ORANGUTAN FACILITY DESIGN

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Introduction

To provide the best care for captive orangutans, it is necessary to replicate as much as possible the important elements of the wild environment.

The challenge of good design is to provide orangutans with species-appropriate habitats, which meet optimum conditions for their physical, psychological and social well-being while satisfying the needs of safety and security (Coe and LaRue 1997).

It is the designers responsibility to exceed the standards rather than to simply meet them. For these reasons it may be useful for facility designers to take a step back and consider some more fundamental issues and options, including some non-traditional alternatives (Coe and LaRue 1997).

Orangutans have evolved in a vertically-oriented, highly complex environment for millions of years and have lived in captive, horizontally-oriented animal care facilities for only a few score years. Nevertheless, these facilities are used as the model for new projects. This perceptual blind spot may severely limit the options we consider. Furthermore, The orangutan's cleverness, persistence, strength and agility have made it a legendary escape artist (Coe and LaRue 1997).

There are clearly two schools of thought when it comes to animal care and exhibition facilities: The *homocentric* view that research and technology, properly applied, will solve all human (and animal) needs. This viewpoint dominated all aspects of zoological design until very recently and still directs most thinking in non-animal display areas (Coe and LaRue 1997).

The *biocentric* view which holds that very little is known about animal needs and that if recreate the conditions in which the species evolved through eons of time are recreated, the animals needs are more apt to be met, including those we may not yet know exist (Coe 1994). This viewpoint has recently influenced the design of natural habitat immersion exhibits and may also provide unexpected insights into the design of off-exhibit areas as well (Coe and LaRue 1997).

The *homocentric* approach dominates animal care operations as well as facility design. Most standards for great apes are based firstly upon

animal health, human safety and convenience. Embury (1993) defines environmental enrichment as "empowering animals to make a choice". A growing literature supports the opinion that animals which exercise greater degrees of control over their environment (environmental choices) suffer less stress related symptoms (Snowdon 1989). It could even be argued at the more subjective level, that the animal with the greatest range of choices in manipulating its environment enjoys the greatest degree of freedom (Coe 1992).

The orangutan's tropical rainforest home can be seen abstractly as a universe of overlapping gradients of animal choices. For example, an orangutan can select an optimal microclimate by climbing to a high, exposed basking perch for warmth or retreating to mid-level shade where a breeze is available. In contrast most great ape standards mandate that indoor holding areas eliminate gradients. Light, temperature, humidity, ventilation, acoustic, visual, olfactory and touch requirements tend to be uniform (National Institute of Health {NIH} 1972; United States Department of Agriculture {USDA} 1991). They allow few choices. Most existing outdoor orangutan exhibits similarly meet these requirements, with over-abundant turf grass and insufficient opportunities for vertical mobility, distant views and shade (Coe and LaRue 1997).

While there is much to be learned from existing great ape facilities, the hope for real improvement lies in learning lessons from nature, from the orangutans themselves and from their finely tuned relationship to their natural habitat (Coe and LaRue 1997).

Galdikas (1995) has estimated that, in the wild, infant mortality is low and that the majority of orangutans live for at least 40 years. Because of their size and strength their exhibits are usually expensive to build. Therefore the exhibits usually need to be designed for a very long life. The most important design question that should be asked of a designer is will the design meet the needs of the animals and the zoo over the life of the exhibit? Therefore the design of an orangutan exhibit must not only meets the needs of the current orangutans at a zoo, but for often up to 20 years ahead. Therefore the design will need to incorporate possible room for expansion, as well as the change in numbers, changes in individuals of varying temperament and the changing age and sex structure of the colony. It may also be prudent to consider the changing priorities of *ex situ* conservation, changes in public attitudes and changes in the goals of captive management of orangutans, which are expected over the life of the exhibit.

The following is designed to be a tool for designers and managers of orangutans exhibits, in the form a checklist of relevant points, which they may want to consider.

Internal Structure of the Exhibit

Galdikas (1978) study showed adult female orangutans have a core range of two to three km^2. The core area is an area a female orangutan nests in and uses more intensively and to the exclusion of any other female. The adult female's home range is between 5 to 6km^2. This home range overlaps with home ranges of other females and provides sufficient food resources for a year-round supply for her and up to two dependent offspring (Rijksen 1978; Rodman 1973; MacKinnon 1974; Horr 1977). Because daughters move out gradually into adjacent ranges to their mothers, the neighbouring females in any given area are usually related.

Adolescent males leave their mothers' home range and travel long distances into territories new to them (Rodman 1973; MacKinnon 1974). This results in the adult males in an area being unlikely to be related to the resident females (Rodman 1973; MacKinnon 1974). In a particular area, adult males are either resident or nomadic (MacKinnon 1974; Galdikas 1978; Rijksen 1978). Galdikas (1978) also found resident adult males may move away from their home ranges when all the resident females have young infants (i.e. unable to become pregnant) and there were seasonal food shortages. The adult resident male's home range (at least 10km^2) takes in part the home ranges of up to five adult females and occasionally may overlap with home ranges of other resident adult males (Rodman 1973; MacKinnon 1974; Galdikas 1978; Rijksen 1978). Adult resident males do not appear to maintain a core range (Galdikas 1978).

It is normally accepted that providing the correct social environment for animals in captivity is one of the major necessity for their well being. There is also a large variation in potential orangutan sociability according to age and sex. Juveniles and sub-adults are naturally far more social than adults are. For example sub-adult males, which are naturally the most social orangutans, as adults become the least social of orangutans. Captive orangutans especially if they are hand-raised are capable of being more social than they are in the wild, but their capacity to modify their behaviour is not totally plastic. There is also a large variation in sociability between individual animals. With such individual, life history, sex and demographic variation, there is the risk that characteristics of a few individuals can over influence the design of exhibits, which may out last the stay of the inhabitants. It is therefore wise to design the exhibit to be able to provide the inhabitants with social contact comparable to wild orangutans for their age and sex. This may be done by designing of placement of

future internal barriers in the exhibit such as walls or vegetation protected by electric fences.

Female orangutans are very territorial. To the extent that recent evidence suggest that some female orangutans are so fearful to roam the forest outside their normal boundaries, because of potential confrontation with the resident, when their territory is degraded by logging they remain in the area eventually to die (van Schaik 2000). It is therefore important that adult female orangutans are allowed to set up their own territories and other adult females are not allowed to enter the area, even if the female temporarily vacates the area. Although the rotation of orangutans through various enclosures does have the potential of behavioural enriching the orangutans through novelty, the stress of this movement out weighs any benefit. Markham (1990) observed captive orangutans take on average two months after an exhibit move until signs of stress were reduced to pre-movement levels. Wild orangutan females tend to set up territories next to their dams. This relationship between females in a given area reduces friction between adult females when exploiting resources on the boundaries of the territories. In captivity, the housing of related females in a zoo, also has the potential to reduce friction between adult females.

The question with orangutans is not are they solitary or gregarious, but what is the appropriate level of social contact they require. Due to the large variation in the appropriate level of social contact between sex/age groups and individuals, it is seldom possible to provide all individuals their preferred level of social contact. In the wild orangutans have the capacity to space themselves from each other and even the most subordinate animals can choose the level of social contact they desire. Neither keeping single orangutans, or small groups of orangutans isolated from even visual contact with other orangutans, or the formation of groups dependant only on numbers of orangutans at a zoo, are desirable management options.

The problem in captivity where orangutans are confined to small areas is that choice by a dominant orangutan rarely coincides with that of the subordinate orangutan. Therefore in captivity the choosing of the appropriate level of social contact is usually decided by the keepers and restricted by the design of the exhibit.

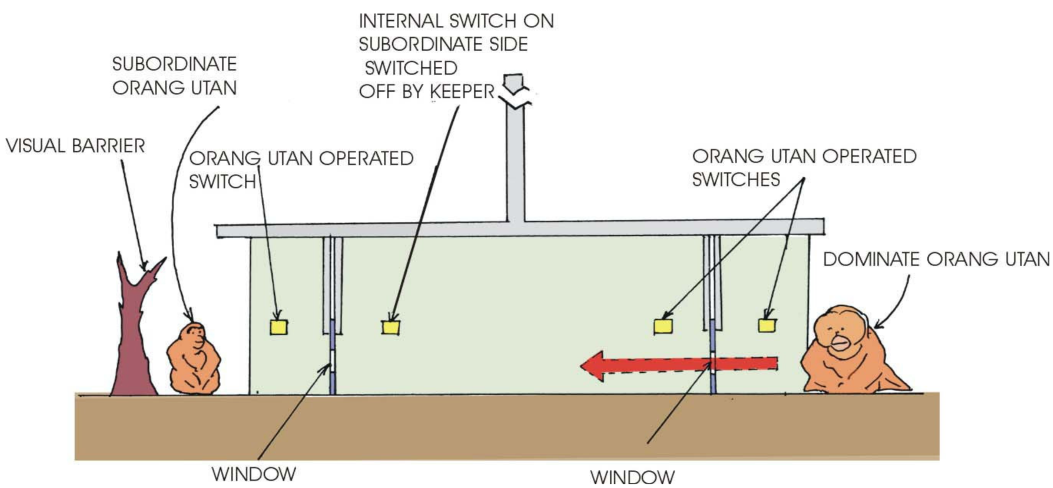
There are potentially three methods of dealing with social contact:

1. Put all orangutans in one area and provide a level of choice through a diverse and complex environment, with multiple internal visual barriers, allowing even subordinate orangutans to choose their level of contact with cage mates. In addition ensure all desirable areas

and facilities are offered to the orangutans are in abundance. The level of success with this approach is highly dependent on the size of the exhibit. The larger exhibit the more choice. Areas to some extent can be made effectively larger by increasing the functional complexity of the internal environment.

2. Place the orangutans in strictly defined natural population units (i.e. Adult female and up to two offspring, Solitary adult males, Juveniles and sub-adults in groups or twos or threes) and allow the keepers regulate the level of physical contact between groups according to individual temperament and known wild parameters. This is often the only effective method available to zoo managers when exhibit space is highly restrictive.

Fig. 2 Suggested Design of Contact Corridors



3. As in method two, place the orangutans in strictly defined natural population units, but allow transfer between groups in adjacent territories according to mutual choice of orangutans. This can be achieved through the placement of corridors between enclosures (See Fig. 2). In this situation the keeper closes the slides and separates the two individuals/groups each night. The slides may be opened each day by sensor-switches operated by the orangutans, with the exception of the inside switch closest to the subordinate animal's enclosure. This switch has its orangutan-operation mode turned off by the keeper. If the dominant orangutan wants to have social contact it raises the slides and enters the corridor. The subordinate animal may view the dominant animal through the slide's window. If the subordinate agrees with the contact it must open the slide for the dominant animal. If the subordinate orangutan makes the first move it can open all the slides to the dominant animal's enclosure. Alternatively, the movement both ways can be made to occur by mutual consent only. There is a visual barrier placed near the slide

windows to prevent any unwanted visual contact between individuals. As well the keeper may close the slides at any time of his/her discretion.

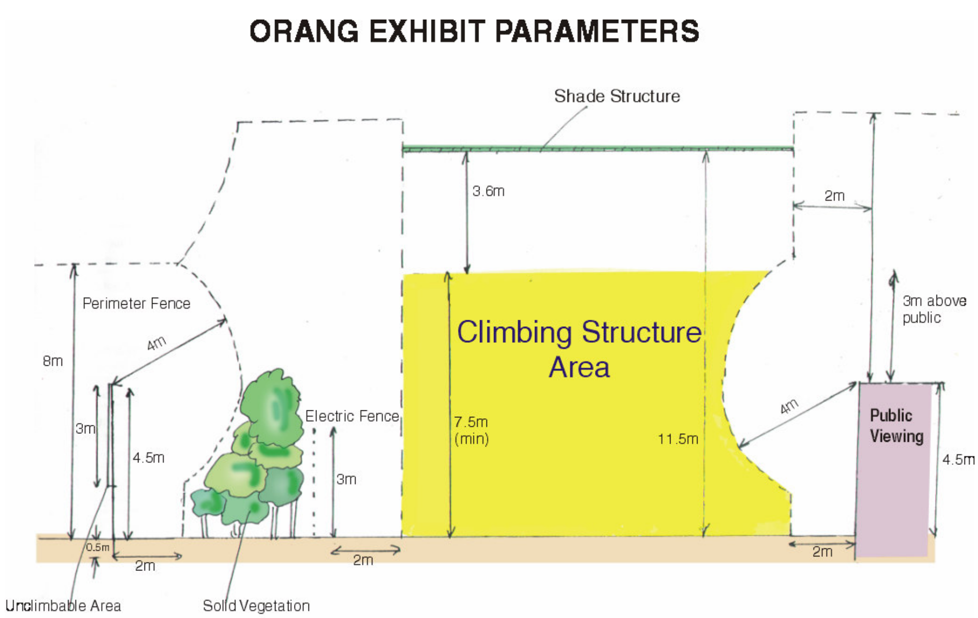
Recommendations

- Where possible all adult females in an exhibit should be related.
- With the exception of between adult males, all orangutans where possible have the possibility of visual contact between all other individuals.
- Exhibits where possible be designed to have the potential to house a complete orangutan social group.
- Exhibits where possible to be designed to have the potential to house orangutans in natural population units within the social group.
- Population units housed separately should not regularly exchange territories.
- Population units of orangutans must be able to have visual escape from other units.
- Zoos should consider designs, which allow the level of social contact to be mediated by the orangutans.
- There should be provision to house animals separately.

Barriers

There are essentially seven kinds of barriers used to confine orangutans. They are dry moats, glass barriers, electric barriers, mesh cages, deep water moats, wall/fences and un-descendible poles.

Fig. 1 Cross Section of an Orangutan Exhibit Design showing the Use of Various Barriers



Glass Barriers
The orangutan's susceptibility to most human diseases has caused major health problems for them in captivity. Glass barriers and wide dry moats have proven to be effective against the transmission of human diseases (Maple 1979). Unfortunately in small enclosures glass barriers can violate the orangutan's natural minimum flight distance (See 2.6.0).

The thickness of glass varies with the size of the opening and should be determined by a specialist. Unshaded glass barriers are used by many zoos as outdoor barriers. If the intent is to create an invisible barrier, reflections quickly give it away. Reflections can also make viewing through unprotected glass nearly impossible under certain viewing conditions. To minimize reflections, viewing glass should be covered such that the viewing area is much darker than the area viewed (Coe and LaRue 1997).

Orangutans can easily break glass if they have access to hard objects such as stones or steel. Annealed or tempered laminated glass with PVB inner layer and glass with intermediate acrylic layers, will remain intact if broken, but the damage is done. Acrylic and other glass substitutes are unbreakable, but can be easily scratched. Glass and acrylic of sufficient strength to contain orangutans is also very expensive (Coe and LaRue 1997).

Dry Moats and Smooth Walls
Smooth walls 3.66m (12') high have been used to contain orangutans at Zoo Atlanta and Oklahoma City Zoological Park. No potential finger holes are present. This eliminates all but the smoothest artificial rockwork or requires an overhang at least 3.05m (10') wide which animals can't climb. Smooth walls tend to be unattractive in naturalistic exhibit areas and it is best to design the facility so that smooth walls, if needed, are not visible to the public. Various types of camouflage paint or mural-type applications may prove useful (Coe and LaRue 1997).

Advantages of smooth walls include the fact that they take up very little space and are only moderately expensive, compared to the available alternatives. Disadvantages include the possibility that the orangutans may improvise a ladder and escape. Preventative measures may limit animal enrichment opportunities (Coe and LaRue 1997).

Moated exhibits with smooth walls are exhibit features at Zoo Atlanta and Oklahoma City Zoological Park. Both zoos have used moats with 3.66m (12)' outside walls, 3.66m (12') in width and 2.44m - 3.05m (8'-10') inside walls (Coe and LaRue 1997). Although these walls have been shown to successfully contain orangutans the wall height must be

sufficient to prevent escape by use of stray objects thrown into the exhibit or objects otherwise obtained by the orangutans, plus allow orangutans to have a wide range of enrichment material.

As with mesh cages, the wall or fence needs to be extended under the ground or angled back into the exhibit.Such moats are nearly invisible when perpendicular to view. However, when moats are parallel to view they may be fully exposed and unattractive. The two most common solutions to this problem are: using plantings or other features to screen public views down into moats, or using a painted or minimally textured smooth wall as the barrier and a planted or other climbable slope instead of an inside wall. Allowing orangutans access into the moat may provide them with opportunities to hide. Using shallow (safe) water areas to fill the base of the moat can discourage this. However, this technique must be done in such a way that contamination, insects and ice formation do not become problems (Coe and LaRue 1997).

Advantages of dry moats include their near invisibility when well placed. Disadvantages include high relative cost and unsuitability in areas with high water tables or shallow bedrock. Like smooth walls, they can be compromised by animals using improvised ladders. Moats also take up a lot of space in smaller exhibits (Coe and LaRue 1997).

Recommendations

- Minimum moat depth is 4.5m (14' 8").
- Smooth Wall or fence height minimum 4.5m (See Fig. 1).
- It is recommended that the last 3m (9' 8") of a wall or fence must be un-climbable
- (See Fig. 1).
- The fence or wall should extend at least 50cm (1' 6") under the ground (See Fig. 1).
- Glass Barriers should be avoided in small exhibits.

Electric Barriers

Electric barriers are regularly neutralised by orangutans and therefore are not recommended as a primary means of constraint. Electric barriers can serve a function as secondary barriers. For example protecting the vegetation inside an exhibit. If Electric Barriers are used to protect vegetation or separate orangutans inside an exhibit they must be of sufficient height and contain a sufficient number of strands to prevent orangutans scaling the fence or shorting out all the wire too frequently. Orangutans seem to vary widely in their tolerance to electricity, and many animals have learned to neutralise hot wires (Coe and LaRue 1997). Concern is expressed that in response to orangutans manipulating electric wires, with various behavioural enrichment objects are no longer made available. This may

compromises environmental enrichment, an essential component of orangutans captive management.

Recommendations

- Electric Barriers: Minimum height 3m, minimum distance between wire 10cm, first 1.5m all positive wires, top 1.5m alternate positive and negative wires. Maximum 6,000 volts, minimum 3,300 volts. Peak current 6.4 amps (See Fig. 1).
- Electric Barriers should only be used as secondary barriers to contain orangutans.

Mesh Cages

Mesh Cage exhibits are the most secure of the barriers used to contain orangutans. They also have the advantage of maximising the amount of arboreal space per area, plus allow for unlimited play objects without fear of escape. They unfortunately are difficult to make visually appealing. Weave mesh is a lot safer as orangutans have been known to unpick weld mesh. Orangutans can dig into the ground, therefore the mesh of the cage needs to be extended under the ground or angled back into the exhibit.

Steel mesh enclosures vary from highly visible rigid frame structures such as the "gorilla villa" enclosure at Columbus Zoological Gardens to the very light and diaphanous cable-supported orangutan enclosure at Cheyenne Mountain Zoological Park. Mesh size and type can vary from the 0.64cm (1/4") diameter x 5.08cm (2") x 5.08cm (2") crimped wire used in holding area enclosures to the new 0.24cm (3/32") diameter 5.1m (2") x 5.1m (2") woven stainless steel cable mesh used at Cheyenne Mountain Zoological Park (Coe and LaRue 1997).

The mesh enclosure also makes it much more difficult for objects to be thrown either into or out of the exhibit area. Mesh may be a more cost-effective option than moats for smaller exhibits, although the price varies depending upon the type of construction and material. The disadvantages of mesh include the fact that viewing must be through mesh or glass and the mesh support structure will intrude visually in naturalistic exhibits. This can be somewhat mitigated by building the mesh enclosure within an existing tree grove so that living trees form a substantial part of all views. Mesh enclosures have been combined with an open water moat at the Metropolitan Toronto Zoo by using smooth transition panels. Other combinations are also possible (Coe and LaRue 1997).

Another form of mesh enclosure is a fence with a 3.05m (10’) overhang or vertical extension which animals can't climb. This solution has been used for gorilla and chimpanzee exhibits at Audubon Park & Zoological Garden, Lowry Park Zoological Garden, North Carolina Zoological Park

and Toledo Zoological Gardens. Deep water is not recommended because of the danger of drowning and because wild orangutans have been observed wading up to their necks in swamps collecting emergent vegetation (Coe and LaRue 1997).

Recommendations

- Mesh wire: 5mm (0.2′) diameter (NSW Agriculture 1995), 5cm x 5cm (0.2′ x 0.2′)
- Woven steel cable mesh: 6mm diameter, 5cm x 5cm (0.2′ x 0.2′) weave.
- The mesh should extend at least 50cm (2′ 4″) under the ground.

Deep Water Moats

Unfortunately, orangutans quickly drown if they fall in deep water moats or pools in enclosures. Infants can also drown in surprisingly shallow water. The incidence of drowning increases when orangutans are likely to enter the water to avoid aggression, retrieve objects from the enclosure or to gain objects thrown into the water by the public. Orangutans have been observed wading up to their necks in both the wild and captivity. Some zoos use electric wires to try to prevent orangutans from entering the deep-water moats. As mentioned earlier, this often results in the absence of any play objects for the animals, to prevent them from shorting out the electric wires. Even this is often not effective as orangutans are usually very skilled at using vegetation or sticks to by-pass or destroy electric wires.

Recommendation

- Deep water moats should be avoided as barriers for orangutans.

Un-descendible Poles

Orangutans can be prevented from escaping by use of poles, which may extend over the public area. The poles must be of sufficient height that the orangutans will not risk jumping in all but the most extreme situations. The poles must be designed to prevent the orangutan from descending the pole. This can be achieved through the use of electric wires or preferably by the placement of a smooth surface area of sufficient diameter to prevent the orangutan from gripping the surface.

Recommendations

- Minimum drop height for a structure over a non-secured area is 8m (26′) (See Fig. 1). N.B. In National Zoo (Washington DC) poles are 15m (50′) high.
- A smooth conical structure should be placed under the poles platform as in Perth Zoo (minimum height 3m (10′), minimum width 1.5m (5′)).

Enclosure and Gate Material

Orangutans are highly intelligent, extremely persistent, patient, strong and skilled at dismantling equipment. They have been know to use their fingernails as "screwdrivers" (McManamon and Bruner 1990). Other examples include loosening bolts and nuts tightened with heavy wrenches and opening locks with pieces of wire and other items they have hidden under their tongues and lips (Coe and LaRue 1997).

Hot-dipped galvanized steel is most commonly used material for enclosure construction. Stainless steel is preferred, but is much more expensive. For enclosure fronts, many new facilities have used 6mm (1/4") x 5cm (2") x 5cm (2") crimped steel mesh. This is preferred over welded wire mesh because the welds can sometimes be broken. Spiral weave (chainlink) mesh has been used, although some animals have unwoven it. Steel bars are not recommended as they allow the animals to reach through the barrier more readily than mesh (Coe and LaRue 1997).

Openings between caging and floors or other elements should not exceed 3cm (1 1/2") for continuous gap and sometimes less, if adjacent to transfer door operators or similar components (Coe and LaRue 1997).

Gates between adjacent holding areas should be located near the cage front to facilitate animal use and prevent animal injury during transfer. Two well-separated gates into major animal activity areas should be included so that a dominant animal cannot block other animals from entering or exiting the area. The size of animal gate openings in orangutan facilities range from 81cm (2’ 8") square to 102cm (3’ 4") square (Coe and LaRue 1997).

Factors to consider in selecting gate movement systems include:

- Frequency of operation
- Cost of construction
- Frequency of maintenance
- Back-up system requirements
- Staff experience

Animal gates or doors made of 0.48cm (3/16") thick steel, or polypropylene (25mm, 1" thick) have been successful at Oklahoma City Zoological Park. Zoo Atlanta uses similarly constructed doors with the addition of steel frames. Plastic materials have the advantage of being better thermal insulators for outside gates and allow some light penetration. They are also lighter in weight, quieter than steel, do not rust and reduce the amount of friction during operation (Coe and LaRue 1997).

Gate closure systems vary widely. Hydraulic gates are used at provide excellent operator control, considerable power and can be fixed in any location. If the orangutans could conceivably gain access to the hydraulic hose, non-toxic hydraulic fluid, such as water should be used. Electric powered gates are used at the Chicago Zoological Park. These operate smoothly, lock in any position, but are slow. Both of these systems require a back-up system in case of power failure (Coe and LaRue 1997).

Manually operated gates include vertical (guillotine) and horizontal (sliding) gates. Swing (hinged) gates are not recommended. Guillotine and sliding gates with a single operating cable have been developed using spring or counter weight-powered throw bolts to lock the gate in a variety of positions. While these gates operate well under ideal conditions, experience has shown that they require frequent adjustment and that debris in the bottom track can prevent closure. Guillotine gates with a continuous steel cable or chain drive has been effective. The chain driven gate system is used at Oklahoma City Zoological Park and can be locked in a variety of positions by securing the operating wheel. Horizontal sliding gates can be operated by any of the above systems or by the use of a push/pull bar. This is the simplest and most cost-effective of gate operating systems. Placement of the gate will determine whether pushing or pulling on the handle opens the gate. Pushing to open the gate is safer for the keeper operating it. If the animal forcibly pushes open the gate, the push rod is thrown away from rather than toward the Keeper (Coe and LaRue 1997).

All gates must have a highly visible locking device, which allows staff to immediately confirm that the gate is secure. Gate control points must provide a clear view of the gates being operated with good view of both sides of each gate while being located well out of reach of the animals (Coe and LaRue 1997).

Positive reinforcement training should be used to condition the animals to transfer (See Training Chapter, this volume). No mechanical system can compensate for problems with animal transfer procedures. For example, the smallest orangutan can effectively block the most powerful gate closure mechanism by simply putting a hand or foot in the opening, thus preventing the gate from closing. Using rapidly moving gates to trap animals is dangerous and may discourage reliable animal transfer in the future (Coe and LaRue 1997).

Keeper Access Doors

Normal access doors are usually 0.9m (3′) x 2m (6′ 8"). Wider and/or taller doors should be provided where access is required for replacing deep bedding, browse or exhibit furnishings. Doors into animal areas should provide good visibility. When glass view-ports are used, they

should be made of an adequate thickness of laminated safety glass. Access doors at barrier walls should be constructed so the animals can't climb them (Coe and LaRue 1997).

Hinged doors should swing into the animal area and designed so they cannot be opened into the keeper area. They should be latched at both top and bottom, not just in the middle. Sliding doors are also satisfactory provided that they are continuously supported on both top and bottom. The initial cost and long-term maintenance is higher than hinged doors (Coe and LaRue 1997).

Wall, Ceiling and Floor Materials/Surfaces

Walls are usually constructed of poured concrete, concrete masonry units or fired clay tiles or blocks. Where hollow units are used, walls should be fully reinforced and the interior voids filled with grout to form solid walls to prevent the animals from breaking through the surface, scratching away the mortar or removing blocks. Solid walls also must provide support for a wide variety of surface mounted structures and equipment. Pipes and conduits are often built into walls where they cannot be reached by the animals. Pipe and duct wall penetrations must be sealed (Coe and LaRue 1997).

Wall surfaces must be cleanable with no small irregularities or pits where fecal material can collect. The following are the most common types:

- Concrete walls that are plastered with a waterproof Portland cement plaster and painted with an epoxy-based paint.
- Masonry walls, which have joints struck flush and are treated with a block-filler to remove pits and painted.
- Glazed masonry units may be used, making sure to use grout between the tiles (Coe and LaRue 1997).

Grout between block or tiles must be very dense and hard. Orangutans have been known to pick out softer types of grout and caulking. Ceilings must have strength, moisture resistance and washability characteristics similar to walls. Floors should be smooth, easily cleanable, moisture proof, non-absorbent and skid-proof. The surface must resist abrasive detergents, disinfectants and urine. Floors should be coved where they meet walls and joints should be minimised. The drain slope should be not less than 2 cm (1/4" to 12"). Floors are generally made of poured concrete. A sealer can be applied to this type of floor. The sealer will require more frequent re-application but is lower in cost. Another alternative surface is epoxy-based which lasts longer (Coe and LaRue 1997).

Climbing Structures

Orangutans are extremely strong, very intelligent and have large reaches. All these attributes need to be incorporated into exhibit designs. They are extremely adverse to jumping at heights and adult orangutans are very unlikely to jump even the smallest distances.

The most important aspect of the captive physical environment for orangutans is the amount of arboreal space available for both rest and locomotion (Maple 1979; Maple and Stine 1982; Jones 1982). Horizontal arboreal pathways and nesting/resting platforms are the main elements of the natural physical environment (Jones 1982). The lack of opportunity for arboreal locomotion promotes lethargy and contributes to obesity (Maple 1980). The combination of lethargy and living on the ground causes health hazards. Coprophagy or playing with faeces often becomes common, especially if there are no other stimulating objects in the enclosure (Hill 1966; Maple 1980). Infection by faecal bacteria causes air-sacculitis, the second most common cause of death in adult orangutans in captivity (Cambre et al. 1980). This disease is totally unknown in wild orangutans (Cocks 1999).

Resting platforms are necessary for the orangutan to fully utilise the climbing structure. There should be a sufficient number of platforms, so that dominant animals don’t exclude subordinates in the group. The climbing structure also needs to be designed to prevent subordinate animals from being trapped.

Many orangutans have hung themselves by accidentally draping loose ropes around their necks. For this reason care must be taken to ensure ropes or artificial vines do not have small enough diameters or are loose enough for them to be firmly secured around an orangutan’s neck.

Climbing, perching and elevated rest areas have been traditionally made of hard, washable surfaces such as steel or dense plastic. Wood is normally sealed to make it non-porous. Non-washable materials such as ropes or fabrics should be discarded when soiled (USDA 1991). Izard and Pereira (in press) have found that properly maintained wood substances have been used for up to 20 years with no indication that they harbour harmful pathogens (Coe and LaRue 1997).

Orangutan activity is maximised by small diameter climbing structures, which can be used for various types of moment. To further stimulate activity the climbing structures need also to have a large percentage of movablity (e.g. ropes and sway poles) and be appropriately spaced.

Orangutans are adapted for an arboreal lifestyle, yet because of their supreme dexterity and strength, they are usually provided with few climbing opportunities. In the wild, orangutans often move themselves by causing branches, vines and small trees to sway in the desired direction until they can reach a new hand hold, transfer to a new perch and repeat the process. Resilient nests made from small branches and broad crotches in larger trees provide rest areas. Most of the orangutan useable world is made of things, which they can move (Coe and LaRue 1997).

By contrast, most environments made for captive orangutans provide fixed furnishings. Large diameter ropes and cargo nets have been used successfully in recent years to add the important dimension of movement. There is of course some hazard of injury and death to animals when using these and other types of moveable furnishings. Assessment and determination of risk versus benefit must, of course, be determined by each institution. Artificial vines made from synthetic fibre rope thinly coated with epoxy have proven to hold up under heavy use by orangutans at the Chicago Zoological Park. These vines may need to be repaired every year (Carol Sodaro, personal communication as cited in Coe and LaRue 1997).

Artificial trees made of steel-reinforced concrete, although stoutly built, have been broken repeatedly by orangutans. More slender, artificial trees fabricated of welded steel pipe with a thin texture coat of concrete have supported chimpanzees at the Detroit Zoological Park. Similar structures coated with epoxy have been used for mandrills and other small primates at Zoo Atlanta. The technology of such construction is improving rapidly and it is predictable that realistic, artificial trees with somewhat flexible limbs attached with flexible joints will be available for orangutans within the decade. This of course depends upon an institutional having sufficient construction budgets to support the improvement of this technology (Coe and LaRue 1997).

As a lower cost alternative, many zoos have installed natural dead trees as climbing structures. One such structure at Zoo Atlanta was 16.8m (55') tall when installed. Appropriate species of healthy living trees cut for this purpose should be used. Trees, which are partly dead when cut are already greatly weakened by wood decay and will not last long. Sound, natural trees cannot be expected to last longer than five to seven years before becoming weakened. Crane access must be maintained to allow for tree replacement and should be considered in determining maintenance budgets (Coe and LaRue 1997).

The San Diego Zoo has used heavy timbers treated with preservatives. Treated timbers last much longer than untreated ones. Types of preservatives vary widely in their toxicity to mammals. Institutions

wishing to use this method must determine that the preservatives used pose no hazard to the animals (Coe and LaRue 1997).

Sway poles made of 5.08cm diameter x 6.10m (2" diameter x 20') extruded glass fiber have been used for orangutans at Oklahoma City Zoological Park. These poles may be irregularly spaced about 2m(6.56′) apart and their tops are inter-connected with loose rope so that the animals cannot bend them too far (Coe and LaRue 1997).

Many captive-born orangutans, especially older adult males are disinclined to use climbing structures even when provided. Design of exhibit features allowing both food enrichment and resting platforms to be provided high in climbing structures may encourage much greater activity among orangutans of all ages. Providing such opportunities is important to encourage species-typical behaviour and should not be considered an extravagance (Coe and LaRue 1997). Most orangutan exhibits tend to be circular, oval, or square with little opportunity or reason to move about. Wild orangutans, by contrast, cover relatively wide areas in search of food following well defined aerial pathways. Ideally, orangutan exhibits would more closely follow this natural model, being linear or perhaps even forming circuits, with continuous overhead pathways. Elevated foraging areas should be provided along the way to encourage use. Long, narrow exhibits allow large trees to grow on both sides, out of reach of the orangutans. These can provide desirable shade, backdrop and ambience. Such linear exhibits could be mesh enclosed or moated.

Recommendations

- Useable arboreal space: should be one of the major parameters used to measure the relative value of different designs.
- Maximum bar/rope width 75mm (3″).
- Climbing structures need to have a large percentage of moveability.
- Ideal inter-structure distance (e.g. bars and ropes) is 2m (6′5″).
- Structures should be designed to prevent subordinate animals being trapped by dominant animals.
- Climbing structures must be a least 4m (1′3″) from the top of external walls or fences ground and 2m (6′5″) from the base of the wall (See Fig. 1).
- There should be three platforms for every orangutan housed in an exhibit (Minimum size 1.5m x 1.5m (5″ x 5″).
- Ropes should be of sufficient diameter or have limited movement (e.g. fixed tightly at both ends) in order to prevent accidental hangings.

Horticulture

Orangutans are commonly kept on turf grass. A rapidly draining growing medium prevents the formation of muddy areas, but increases the need for fertilisation

A planting strategy, which has worked at Perth Zoo is to plant a super abundance of smaller plants and allow them to become established before allowing the animals exhibit access. This works best in larger exhibits (Coe and LaRue 1997). Electrified wire plant protection systems work well with many individual orangutans and are worth using but are not totally orangutan proof. Some animals are adept at using sticks or other tools to break or short circuit the systems, while others seem to enjoy grasping the wires.

Fibreglass or epoxy has been used to make realistic artificial bark structures, which protect the trunks of larger trees in exhibits. Electrified aerial roots or other hot wire configurations at the top of these 4m (12' to13') structures discourage climbing. This allows the animals free access to the base of the protected tree, providing much needed shade. Such systems have been successfully used for gorillas at Zoo Atlanta and Oklahoma City Zoological Park and with chimpanzees at Detroit Zoological Park and Oklahoma City Zoological Park. This system may also work to protect large shade trees in orangutan exhibits (Coe and LaRue 1997).

Access to the outdoor exhibit should be provided for the occasional maintenance and replacement of planting and large furnishings (Coe and LaRue 1997).

Enclosure Security

Orangutans must be considered to be potentially dangerous animals. Therefore, safety and security are important elements of facility design. Security design has two main goals: to keep unqualified people away from the animals and to contain the animals and prevent their escape (Coe and LaRue 1997).

Since safety is clearly linked to knowledge and experience, a well-designed animal care facility can be thought of as a series of security zones granting greater degrees of access based upon qualification to interact with the animals (Coe and LaRue 1997).

Institution wide security is usually a fence or other barrier whose characteristics are governed by USDA or other standards. Its purpose is to keep out unwanted people, stray dogs, and may serve as a back-up containment barrier (Coe and LaRue 1997).

The public visitor zone is the area used by zoo guests. Barriers between the public and areas into which animals can reach are generally 1.07m

(3’ 6") high with openings no greater than 10.16cm (4") in any direction. There should be no horizontal members, which could form a ladder. When this barrier is not an exhibit viewing area and is hidden by vegetation, many facilities have used 1.22m (4’) or higher steel mesh fencing. Each facility should verify the appropriate height for public security barriers based upon local government ordinances (Coe and LaRue 1997).

Inside buildings, the public is generally separated from staff and animal areas by locked doors. General service areas are generally accessible to any staff or delivery person. It is essential that these areas be well separated from animal areas. Outdoor areas include service drives and yards and planting areas. Indoor areas include staff and food preparation areas and mechanical equipment rooms (Coe and LaRue 1997).

Secondary animal security areas are those areas immediately adjoining areas containing animals. Since animals occasionally escape into these areas, they should be designed to be as "orangutan-proof" as possible (Coe and LaRue 1997).

It is essential that staff have complete visibility of these areas before entering. ‘Dog legs’ and ‘blind spots’ must be avoided. Some facilities use parabolic mirrors to compensate for these problems, but it is better to eliminate these areas. Where corridors change direction and blind spots are unavoidable, careful placement of an additional mesh barrier and security doors can provide an additional security zone with good visibility (Coe and LaRue 1997).

Primary animal security areas are those areas normally occupied by the animals and those areas occasionally occupied by unrestrained animals such as shift areas and transfer chutes. It is essential that staff in secondary animal security zones have excellent visibility into primary security areas so that staff can verify the rooms are empty and secure before they enter (Coe and LaRue 1997).

Where secondary security areas provide access into large complex indoor or outdoor exercise or display areas it may not be possible to insure complete visibility of the area before entering. Therefore, the following two precautions are essential:

- Excellent visibility of the animal area immediately beyond the door, including overhead space.
- The ability for staff to quickly account for the location of all animals to determine that no animals are present prior to opening the door (Coe and LaRue 1997).

Provisions must be made to insure that animals will not be released into any area, which is already occupied by another staff member (Coe and LaRue 1997).

Indoor Holding Areas

The requirements of holding areas can vary according to the type of husbandry use intended, the number of animals expected to use it concurrently and the amount of time they are expected to occupy the space. Of course most spaces will be used for a variety of functions (Coe and LaRue 1997).

Shift Rooms

Shift rooms would normally be used by up to two compatible animals for a few hours or less while other areas are cleaned or during transfer operations. Since shift rooms may be used for extended periods, it is highly desirable to make them the size of normal night rooms (Coe and LaRue 1997).

Day Rooms

Day rooms, also known as community rooms or exercise rooms, are larger; 3.66m x 6.10m x 6.10m high (12' x 20' x 20') is the minimum desirable size to consider. A much higher space is desirable to accommodate the orangutans vertical spatial orientation (Coe and LaRue 1997).

Day rooms should provide opportunities for enrichment with multiple opportunities for climbing, perching, feeding, exploratory, manipulative or other physically and mentally stimulating activities. Day rooms should be complex enough to allow individuals to separate themselves from others if they wish. Many of the recommendations made previously regarding orangutan climbing structures applies to the furnishing of the day rooms. *Ad lib* access to water is also needed (Coe and LaRue 1997).

Day rooms can be used for positive reinforcement training sessions, so locking ports where materials can be transferred back and forth may be useful. They are also useful for animal introductions. A 'howdy' wall or gate is needed for this purpose. This is a double mesh barrier through which animals can touch each other without full physical contact (Coe and LaRue 1997).

In many zoos, day rooms may also be public exhibits. In facilities with larger collections, day rooms provide exercise opportunities for animals that are not on public exhibit.

While very natural-appearing exhibits are difficult to achieve indoors progress is being made. St. Louis Zoological Park, Henry Vilas Zoo, and

Pittsburgh Zoo have used painted murals to suggest a rain forest diorama. However, orangutans can be destructive to painted surfaces. Woodland Park Zoological Gardens is developing indoor orangutan displays with a backdrop of tropical plants separated from the apes by a strong fine-woven steel cable mesh. Pittsburgh Zoo has developed similar indoor displays for smaller primates (Coe and LaRue 1997).

Quarantine Areas

Quarantine Areas are used to isolate animals, which are ill or undergoing health screening. Waste drainage must be separate from other holding areas to prevent cross contamination (McManamon and Bruner 1990; USDA 1991). These enclosures are similar to night rooms and day rooms, but are isolated from other animal zones and have negative air pressure relative to surrounding areas. Quarantine areas should ideally connect to the outside service area so that new animals can be brought in without contaminating other holding areas (Coe and LaRue 1997).

Medical areas should include the following features as recommended (McManamon and Bruner 1990, as cited in Coe and LaRue 1997):

- An examination room for taking blood samples, suturing wounds, and other minor surgical procedures. This room should be able to hold veterinary equipment and supplies.
- Emergency equipment including oxygen, electrocardiogram machine heat lamps, intravenous fluids, anaesthetics, immobilisation equipment.
- A radiograph unit should be available for fractures (if animals are young, a portable unit may be sufficient).
- A small laboratory with a microscope for examination of faecal samples. Other laboratory analyses, such as blood tests, can be performed on-site or at another facility.
- A separate necropsy room with its own entrance if other facilities do not exist within a reasonable distance, cooler or refrigerator and storage or incinerator.
- A sterile surgical area.

Night Quarters

Night quarters or Night rooms should be no smaller than 2.4m wide x 3.5m deep x 2.4m high (8'x 12'x 8'). Night quarters usually have elevated sleeping platforms or nesting provisions and *ad lib* access to water. Flexible provisions for behavioural enrichment are required, and animals should be given as much control as possible over their environment (Coe and LaRue 1997).

The time orangutans are confined to their night quarter is a valuable time to monitor their health and collect urine and faecal samples.

Ideally each adult orangutan (or adult female with a dependent infant) should have its own individual night quarter. Even if this were not the current practice of the zoo, the variation in the groups over time and individuals would make this a sensible design parameter. This also allows food, urine, faeces and menstruation to be monitored on a regular basis. Juveniles and sub-adults should also ideally have individual night quarters, but if there is not enough room to allow this they should be kept in pairs in the night quarters. Care should be taken to choose compatible pairs of about the same size and dominance status. Except with dam and dependant offspring below eight years of age, orangutans do not readily share food. For this reason all orangutans after the age of eight should be given the option of their own night quarters to allow all animals to receive a balanced and monitored diet. Some zoos have overcome the difficulty of food sharing in group housed orangutans through positive reinforcement training.

Data analysis indicates that there are certain high hazard events in the life of a captive orangutan (Cocks and Collier 1998). These include during or shortly after transportation between zoos. One in 20 die within one month of arrival and one in eight die within the first year. With increased cooperation between zoos and the regional management of breeding, the transportation of orangutans is likely to become increasingly common. Therefore it is important to come up with exhibit designs to minimise the risk of mortality associated with transportation. The provision of an interchangeable night quarter door with an opening for the attachment of a transport crate allows for crate training of out-going animals and the quick release of in-coming animals.

Recommendations

- Where possible each adult orangutan (or adult female with a dependent infant) should have its own individual night quarter.
- Minimum size 2.4m width x 3.5m depth x 2.4m high (8′ x 12′ x 8′).
- Unless the zoo already has a quarantine area suitable for orangutans, one should be incorporated into exhibit design, including a separate drainage system.
- Although metabolic squeeze cages are used less frequently with the increased use of Positive Reinforcement Training squeeze cages can provide an additional management tool. They are usually most effective when they are placed in areas where the orangutans moves through them on a daily basis.
- The area must be rodent proof.

- Adequate lighting needs to be provided for orangutans occasionally confined during the day and inspection of the animals by the keeper (minimum 30 foot candles, 1m above the floor).
- Public or other noise especially above the orangutans should be eliminated, or at least reduced to a minimum.
- Night quarter need to provide arboreal nesting sites as well as suitable nesting materials.
- Drainage is recommended to be outside of the night quarters and flow into a large industrial sized grease trap. All surfaces must slope towards this point.
- Behavioural enrichment options need to be provided for orangutans confined to night quarters.
- Floors should slope to the drain and be covered with epoxy-based paint.
- Walls should be also coated with a smooth easily cleanable and durable surface such as epoxy-based paint.
- Roof ideally should allow for arboreal locomotion, i.e. mesh roof.
- Food hoppers should be incorporated to provide more flexibility in feeding orangutans.
- Steel Bars are not recommended as they allow possible dangerous amount of contact between orangutan and keeper.
- Maximum gaps between doors, etc: 3cm (1')
- For strength doors should open into the night quarters.
- All night quarters should be connected for the orangutans with slides.
- A safety race should be provided.
- Horizontal gates should be pushed to open, so to reduce injury to the keeper from the handle if the orangutan throws open the slide.
- The provision of an interchangeable night quarter door with a opening for the attachment of a transport crate.

Bio-Floors
Bedding is used regularly to promote species typical behaviours and to increase foraging time during food enrichment activities. Chamove (1982) has shown it facilitates behavioural enrichment and to inhibit bacterial growth over time. Deep bedding works best in areas where it is contained by walls or curbs and where provision are made for easy removal and replacement. These operations should be planned for in the facilities design (Coe and LaRue 1997).

Exhibit designers may want to consider the bio-floor, a new night quarter floor surface. This floor uses a deep litter system on top of a

drainage membrane. It has been shown to be time efficient, hygienic and more stimulating for the orangutans. Examples of zoos, which successfully use Bio-Floors, are Apenhuel and Zurich. Observed problems have been reduced opportunity to collect urine samples and wood frames rotting.

Recommendations

- Depth: minimum 40cm (15′), optimum 50cm (19′).
- Coat concrete first
- Use natural soaps only
- Never remove substrate
- Check pH twice a year (Low pH is below 7)
- If vermin get in the substrate should be flood with water

Climate Control

Before the 1930's, orangutans were often kept in high temperatures and humidity made to reflect their tropical homeland (Ulmer 1957; Hediger 1970). This produced ideal conditions for bacterial diseases, which in combination with infectious contact with humans usually reduced the life span of captive orangutans to only four to five years (Ulmer 1957). Orangutans readily acclimatise to regional conditions. With heated night dens in cold climates, shelter and shade provided, orangutans are usually adaptable to most environments (Brambell 1975). The combination of low temperatures and high humidity has also been linked to health problems in orangutans.

Orangutans require the ability to control their environment by moving to and from different microenvironments within the exhibit. This is not only a physical need, but the variations within the exhibit can be considered a form of behavioural enrichment or source of stimuli, which can be controlled by the orangutans. To allow these variations to be controlled by the orangutan they need to be accessible to all the animals in the exhibit.

Temperature and light are close correlates in nature. High, bright basking perches can have supplemental heat, while darker areas can be cooler. Minimum recommended average temperatures are 18°C (65°F); with maximum temperatures of 28°C (84°F). Outdoor areas must be provided with shelter from sun, rain, and chilling winds. A sufficient number of shelters must be provided to prevent dominant animals from denying access to other animals (Coe and LaRue 1997).

Ventilation should be adequate to eliminate dampness and odour. Ventilation can be unequally distributed, with greater flow near the floor to encourage evaporation and at high elevations to mimic an arboreal breeze. Ten to fifteen air changes per hour are recommended

for small areas or areas which contain high numbers of animals. This same level is used for areas of potential contamination such as sterile surgical areas, necropsy rooms, and waste storage areas (NIH, 1972). Air entering animal rooms should be fresh be exhausted without recirculation (100% air exchange in animal rooms or equivalent if possible). Separate zoning of air systems, to prevent cross contamination should be a part of any non-human primate facility (McManamon and Bruner 1990 as cited in (Coe and LaRue 1997).

It is very energy inefficient to void high quantities of conditioned air in large day rooms or indoor exhibit areas where there is a very large volume of air per animal provided in the space enclosed. Ventilation requirements for such areas should be determined individually on a performance basis. Besch (1980) suggests that ventilation requirements should be based upon a rate per animal. Woods (1975) agrees with this approach and found it an energy efficient means to provide an odour free environment. It is often wise to design a multi-stage ventilation system, which can be run at low or high settings depending upon the animal occupancy levels of the areas at a given time (Coe and LaRue 1997).

All duct-work must be protected from the animals. No insulating material over duct work can be within an animals' reach or near areas to be hosed, unless waterproofed (Coe and LaRue 1997).

Humidity levels should range between 30% to 70%. McManamon and Bruner (1990) state that orangutans are vulnerable in conditions of low temperature and high humidity. Humidity is strongly affected by temperature and should be considered together with ventilation to provide a comfortable environment. Olgay explains the relationship of 'comfort zone' to the interaction of temperature, humidity and ventilation (Olgay 1992, as cited in Coe and LaRue 1997).

In a rain forest, humidity levels vary widely from hour to hour and location to location. For example, humidity levels in the tree tops exposed to full sun are much lower than on the forest floor. These gradients should be considered when designing large indoor activity areas (Coe and LaRue 1997).

Recommendations

- Shelters must provide protection from rain, sun and wind.
- Sufficient amount of shelters must be provided to prevent dominant animals from denying access to the subordinate animals.
- Shade structures at least 3.6m (12') above orangutans climbing structure ground (See Fig.1).

- Recommended minimum temperature: 18 degrees Celsius (65°F).
- Recommended maximum temperature: 28 degrees Celsius (84°F).
- Recommended minimum ventilation: 10 to 15 air changes per hour, without re-circulation.
- Recommended humidity: 30 to 70%

Lighting

Illumination standards recommend that illumination be uniformly diffused throughout the facility (NIH 1972; USDA 1991). A more naturalistic solution would be to provide a two-part lighting system. Light levels should vary following a natural model; bright near the top of the space, darker at floor level. Animals can be allowed to manipulate light levels and even colours by using devices which they can activate remotely. An override utility light system can take care of cleaning and surveillance needs during the relatively few minutes each day when keepers are present. NIH (1972) recommends that at least 30 foot candles 1.0 m (3.3') above the floor. All lights should be mounted outside the cage, and far enough away to avoid breakage, especially if branches are provided as browse. Mount fixtures in waterproof and shatterproof enclosures (Coe and LaRue 1997).

Access to natural sunlight should be a basic design requirement. O'Neill (1989) recommends viewing windows as a source of behavioural enrichment. NIH (1972) recommends against use of exterior windows and skylights because they create variations in temperature and photoperiod although this variation is more natural for the animals. Fluorescent or natural spectrum bulbs are required when the animals do not have access to natural sunlight. Lindburg and Coe (in press, as cited in Coe and LaRue 1997) express concern that "in circumstances requiring long term exposure to artificial light, particular care must be given to the implications for primate health" (Coe and LaRue 1997).

Acoustics

Acoustic environments in a captive setting are much different than a natural environment. Mechanical equipment required to move large volumes of air can be a major source of indoor noise pollution and appropriate noise dampening techniques should be incorporated into the design of building mechanical systems. Unfortunately, most noise absorbent materials are not waterproof. The following can be used to reduce noise levels:

- Resilient flooring
- Nylon or polypropylene glides
- Cover plates
- Animal gates

- Deep bedding
- Electronic noise neutralising devices
- Environmental sounds and music

Ideally the animals could have the option to choose what they wanted to listen to (Coe and LaRue 1997).

Tactile Environment
The tactile environment can be best satisfied by providing a variety of impermanent furnishings and objects (Coe and LaRue 1997).

Olfactory Environment
The olfactory environment can be stimulated with disposable items. The olfactory impact of cleaning agents on animal health and welfare should be considered. Unfortunately, little information exists regarding orangutan olfactory preferences (Coe and LaRue 1997).

Visual Environment
The Visual environment can be provided in a variety of ways. For example, dramatic tropical colours could be used with epoxy paints in simple patterns, which are easily repainted, or changed, using stencils. Indoor planting has served as successful backdrops at several zoos including National Zoological Park, Lincoln Park Zoological Gardens and the Dallas Zoo. The Dallas Zoo has tropical plants surrounding their gorillas' off-exhibit day room (Coe and LaRue 1997).

Visual Escape and Flight Distance
Orangutans are basically solitary, using distant visual monitoring as their main type of social contact. In the wild, their native rainforest enables the orangutans to space themselves, hide from and avoid conflict with each other. Maple (1980) and Maple and Stine (1982) suggest increased available spatial volume and increased complexity of the environment and visual barriers to provide escape routes can reduce social stress in captivity. Maple (1979) observed that in small enclosures, glass barriers could violate the orangutan's natural minimum flight distance, which he observed to be six metres (20'). He suggested that enclosures be made much deeper to allow the orangutans to establish their own minimum flight distance. Stress in arboreal primates is reduced if they are allowed to be higher than the public (Chamove et al 1988). In addition public viewing from multiple directions can reduce the perception of security for orangutans.

Recommendations
- With the exception of dam-infant groups, orangutans where possible be able to have visual escape from conspecifics.

- Orangutans must have visual escape from the public.
- Public viewing should only be from one direction.
- The majority of the climbing structures must be 6 m (20′) from the public (10m (32′) optimum).
- Orangutans must be able to get higher than the public.

2.7.0 Enclosure Size

Every captive management goal should be aimed at providing as close as possible the conditions the animal experiences in the wild. There is no rule for this parameter except that there is no way a zoo can provide the space which comes close to wild parameters. Although functional complexity and shape of an exhibit can decrease some of the adverse effects of small exhibits, designers should take into account that certain benefits of volume and surface area can not be provided for in any other way. In addition, the changing public views on captive great apes need to be considered.

Recommendation

- The bigger the better.

Water

Orangutans need access to a constant supply of fresh clean water daily (Yerkes & Yerkes 1929; Brambell 1975). As well as drinking water both wild and captive orangutans often use water for play activities. Water troughs, which refill automatically, waterfalls, shallow pools or streams, can provide sufficient water for drinking and play, without the chance of drowning (Brambell 1975; Maple 1980; Jones 1982).

Water must be fresh, potable and of human drinking quality. The most efficient way to offer drinking water is through nipple drinker, push-button, or other automatic systems, but some animals will try to plug drinking lines up with straw or dismantle them (Coe and LaRue 1997).

Drains including trench drains should be located outside of cages in keeper aisles, for ease of cleaning. Drain covers should have small holes to prevent hay and food from clogging the drain. A basket in the drain will also help. A minimum sanitary drain pipe size of 15cm (6"). Large pipe size does not prevent clogging. Pitch, water velocity and maintenance practice must also be considered. Frequent clean-out points are helpful. Drain-traps are required by the USDA (1991) to prevent the back-flow of gases and sewage (Coe and LaRue 1997).

Recommendations

- Water should be of human drinking quality.
- Shallow self-filling water should be provided to the orangutans at all times.

Activity Patterns and Behavioural Enrichment

Orangutans rise between 6am and 9am (Davenport 1967; Horr 1972; MacKinnon 1974; Rijksen 1978). They start foraging near the night nest and then travel slowly away during the morning, resting and foraging until approximately 12 noon, when they sleep or rest for up to two hours. In the afternoon they travel faster, eating as they move, travelling greater distances than in their morning activity. A night nest is built just before sunset and they remain there until after sunrise.

The daily routine of the orangutan is not affected by light rain, but in very heavy rain all activity ceases as it takes shelter or makes a 'rain-nest'. During these days they build their night nest earlier and sleep longer (MacKinnon 1974). On dry days their midday resting time is increased, but their early morning and early evening activity becomes more intense (MacKinnon 1974).

Daily routines have been quantitatively assessed by five field workers (Davenport 1967 and Galdikas 1978). Galdikas (1978) gives data for 14 individuals (See Table 1).

Table 1: Activity Budget for Wild Orangutans

Activity for 14 individuals	**% Daily Activity Time**	**Range**
Foraging	60.1	41.4 - 72.3
Resting	18.2	7.1 - 31.0
Moving	18.7	11.9 - 25.6
Copulating	0.1	0.0 - 0.6
Long-calling	0.3	0.0 - 0.8
Agonistic Display (at researcher)	1.3	0.0 - 5.3
Nest Building	1.1	0.8 - 1.4
Foraging Index*	3.2	1.8 - 6.5

* The foraging index measures the ratio of foraging time to travelling time and acts as a guide to the efficiency of individuals and density of food supplies in study areas (Rodman 1973).

Until recently, the design of the captive environment has taken very little account of the daily activity patterns of wild orangutans (Maple 1980). This has led many zoo managers to believe orangutans to be naturally lethargic and obese (Yerkes & Yerkes 1929; Harrison 1962). The mid 1970s marked the beginning of a growing awareness, in the zoo world, of the need to improve the captive environment of primates to stimulate species-specific natural behaviour and increase activity levels. Unfortunately, very little quantitative or qualitative evaluation of the effect of any improvements in the captive environment has been carried out and even less has been published (Markham 1990). One study was conducted by Wilson (1982) who

investigated the activity levels of 68 groups of orangutans in 41 European zoos in relation to the captive environment. The environmental factors recorded were useable surface area and the number of fixed, moveable and temporary objects. Wilson concluded the environmental complexity, such as fixed moveable and temporary objects, were more important to orangutans than the size of the enclosure, the frequency of feeding or the available surface area.

The environmental enrichment of orangutan exhibits is often restricted by the zoo manager’s desire to display a naturalistic environment for the orangutans. Artificial objects and climbing structures, which are some times the most stimulating, may be absent in exhibits to provide for a ‘naturalistic display’. Jones (1982) recommends that any safe manipulable objects, which can increase activity and natural behaviour should be encouraged. The periodic variation of the objects presented to orangutans is of benefit, to allow an additional increase in activity associated with their novelty (Maple 1979). The introduction of new habitats, objects or activities, however, should be done gradually and with caution, especially with older animals not subjected to change in the past, because of the conservative nature of this species (Maple 1979).

Recommendations

- Orangutans should be provided behavioural enrichment to meet levels of activity of wild counterparts.
- Captive orangutan activity patterns should broadly reflect the patterns of wild orangutans.

Conditioning

Orangutans are highly intelligent animals. This makes them very susceptible to boredom-induced stress. It has long been noted by keepers that in the case of chimpanzees, ex-circus animals have a greater success in breeding than zoo chimpanzees raised in inappropriate conditions. It is believed that the amount of mental stimulation is more important than whether the mental stimulation is 'natural'. Morris (1959) as cited by Maple (1980, p. 225) wrote:

"Far from being overworked, exhausted chimpanzees, these demonstration chimps are by far the healthiest, most intelligent, and most alert that I have ever seen in captivity. They obviously benefit tremendously from their varied and complicated activities and one is immediately struck by the need for introducing some similar kind of occupational therapy for adult chimpanzees and for other primates."

There may be no reason why zoos should be shy of using circus techniques. These may result in healthier animals and greater

subsequent breeding success and zoos should embrace them as valuable management aid. It is only recently that zoos, have seriously looked at the benefits of orangutan training. Animals being mentally and physically healthier if they have 'work' to do (Maple 1980). At Brookfield Zoo an incompetent orangutan mother was trained to nurse her own baby. At Perth Zoo a diabetic orangutan named 'Hsing Hsing' was trained to take insulin injections and blood samples (Leif Cocks, personal observation). These two examples indicate how the training of great apes has additional benefits in the areas of maternal behaviour and medical treatment.

Recommendations
Positive reinforcement training should be considered as management tool for orangutans. Laule recommends that the following be provided in facility design to promote animal training programs (Laule 1995, as cited in Coe and LaRue 1997):

- Good visual access of the animals in all areas by caregivers.
- Multiple access points for care giver/animal interaction both on and off exhibit, including spaces large enough for multiple caregiver and multiple animal interactions.
- Multiple shifting points between areas that allow keeper access to animals as they move and allow animals to shift toward keepers rather than away.
- Built-in mounts for husbandry and medical apparatus such as blood collection sleeve, blood pressure cuff, and urine collection pan.
- Good lighting and large enough mesh access points for safe treatment of superficial wounds and delivery of injections.
- Multiple and connected off-exhibit spaces with no dead ends. Dividers that allow protected visual and tactile access between animals for enhancing introductions and for ease of separating socially housed animals.

Numbers of Orangutans
The more orangutans each zoo holds, the more zoos can contribute to the species survival. This of course has resource implications for the zoos. Besides these there are two factors, which need to be considered when, deciding the number of orangutans to hold:

- Are there enough animals for the zoo to hold a complete orangutan social unit (i.e. at least one adult male and two or more related adult females with offspring)?
- Is there enough breeding occurring to pass on maternal behaviour from one generation to the next?

Although orangutans are often described as solitary this often ignores the fact that they have a rich social system, which although

contact between individuals are less frequent and less physical than in other great ape species, is just as necessary for psychological well being.

The psychological well being of an orangutan is highly dependent on its experience as an infant. The extreme result of inappropriate infant experience is hand-raising. Hand-raising reduces longevity, increases presence of stereotyped behaviour and increases occurrence of infant rejection by females (Cocks 1998). The quality of maternal care a female provides her infant is highly dependant on the amount and quality of maternal experience she experiences from either her dam, or another adult female, during her juvenile and subadult years. Therefore the births of infants should be spaced in the group to allow juvenile or subadult females to gain appropriate experience before being allowed to reproduce. Wild adult females on average have their first infants at 15 years with an eight year inter birth interval (Galdikas 1978). The reduction of these periods in captivity significantly reduces a female's longevity (Cocks 1998). By maintaining a natural breeding timetable a zoo conservatively requires four adult females, or liberally three adult females (with some risk of too many male babies interrupting the timetable), to maintain the transference of maternal behaviour between generations. It is possible to maintain maternal behaviour between zoos through the transference of adult females, transportation of orangutans where possible should be kept to a minimum (Cocks & Collier 1998).

Recommendations

- Zoos where possible hold at least one adult male and at least two or more related adult females with offspring.
- To maintain maternal behaviour and reduce the cost and risk of transportation between zoos, a zoo where possible holds at least three, preferably four adult females.
- The births of infants should be spaced to allow juvenile or subadult females to gain appropriate experience before being allowed to reproduce.
- When possible females should not be bred before age fifteen.

Pest Control

Control of pests must be integrated into both management practices and design. In food preparation and staff areas, provide 1.91cm (3/4") of space between the back of shelves and counters and the wall. Some zoos prefer shelves made from wire mesh rather than solid material and avoid using doors on cabinets. In exhibit areas, provide access points into the voids inside artificial rocks and trees. Large voids require an access port large enough for occasional entry. Smaller voids should be provided with 15.24cm (6") diameter access ports. These ports must be outside animal areas or be orangutan

proof . In animal holding areas, voids formed in the steel fabrication of the caging must be filled, sealed or provided with access. Avoid narrow spaces between caging and walls if possible. Where necessary, these narrow spaces can be filled with caulking and be out of animal reach (Coe and LaRue 1997).

Non-Chemical Immobilization

Special research and care areas to provide some form of non-chemical immobilization are desirable. This can be provided in the form of a wheel mounted squeeze or transport crate, which can be securely coupled to holding facilities. Ideally this can be mounted over a scale. Transport crates are also useful for crate training. Yerkes Regional Primate Research Center uses transport crate rides as a form of enrichment. Transport crates can also fit into shift cages so that they connect adjacent animal rooms. Metabolic/squeeze cages may be built into the facility. These cages have open mesh floors and are elevated above a large collecting pan where faeces or urine can be collected for analysis (Coe and LaRue 1997).

Storage Areas

Storage areas should have easy access to the outside service area areas yet be convenient to animal areas. The USDA (1991) requires that supplies of food and bedding be stored in a manner that protects the supplies from spoiling, contamination, and vermin infestation. Tool storage should be convenient to work areas, but well out of reach of the animals. Storage for soiled bedding, animal and food wastes, etc. must be isolated from vermin and insect pests. Ideally, the path by which waste products are taken from animal areas to waste receptacle areas should not connect to areas where clean food or bedding is transported, stored or prepared. Food preparation areas usually serve several exhibit areas. Many provide at least the following: large double sink and counter, shelves, microwave, refrigerator, desk, bulletin board, and window or skylight. The ventilation and air movement system should be separate from that of the animals and should be separated from noises associated with food preparation (Coe and LaRue 1997).

Utility Systems

All items must be out of the reach of the animals. This range of reach can be determined by the amount of hand/arm that can go through the mesh or enclosure front with the length of a browse stick added on (Coe and LaRue 1997).

Electrical Systems

Electricity must be provided for refrigerators, lighting, heating and cooling. A back-up generator and emergency lighting system should be provided. A dedicated electrical circuit (a separate electrical circuit

which will not have interference from other equipment) should be available for use of special medical equipment, such as radiograph or electrocardiograph machines or special lights. If this is not possible in all areas, at least one separate medical evaluation area should have it (McManamon and Bruner 1990). Electrical outlets should be ground fault interrupter type with waterproof housing mounted at least 10cm (4') above the floor. Behavioral enrichment devices should also be provided with their own dedicated electrical circuits (Coe and LaRue 1997).

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