ZOO HORTICULTURE

A Rationale And Overview Of Zoo Plant Collections And Naturalistic Exhibits

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ABSTRACT

Today's zoos are undergoing a renaissance in their exhibition, education, conservation, and research programs. The inspiration for this renaissance is the destruction of the Earth's dwindling natural habitats at the hands of an uninformed human populace. Zoo horticulture, and the resulting plant collections, contribute to beautiful zoo surroundings, naturalistic exhibits having ecological integrity and encouraging natural animal behaviors resulting in a high level of visitor education and enjoyment. Naturalistic exhibits, commonly representing particular habitats from specific geographic locations, are dependent upon the creative use of plants for their integrity.

TABLE OF CONTENTS

INTRODUCTION

Zoos have a universal appeal to people of all ages, educational backgrounds, economic standings, and races. Even in a sports and media-mad culture like ours, zoos continue to attract large numbers of visitors. This seemingly inherent appeal of the zoological garden makes it a logical center for a broader approach to ecological, environmental, and natural history education. Many people who would not consider making a special trip to a botanical garden will visit a zoo and, perhaps, be aware of the plantings.

Today's zoos are undergoing a renaissance in their exhibition, education, conservation, and research programs. The practice of horticulture in zoos is an integral part of this renaissance. In fact, growing plants in zoos is recognized as a specialized area of horticulture - zoo horticulture.

The inspiration for this zoo renaissance is the recognition by zoo staff of the Earth's dwindling natural habitats at the hands of a destructive and uninformed human populace. Zoo professionals appreciate the importance of habitats and their preservation as the key to the long term preservation of the Earth's wildlife. Hence, zoo programs are expanding their focus from a

zoological to an ecological scope, one in which the natural habitat is a focal point and plants, as well as animals, play a larger role.

The practice of horticulture in zoos is becoming a more sophisticated part of zoo programs. In the article, "A Glass Menagerie", Beth Rawnsley aptly describes the challenge for the zoo horticulturist; "today's zoo horticulturist..., lacking a comprehensive heritage of research on plants for zoos, needs the imagination of a pioneer and the interdisciplinary resources of a renaissance scholar. How do you plan an exhibit that provides for the animal's needs, encourages mating, withstands a climate unlike its native habitat, educates the public about an ecosystem, allows for easy maintenance, looks good, is non-toxic, and won't break a tight budget?" (Rawnsley, 1982).

Zoo horticulture is a young, evolving field with challenges far removed from the standard traditions of horticulture and landscape architecture. In addition to growing colorful flowers and shade trees, it is the modern day task of the zoo horticulturist to create natural settings where animals are perceived in the context of their natural surroundings.

People have always been intrigued by exotic animals. Centuries ago, the early princes of China kept exotic animals in 'parks of intelligence'. This early reference to the educational potential of the zoo seems highly prophetic in our age of endangered species and declining habitats. Though the parks of intelligence were usually situated in a park-like or wooded setting, it was not until Louis XIV deliberately planted trees, shrubs, and flowers around an between the cages of his menagerie to conceal the ugly bars and fences that horticulture began to take on a special role in the zoo. During the French Revolution, botanists at the famous Jardin des Plantes in Paris begrudgingly accepted Louis' menagerie for safe keeping. Thus, in 1793, the Menagerie du Jardin des Plantes became the first public zoological garden in the western world.

During this period, botanical gardens were regarded as serious, scientific institutions, while menageries were institutions visited for amusement and entertainment. The subsequent combination of the Versailles menagerie and the Jardin des Plantes, along with the public success of this combination, shed new light on the menagerie as a place for learning.

The establishment of the London Zoo in 1868 set a standard for traditional zoo design as a new type of

urban park where plants played a primarily esthetic and peripheral role in animal display. Not until the revolutionary ideas of Carl Hagenbeck became known did the potential for combining plants and animals become appreciated. Carl Hagenbeck, German zoologist and animal dealer, created Stellengen Gardens in Hamburg during the early part of this century. Stellengen Gardens changed the course of zoos just as abruptly as the Menagerie du Jardin des Plantes had over a century earlier. Helen Horowitz, in an article entitled "Seeing Ourselves Through the Bars" explains:

> He placed tropical animals out-of-doors even in winter and found that they became acclimated quickly and thrived in the fresh air. He gave them room to roam and rocks to climb and put gregarious animals and compatible species together. Most dramatically, he took away bars and substituted ditches, moats, and high artificial rock piles, thereby creating the illusion of freedom in the wild. He intensified the illusion by placing predators and prey in the same scene, separated by invisible trenches. The impact is still being felt. More accurately, only now are American zoos fully appropriating Hagenbeck's innovations (Horowitz, 1981).

Carl Hagenbeck's natural approach to animal display opened the door to a more creative use of plants in zoos to establish the appropriate interpretive contexts for animal display.

THE VALUE OF HORTICULTURE IN ZOOS

The increasing value of horticulture in zoos has as its basis, four underlying factors: esthetics, a new understanding of ecology, greater insight of animal behavior, and the desire to achieve higher levels of public education.

Attractive exhibits and grounds not only provide a natural setting where visitors may passively enjoy the samplings of nature, but also are the esthetic carrot that lures the visitor toward a unique learning experience. Many visitors to the Bronx Zoo may not fully appreciate the botanical differences between Cornus mas and Cornus officinalis, but few who visit the zoo in early spring will fail to notice their soft, golden yellow inflorescences.

Our new understanding of ecology mandates a stronger botanical emphasis at the zoo. Populations of plants and animals taken from the wild demonstrate structural, physical, and behavioral adaptations based on the conditions of their niche, habitat, community, and ecosystem (Clapham, 1973). Many recent innovations in exhibit design and zoo technology, including zoo horticulture, are based on this understanding.

An ecosystem can be looked upon as a homeostatic unit with all of its parts operating in a dynamic equilibrium (Udvardy, 1969). This concept forms the basis for concern over endangered species and the corresponding conservation movement in which zoos play an important part. Our attitude toward natural ecosystems and their restoration or replication should be based on an appreciation of their complexity. Zoo horticulture plays a strong role in zoological exhibits that display and interpret animals and plants as interdependent life forms and strive to convey the principles of an ecological reality.

Zoos belong to that group of museums which collect living organisms for educational, scientific, and exhibition programs. The exhibits affect the well being and behavior of the animals they contain. Zoological exhibits have traditionally been too confining and oversimplified in terms of shape and contents. Simplified living conditions affect not only the reproductive behavior of animals, but also habits, social behavior, feeding behavior, and the entire behavioral matrix.

Plants and plant parts are important habitat components that elicit particular behavioral responses from many animals (Hediger, 1968). Plants can be used in

animal exhibits to create private spaces and to screen incompatible species from each other, create the illusion of a safe distance from threatening objects, act as sign posts for scent marking, and divert restless species deprived of the natural distractions of life in the wild. Zoo horticulturists help maintain healthy animals by providing the vegetation necessary to stimulate, support, and satisfy their natural repertoire of behaviors.

Beautiful surroundings, ecological integrity, and natural animal behaviors are necessary for a high level of visitor education at the zoo. Zoo horticulturists are valuable contributors to the planning and implementing of zoological themes and exhibits that show animals interpretively. No amount of written interpretation will enable visitors to fully appreciate zebras and their habitat if the animals are displayed in a blacktop yard surrounded by brick and concrete. Proper orientation means that a visitor observing tropical animals must also perceive the green luxuriance of their tropical homeland. Zoo settings influence our feelings about the value of the animals and their habitat. By broadening their educational potential through creative horticulture, zoos will more effectively advocate the cause of habitat preservation.

PLANT COLLECTIONS IN THE ZOO

Zoo horticulturists strive to create the appropriate contexts for observing wildlife. Through the creative selection, use and maintenance of the appropriate plants, provocative naturalistic landscapes take shape to heighten the zoo visitors awareness of animal/habitat relationships. Within the context of the zoological exhibit, it is possible to establish and interpret plant collections in a manner that reveals new relationships between individual plants, plant groups, and other living things. This is the essence of what a plant collection is all about.

According to Oscar Handlin, former librarian at Harvard University, a collection is an assemblage that affords meaningful contexts for the items it contains, and it reveals their relationships to one another and to the rest of the world (Phipps, 1985). Considering this definition, it is perfectly valid for the staffs of zoological gardens to consider all or part of the array of plants within the holdings of the institution as a collection.

As the fourth curatorial department in the zoo, along with mammals, birds, and reptiles/amphibians and other creatures, horticulture carries the burden of

organization at a level indicative of curatorial status. Curators are designated as such because it is their role to thoughtfully select, from among a jumble of things, plants, animals, etc., those groups worth conserving in enlightened anticipation of tomorrow's needs. Curators manage collections as conceptual entities according to the goals and objectives of the organization. Plants in the zoo can and should be managed as a conceptual entity though they may be subordinate to the animal collection in the goals and purposes of the institution. With this understanding, many zoo horticulturists are positioned within the zoo administrative hierarchy under the general curator and maintain the title of curator.

Plant collections in zoological gardens usually differ, conceptually, from botanical garden and arboretum collections. Zoo plant collections usually conform to a de-facto set of collecting criteria imposed by the arrangement of the animal collection, the nature of the animal collection, and the theme utilized for the presentation of the animal collection. Hence, zoo plant collections are rather unorthodox in the traditional style of taxonomic and economic collections. Plant collections at zoos are most often based upon geographical and ecological relationships. However, a strong line may exist in collection themes between exhibit and visitor areas. Visitor areas, restaurants,

comfort stations, etc., may be landscaped in a strictly esthetic scheme. Exhibit areas, on the other hand, are often landscaped with plants significant to the prevailing exhibit themes.

The institutional collection of the zoo consists of the sum of all plants and animals permanently contained within the institution and managed according to explicit criteria related to the roles and services of the institution. The plant collection may consist of several subordinate collections, e.g., the tropical Asian plant collection, the epiphyte collection, or the conifer collection. Zoo plant collections are an interlocking series of hierarchies consisting of groups and individuals whose place in the institutional collection most always relates to the animal collection and corresponding exhibit themes.

Collection management is facilitated by establishing a workable set of guidelines for the management and control of the collection, otherwise known as a collection policy (Malaro, 1979). A collection policy serves to define the purpose, scope, and role of the plants used at the zoo. The collection policy affords some measure of financial accountability for zoo horticulturists who must carefully consider if they can afford to maintain plants that have no well-defined role in the zoo. In the face of

achieving a high level of cooperation among a dynamic group of individuals, the collections policy serves to eliminate uncertainty. The collections policy helps to insure the continuity of the plant collection over time in line with the goals and objectives of the zoo (Lighty, Unpub.). Lastly, the collection policy sets a departmental baseline from which to build an organized collection.

NATURALISTIC EXHIBITS

Zoo horticulturists are placing more emphasis on the naturalistic approach to landscaping the zoo. This has developed with the shift in focus by zoo administrators and curators away from the 'postage stamp' collection- one of everything - to the breeding group. The naturalistic approach toward animal exhibit design places the interpretive emphasis on the complex interplay between taxonomic groups and their ecological relationships.

The naturalistic landscape usually functions in several ways. As it relates to exhibit animals, the naturalistic landscape should function to stimulate and/or accommodate natural behaviors. As it relates to zoo visitors, the landscape should be educational and esthetic. These functions become more pointedly

emphasized in closer proximity to either the animals or the visitors and more carefully blended in the middle ground.

To successfully create naturalistic landscapes zoo horticulturists must rely on an understanding of natural history, how plants and animals live and how they are peculiarly adapted to their natural habitats. This understanding should provide clues about those conditions which should be incorporated into the naturalistic landscape so that it will function as intended.

Unfortunately for the zoo horticulturist, field observations are often considered a luxury or a post graduate exercise. Observing and photographing plants and plant groups/associations in nature can be a valuable reference for creating naturalistic landscapes. If one cannot trek the Himalayas, then observing analogous plant formations along the high ridges of the Smokey Mountains will suffice as a reference point in conjunction with the appropriate literature reviews. The naturalistic landscape should have credibility to all visitors, regardless of their level of scrutiny.

Zoo horticulturists cannot hope to recreate natural habitats, but they strive to transpose the natural conditions created by plants in the wild into

naturalistic landscapes in the zoo. Toward this end, strictly ornamental plantings that have little or no relationship to the thematic display of plants and animals, or interpretive value in this respect, are relegated to non-exhibit areas of the zoo. This in no way restricts the esthetic role of plants in the naturalistic landscape. Habitats and phytogeographic regions have their own, special, representative population of ornamental plants.

The naturalistic landscape may include plants and plant groups which merely suggest the vegetation of particular habitats. Plant 'analogs' are often useful within naturalistic exhibits modeled after a particular habitat where the native plants of that habitat will not survive. These plants should be sufficiently hardy and physiognomically appropriate. Physiognomy is the form and architectural pattern that determines not only the appearance of the community, but also many of the ways in which the various species interact with one another. The implications of this for selecting plant analogs is the emphasis on the appearance of reality rather than botanical exactitude. The selection and use of plant analogs for the naturalistic landscape is usually governed by the botanical collections policy.

Zoo horticulturists try to avoid using artificial material wherever possible. Artificial material, in abundance, can obscure the important link between plants and animals that should be conveyed to the zoo visitor. However, artificial elements, when skillfully and imaginatively combined with live plants, can effect a sense of realism beyond what might have been possible with plants alone. Further, to achieve a particularly high level of credibility with naturalistic landscapes, dead plant material is often used to blur the lines between live and artificial elements, create the sense of an evolving, living habitat, as well as provide for the perching and climbing needs of the animals.

The landscape guidelines presented by Jones and Jones, Inc. in the Woodland Park Zoo Plan (Jones & Jones, 1976) are useful for any zoo horticulturist planning naturalistic or any other type of zoo landscape:

1. The landscaping should be appropriate within the overall presentation theme of the institution.

2. The landscaping should be appropriate within its geographic, geologic, or ecologic setting as described in the exhibit scenario.

3. The landscaping should be appropriate for the

setting into which it is placed.

4. The landscaping should be appropriate to the visual/esthetic function for which it is intended.

5. The landscaping should be appropriate to the physical function for which it is intended.

6. The landscaping should be appropriate to the educational and behavioral response intended.

7. The landscaping should be appropriate in all ways to the well-being of the resident animals and the visiting public.

SPECIAL CONSIDERATIONS FOR IMPLEMENTING NATURALISTIC EXHIBIT LANDSCAPES

Consider horticulture as though it were a game of chess. On one side of the board are pieces representing the knowledge and tools necessary to culture plants. The other side of the board is occupied by pieces representing the limiting factors acting upon plant culture. It is the job of the horticulturist to manipulate knowledge and tools to successfully control the limiting factors. Consider zoo horticulture, as it

pertains to exhibit interiors, as a three dimensional game of chess. A game in which two playing boards are superimposed over one another, effectively doubling the limiting factors, the necessary knowledge and tools, and the possible interactions involved between them. Zoo horticulturists must be able to identify and plan for the added dimension of animal interfaces with plants.

Animals complicate the task of growing plants in their exhibits primarily by exercising their broad, and often plant-damaging repertoire of behaviors. These behaviors range from the fairly simplistic such as loccomotion, scratching, etc. to more complicated rituals such as territorial marking, courting, feeding, nest building, etc. These behaviors are part of the many ways that animals utilize their habitats. These behaviors must be identified and given due consideration in the planning of naturalistic exhibits.

Some strategies for zoo horticulturists to consider in an effort to ameliorate the damaging impact of animal behaviors, excluding the use of protective, yet, obtrusive hardware, are as follows:

-- Feeding Damage

1. Distasteful plants.
2. Morphologically repellent plants.
3. Chemical repellents.
4. Plant positioning.
5. Browse provisions.
6. Guild plantings.

-- Other Damage

1. Resilient plants.
2. Morphologically repellent plants.
3. Plant positioning.
4. Alternate routes.
5. Guild plantings.

The challenge for the zoo horticulturist is the unpredictability of success or failure with any of these strategies. The more familiar the zoo horticulturist is with the natural and captive behaviors of the animals to be exhibited, the more likely the appropriate strategies will be applied with success. These strategies will be explored in more detail in the following paragraphs.

One should make every attempt to select plants that are distasteful to herbivorous animals. The selection is complicated, primarily, by two obscure factors: it is difficult to determine what is distasteful to any given

animal, and, plants known to be avoided in the wild may be tolerated in a restricted environment. Ecological monographs of particular animal species often list preferred and avoided food plants. A survey of successful plant combinations with specific animals at other zoos may also yield useful information. It is possible, if approached with caution, to select plants known to be mildly toxic in that they are often distasteful, particularly if they have milky sap. Animals that are not obligate folivores are more easily deterred.

Zoo horticulturists often use, with limited success, chemical repellents. Unfortunately, chemical repellents, often designed for a limited number of animal species, do not repel animals equally, if at all. Repellents should always be tested for phytotoxic effects before they are used on a broad scale. A serious maintenance concern is the need to frequently reapply repellents to maintain adequate strength. One should consider using repellents on plants in new exhibits prior to introducing the animals; this may help to 'imprint' them in an avoidance of the plants.

Plants with thorns, glochids, bristly hairs or other armature may be useful with herbivores. How useful depends on the nature of the plant structure, the feeding

behavior of the animal and, perhaps, the specific biting and chewing behaviors they use. There are many cases of adaptive morphology in this regard, the best known being the giraffe and the acacia tree.

Plants can often be positioned within exhibits so that they are inconvenient for feeding. There are also plants that carry their edible parts in inaccessible locations. Certain birds and arboreal mammals require a particular kind of perch for feeding. Planting designs that do not place plants in perching positions or utilize plants unsuitable for perching can be useful in this regard. Hornbills, for example, cannot perch on slender, flexible branches and small, browsing antelope cannot reach the edible parts of trees.

It has become common practice for zoo horticulturists to provide 'browse', leafy branches, for animals on exhibit. This material provides passive fodder, objects for manipulation and relieves the pressure of such activity on exhibit plants. Browse is usually collected from the zoo grounds or from a browse nursery established specifically for this purpose and is composed of particularly desirable plant species.

In certain habitats, plants occasionally grow in small multi-species aggregations called 'guilds' (Spurr &

Barnes, 1980.). These tend to form in areas where plants come under heavy browsing pressure. Plants with undesirable browse characteristics grow on the periphery of a guild while desirable plants will survive in the center of this protective community. Zoo horticulturists can create their own guilds of plants. Few plants survive in gorilla exhibits with the exception of barberry, Berberis species. Perhaps a large planting of barberry would adequately protect more delicate plants.

Many animals, herbivorous or otherwise, will damage plants just by active contact with them. Primates and monkeys are particularly troublesome. Climbing, swinging, jumping, nest building, probing and other activities can be very damaging to plants. Zoo horticulturists must spend time assessing the most potentially damaging activities a particular animal will exert on a plant and select plants accordingly. Animals that climb, swing, and jump through the plants will require very resilient, flexible plants for their exhibits. For example, the cecropia tree, Cecropia palmata, is a very brittle tree, easily damaged by large rambunctious primates or birds. On the other hand, trees in the genus Ficus, because of their flexibility, would be much better suited for such an exhibit. Ground cover plants must be resilient against terrestrial animals.

The morphology and growth habit of some plants may be undesirable to arboreal animals. Climbing animals may find thorny plants uncomfortable and dense plants inaccessible. Some animals prefer to sit or perch in trees with an open crown so that they can easily survey the surrounding territory while others prefer to hide. Plant locations can be very important relative to one another and other objects that will provide a perch. Some birds, such as hornbills, damage plants on which or near which they frequently perch because of their bill grooming behaviors. Particularly vulnerable plants should be placed away from favored perches.

Arboreal animals usually have characteristic modes of travel through and between plants. If these can be ascertained, this knowledge can be applied to the exhibit design and plant locations to minimize damage. For example, gibbons, with their agile, brachiating mode of travel, use lianas and vines as pathways through the forest. They tend to prefer vines and tree branches of a diameter comfortable for their grip. A gibbon exhibit with an adequate supply of vines for travel, either real or artificial and of appropriate diameter, will provide the greatest buffer for exhibit plants.

Zoo horticulturists are always looking for ways to combat soil compaction, a major problem in exhibits

containing hooved animals. Innovative ideas associated with golf course and athletic field management in addition to urban horticulture are useful for solving this problem. Loose, well drained aggregate soils composed of sand, gravel, and provided with irrigation are compaction resistant and suitable for tree roots and stoloniferous grasses. The latest recommendations for constructing and cultivating golf course greens are a useful guide.

NATURALISTIC LANDSCAPES FOR EXHIBIT SUPPORT AREAS

Zoo visitors should feel a part of the exhibit, immersed in the habitat themselves. Hence, naturalistic landscapes should carry over into exhibit support areas. The exhibit support areas of the zoo offer the zoo horticulturists unlimited opportunity to exercise their horticultural expertise without the limitations imposed by the animals. Exhibit support areas are those areas that come under the direct influence of nearby exhibits or are designed to accommodate exhibit viewing and other learning experiences related to the exhibit. Important functions of the exhibit support area are:

1. The visitor should feel immersed in the characteristic landscape of the exhibit.
2. Based on the dictates of the plant collections policy, the landscape should replicate the natural habitat as faithfully as possible.

3. The landscape should serve to restrict the visitors view to those elements of the exhibit that contribute to the authenticity and drama of the experience.

4. The landscape should restrict views so that the entire habitat is not visible from any one point.

IMPLEMENTING THE NATURALISTIC LANDSCAPE: A CASE STUDY

Under nearly one acre of glass, the New York Zoological Society's new JungleWorld introduces visitors to the rainforest, mangrove swamp, and scrub forest of Asia - a living tribute to the vanishing tropical ecosystems of the world. Each habitat has its own hydrological, geological, botanical, and zoological features.

JungleWorld is a brick and masonry building sited in an approximately east/west orientation. The roof is entirely glazed with single pane, pebbled, reinforced glass with a solar transmittance of 89%. Climate control is achieved through a forced air system utilizing oil-fired boilers for heat and hot water and a chiller-absorber for cooling. Passive ventilation is achieved by regulating automatic vents located in the eaves.

The approach toward planning and implementing the plantings in JungleWorld was guided by two objectives: the primary objectives of the installation, as stated

previously, and the botanical collection policy of the New York Zoological Society. Under 'acquisitions', the policy states: "...obtain plants for use in and around animal exhibits, both indoors and out, that are, to the extent feasible, integral to the prevailing exhibit theme". Based on these guidelines, JungleWorld was to be as botanically realistic as possible.

The first step in planning the exhibit design was to determine the critical habitats of the exhibit animals and the key indicator plants of those habitats. Plants were selected from the literature based on the following criteria: abundance, physical prominence or importance in the vegetative texture of the habitat; importance to the exhibited animals. The scrub forest and mangrove swamp are so narrowly defined as habitats that determining key indicator plants was relatively easy. The rainforest habitat required a good deal more sorting and selection from vast lists of unfamiliar Latin binomials.

The list of key indicator plants was further edited and other plants added based on additional criteria: toxicity; durability; special educational attributes; esthetics. The final plant list for JungleWorld was determined by cross-referencing plants that conformed to both sets of criteria. Some plants included on the list were of particular educational significance, such as

Rafflesia arnoldii, the world's largest single flower. Certain key indicator plants had to be excluded from the list because of their particular growing requirements, such as certain halophytes associated with the mangrove swamp habitat.

The exhibit designs consisted of plan views showing the locations of the major landscape elements - primarily trees. The locations of the major plants were determined by the following criteria: proximity to artificial elements; spacial limitations; proximity to walls; sight lines; camouflage; predicted spatial use by animals; logic according to habitat physiognomy; esthetics. Detailed design features were based on photo-references of actual scenes in nature having similarity to a particular portion of JungleWorld and the microclimate at that location. No plans were executed to show the exact locations of the lesser landscape elements in the rainforest landscape such as groundcover, vines, epiphytes, etc. These landscape elements were quantified by a determination of the space available, and the percentage of that space which should be devoted to a particular kind of plant based on its relative importance to the natural habitat - key indicator. These plants were acquired in large groups for mass planting. This design style necessitated a great deal of on-site supervision.

The landscape plans were implemented with the search for the appropriate plants. The key indicator plant list had to be amended with alternates since so many species were unavailable. Alternate plants had to meet a somewhat less stringent level of integrity relative to the plant collection policy. In certain cases, however, note was made of those plants that, if unobtainable, would significantly reduce the botanical integrity of the exhibit and those would be pursued with diligence.

After preparing the planting areas with adequate drainage and soilless growing medium, plants were installed. Several techniques and pieces of equipment were used to move plants. The equipment list consisted of 1 three-ton capacity forklift, a winch-truck of similar capacity, one 2-1/2 ton capacity pallet jack, two 1-1/2 ton capacity chain hoists, and a home-made trunk cradle on a dolly. Use was made of several 3/4" bull lines and 12' nylon straps as well. The heavy equipment was used to unload trucks and move large plants to the entry of the building. All large plants were moved within the building using a system of ramps, constructed of plywood, 2" x 10" planks, and soil bags for support along with the pallet jack and/or chain hoists. Trees were lifted into hard to reach planting areas by chain hoists and guy ropes.

The largest plants were installed first and smaller plants, accordingly, thereafter until each exhibit was completed. To enhance the dimensions of the planting and amplify a feeling of encroaching vegetation, all plants, particularly the larger trees, were leaned over pathways, into views, and away from walls to avoid shadows. Most of the tenets of good landscape design were cast aside in an attempt to achieve more realism. Using field descriptions, textbook photographs, borrowed and personal slides as inspiration, the jungle began to take shape.

Understory and secondary plants were placed by sight as dictated by a particular location and the ambience created by the larger plants. Broad, asymmetrical colonies of single species gradually integrated and disappeared into other colonies of differing plants. Vines, ferns, and epiphytes were sprinkled into the setting wherever a spot presented itself. Grasses were used wherever appropriate to lend an additional air of realism and weediness to those areas representing ecotones and pioneer communities. Dead material was added last to achieve the final touch of realism.

CONCLUSION

The relatively recent and growing wave of interest in zoo horticulture is part of a rising tide of interest in environmental education. The new zoo, as an environmental park with a stronger botanical orientation, seeks to integrate facets of botany and zoology in a manner indicative of nature.

Zoo horticulturists will continue to experiment with plants and planting schemes in and around zoological exhibits. Their experiments will be based upon their knowledge of captive and wild animal behaviors, habitats, ecology, phytogeography, and observed interactions between captive animals and plants. Zoo horticulturists will discover a wealth of information in the libraries, on the grounds, and at the programs offered by horticultural and botanical institutions.

Zoo horticulture plays a functional and educational role in the zoo, particularly those zoos striving to be effective conservation and instructional facilities. Zoos that display plants and animals have a greater potential to offer the public an image of these organisms as integral parts of the natural world. Botanically and zoologically integrated exhibits serve to foster a keener appreciation of life itself. The survival of zoos,

conservation programs, and indeed, the entire biota, depends upon informed and responsible human beings.

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ZOO HORTICULTURE

A Brief Survey of Plants Used in Hoofed Stock Exhibits

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ABSTRACT

The use of plants in and around mammal enclosures for creating habitats and reinforcing exhibit themes is a desirable trend that has taken shape largely through trial and error. Hoofed stock exhibits constitute one of the major horticultural problems at the zoo. Information from 77 zoos concerning the success or failure of plants in hoofed stock exhibits was collected. Data on 233 exhibits are summarized, including a subjective review and analysis. There were 499 responses concerning individual plants and their condition. In total, 118 mammals and 336 species of plants were reported on. The dominant vegetation used in hoofed mammal exhibits are trees and turf grass.

INTRODUCTION

The use of plants in and around mammal enclosures for creating habitats and reinforcing exhibit themes is a desirable trend that has developed largely through trial and error. Personal observation at various zoos and discussions with zoo horticulturists clearly indicate that growing plants in hoofed stock exhibits is one of the major horticultural problems at the zoo. Ungulates -- hoofed mammals -- compact the soil around plants thereby disrupting the penetration of water, gases, and nutrients to plant roots. The trampling and divoting caused by hooves can physically damage surface roots and individual grasses in turf cover. Ungulates are vegetarians and can damage exhibit plants by feeding upon them. Plants also make convenient tools for grooming fur, horns, and antlers. Grooming behaviors, which usually involve rubbing some part of the body against the plant, can damage plants by girdling or crushing plant parts. Many ungulates also mark their territory for identification with a scent. This may involve some type of physical contact which can girdle or crush plants, or chemical damage from urine and other substances used for scent.

Little information is available concerning plants used for hoofed stock exhibits. Zoo horticulturists lack a base of information concerning plants which survive in ungulate exhibits. Consequently, zoo horticulturists often duplicate the mistakes of others, and there is no opportunity to build on the work undertaken at other zoos. Hence, a survey of plants used in hoofed stock exhibits seemed an appropriate undertaking. The survey

described was formulated to gather the following information: the most commonly exhibited hoofed mammals; plants used in hoofed mammal exhibits; the condition of plants used in hoofed mammal exhibits; the types and extent of contact between plants and mammals; and the forms of plant protection used in these exhibits.

THE SURVEY

A tabular survey form was devised that asked each recipient to report the condition of different plants used with ungulates in individual exhibits (see Appendix 1). The survey form was accompanied by a cover letter explaining the need and purposes for obtaining this information. Two follow-up notices encouraged participation in the survey.

The survey went to 132 zoos that were members of the American Association of Zoological Parks and Aquariums. The zoos chosen had annual budgets of $100,000 or more. I received 77 responses, 70 of which contained useful information. In addition to listing the names of plants, their condition, and the hoofed mammals combined in zoological exhibits, a subjective cross-tabulation and the results from selected bits of survey data are provided.

The survey data for exhibit area, number of mammals in each exhibit, number of plants in each exhibit, and the plant condition were consolidated into a small number of categories for easy interpretation. The condition classes were consolidated into "poor" (dead, poor) and "good" (fair, good, excellent, rampant) on the basis of a preliminary review of the data indicating the dominence of these two classes of condition.

SURVEY RESULTS AND DISCUSSION

The results came from 233 mono-specific exhibits and 499 plant records. Mammal names according to Corbet and Hill (1980). Plant names were cross-referenced with Hortus Third (L. H. Bailey Hortorium, 1980). Those not listed in Hortus Third were recorded as listed on the survey.

The dominant mammal and plant species reported in the surveys are listed in Tables 1 and 2. Appendix 2 contains a list of the most commonly exhibited mammals and the plants in good condition associated with them. Mammal exhibits were evenly split in size between small (51%) -- $\leq$ 4,000 square meters -- and large (49%) -- $\geq$ 15,000 square meters. Most exhibits contained 2-5 mammals (47%) followed by 6-10 (22%), 11 or more (15%), and 1 mammal (14%). Trees were the most common type of plant (65%) used in hoofed stock exhibits followed by turf (30%), small trees (6%), and shrubs (3%). Thirty-six percent of exhibits had only 1 individual plant while 34% of the exhibits had 2-5 plants, 20% had 5-10 plants, and only 11% had 11 or more plants. There were over twice as many plants reported in poor condition (72%) as in good condition (28%). Most of the exhibits had plants that were, at least partially, eaten (40%), while 33% reported no contact, and 27% of the exhibits had plants suffering from trampling damage. The predominant form of plant protection is chain link steel fencing around tree trunks. The many forms of protection reported in the survey and the percent of the total for each are listed in Table 3. Sixty-one percent of the total number of plants reported in the survey were protected in some way.

TABLE 1: Mammal species reported in over 2% of the exhibits. (N = 233)

MAMMAL SPECIES	NUMBER OF EXHIBITS	PERCENT
Elk (*Cervus elaphus*)	11	5
Giraffe (*Giraffa camelopardalis*)	9	4
White-tailed deer (*Odocoileus virginiana*)		
Grant's Zebra (*Equus burchelli*)	8	3.4
Llama (*Llama glama*)	7	3
Eland (*Tragelphus oryx*)	6	2.6
Dromedary camel (*Camelus dromedarius*)		
Bison (*Bison bison*)		
Brazilian Tapir (*Tapirinus terrestris*)	5	2.1
Reeves muntjac (*Muntiacus reevesi*)		
Sable antelope (*Hippotragus niger*)		
White-tailed gnu (*Connochaetus gnou*)		
Black rhinoceros (*Diceros bicornis*)		
Pere David deer (*Elaphurus davidianus*)		
African elephant (*Loxodonta africana*)		

TABLE 2: Plant species reported in 3% or more of the exhibits.

PLANT SPECIES	NUMBER OF EXHIBITS	PERCENT
Bermuda Grass (*Cynodon dactylon*)	48	21
Blue Grass (*Poa pratensis*)	28	12
Rye Grass (*Lolium perenne*) Tall Fescue (*Festuca arundinaceae*)	21	9
Poplar (*Populus deltoides*)	19	8
Sycamore (*Platanus occidentalis*)	14	6
Post oak (*Quercus stellata*) American elm (*Ulmus americana*) White ash (*Fraxinus americana*) Tree of heaven (*Ailanthus altissima*)	12	5
Fescue (*Festuca* species) White oak (*Quercus alba*) Poplar (*Populus fremontii*) Pin oak (*Quercus palustris*)	9	4
Red maple (*Acer rubrum*) Mulberry (*Morus* species)	8	3.4
Sugar maple (*Acer saccharum*) Red cedar (*Juniperus virginiana*) White pine (*Pinus strobus*)	7	3

TABLE 3: Types of plant protection and percents of all protected plants. (N = 206)

Protection	%	Protection	%
Chain Link	41	Steel	5
Wood	25	Snow Fence	4
Chicken Wire	11	Railroad Ties	3
Logs	7	Electrical Wire	2
Rocks	7		

Six out of 9 plant species in Table 4 are "pioneer" species, plants that can often be found in disturbed habitats and are adaptable to adverse conditions. This might be a useful criterion for selecting suitable candidates for exhibit landscapes. Mammal species having a majority of the plants associated with them in poor condition graze and browse, a feeding strategy that is broad and, perhaps, destructive in zoological exhibits. The majority of mammals in Table 6 graze or browse, specific feeding strategies that may allow for more flexibility in the use of plants in their exhibits; most of the plants associated with these mammals are reported in good condition.

TABLE 4: Plants in good condition exhibited with the largest number (≥6) of different mammal species.

Acer negundo (P)	Liriodendron tulipifera
Acer species	Prunus serotina (P)
Ailanthus altissima (P)	Quercus alba
Juniperus virginiana (P)	Quercus marilandica (P)
Liquidamber styraciflua (P)	

TABLE 5: Mammal species exhibited with plants in a poor condition in 66% or more of their cases.

Alcelaphus buselaphus	Gazella dama
Camelus ferus	Gazella granti
Camelus dromedarius	Llama guanicoe
Capraibex sibirica	Loxodonta africana
Ceratotherium simum	Oryx leucoryx
Cervus nippon	Ovis dalli stonei
Equus burchelli	Rupricapra rupricapra
	Tragelaphus spekei

TABLE 6: Mammal species exhibited with plants in a good condition in 66% or more of their cases.

Alces alces	Equus grevyi
Ammotragus lervia	Giraffa camelopardalis
Antelope cervicapra	Hippotragus niger
Bos mutus	Llama glama
Cervus elaphus	Odocoileus hemionus
Connochaetes gnou	Ovibos muschatus
Damaliscus dorcas	Tapirinus terrestris
Elaphurus davidianus	Tragelaphus oryx

Large percentages of all plants were reported as suffering from feeding damage (40%) and trampling damage (27%). Most of the plants that were reported in poor condition suffered contact-caused or soil compaction damage (Table 7). I would consider these plants to be particularly susceptible to the potentially damaging behaviors of hoofed mammals. Typically, grasses suffer from both feeding and compaction. Maples are vulnerable to both types of contact due to their sugary sap, which entices mammals to chew bark, and shallow roots which are sensitive to trampling damage and compaction. Plants from Table 8 may be particularly tolerant of the damage that is possible through contact with mammals. There are mixed results concerning the condition of maples in different exhibits (Tables 7 and 8). As expected, plants having little contact damage from mammals were reported in good condition (Table 9). One could assume that these plants are avoided or ignored by their associated mammals. The overlap between the plants in Table 9 and Table 7 may be indicative that plants in Table 9 are protected in some manner. In addition, note that bermuda grass (Cynodon dactylon) is included in Table 9. This could be explained by the fact that, of those commonly exhibited mammals and associated plants in good condition (Table 6), bermuda grass was reported most often with mammals that graze and browse and those that only browse. In such cases, bermuda grass may not come under heavy grazing pressure.

TABLE 7: Plants in poor condition with over 50% reported as having been damaged by mammals.

EATEN	COMPACTION
Acer saccharinum	Acer saccharinum
Acer saccharum	Acer saccharum
Lolium perenne	Betula papyrifera
Poa pratensis	Lolium perenne
Rhus species	Pinus strobus
Populus tremuloides	Platanus occidentalis
	Poa pratensis
	Rhus species

TABLE 8: Plants in good condition with over 50% reported as having been damaged by mammals.

EATEN	COMPACTION
Crataegus species	Acer saccharinum
Prunus serotina	Acer saccharum
Quercus marilandica	Poa pratensis
	Rhus species

TABLE 9: Plants in good condition with less than 50% reported as having been damaged by mammals.

EATEN	COMPACTION
Cynodon dactylon	Betula papyrifera
Fraxinus pennsylvanica	Liriodendron tulipfera
Juniperus virginiana	Pinus strobus
Liriodendron tulipfera	Platanus occidentalis
Platanus occidentalis	Prunus serotina
Quercus stellata	Quercus alba
Robinia pseudoacacia	Quercus stellata
Ulmus americana	Robinia pseudoacacia
	Salix nigra
	Tsuga canadensis
	Ulmus americana

The many forms of protection reported in the surveys were used primarily with trees. Fencing, wooden planks, and other barriers are commonly placed around tree trunks to protect the bark. Chain link, box wire, and other types of fence protection will adequately protect tree bark and be unobtrusive if painted the appropriate color. This type of protection becomes a maintenance problem in that it must be adjusted periodically to avoid girdling the trunk. Many institutions use natural objects such as rocks and brush to protect trees. This material must be carefully placed in conjunction with planting locations so as not to look contrived. Trees planted in natural groupings or groves are easier to protect than individuals. In addition, trees in groves form their own protected root zone on the interior of the grove. Forms of plant protection must be tailored to the particular damaging behaviors of the exhibited mammals.

These results that trees and turf dominate the vegetation of hoofed stock exhibits. This is due to their resilience to the damaging behaviors of hoofed mammals and the diligence with which they are nurtured by the zoo horticulturist. Trees can be installed within ungulate exhibits in a sufficiently mature state to be more tolerant of the limiting factors present. The most useful trees are those that have proven adaptability to adverse conditions. Their predominance in hoofed stock exhibits probably reflects their availability as much as suitability for these mammals. However, many of these trees such as sycamore (Platanus occidentalis), tree of heaven (Ailanthus altissima), and poplar (Populus deltoides) are noted for their tenacity and weedy

nature. In addition, of the 43 different tree species commonly listed in good condition, over one-half (24) possess some potentially effective defense against browsing mammals. Potentially useful defenses include thorns, spines, and repellent or distasteful saps and tissues. Honeylocust (Gleditsia triacanthos), black locust (Robinia pseudoacacia), and hawthorn (Crataegus species) all possess thorns. Ficus species, mulberry (Morus species), and the chinese tallow tree (Sapium sebiferum) all have a milky, repellent sap. Based on personal observation at the New York Zoological Park, tree of heaven (Ailanthus altissima) is meticulously avoided by several different species of hoofed mammals, most likely due to its bitter tasting bark and cambium (Staff, L.H.Bailey Hortorium, 1976). Several species of oak are included in this group and the tannins they possess in their tissues are difficult to digest (Kingsbury, 1964). Though there is no evidence presented here to show that these defensive attributes account for the condition of the above plants with hoofed mammals, the fact that the majority of plants in this group possess these attributes makes them worthy of consideration.

Turf grasses are being developed that are more tolerant of wear, compaction, and mowing, qualities that are important for use in hoofed stock exhibits. Not surprisingly, the most useful turf, bermuda grass (Cynodon dactylon), is very stoloniferous and, therefore, tenacious. Unfortunately, there is no commercial source of quackgrass (Agropyron repens), an incredibly tenacious weed which might be useful for hoofed stock exhibits based on the success of the bermuda grass. The San Diego Wild Mammal Park

reported good success with kikuyu grass (Pennisetum clandestinum), a coarse and highly stoloniferous grass. This grass will survive only in warm climates, although zoos in colder climates should consider using Pennisetum flaccidum which has a similar growth habit.

Three important, synergistic factors that impact upon the condition of plants in an exhibit are exhibit area, the number of mammals present, and the mass of those mammals. These factors are best represented as an expression of exhibit mammal biomass -- (mammal mass x mammal number)/M^2 of exhibit space. The mammal mass categories in Table 10 were derived from mammal weights in Corbet and Hill, 1980.

TABLE 10: The distribution of plants in a poor condition based on mammal biomass/exhibit size.

Exhibit Mammal Mass (Kg)	% of Total Exhibits	Exhibit Size: 4000 Sq.M. Kg/Sq.M.	4000 Sq.M. #Ex.	4000 Sq.M. % Poor	15000 Sq.M. Kg/Sq.M.	15000 Sq.M. #Ex.	15000 Sq.M. % Poor
0-250	1	0-0.06	3	60			
250-500	5	.07-.13	12	63			
500-1000	18	.14-.25	31	63	.03-.07	12	47
1000-3000	30	.26-.75	39	83	.08-.2	30	71
3000-4000	38	.75-1.0	30	84	.21-.26	55	67
4000-6000	6	1.1-1.5	4	77	.27-.4	10	82
>6000	2				>.4	9	70

The greatest percentage of exhibits in Table 10 (38%) carried an mammal biomass of 3000 - 4000 Kg which is equivalent to the weight of 1 bull elephant, 70 impala, or 10 zebras. Note that 7 out of 11 categories in Table 10 had a lower overall percentage of plants in poorer condition than the total (72%). Of these, one category actually has a minority (47%) of plants in poor condition. The exhibits with the smallest biomass load, .03-.07 Kg/M^2, are those, not surprisingly, with the smallest percentage of plants in poor condition. Though many climatic, edaphic, and mammal behavioral factors are not considered here, it could be expected, based upon the data in Table 10, that exhibits with a biomass load of .26 Kg/M^2 or less are better candidates for successful plant culture.

It might be useful to compare a "successful" hoofed stock exhibit from among all those surveyed with the general data. A successful exhibit is one containing several kinds of plants in a good condition. Consider a 15,000 M^2 exhibit at the New York Zoological Park that contains 4 Grevy's zebras for 7 hours per day, 7 months per year. This exhibit contains an mammal biomass of 1,428 Kg, or .09 Kg per square meter of exhibit space. This biomass load is less than one eighth of the biomass for the majority of exhibits from all surveyed zoos. Unfortunately, this survey did not measure hours of exhibit occupation, mammal weight distribution, hoof size, and other relevant data for serious considerations concerning biomass. The area of this sample exhibit is larger than the majority of exhibits surveyed. The exhibit contains a healthy and continuous ground cover composed

primarily of tall fescue (Festuca elatior), perennial rye grass (Lolium perenne), and bluegrass (Poa pratensis). This turf mixture conforms to the majority of turf data reported in the surveys. The turf is grazed by the mammals while they are occupying the exhibit, but it remains in good condition. Although the condition of the turf is probably due to several unknown factors, its tolerance of close cropping, the total mammal biomass in the exhibit, the hours the mammals occupy the exhibit, and the size or biomass per square meter of exhibit space certainly play a role.

There are no shrubs or forbs in this sample exhibit. There were very little data in the surveys pertaining to shrubs or forbs. They do not appear to be good candidates for hoofed stock exhibits. Shrubs are easily damaged by trampling and highly susceptible to browsing damage due to their thin bark and easy-to-reach foliage and buds.

Three species of trees occupy the sample exhibit: sycamore (Platanus occidentalis), tree of heaven (Ailanthus altissima), and aralia (Aralia spinosa), which could be considered a large shrub. Survey data indicated sycamore and tree of heaven to be relatively successful candidates for hoofed stock exhibits. Aralia was not a common component of hoofed stock exhibits, but it is conspicuously successful in the sample exhibit. All trees in the sample exhibit are planted in tight groves - difficult for mammals to walk through. In addition to exhibit size, biomass, and other factors attributing to the success of the turf, mammal feeding strategy may come into play in regard to the success of

the trees. Zebras are grazing mammals and do not, given an adequate plot of turf, browse woody plants. Also, since the trees are planted in tight groves, making it difficult for mammals to compact and trample the root zones on all sides, they do not suffer from any of the obvious effects of soil compaction. The total mammal biomass in the exhibit undoubtedly affects this condition as well. There are a total of 28 aralias, growing in two groves, 12 sycamores in one grove, and 36 trees of heaven growing in three groves. Obviously, these numbers are way above the majority -- 1 plant per exhibit -- reported in the survey data.

SUMMARY

Trees and turf are most successful in hoofed stock exhibits although plants generally do poorly in this environment. Hoofed stock exhibits are unduly difficult for the zoo horticulturist to maintain because they are often over-stocked with mammals. Ungulate exhibits with a biomass load over .26 kilograms per square meter are likely to be unsuitable for growing plants.

Many of the so called "weed" trees, such as ailanthus, boxelder (Acer negundo), mulberry (Morus species), and poplar (Populus species) are good selections for hoofed stock exhibits. Trees recommended for urban horticultural settings are good selections for hoofed stock exhibits if adequate consideration is given to the particular damaging behaviors of the mammals present in regard to the useful characters of the tree. In addition to these criteria, one should consider trees that possess physical and/or chemical defenses, such as thorns or distasteful foliage. This strategy is complicated by the difficulties associated with determining what is distasteful to any given mammal, and plants known to be avoided in one exhibit may be tolerated in another.

Trees become more self-protecting if they are planted in groves. Individual trees can be adequately protected, if necessary, with a collar of chain link attached to itself and not directly to the tree. Groves of trees can be protected in several ways: taught wire, fencing, rocks, brush, logs, etc. Hardware protection must be periodically checked for adequate clearance around tree trunks.

Turfgrass should be highly tolerant of wear and close-cropping. These are highly sought-after traits by athletic field managers as well as zoo horticulturists. New turfgrass cultivars, cultivar blends, species, and species mixtures developed for athletic fields may be useful for hoofed stock exhibits. Turf-type bermuda grass (Cynodon dactylon) cultivars are good selections for warm season climates while perennial rye (Lolium perenne), tall fescue (Festuca elatior), and blue grass (Poa pratensis) cultivar mixtures are suitable for cool season climates. Where feasible, consider rough mixtures of quackgrass (Agropyron repens), path rush (Juncus tenuifolia), and orchard grass (Dactylus glomerata).

To develop a useful model it will be necessary to collect detailed information on exhibits pertaining to one species or commonly associated species of mammal, such as zebras. Some of the important data to collect are: exhibit area; exhibit topography; climatic factors; exhibit soil type and quality; exhibit soil moisture content; total mammal biomass per exhibit area; total hours exhibit area is occupied; mammal exhibit use patterns; type & amount of exhibit vegetation; distribution of exhibit vegetation; condition of individual plants; and horticultural practices applied to the exhibit.

As more zoos change their collecting strategies to emphasize breeding groups as opposed to `postage stamp' collections they should be able to devote more space to a limited number of hoofed mammal species.

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APPENDIX I

SURVEY FORM

HOOFED STOCK EXHIBITS

0-dead 4-excell.
1-poor 5-rampant
2-fair 6-mimics native habitat
3-good

1-grazed/girdled
2-trampled/compacted
3-no animal contact

SIZE sqft-A.	LIST ALL ANIMALS NO.	LIST ALL PLANTS NO.	0	1	2	3	4	5	6	1	2	3	OTHER STATE	COMMENTS
6500 sqf	Blesbok Damaliscus sp. 6	Gleditsia triacanthos 2					✓		✓			✓	protected: wood barracade	
		Miscanthus sinensis 12 clumps				✓			✓	✓				
		Poa pratensis 'Merion'		✓						✓	✓			requires weekly irrigation
	SPACE BETWEEN	EXHIBIT ENTRIES												
8700sqft	Steenbuck Raphicerus sp. 6	Crataegus phaenopyrum 4				✓			✓	✓				Steenbuck
	Grey Duiker Sylvicapra sp. 4	Berberis tricanthophora 8					✓		✓			✓		
		Miscanthus sinensis 6 clumps			✓				✓	✓	✓			Steenbuck
		Poa pratensis 'Victor'		✓						✓	✓			Steenbuck Grey Duiker
	SPACE BETWEEN	EXHIBIT ENTRIES												
2 Acres	African Elephant Loxodonta sp. 4	Acacia decurrens 2				✓			✓		✓		protected: steel barracade	needs soil aeration
		Andropogon virginicus 12 clumps		✓					✓		✓			

SAMPLE

APPENDIX 2

MOST COMMON MAMMALS

AND PLANTS IN A GOOD CONDITION

The following list is composed of the most commonly exhibited mammals and the plants in good condition associated with them. Plants are listed by scientific name only without italics. Those plants appearing with an asterisk are completely unprotected in the exhibit. The feeding strategy of each mammal is indicated following the scientific name with a `G' for grazers or grass eaters, `B' for browsers or woody plant eaters, and `GB' for mammals that graze and browse.

1. Elk (Cervus elaphus) GB:

Acer saccharum*, Acer species*, Betula papyrifera*, Carya illinoinensis*, Carya ovata, Celtis occidentalis*, Fraxinus americana*, Fraxinus pennsylvanica, Pinus ponderosa, Platanus occidentalis*, Poa pratensis*, Populus deltoides*, Quercus rubra, Quercus species*, Quercus virginiana*, Sapium sebiferum*.

2. Giraffe (Giraffa camelopardalis) B:

Acer negundo, Cortaderia Selloana*, Cupressus macrocarpa, Festuca arundinaceae*, Gleditsia triacanthos, Morus species, Pinus ponderosa*, Populus deltoides, Robinia pseudoacacia, Tilia americana.

3. White-tailed deer (Odocoileus virginiana) GB:

Acer species, Cercis canadensis, Cynodon Dactylon*, Fraxinus americana, Liriodendron Tulipifera, Pinus strobus*, Pinus taeda*, Platanus occidentalis, Populus deltoides*, Quercus alba, Quercus rubra, Thuja occidentalis, Tsuga canadensis*.

4. Grant's zebra (Equus burchelli) G:

Acer platanoides, Ailanthus altissima*, Carya ovata, Cupressus macrocarpa, Ficus rubiginosa, Fraxinus americana, Fraxinus pennsylvanica, Gleditsia triacanthos, Malus species, Morus species, Platanus x acerifolia*, Poa pratensis*, Populus deltoides,

Quercus alba*, Quercus species, Ulmus americana.

5. Llama (Llama glama) G:

Acer negundo*, Ailanthus altissima, Festuca species*, Ficus benjamina, Fraxinus americana, Liriodendron Tulipifera, Lolium perenne*, Magnolia grandiflora, Platanus occidentalis, Poa pratensis*, Populus deltoides, Quercus alba*, Quercus species, Pluchea odorata*.

6. Eland (Tragelaphus oryx) B:

Bromus species, Gleditsia triacanthos, Lolium perenne*, Pinus ponderosa, Platanus occidentalis, Poa pratensis*, Populus deltoides*, Quercus rubra*.

7. Dromedary camel (Camelus dromedarius) G:

Ailanthus altissima*, Celtis occidentalis, Cynodon Dactylon*, Festuca species, Lolium perenne*, Poa pratensis*, Trachycarpus Fortunei, Ulmus crassifolia.

8. Bison (Bison bison) G:

Acer negundo, Acer saccharum, Betula papyrifera, Carya illinoinensis*, Celtis occidentalis, Cynodon Dactylon*, Festuca species*, Ficus retusa, Fraxinus americana, Fraxinus pennsylvanica, Gleditsia triacanthos, Morus species*, Populus deltoides, Quercus alba*, Quercus palustris*, Quercus virginiana, Salix babylonica, Salix nigra, Thuja occidentalis*, Tilia americana, Ulmus americana*.

9. Brazilian Tapir (Tapirinus terrestris) GB:

Acer platanoides*, Cynodon Dactylon*, Fraxinus pennsylvanica, Phoenix dactylifera, Populus deltoides*, Salix species.

10. Reeves muntjac (Muntiacus reevesi) GB:

Cynodon Dactylon*, Lagerstromia indica, Liriodendron Tulipifera, Magnolia grandifolia, Morus alba*, Platanus x acerifolia*, Populus Fremontii*, Quercus rubra*, Tsuga canadensis*.

11. Sable antelope (Hippotragus niger) GB:

Acer species, Cynodon Dactylon*, Liquidamber styraciflua, Pinus ponderosa, Pinus taeda, Poa pratensis*, Populus Fremontii, Quercus marilandica, Quercus stellata, Salix nigra.

12. White-tailed gnou (Connochaetes gnou) GB:

Acer negundo*, Ailanthus altissima*, Celtis occidentalis, Cercis canadensis, Eucalyptus species, Fraxinus americana*, Gleditsia triacanthos, Malus species*, Morus species*, Populus Fremontii*, Rhus species*, Robinia pseudoacacia.

13. Black rhinoceros (Diceros bicornis) B:

Acer species, Ailanthus altissima, Festuca rubra*, Fraxinus americana, Lolium perenne*, Quercus species*, Robinia pseudoacacia.

14. African elephant (Loxodonta africana) B:

Acer platanoides, Acer rubrum, Cynodon Dactylon*, Gleditsia triacanthos, Platanus occidentalis, Robinia pseudoacacia, Pennisetum clandestinum*.

15. Grevy's zebra (Equus grevyi) G:

Acer species, Ailanthus altissima*, Bromus species, Eucalyptus species, Fraxinus americana*, Gleditsia triacanthos, Malus species, Morus species*, Pinus ponderosa, Pinus strobus*, Platanus occidentalis*, Populus deltoides, Populus Fremontii*, Platanus racemosa.

16. Thomson's gazelle (Gazella thomsonii) G:

Crataegus species*, Festuca arundinaceae*, Gleditsia triacanthos, Liriodendron Tulipifera*, Lolium perenne*, Quercus alba*, Taxodium distichum*, Tsuga canadensis*, Ulmus americana*.

APPENDIX 3

MASTER FILE OF PLANTS AND MAMMALS

PLANTS

Acacia Baileyana
Acacia Farnesiana
Acacia longifolia
Acer campestre
Acer macrophyllum
Acer Negundo
Acer platanoides
Acer rubrum
Acer saccharinum
Acer saccharum
Acer species
Aesculus glabra
Aesculus hippocastanum
Agapanthus orientalis
Agathis robusta
Agropyron elongatum
Agropyron sibiricum
Agropyron trachycaulum
Ailanthus altissima
Albizia Julibrissin
Alnus species
Andropogon Gerardi
Aralia spinosa
Arecastrum Romanzoffianum
Asclepias species
Asimina triloba
Baccharis pilularis
Baccharis sarothroides
Bambusa vulgaris
Bauhinia variegata
Berberis species
Betula nigra
Betula papyrifera
Betula species
Bougainvillea glabra
Brachychiton acerifolius
Brassaia actinophylla
Bromus species
Bursera Simaruba
Butia capitata
Callistemon citrinus
Carnegea gigantea
Carpinus caroliniana
Carpobrotus chilensis
Carpobrotus edulis
Carya cordiformis
Carya glabra
Carya illinoinensis
Carya ovata
Carya tomentosa
Casuarina equisetifolia
Catalpa bignonioides
Catalpa speciosa
Cedrus libani
Celtis sinensis
Celtis laevigata
Celtis occidentalis
Cercidium microphyllum
Cercis canadensis
Cereus peruvianus
Chamaecyparis pisifera
Chamaecyparis species
Chamaerops humilis
Chorisia speciosa
Citrus Aurantium
Citrus species
Cladrastis lutea
Cocos nucifera
Conocarpus erectus
Cordyline indivisa
Cornus mas
Cornus racemosa
Cornus sericea
Cortaderia Selloana
Cotoneaster species
Crataegus species
Cupressus macrocarpa
Cynodon Dactylon
Cyperus albostriatus
Cytissus scoparius
Delonix regia
Diospyros virginiana
Elaeagnus angustifolia
Elaeagnus pungens
Elymus canadensis
Encelia farinosa
Eragrostis curvula
Eragrostis species
Eriobotrya japonica
Escallonia species
Eucalyptus camaldulensis
Eucalyptus species
Eucalyptus Globulus
Eucalyptus maculata
Euonymus alata
Euonymus cordata
Euonymus japonica
Fagus grandifolia
Fatsia japonica

Brusfeltiana species
Cedrus deodara
Chamaedorea macrocarpa
Chamaedorea Seifrizii
Cinnamomum glanduliferum
Cupressus cunninghammii
Dietes vegeta
Erythrina caffra
Ligustrum japonicum
Ilex aquifolium
Melia Azedarach
Musa species
Olea europaea
Olmediella Betschlerana
Pennisetum clandestinum
Pennisetum villosum
Philodendrom x Evansii
Philodendron Lundii
Phoenix canariensis
Pinus halepensis
Pinus roxburghii
Pinus wallichiana
Podocarpus gracilior
Populus candicans
Pluchea odorata
Quercus agrifolia
Rhus lancea
Rhus laurina
Schinus molle
Tecomaria capensis
Tipuana Tipu
Pittosporum rhombifolium
Platanus racemosa

MAMMALS

Addax nasomaculatus
Aepyceros melampus
Alcelaphus buselaphus
Alkcelaphus caama
Alces alces
Ammotragus lervia
Antidorcus marsupialis
Antilocapra americana
Antilope cervicapra
Bison bison
Bison bonasus
Bos gaurus
Bos javanicus
Bos mutus
Bos primigenius Aurochs
Boselaphus tragocamelus
Bubalus arnee
Bubalus depressicornis
Camelus dromedarius
Camelus ferus
Capra aegagrus
Capra falconeri
Capraibex siberica
Capricornis crispus
Cephalophus dorsalis
Cephalophus monticola
Cephalophus niger
Cephalophus sylvicultor
Cephalophus zebra
Ceratotherium simum
Cervus axis
Cervus dama
Cervus duvauceli
Cervus elaphus
Cervus eldi
Cervus nippon
Cervus porcinus
Cervus unicolor
Choeropsis liberiensis
Connochaetes gnou
Connochaetes taurinus
Damaliscus dorcas
Damaliscus korrigum
Damaliscus lunatus
Diceros bicornis
Elaphurus davidianus
Elephas maximus
Equus africanus

Equus burchelli
Equus ferus
Equus grevyi
Equus kiang
Equus zebra
Gazella dama
Gazella dorcas
Gazella granti
Gazella leptoceros
Gazella spekei
Gazella subgutturosa
Gazella thomsonii
Giraffa camelopardalis
Hemitragus hylocrius
Hemitragus jamalhicus
Hippopatamus amphibius
Hippotragus equinus
Hippotragus niger
Hydropotes inermis
Hylochoerus meinertzhageni
Kobus ellipsiprymnus
Kobus kob
Kobus leche
Kobus megaceros
Litocranius walleri
Llama glama
Llama guanicoe
Llama pacos
Loxodonta africana
Madoqua kirki
Madoqua species
Mazama americana
Muntiacus Muntjak
Muntiacu s reevesi
Muntiacus species
Neotragus moschatus
Odocoileus hemionus
Odocoileus virginiana
Okapia johnstoni
Oreamnos americana
Oryx dammah
Oryx gazella
Oryx gazella callotis
Oryx leucoryx
Ourebia ourebi
Ovibos moschatus
Ovis ammon
Ovis aries
Ovis canadensis
Ovis dalli stonei
Ovis orientalis

Rangifer tarandus
Rhinoceros unicornis
Rupricapra rupicapra
Saiga tatarica
Sylvicapra grimmia
Sus scrofa
Synceros caffer
Tapirinus bairdi
Tapirinus indicus
Tapirinus terrestris
Tayassu tayacu
Tragelaphus angasi
Tragelaphus derbianus
Tragelaphus euryceros
Tragelpaphus imberbis
Tragelaphus oryx
Tragelaphus scriptus
Tragelaphus spekei
Tragelaphus strepsiceros
Bos primigenius
Cephalophus grimmia