apes, for example, spend most of the 16 h overnight period when care staff are off work in sterile, 5 m × 5 m × 3 m BOH enclosures. The obvious conclusion is that zoo welfare standards are reinforced selectively, favoring public display areas and day exhibits over BOH areas. Whether this is a result of a continuing reliance on “modern architectural functionalism” and human-oriented convenience, as suggested earlier, or simply tradition, this double standard greatly reduces the welfare of primates in many BOH environments.

While construction and operating costs can also limit innovation, careful and creative design need not result in excessive costs over the long term. Promoting optimal animal welfare is likely to increase animal care staff workloads or increase caregiver numbers. However, these costs must be considered holistically. We believe excellence in animal care supports excellence in staff morale, motivation, and professionalism, as well as in meeting community animal care and wellbeing expectations.

2. Management Environments

“Someone keeps raising the bar! Just when we are proudest of hard-won improvements for great apes in zoos, research centers or sanctuaries, we are confronted with demands to do better. These come from regulatory agencies, advocacy groups and the apes themselves. But most of all they come from our own dissatisfaction between what we see and what could be”.

J. Coe, zoo planner [22].

Advances in animal care and management techniques such as those discussed below often precede improvements in the design of built facilities, which usually take much longer to implement. Often, advanced management techniques such as positive reinforcement training, good caregiver–animal relations, and animal enrichment programs can compensate for some facility design limitations and suggest directions for future design improvements. Newer built environments must be designed to accommodate and support these management advances.

There are vast differences between what are considered “good” and “bad” zoos, sanctuaries, and animal research facilities. We use the term “professional” to indicate practices we consider to be good, holistic animal management with the animal, caregiver, and occasional BOH tour visitor in mind. Professionalism means continuing to ask if this is the best we can be and do, if it is in the best interests of the animals, and does it support good caregiver wellbeing and achieve education, research, and conservation goals? However, it must be noted that many zoos and related facilities globally rarely rise to this standard.

2.1. Animal Welfare

“Optimal animal welfare requires big ideas that enable zoos to live large, long and well.”

T. Maple, animal behaviorist [23].

While basic elements of welfare, such as freedom from pain and suffering, poor nutrition and health, and unsuitable physical and social environments, remain important both on-exhibit and in BOH areas, contemporary animal welfare encompasses environmental, behavioral, and psychological aspects, promoting positive welfare states [24] and necessarily subjective consideration of the animals' feelings [25]. Professional zoos and sanctuaries globally are evolving welfare standards from surviving (early modern zoos) to coping (better present zoos) to flourishing [26], promoting optimal animal welfare. One major trend gaining global support is considering animals' lives in terms of the Five-Domain Model [24]. This approach assesses welfare in an integrated, holistic manner, encompassing both negative and positive welfare states, with "extra points" awarded to positive states for: "(1) . . . availability of opportunities for animals to engage in self-motivated rewarding behaviors, (2) . . . actual use of those opportunities and finally, (3) . . . cautious judgements about the degrees of positive affective engagement the animals may experience" [22]. The animal competence model [27] supports an animal's ability to exercise choice, take control, engage in complexity, and experience variety, leading to lifelong physical and behavioral competence. A holistic animal welfare approach considers the whole of an animal's life and experiences 24/7 across its lifespan and must include all spaces an animal inhabits, including BOH areas [5,7]. Different yet collaborative tools for animal welfare assessment also further optimal welfare [28]. A universal animal welfare framework for zoos [14] and an animal welfare risk assessment process [29] can be used to identify risks and determine priorities, including those related to BOH areas.

2.2. Relative Freedom

A major frontier in welfare science and design is providing the animals themselves with greater degrees of agency and choice in their own lives and, thus, more relative freedom. Špinka noted the following: "Agency is a central adaptive characteristic of animal life" [30], and he proposed four levels of agency, namely (1) passive or reactive, (2) action-driven, competence-building, and aspirational agency.

A recent paper by Browning and Veit on the relationship between freedom and animal welfare in the wild and in zoos [31] demonstrated how the best zoos are increasing levels of instrumental, i.e., practical and actionable, freedom by providing animals in their care with enhanced agency, opportunity, and competence. While a broad discussion of this subject is beyond the scope of this work, we highlight this important insight:

"Proactive behaviour, as opposed to simply reacting, is important for the lives of most animals to ensure they do best in survival and reproduction. It is thus likely that such proactive behaviour will be guided by proximate mechanisms that are linked to welfare, such as preferences and positive affect. The very act of exercising such agency may itself be pleasurable, as well as building up competencies that allow the animal access to a greater range of future positive effects".

H. Browning, animal welfare researcher [31] (p. 8).

The welfare benefits of animal agency and control are related to opportunities provided in their environment. BOH environments are traditionally controlled entirely by human caregivers for passive animals. However, the examples cited below and, in the appendix, illustrate ways to greatly increase opportunities for the active exercise of agency by primates themselves.

2.3. Human–Animal Relationships

"In animal welfare, it is the animal's own perspective that matters—not ours".

H. Browning, [31] (p. 3).

Effective human–animal relationships include considering the lives and perspectives of animals and how they see us and their world. This is achieved using a balance of behavioral science and empathy and is fundamental to understanding how other animals see us [31–33] and determining which human actions may be perceived as enriching or

detrimental by the animal. Good human–animal relationships benefit new, well-designed environments. “A habitat that allows for a wide range of behaviors improves the ability of the caregiver/manager to detect changes in behavior more quickly”, T. L. Bettinger, animal behavioral management specialist [32–34] (p. 38).

Human–animal relationships and positive reinforcement staff and animal training (our next section) are mutually beneficial.

“Being able to build the relationship between staff and the animals is a huge payoff. If you spend more time with them, even if it’s in passing them and just being present, desensitizes them and they are more trusting and relaxed. I think that constant presence and activity is very reinforcing and enriching to the animals. We (animals and care staff) truly work together, every day, all day!”

(J. Franklin, Mammal Curator/Supervisor of Animal Training, Louisville Zoo. Personal communication, 19 February 2019).

2.4. Positive Reinforcement Training

“Mastering knowledge of what works in getting others to perform in a manner you wish is not the same as providing the opportunity for them to choose paths that are enriching.”
H. Markowitz, pioneering zoo animal behavior expert;

[35] (p. 228).

Positive reinforcement training (PRT) and good human–animal relationships facilitate day-to-day care, as well as enrichment, research, conservation, and educational activities. While PRT activities should be possible both on and off the exhibit, most management training occurs in BOH areas. PRT training programs have shifted from common, coercive practices to willing, voluntary collaboration by the animals [36,37]. These BOH PRT conditioning and management practices require care staff to have easy access to most animal areas, including transfer points and raceways (linear animal movement corridors). For example, staff pathways are often parallel to longer raceways. Continuous, or at least convenient, training access to all BOH animal areas must be considered during facility design. While training may initially take considerable time and effort and is a life-long process for both caregivers and animals, the resulting collaboration saves staff time in the long run.

2.5. Improving Management Operations

Much is required of modern animal caregivers. Daily tasks range from menial (e.g., cleaning up after animals and renewing substrates) to skilled and technical (e.g., preparing and dispensing complex diets and daily medications, animal training, behavioral observations, and data keeping). Combining safe and efficient BOH operations while ensuring time to foster close caregiver and primate relationships is essential. When considering management systems, we should explore which provide the best long-term, sustainable welfare outcome for all the stakeholders. Kelling et al. [38,39] showed how modern “human factors analysis” balanced with “animal factors design and operational sequence diagramming” can improve overall staff efficiency while supporting improved animal welfare. One interesting aspect of this approach is for caregivers to see animals as coworkers [36].

2.6. Applied and Built-in Environmental Enrichment

“The discrepancy between control of stimulus and response variables in captivity vs. natural environments, first elaborated by Hediger, may be the most fundamental issue in enrichment”.

Markowitz, [35], p. 228.

Professional environmental enrichment (EE) programs are strategic and goal-oriented, including social, sensory, nutritional, cognitive, and other species-specific and individual considerations. Biological and functional relevance to the animal is key when changes in the environment are made or when items are added that are meant to stimulate behavior [39–41].

Until recently, the EE focus has been on remedial enrichment compensating for program or facility deficiencies and has been directed toward the question “What can we do to enrich the lives of the animals? A desired shift would be to ask, “How can we support the animals to enrich their own lives?” From the animals’ perspectives, “passive enrichment” includes things performed by caregivers to passive animals, such as providing comfortable room temperatures, and “active enrichment” includes providing temperature choices for the animals to select. These include built-in opportunities made available by caregivers and used by animals when they wish. Whether functional, naturalistic, or a combination, a well-designed combination of structural, spatial, and management environments creates dynamic, opportunity-rich, unpredictable, and enriching BOH environments.

3. Structural Environments

Structural environments, the actual physical environments in which animals live in BOH areas and the focus of this section, are determined by the management environments, the programs and policies used to operate primate facilities that we discussed. Here we discuss enclosing structures, their organization and connectivity, bio-floors, caging, furnishings, and built-in electronic systems.

The organization and design of these structural enclosures must be sufficiently flexible to aid in the management of weather changes, social groups (including fission–fusion and hierarchical changes), bachelor male management, mixed-species separations, or isolation for breeding, birthing, rearing, or wound management [12,42].

3.1. Building Enclosures, Walls, Floors, and Ceilings

Most primate facilities outside the tropics are made of masonry or concrete with hard, durable floors, walls, and ceilings surfaced with even harder ceramic tiles or epoxy finishes. While sturdy and long-lived, these forms of construction are expensive to build and remodel and share few attributes with the natural environments in which primates evolved. The Dallas Zoo (Texas, USA) gorilla BOH area, developed about thirty years ago, demonstrates a more flexible approach. This was built using a relatively low-cost and changeable agricultural steel shed construction, creating a large, weather-controlled indoor envelope. Free-standing mesh walls and roof areas provide animal containment, allowing caregivers access to all sides of the animal enclosures. Deep, litter bio-floors were used (see more below), and above the caging, the higher building can be heavily insulated for both climate and acoustic mitigation. Large industrial doors open to provide natural ventilation and natural light photoperiods.

The Realm of the Red Ape exhibit in Chester Zoo, UK, provides orangutans with 24/7 access to three ten-meter-high indoor mesh enclosures, allowing the apes full, three-dimensional use of these vertical spaces.

3.2. Bio-Floors

Organic bedding or litter with proven hygienic properties was first used for small primates to forage in [43]. It can also greatly reduce water use and cleaning time and dampen sound. Shallow, organic bedding is commonly used over concrete floors in older BOH facilities. The use of deep, more permanent bio-floors with drainage plumbing is ideal for development in new facilities [44,45].

Bio-floors need to be dampened occasionally to prevent dust and need to be monitored for disease, fungal spore, rodent, or insect problems. To avoid and reduce rodent or insect infestations, the installation of a drenching system is recommended. Dublin Zoo, Ireland, uses larger bark chips combined with peat moss as deep litter in the gorilla BOH enclosure, as shown in Figure 2. For more about bio-floors, see [45].



Figure 2. Bio-floor with vertical vegetation attachments in BOH gorilla group area at Dublin Zoo, Ireland. Photo: G. Creighton.

3.3. Caging, Animal Gates, and Operating Systems

BOH animal enclosure hardware, often called caging, varies in size, materials, and functionality based upon tradition and caregiver preference. Typical examples include staff doors, feeding slots, blood draw sleeves, waterers, vertical and horizontal sliding animal gates, and locking systems. Mechanisms to operate gates, doors, and other features should be user-friendly and, preferably, operable with one hand. The gate operator must have a clear view of the area around the gate. Remote gate operation using closed-circuit television is also an option.

In 1999, the Orangseum facilities at Apenheul Primate Park, Netherlands, installed hydraulic slide doors, of which 10 slide doors can be put in positions that the orangutans can operate themselves. The animals have access to these enclosures 24 h a day.

In the future, automated gates could be programmed to open by preselected animals using their individual radio frequency identification (RFID) microchip implant codes. This

gives selected animals the choice and opportunity to visit multiple areas when caregivers determine this is safe over the 24/7 period [46].

When possible, primates use caging walls and ceilings as climbing surfaces, greatly expanding the accessible area compared to masonry or concrete enclosures. While solid dividing walls are sometimes needed, should most caging always be rigid steel and concrete? Rigid steel structural frames are usually noisy (see Section 4.9). Alternatively, enclosures can be made with woven stainless-steel cable netting, which is quieter and more transparent. Plastics such as polycarbonate or HDPE (high density polyethylene) used for moving gates are rust-proof, quiet to operate, and long-lived, which can offset higher construction costs. Caging can be fixed and rigid or flexible, draped, and easily expandable. With thoughtful design, caging enclosures can transform from what Robert Sommers calls “hard architecture” to “soft architecture” [23], p. xii.

Flexibility of structure, including opportunities to add living or structural vegetation, can provide complexity in BOH areas with the ability to change things regularly (see Figure 3).



Figure 3. Flexible BOH for common marmosets at the Biomedical Primate Research Center, Netherlands. Photo: S. Brando.

3.4. Building and Caging Layouts and Connections

Built-in arrangements and connections between primary outdoor and indoor exhibits and BOH areas can stifle or encourage animal behavioral opportunities. We have visited zoos in many different countries in which the animals had either large outdoor areas or highly confined and sterile indoor areas. They had no intermediate opportunities. An effective model used at both the Denver Zoo (Colorado, USA) and the Oklahoma City Zoo, (Oklahoma, USA) great ape facility primate areas is organized as shown in Figure 4. This facility was designed so that great apes could visit a wide variety of different spaces, including enriched group rooms (indoor exhibits), during periods that staff are absent.

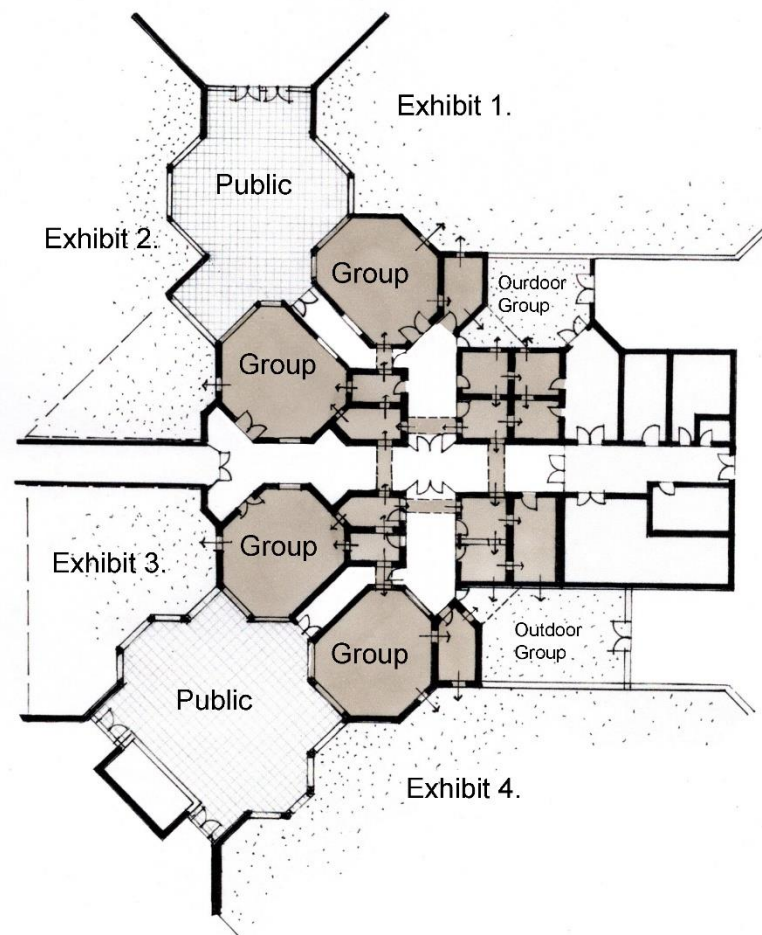


Figure 4. BOH great ape facilities at the Oklahoma City Zoo, Oklahoma, USA. Grey indoor areas are designed to provide 24/7 access. Image: J. Coe.

3.5. Animal Movement and Rotation Systems

A major development benefiting animals in BOH areas is the interconnection of multiple animal areas using gates and raceways, which also provides animals with enriching opportunities for exercise and investigation. The Denver and Oklahoma City Zoos use simple area-to-area connecting gates (no raceways) called a “through-area animal transfer system”. At the Louisville Zoo, Kentucky, USA, a more expensive but more flexible “bypass animal transfer system” connects to, but also bypasses, each use area [47,48]. An animal can go from one area to another without disturbing animals in areas between. When building transfer systems such as tunnels, raceways, and weighing and constraint stations it is important to have multiple entries and exits for a flexible circuit. Thus, primates have multiple options, decreasing the likelihood that doors and tunnels are blocked by higher-ranking individuals or that animals can be cornered. Safe, convenient access for training and rewarding must be provided near all transfer gates and raceways.

Interconnected animal areas are called “flex,” “rotation,” or “alternation” enclosures. They are designed to accommodate single or multiple species with similar security, behavioral, and environmental requirements flexibly and consecutively (for example, see Figure 5). Animals benefit from access to multiple volumes of space and behavioral opportunities [48].

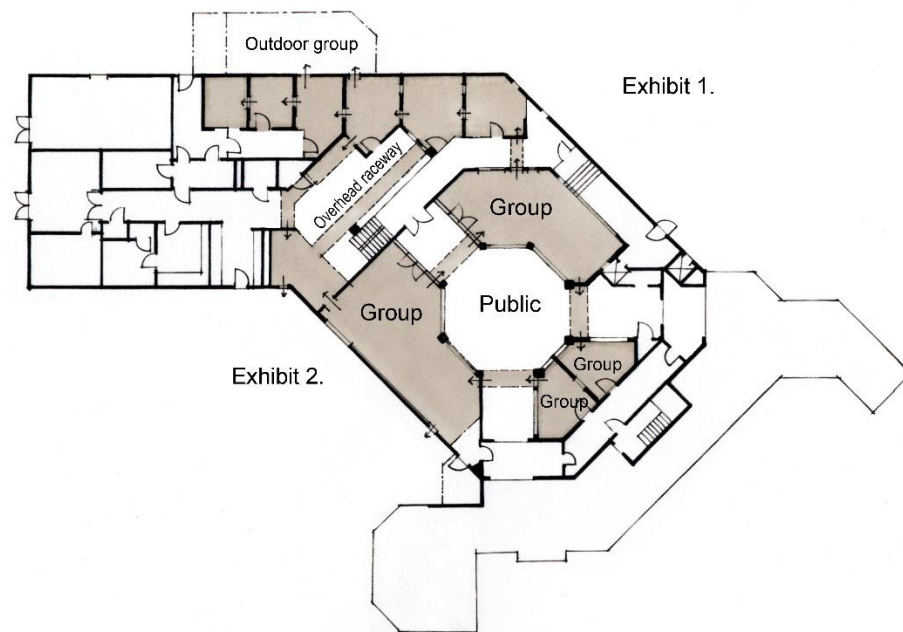


Figure 5. Layout of display and BOH areas for gorillas at the Louisville Zoo, Kentucky, USA. Grey areas are accessible to gorillas 24/7. Note the variety of areas and routes open to the gorillas. Image: J. Coe.

3.6. Furnishings

“An enclosure does not need to be huge or natural; the key is that the enclosure has structures and furnishings that allow the animal to exhibit a wide range of behaviors.”

T. L. Bettinger [34], p. 38.

Furnishings, the fixed or removeable elements within BOH areas, must adequately and appropriately substitute for features of the animals’ natural habitats, serving the same purposes to the animals. Whether made of natural or synthetic materials, rigid or flexible, permanent or temporary, “nature is the norm”, as David Hancocks reminds us [49] (p. 146). Much has been published about furnishings [50–52], and many examples of useful add-on enrichment features can be found through websites and publications such as “Environmental Enrichment for Captive Animals” [6], as well as the writings of Hal Markowitz [35] and others [6,50,53]. Therefore, we focus on opportunities for built-in features, including enclosure materials, and making furnishings (shelves, platforms, and climbing structures) more responsive to animal use and to change. Often, BOH furnishings are rigidly fixed, while many of the surfaces primates use in forest habitats are flexible and move when used. Fortunately, it is becoming more common to see ropes, old firehoses, and other flexible climbing features in BOH primate areas, as they are in animal exhibit areas [52]. Non-rigid environments also tend to increase social attention and interaction; animals must stay alert, as actions such as jumping off a connected swinging branch might cause other animals to lose their balance. This flexible approach requires good access from delivery points to use areas and ample room for the cleaning and storage of changeable items.

It is important to remember the behavioral benefits many primates seem to receive from the destructive use of replaceable furnishings.

Much more can be attempted to improve opportunities for animals to develop stronger bodies, better balance, greater agility, curiosity, and confidence, named physical and behavioral competence [27]. Maple and Purdue [23], p. 50, linked physical fitness to overall wellness and described it as “... an important dimension in preventative medicine.” For aging or disabled primates and those in poor physical condition, such as overweight primates, adjustable climbing structures can be set at easily reached positions with browse

feeders or other incentives attached. As animals gain strength and motivation, climbing structures and browse feeders can be raised using built-in winches, perhaps from outside the enclosure, as in the Los Angeles Zoo orangutan exhibit, but adapted to BOH areas. Small, built-in winches avoid the need for care staff to climb or manipulate heavy objects, and enrichment features can easily be altered for servicing [53]. Novelty and variety can be provided for the animals without requiring unusual amounts of staff time because access and placement are made easier.

A recent trip to Costa Rica by one of us (Brando) highlighted the importance of seeing how wild primates use space and natural furnishings. Sometimes they use only one tree in the forest, but they use it from top to bottom. Designing the BOH area as a ‘forest floor to a tree crown habitat’ can greatly increase the functional space, thinking of all aspects—walls, floor, and ceiling—including flexible and fixed structures with different characteristics.

3.7. *Electronic Features and Animal–Computer Interaction (ACI)*

Electronic features are largely built into structures and are, thus, presented in this section, although they can strongly overlap with training, research, and environmental enrichment management practices and regulation of the ambient environment. The rapid development of electronic technology has provided useful tools for enriching, monitoring, and evaluating animals both on-display and in BOH areas. For an overview of monitoring systems (such as accelerometers to measure vibrations, GPS to determine location, bioacoustics to measure natural sounds, thermography to determine temperature, and individual identification using RFID), see [54]. Touch-screen computers, some accessible to the apes 24/7, in primate cognitive research has been found to be enriching [55–57]. Simple computers can allow both pre-programmed and remote operation of such devices as gates, feeders, touch screens, climate controls, and other enrichment features, as well as surveillance, security, and alarm systems, all accessible by smart phone from nearly anywhere in the world. Such systems have potential for use with primates and are already being used with elephants at the Dublin Zoo (G. Creighton, Global Elephant Care; personal communication, 12 January 2018).

These are all systems used by animal care staff. This paper is more concerned with electronic technology that can be used by the animals themselves to promote their own wellbeing. For example, animals can use RFID and motion sensor technology to activate a myriad of enrichment services [46] while activating research monitoring systems. Such systems can simultaneously enter datapoints and video images, perhaps linked to facial recognition software, into research programs around the clock. Several Australian species recovery programs are using RFID-controlled “smart gates” to give recently released animals access to individualized food and shelters [58]. It is highly likely that crossover benefits can be found for primates in zoos, sanctuaries, and research labs. Novel technologies can also bring problems, especially with frequent specialized maintenance and rapid obsolescence.

The systems above are examples of animal–computer interaction (ACI), a promising new field using creative digital tools, including devices operated by the animals themselves, to improve animal welfare, support research, and enliven zoo visitor experiences. Such applications could benefit BOH features, including applications available to animals 24/7 (see [59] for a general introduction to this pioneering field).

No matter how automated animal care becomes in the future, the relationships between caregivers and animals remain central to professional animal care. We believe having enough staff to provide high-level animal care, training, enrichment, observation, and reporting, as well as interacting with the public and researchers, is essential to success.

4. **Spatial Environments**

All primates need accessible vertical spatial volume. Primate area standards should be expressed in these terms rather than floor areas [3,60,61]. Gorilla and chimpanzee BOH areas are, on average, 40 times smaller than exhibit areas [2], even though these apes may

spend up to three times more time in them. The quality of space and its orientation is important. Pioneering zoobiologist Hediger abhorred cubic enclosures, saying “... in the zoo the cube is the most unbiological and therefore most inappropriate of all spatial forms” [8], p. 196. However, BOH structures are almost universally cubic or rectangular in form [1]. Other, more complex forms should be studied for BOH enclosures, such as multisided polygons. Figures 4 and 5 show examples of less cubic enclosures.

4.1. Subjective Space and Intuitive Design

BOH space has both quantitative and qualitative, or subjective, aspects, as perceived by both animals and caregivers. Furthermore, relative position in space is subjectively important to animals inhabiting the area. While we must be aware of anthropomorphic tendencies, we believe it is possible for experienced caregivers and designers to envision how the areas would feel from a primate’s perspective. Critical anthropomorphism, meaning the application of testable cognitive, emotional, and behavioral processes in other species, informed by the rigorous incorporation of empirical knowledge could be used as an approach [62]. We suggest empathy be added to this list of hard science. For example, would the BOH space feel safe, accessible, welcoming, useful, comfortable, and interesting to the animal? Should designers, caregivers, and managers spend a night in BOH primate enclosures themselves? Preference testing is one method to gain insights into animal preferences and needs [63,64]. It has been used with a wide variety of animals, giving insights in structural preferences (gorilla: [65], window view, orangutan: [66,67]) and could be used to gain more insights into BOH subjective space and design. However, objective studies of animal preferences must follow design and construction work, requiring designers to employ past assessments, yet make a leap of faith and creative empathy in improving on past models. Several major BOH zoo design breakthroughs, such as those shown in Figures 6 and 7, came as strokes of creativity and are now widely accepted, yet still await empirical testing.



Figure 6. Day room with 24/7 access for gorillas at the Denver Zoo. Note high windows for viewing and basking. Photo: J. Coe.



Figure 7. BOH rooftop extension at the Dehiwala Zoo in Colombo, Sri Lanka, allowing the chimpanzees to see the stars at night. Photo: Dammika Malsinghe.

4.2. Views and Vistas

Views and vistas from BOH areas seem to be both an objective and subjective need. In 1989, P. O'Neill [67] suggested the importance of giving all animals extended views and vistas, including from BOH areas as enrichment requirements. Since then, we have followed this advice. For example, in the BOH group rooms at the Denver Zoo where gorillas and orangutans spend cold days and most nights, elevated sleeping perches are adjacent to windows where the apes can see approach routes within the zoo, views into the surrounding neighborhood, and the night sky, as well as bask in the early morning sun (see Figure 8). The Biogen Research Laboratory in Maryland, USA, uses glass barriers, allowing chimpanzees in medical isolation to have good views of their neighbors and approaching caregivers. Curtains or other visual barriers can be added to provide temporary visual barriers and privacy. The BOH facility for chimpanzees at the Los Angeles Zoo, CA, USA, is topped with a penthouse of nearly transparent woven stainless-steel cable netting (see Figure 6), in addition to the usual indoor night rooms. Animal care staff relate that some apes prefer to sleep under the stars on warm nights. During the day, they have extensive views across the zoo grounds. The Dehiwala Zoo in Colombo, Sri Lanka, also provides a rooftop penthouse with wide views for its chimpanzees (see Figure 6).



Figure 8. BOH chimpanzee penthouse at the Los Angeles Zoo, CA, USA. Photo: J. Coe.

4.3. Vegetation

It is widely reported that indoor plantings benefit humans in both workplace and domestic environments [68,69]. If true for humans, would not plantings be beneficial for our close primate relatives as well? The Dallas Zoo gorilla BOH containment areas were surrounded by tropical plantings as a promising innovation designed to benefit gorilla welfare (see Figure 9). However, likely due to low light levels, poor soil quality over time, the use of cleaning chemicals, and dust from bio-flooring, only some of the original plants remain (Dallas Zoo historian K. Zdrojewski, personal communication, 12 February 2019). Perhaps these problems could be avoided by early collaboration with horticulture staff and special training for animal care staff in managing BOH plantings. If living plants cannot be used or can only partly be used, there are other opportunities to use vegetation within BOH areas, as in the gorilla BOH at the Dublin Zoo shown in Figure 10. These not only add variety and diversity to BOH areas, but can provide opportunities for hiding,

play, climbing, and foraging for insects or fresh leafy browsing during the long hours that primates are not in outdoor areas.

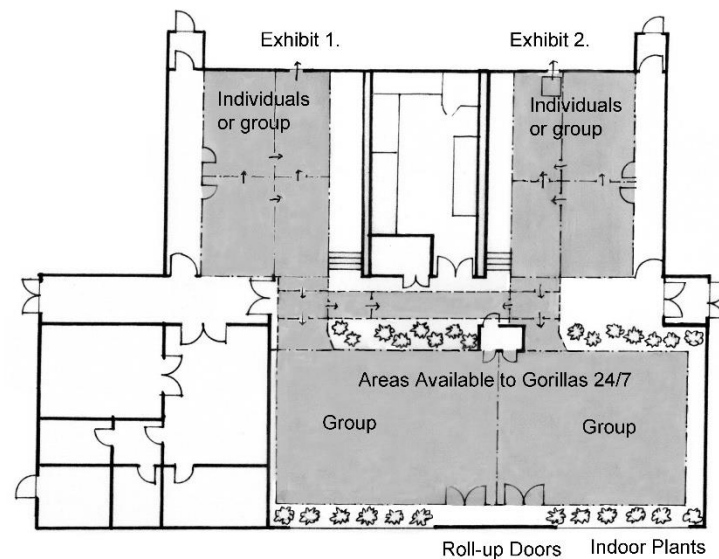


Figure 9. BOH for gorillas at the Dallas Zoo, Texas USA. Grey areas provide gorillas 24/7 access. Note surrounding vegetation. Image: J. Coe.

4.4. Ambient Environments

This section describes the non-material qualities occurring in BOH spaces inhabited by primates and caregivers and includes elements such as light, temperature, humidity, ventilation, smells, and sounds. These all vary in intensity, distribution, spectrum, and periodicity (daily, seasonal, and longer cycles).

Forest-living primate species move through changing ambient gradients of seasonality, light intensity, and spectrum, as well as temperature, humidity, air movement, olfactory, auditory [70], and tactile qualities and intensities. Importantly, these wild primates have the agency to choose the most suitable combination of ambient conditions to meet their individual and group needs simply by moving through their highly varied and changing environment. While sub-optimal natural conditions also frequently occur due to weather, social, or other challenges, wild animals are usually able to take counteractions.

BOH ambient environments include things that happen to the animal (passive ambient environment: for example, a caregiver sets general temperature levels and uniform light levels) and things the animal controls (active ambient environment: for example, primates able to control local temperature levels or move through BOH temperature, light, humidity, sonic, etc., gradients to suit their own preferences). Thus, manipulation of the ambient environment by the animal, if it chooses to, is a form of environmental enrichment and an exercise in choice and control.

Visual complexity is extremely high in forest canopies, along forest trails, and in clearings. The opposite applies to most BOH rooms. Visual opportunities (color and pattern) and spatial (form and volume) and tactile environments are typically extremely uniform to lower construction and maintenance costs and to maintain hygiene standards, especially in lab animal facilities. As a result, animals living in these sterile, impoverished ambient environments are unable to experience the visual and spatial stimuli typical of their wild cousins' habitats. We believe a major problem is the lack of ambient gradients animals in BOH areas can move through to optimize combinations of factors for their comfort or use (Table 1) [71,72].



Figure 10. Enrichment plants provided in BOH gorilla group area at Dublin Zoo, Ireland. Photo: G. Creighton.

4.5. Light

In keeping with the natural model, BOH lighting should closely resemble the changing spectra, intensity, distribution, and timing of natural outdoor light. One example is the use of full spectrum glazing in skylights and windows. Recently, there has been a move to replace blue-tinted light with a more natural amber source when artificial light is needed, especially as natural rest periods approach [70]. Gradually fading artificial light in and out is beneficial, so diurnal primates are not plunged in and out of lightness and darkness in enclosures without natural light [73]. Light–dark cycles are essential to support natural circadian rhythms and essential for health body function, including an intermediate crepuscular period, which is important for animals spending extended time in BOH areas. In addition, both natural and artificial light should provide gradients from which the primates may choose in larger spaces or can modify lighting themselves [7,12,13]. A separate, secondary, staff-operated cleaning light system is also required to facilitate proper hygiene.

The need to eliminate light pollution from exterior sources, such as pathway, hallway, or security lighting, as well as indoor light pollution sources such as illuminated exit lights, is preferred, and advised [7,18,70]. Subtle BOH night lighting at moonlight levels is beneficial for animal movement after dark, especially for species and individuals that are active and socializing or using enrichment features during dark hours in the absence of staff.

Table 1. Overview of ambient problems and opportunities.

Ambient Problems	Ambient Opportunities
Light of uniform quality, quantity, and distribution.	Gradients to provide choice and control. Two-stage lighting: one for cleaning, another for animal needs. Full spectrum: mimic daily and seasonal variation.
Gradual dimming during crepuscular periods.	Health requirements, circadian rhythms, etc.
Create moonlight-like conditions overnight for nocturnal primates and others active at night.	
Screen visible exterior 'Exit' illumination signs.	
Temperature uniformity.	Study norms in nature.
Create gradients.	
Humidity excess.	Humid or wet floor and shelves. Use biofloors to reduce washing, but with daily dampening to reduce dust.
Eliminate strong-smelling disinfectants.	
Keep different species in different areas. Evaluate from animal's standpoint.	
Lack of outside views.	Outside views provide animals both information and potential enrichment.
Video enrichment.	
Problem: color uniformity.	Develop BOH color scheme following light, dark, and color gradients mimicking natural habit, retreat areas with darker colors, high-intensity colors in centers, and darker around tunnels and openings.
Taste and chewing: Effect of smell on taste?	Provide chewing opportunities as oral enrichment; test for preferences.
Lack of tactile variation and complexity.	Climbing surfaces.
Deep litter and bedding.	
Variety of furnishing and sleeping surfaces.	Encourage uses of flexible surfaces.

4.6. Air

Proper air quality and temperature is generally considered essential to health and comfort. This section broadly covers aspects related to air quality such as temperature, humidity, and ventilation, including seasonality. Wrangham [74] reported that wild chimpanzees were most active during a temperature range of 23 C to 28 C. Natural seasonal temperature ranges in the eastern lowland gorilla habitat at Mbeli Bai are given in the AZA Gorilla SSP [13], p.10. Based upon this general natural model, BOH temperatures should show daily and seasonal variation in this range while providing warmer and cooler areas the apes may select if they choose, with the opportunity to control localized heating or cooling devices. A similar model based upon field data could be applied to other primate species. Excellent information on the interactions of temperature, humidity, and ventilation in creating comfort zones for humans, which may be applicable to other primates and caregivers, can be found in [75].

4.7. Olfactory

Traditionally, olfactory conditions may be determined by caregivers' or inspectors' olfactory sensitivity rather than the primates. Strong-smelling BOH disinfectant chemicals chosen to maintain hygiene may be stressful to the animals [34], while scent-marking primates such as tamarins and marmosets may be deprived of important behavior needs [73]. Some new-world primates such as squirrel monkeys may have scenting abilities equal in some applications to those of canids [76]. Are such primates offended by cosmetic scents worn by caregivers? Certainly, some new-world primates actively scent-mark, and gorillas have an unmistakable smell. What ambient olfactory environment do primates prefer? These are essential aspects of the BOH environment for most species. If humans find BOH smells offensive, how do the primates feel? Are there better ways to maintain proper hygiene? Steam cleaners, if proven successful in BOH conditions, may be able to replace strong disinfectants, hose washing, and high-pressure washers, reducing noise and removing aerosol particulate concerns with the bonus of rapid drying.

4.8. Tactile

Primates evolved in rich, tactile environments, and touch is an important means of identifying materials. Gripping suitability is important to primate mobility. Expanding tactile opportunities in BOH areas, including activities reached through cages, increases the options for animals to engage with and choose from when care staff are absent. Grooming and foraging boards and materials such as shavings, as tactile enrichment, have been used [74], as well as social contact and grooming between primates and between primates and caregivers.

4.9. Acoustic

"Many zoos are acoustically boring for species whose dominant sense is audition; that is, they lack acoustic complexity and variation (including temporal) that would be encountered in the wild. For example, no dawn bird chorus".

(Robert Young, animal behavior and environmental enrichment specialist, personal communication 24 July 2021.)

The BOH acoustic environment is divided into two types: beneficial sounds and stressful noise. Table 2 gives an overview of acoustic problems and opportunities.

Noise is defined as any sound that is undesired or interferes with one's hearing (<https://www.merriam-webster.com/dictionary/noise>) (accessed on 18 June 2022). What is considered noise is species-specific and dependent on the individual, and noise from both within and outside BOH areas can be a stressor [75–77]. Soltis noted the following: *"A general guideline for noise exposure to animals may be difficult due to, among other things, different frequency ranges of hearing for different species and individuals; species and individuals' reactivity; differences between chronic and acute exposure to noxious sound; and differences in characteristics of sounds"* (J. Soltis, sensory environment researcher, Disney Animal Kingdom personal communication, 8 February 2019). For detailed discussions of harmful effects of anthropogenic acoustic environments, see [77–79]. Several types of noises and their potential impacts on animals have been studied [80–82]. BOH areas may provide a haven when animals seek to evade external noise generated by visitor crowds, entertainment, or construction or when building acoustic insulation is inadequate. External noise may be especially vexing when it coincides with the animals' natural rest periods.

Table 2. Overview of acoustic problems and opportunities.

Acoustic Problems	Acoustic Opportunities
Stress from sharp and loud sounds.	Update standards to limit this in new construction and moderate it in existing structures. Many acoustic engineering materials are available.
Clanging of steel doors and gates. Use of woven stainless-steel netting rather than rigid steel bars and mesh. No standards for noise levels based upon nature.	Use of high-density polyethylene for gates and cover plates. Sound quality for lab animals should model acoustic environment. Search bird-call recording archives for useful evidence of primate soundscapes from similar natural habitats.
Mechanical noise generated by motors, pumps, and fans and from the movement of water and air through mechanical systems.	Acceptable ambient noise levels should be specified at the beginning of design based upon studies in wild habitats. Low-velocity ventilation makes less noise than high-velocity systems. Provide acoustic dampeners and isolation for motors, pumps, and fans. Engineering solutions are available. Steam cleaning, where possible, reduces noise compared to pressure washers.
Animal-generated noise for animal and staff safety and welfare.	More research is needed on cleanable, durable, acoustically absorbent materials and finishes. Provide acoustic isolation between species or within species (example: between a gorilla family group and a bachelor group).
Noise reflected from hard surfaces.	Avoid parallel, hard, noise-reflective surfaces.
Visitors and construction noise outside BOH.	Provide acoustic insulation and double or triple glazing. Avoid construction during animal rest periods.
Engineering solutions to improve acoustic insulation.	
Music for primates.	Provide soundscape, ideally with animal choice.
Noise cancellation.	Noise-cancelling technology may be beneficial in small, localized areas such as retreat areas or nest boxes. Best for constant noise frequency; less useful for changing frequencies.

Built-in BOH internal noise sources include clanging steel gates and counterweights, mechanized gate operating systems, ventilation systems, plumbing, and pumps. The noise of the ventilation in one orangutan BOH exceeded external concert noise [77]. Available technologies exist for noise reduction. Built-in internal noise sources can be avoided with proper design and construction but are difficult to correct in existing facilities. Pressure washers are a common internal noise source. When multiple species are housed within hearing-range of each other, species-typical sounds from one species may become disruptive noise to another. Noise-cancelling technology works best for predictable, constant noise in highly localized areas (J. Soltis, personal communication, 8 February 2019) and may be effective in providing a degree of acoustic isolation in small primate nest boxes, for example.

Once noise is counteracted, it is possible to add BOH soundscapes. Anthony, noting the lack of data on noise tolerance in laboratory animals, suggested creating acoustic environments similar to those found in the species' natural habitats [82]. What is the natural acoustic environment of a given primate species, and how does it differ in a BOH environment? Natural sound levels of 40 db were observed in field studies of *callitrichidae* in Brazilian tropical forests, whereas a modern office would be 55 db (Robert Young,

personal communication, 24 July 2021). Natural sounds vary in intensity, frequency, quality, directionality, time of day, season, and significance to species and individuals. Young noted that the use of proper sound projection systems is also important: “*In the wild sound is 4-dimensional, and stereo-sound systems do not reproduce the wild—you need a 360-degree sound system to do this. The animal should live in the sound, the sound should not be projected at the animal*”.

Possible sources of natural ambient soundscapes for use in BOH areas include privately owned, globally recorded soundscapes (<https://www.wildsanctuary.com/>) (accessed on 18 June 2022) and archives of bird calls from all over the world (i.e., from the Cornell University Ornithology Laboratory). Specific birds from the same habitats as the housed primates can be identified, and recordings can be used to approximate these acoustic environments.

Are natural environmental soundscapes or selected music more attractive to primates? No significant effect of auditory environments on gorillas’ behavior was found, although the animals tended to show more relaxation-related behaviors during ecologically relevant sounds than during non-relevant classical music and non-auditory control conditions [83]. There is evidence supporting using quiet music during non-human animals’ active periods if this practice is introduced with an awareness of the risks to welfare and research [84]. While some sounds may seem to be beneficial to animals under certain conditions, more research is encouraged in animal sound preferences as enrichment opportunities [85]. Masking sounds can be aversive, particularly for small, prey species such as *callitrichidae* that rely on auditory alarm calls to maintain vigilance [86]. See [78] for an extensive acoustic search of the literature, a useful glossary of acoustic terms, and studies of acoustic environment on several primate and other species, as well as zoo visitors. Considering combining different sensory and other experiences, e.g., scent [87] cognitive [88], and tactile opportunities [89] promotes dynamic animal care programs with a wide variety of affordances.

Further insights on sound and the effects of auditory enrichment can be found for baboons [90], as well as stereo music enrichment in chimpanzee [91] and Lar gibbons (*Hylobates lar*) [92].

5. Conclusions

The previous sections discussed limiting traditions and future opportunities. This section suggests the need to integrate empirical evaluation and evidence-based decision making with creativity, empathy, and experience-based intuition to design and operate a greatly improved generation of BOH programs.

5.1. Evidence plus Action-Based Design

While all BOH facilities and management programs benefit from both informal internal and formal external evaluation, innovative programs have a special opportunity to confirm progress with pre- and post-occupancy evaluations and to share both successful and not-so-successful outcomes. The increased use of integrated computer- and video-linked features makes around-the-clock 24/7 coverage available. Clever search software should make the evaluation of these records less time-intensive, especially in university collaborations. Such research should be interdisciplinary and cross-cutting, documenting benefits for animals, caregivers, and the institution. While research and evaluation have a cost, this expense should be a line item included in the overall cost of design and construction. If thoughtfully used, the investment in evaluation should be returned in lessons learned and problems avoided for future projects and in providing evidence to support the success of the institution’s animal welfare initiatives and goals.

How do we determine the ideal BOH management and physical environments for a given species? First, we must rely more on findings from the field and apply them to BOH environments [93,94]. Next, we must strive to operate on an evidence-based approach and advanced animal welfare models [7,15,16].

As Seidensticker and Doherty noted, “*The animal person knows there is a problem, but there is little in the way of empirical evidence to support these concerns*” [9]. Thus, designers are often left to follow traditional standards or to attempt innovation using their and their client’s best judgement, hopefully with empirical evaluation to follow. In the absence of research findings, “critical anthropomorphism” [62], empathy, creativity, and common sense should be used. The need for more research should not prevent new initiatives or old wisdom (e.g., work by H. Hediger and H. Markowitz) from being tried and tested. For far too long, zoos have copied other zoos without innovation or empirical evidence of earlier models’ successes by contemporary standards or asking the critical question “why”?

5.2. *Toward a New Synthesis: The Integrated Design Model*

Standards, facilities, and programs need to reconsider basic attitudes, assumptions, and procedures by reasserting natural models, including opportunities for animal choice and control over BOH environments on a 24/7 basis [7]. How can BOH areas be designed and managed to be much more appropriate and facilitative for animal occupants while also optimizing management functionality and flexibility? Can monkeys really run the monkey house, including the BOH area, using animal–computer interactive features such as RFID, motion sensing, and touch-screen technology, indirectly recording their own behaviors on research computers?

Over twenty-five years ago, in their widely read appraisal of zoo management systems (and, thus, designs based upon these philosophies) Seidensticker and Doherty [9] described four basic zoo models:

1. The zoo exhibit management model, summed up by the slogan “zoos are for people!” Animals were seen as valuable exotic objects, and large collections were celebrated.
2. The ethological animal management model. This philosophy was developed by Hediger and colleagues and was later followed by landscape immersion exhibits.
3. The medical animal management model. “The medical model stresses the reduction of environmental complexity to make the captive environment cleaner and safer and to give managers greater control over the health of the animal. The medical animal management model emphasizes direct human technological intervention rather than approximating the wild condition.” This is the basis of contemporary lab animal management, as well as most BOH facilities in zoos.
4. The humane animal management model was concerned with ‘cradle-to-grave’ animal care, and individual animals were managed like house pets. There was little concern for zoo visitor interests. This approach evolved into today’s animal sanctuary movement.

We suggest adding a new synthesis: the “integrated design model”. It is based upon the full integration of the separate Seidensticker and Doherty management and design models applied to zoos and other primate care facilities and, particularly, to BOH areas. We suggest a single, unified design model blending Hediger’s “back to nature” perspective with traditional concerns for hygiene, safety, functionality, and the evolving animal welfare emphasis. This model needs to be actioned with a balance of science, empathy, intuition, and creativity. Rather than blindly following tradition, we need to return to basic questions such as “Why are we doing this? Who are we doing this for? What could the animals’ points of view be? What is meaningful? What is older or newer, but different and better?” All animals should live 24/7 in species-specific, opportunity-rich environments. However, even if BOH areas evolve to be equal to zoo exhibit areas in animal welfare benefits and if no practical distinction were to exist, the design of structural, spatial, and management environments should be supported, but not limited, by evidence-based case studies and well-reasoned, evaluated, and published prototypes. Promising but unproven innovation continues to be an essential ingredient to prevent stagnation. Practical and flexible management needs and the resulting environments must become fully integrated with primate welfare needs, including greatly increased animal agency. Caregiver–animal collaboration and smart technology opens access to multiple benefits,

such as self-managed access to resources and preferences, giving primates back their occupations and competence and a chance to flourish in all areas, including BOH areas in zoos, sanctuaries, and research facilities.

Additional ideas and examples of better practices can be found in the Section 6.

6. Examples of Distinctive Designs and Existing Facilities

Looking ahead, why must BOH enclosures be rigid boxes when arboreal creatures often evolved in swaying, soft-edged environments? In 1998, Carlos Farfam suggested the use of prefabricated, 'soft', self-supporting cylinders of stainless-steel woven mesh that moved slightly when the primates within moved. In cold climates, zoos, sanctuaries, and research centers could link several such enclosures within a large, passive solar conservatory structure surrounded with tall living plants. The linked cylindrical enclosures would be connected to outdoor or display areas or could be designed as animal displays for small primates. This conceptual image illustrates a variety of moveable furnishings mounted flexibly within such structures, which could also include many animal-activated features, such as smart gates, heaters, fans, feeders, and cognitive enrichment and research devices (see Figures 11 and 12). Traditional construction values, such as prefabrication and standardization, could thus be combined to create changeable, naturalistic primate structural and spatial environments (see Figures 11 and 12).

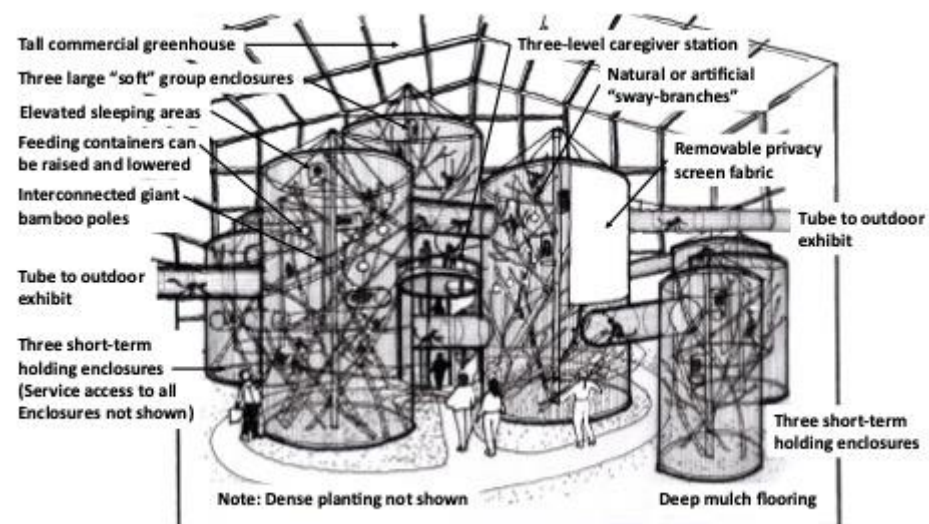


Figure 11. Flexible, 'soft', self-supporting cylinders of stainless-steel woven mesh.

Louisville Zoo's Gorilla Forest (Figure 13) opened in 2003. While known for its two large outdoor exhibit areas, the most notable thing about its BOH is that, in addition to four interconnected bedrooms and three quarantine rooms, gorillas have 24/7 access to four large and highly enriched day rooms arranged in a circle, allowing eleven gorillas to rotate between night and day rooms and around a circle of day rooms, having a wide choice of after-hours secure areas (also see Figure 5).

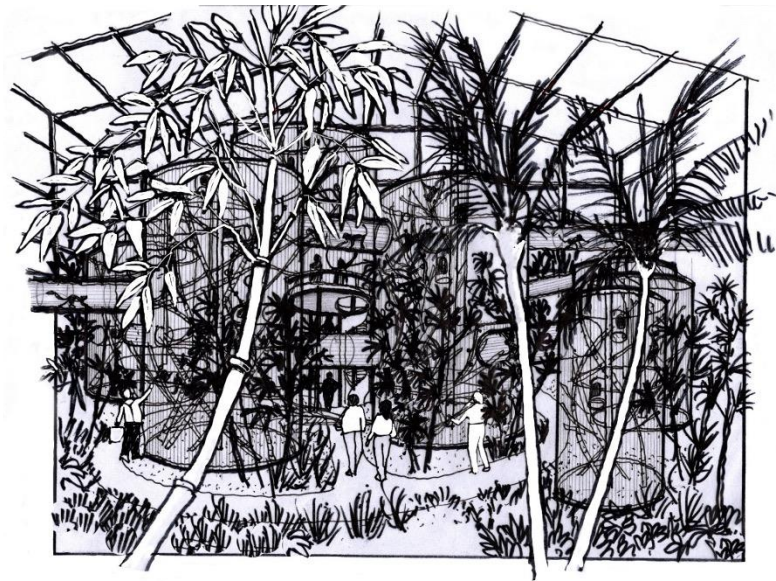


Figure 12. Descriptive view with tropical planting, including indoor growing fruit and browsing.



Figure 13. Louisville Zoo's combined display and 24/7 BOH areas. Image: J. Coe.

The Center for Great Apes in Wauchula, Florida, opened in 1993 as a sanctuary for orangutans and chimpanzees rescued from the entertainment industry. In 2000, Director Patti Ragan began connecting existing domed exercise enclosures with a system of overhead aerial trailways suggested by Coe. Now, after twenty-five years of operation, the center houses sixty rescued apes housed in twelve climate-controlled, hurricane-proof night buildings, as well as a clinic and quarantine area. Eighteen large outdoor exercise enclosures connect to about two thousand five hundred meters of elevated trailways, some 4.5 m above service pathways, immersed in subtropical forest. Each group of apes has access to extended trailway segments used to display, surveil, browse from nearby vegetation, or explore their areas whenever they choose. In addition to these built-in enrichment features,

the center also has an active environmental enrichment program. Director Ragan reports that this considerable infrastructure of the large play habitats and elevated trailways (see Figure 14) not only benefits the great apes, but their active use and heightened welfare also inspire her staff, volunteers, and donors, who gladly support the cost of construction. Ms. Ragan also knows of five other great ape sanctuaries and research centers now using trailways in various ways (P. Ragan, Founder, Center for Great Apes, Wauchula, FL, USA; personal communications, 17 August 2018 and 21 February 2019).

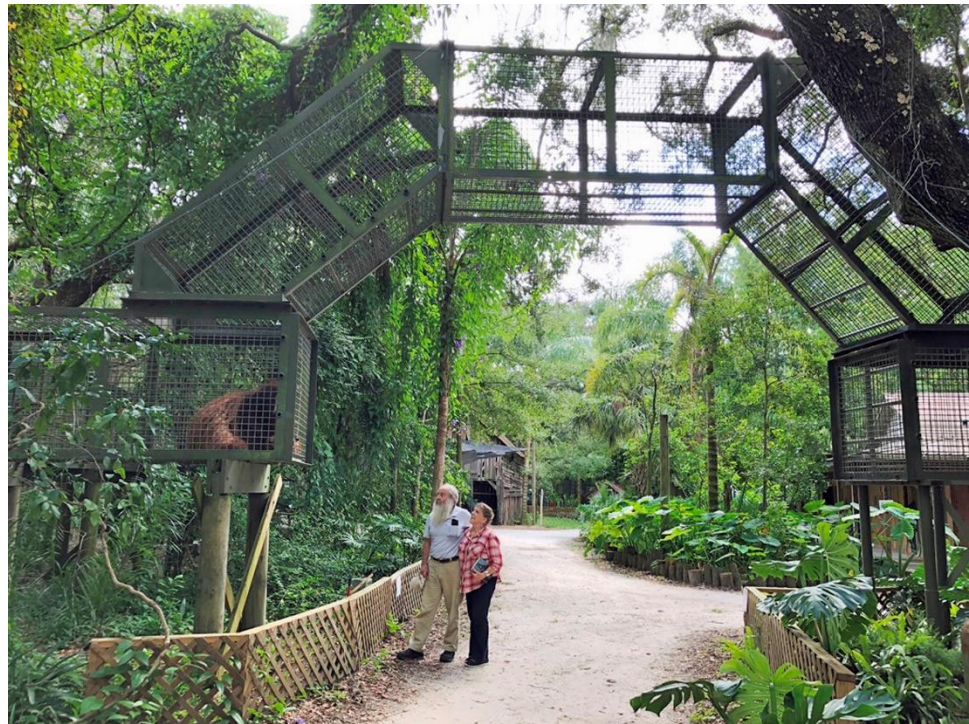


Figure 14. Large play habitats and elevated trailways at the Center for Great Apes. Image: J. Coe.

The Biomedical Primate Research Center (BPRC) is a scientific research institute in the Netherlands. Different species of primates are bred and housed there, including the common marmoset. The marmosets are housed in large indoor and outdoor enclosures, which are always accessible based upon primate choice. Detailed thought went into the layout and accessibility of the different areas, so there are always multiple entry and exit strategies possible for the animals. Instead of hand-catching, balcony boxes are provided, which can be used as separation areas. From an early age, the animals are used to entering and being separated in the balcony box with the encouragement of positive reinforcement training techniques. These balcony boxes can be taken out of the enclosure and put on a scale, which allows for frequent measurements of the animals' bodyweights. There are many indoor and outdoor furnishings to ensure that there is enough for every animal, creating 3D space for climbing, running, playing, and relaxing. The walls have built-in heating, so animals sitting on the perches next to the wall can be comfortable. Flexible willow branches and thick ropes create walking routes for the animals indoors, as well as between the indoor and outdoor areas. Hammocks are placed around the indoor area for sleeping and socializing. Initially, deep litter was used, but ants living in the deep litter created a problem for the staff, not the animals. The indoor areas now have a thick layer of sawdust, and the marmosets are seen foraging on the floor a lot more frequently. In the outdoor area, fig and bamboo plants in large containers are placed for the marmosets to use and explore (see Figure 15).



Figure 15. Back-of-house areas at the Biomedical Primate Research Center (BPRC). Photo: BPRC.

Often, funding for new facilities or major renovations is lacking, and years can pass before new enclosures, outdoor or indoor, materialize. Fortunately, ‘quick-fix’ amendments can be made in the meantime. There are always changes that benefit animals, such as adding more enriching structures and opportunities. Extra space can be created by attaching smaller cages to the already-existing cages, which can be easily removed to keep the corridor accessible during the day (see Figure 16). Attachment points can be added on walls and ceilings, allowing the attachment of hammocks, shelves, nest boxes, and other furniture appropriate for the species and individuals who live there. With smaller and lighter species such as marmosets, it might be possible and safe to attach structures, such as nets, to window frames to increase usable surface areas. Where possible, corridor areas can be turned into useable space for small primates when staff are not present. Such smaller cages and climbing structures using caregiver areas can be seen in the photo from the Helsinki Zoo in Finland. The key is to focus on what is possible and where there are opportunities for change.



Figure 16. Expanded back-of-house areas using the care staff area when caregivers are not present. Photo by Helsinki Zoo.

Author Contributions: Conceptualization, S.B.; methodology, S.B. and J.C.; investigation, S.B. and J.C.; writing—original draft preparation, S.B. and J.C.; writing—review and editing, S.B. and J.C.; visualization, J.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Authors are self-employed and not employed by institutions. No institutional approvals required.

Informed Consent Statement: Not applicable.

Data Availability Statement: This review commentary did not report new data.

Acknowledgments: We would like to thank the following people for their help in providing materials, including photos and personal communications, for the case studies and for constructive feedback

in the preparation of this manuscript: Gerry Creighton (Dublin Zoo), Merja Wahlroos (Helsinki Zoo), Keith Zdrojewski (Dallas Zoo), Patti Ragan (Center for Great Apes), Dammika Malsinghe (Dehiwala Zoo), Jane Anne Franklin (Louisville Zoo), Robert Young (University of Salford), J. Soltis (Disney Animal Kingdom), and Annette Louwse (BPRC). Other plans and photos are the property of the authors.

Conflicts of Interest: The authors declare no conflict of interest.

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