Abstract

We analyzed the importance of exotic game ranching for the conservation of native plants and animals in the Texas Hill Country. We focused on non-native herbivorous artiodactyls that have become an integral component of the Texas Hill Country ecosystem. We examined information about habitat, reproduction, and diet of these species, and the possible competition that may occur between exotic and native species in the Texas Hill Country, like white-tailed deer. We also analyze the socio-economic factors that motivate the expansion of exotic game ranching. We found that the Edwards Plateau is the natural region in Texas with the highest density of exotic game species. Moreover, the Axis deer is the exotic species that has had the highest population levels over the last several years. Biological information about feeding behavior revealed that white-tailed deer are an inferior competitor to exotic species and that this native species is the first species to suffer under intense competition. Exotic game species replace white-tailed deer on poor quality or overgrazed range. We suggest that expansion of exotic game ranching in the Texas Hill Country can serve as a tool for conservation of the Edwards Plateau. On the one hand, game ranching can diversify the economy of ranchers by providing venison for market, agricultural tax exemptions, and trophy hunting, and, on the other hand, by controlling free-ranging exotic species that compete with white-tailed deer and other native ungulate species.

Resumen

Se analizó la importancia del manejo de artiodáctilos exóticos para la conservación de la flora y fauna nativas de la región de Texas Hill Country también llamada meseta de Edwards. Los artiodáctilos exóticos se han convertido en un componente integral del ecosistema en Texas Hill Country. Estudiamos la información existente acerca del hábitat, reproducción y dieta de estas especies así como la posible competencia con las especies nativas de Texas Hill Country, como el venado cola blanca. Se analizaron los factores socio-económicos que han sido motor para la expansión del manejo de exóticos en esta región de Texas. Encontramos que la meseta de Edwards es la región de Texas con una mayor densidad de artiodáctilos exóticos, siendo el venado Axis la especie con los niveles más altos en la población a través de varios años. La información biológica recabada sobre la conducta alimenticia revela que el venado cola blanca es un competidor inferior a las especies exóticas siendo la primer especie nativa en sufrir daños bajo una competencia intensa. Las especies exóticas remplazan al venado cola blanca en tierras sobrecargadas o de baja calidad. En el presente estudio sugerimos que el manejo adecuado de especies exóticas de artiodáctilos puede contribuir y tener un papel clave en la conservación de Edwards Plateau. Por un lado, el manejo de exóticos puede diversificar la economía de los rancheros proporcionándoles un mercado de carne, abstenerse del pago de impuestos agrícolas e ingresos por caza mayor, y por otro lado, controlando el libre pastoreo de las
Exotic species have increased in abundance in many natural ecosystems and their impact on native species is of critical concern for conservation biologists (Luken 2000; Mack et al. 2000; Pimentel et al. 2000). Since both exotic plants and animals alter community structure and function and can reduce abundance or increase extinction of native species (Beckett et al. 1998; Bruce et al. 1995; Gordon 1998; Mauchamp 1997; Suarez and Case 2002), they must be considered in the overall processes of conservation planning and ecosystem management. Creation of preserves and restoration of habitats must consider or plan for potential invasion and consequent impact by exotic species. In addition, and of potentially more importance to conservation biologists, is that numerous anthropogenic activities may accelerate the rate of invasion by exotic species, e.g., climate change, habitat fragmentation, urban sprawl (Donovan et al. 1997; Brawn and Robinson 1996).

Exotic game species in the Texas Hill Country present numerous issues with regard to conservation of native plants and animals of this area. We focus primarily on non-native herbivorous artiodactyls that were introduced for game ranching and have become an integral component of the Texas Hill Country ecosystem. We examine habitat, reproduction, and feeding behavior of these exotic species, outline circumstances under which competition may occur between exotic and native species, and consider economic and sociological motivating forces behind growth of the industry of exotic game ranching. Finally, we discuss directions in which conservation efforts may proceed given existing knowledge concerning exotic game ranching in this region.

Legal Restrictions and Historical Background of Exotic Game Species

Federal controls on exotic game animals limit their introduction into the United States. The Lacey Act of 1900 was the first law that regulated introductions. It stated that “... it shall be unlawful for any person or persons to import into the United States any foreign wild animal or bird except under special permit from the United States Department of Agriculture” (Ramsey 1969).

The state of Texas has few laws that regulate management or harvesting of exotic game animals. Article 978 of the Texas Penal Code of 1925 grants the Texas Parks and Wildlife Commission “... the authority, power, and duty to provide by proclamation, rule or regulations, periods of time when it shall be lawful to take a portion of the wildlife resource of said counties....” (Ramsey 1969). Section 15 of this Article defines the wildlife resources to be game animals and game birds. This law grants power to the state to regulate hunting of these game species.

Article 892, which defines animals considered to be game animals, was revised in 1965 to exclude exotic game from the legal definition of game species. It states “wild deer, wild elk, wild antelope, wild desert bighorn sheep, wild black bear, wild gray or cat squirrels, wild fox squirrels or red squirrels, collared peccary or javelina, and the American bison or buffalo are hereby declared to be game animals within the meaning of this Act” (Ramsey 1969). Because they are not game animals, exotic game species are exempt from all state laws regulating hunting and management policies promulgated by the Texas Parks and Wildlife Department (TPWD). As such, they are in the same legal category of private property as domestic livestock. Domestic livestock also are considered private property and all management decisions such as stocking rate, method of grazing, and period of harvest are determined by individual landowners. This legal status of exotic species, particularly when they are not contained in the manner of traditional domestic livestock, creates ambiguities in terms of broad-scale management goals.

History. The first introduction of exotic deer (axis, sika, barashinga, and sambar) and blackbuck
antelope to Texas is thought to have been in early 1940’s (Winckler 1985). Currently, six species compromise 77% of total confined exotic animals and 99% of free-ranging exotic game animals in the state: the axis deer (*Axis axis*), fallow deer (*Dama dama*), sika deer (*Cervus nippon*), blackbuck antelope (*Antilope cervicapra*), nilgai antelope (*Boselaphus tragocamelus*), and aoudad sheep (*Ammotragus lervia*). Nilgai antelope represent 49% of total free-ranging exotic animals in Texas, but are found predominately in south Texas.

**Study Site.** Gould (1969) defined 10 natural regions of Texas based upon an environmental analysis that included examination of ecological factors such as climate, soil, topography, and biota. Relative to other natural regions of Texas, the Edwards Plateau has the highest concentration of exotic game ranches and contains 68% of the total number of confined exotics within the state (Texas Parks and Wildlife 1989). The magnitude of growth in exotic game ranching with respect to six major exotic species is illustrated by analyzing the number of exotics between 1966 and 1988 (Texas Parks and Wildlife 1989).

The Edwards Plateau contains approximately 9.6 million ha of rolling hills and spring-fed streams that cut across limestone-underline soils, forming canyons and steep hillsides; this is the so-called Hill Country of Texas. The Edwards Plateau extends from Brewster and Pecos counties in the west to Llano, Blanco, and Hays counties in the east, and from Nolan and Taylor counties in the north to Uvalde County in the south. This area forms an ecotone between the Mixed Mesophytic Forest of the eastern USA, the Madrean Evergreen Woodland of Mexico, and the Great Plains grasslands of the central USA (Amos and Gehlbach 1988). Each of these ecosystems is represented within the Edwards Plateau to varying degrees and in characteristic combinations. Rainfall on the western edge is 38 cm/year and on the eastern edge is 84 cm/year (Gould 1969). There are 271 days/year without precipitation and the most rainfall is during May, June, and September. Subfreezing winters and hot summers with occasional short droughts characterize the climate.

Limestone soils support woodlands dominated by oaks and juniper (especially live oak, *Quercus virginiana*, and Ashe juniper, *Juniperus ashei*). Granite soils contain oaks almost exclusively. Upland soils are dark, calcareous clays and clay loams that are largely stony and gravelly. Bottomland soils include minor areas of dark, calcareous clayey alluvial soils. Flatter areas with deeper soils are characterized by shortgrasses (common curly mesquite, *Hilaria bellangeri*; Texas grama, *Bouteloua rigida*; buffalo grass, *Buchloe dactyloides*; and Texas winter-grass, *Stipa leucotricha*). Steeper areas with shallower soils contain midgrasses (little bluestem, *Schizachyrium scoparium* and side-oats grama, *Bouteloua curtipendula*; Amos and Gehlbach 1988).

The Edwards Plateau is rangeland predominately, with agriculture confined to deeper soils and valleys. The excellent mixture of forage plants in this area supports cattle, sheep, and goat ranches.

**Competition Between Exotic, Native, and Domestic Ungulates**

The Edwards Plateau is a center of Texas ranching and livestock operations. This area also contains habitat for 3.5 million native white-tailed deer (Texas Parks and Wildlife 1990). One of the most pressing issues is to understand the impact that exotic species may have upon native species present in the Texas Hill Country and to learn whether presence of exotic game species affects potential competition between native and domestic herbivores. Such evaluations are key to establishing management policies for exotic game species in the Texas Hill Country. To formulate conservation goals and to judge the desirability of exotic game ranching, it is important to understand the ecology of exotic, native, and domestic herbivores as well as the native vegetation of the area. Biological characteristics of exotic game species and their interactions with the habitat on the Edwards Plateau form a knowledge base with which interactions among different herbivores, wild and exotic, may be evaluated (Annex 1, 2).

Exotic game species, native species, and domestic ungulates are all integral elements of the Texas Hill Country ecosystem. Interactions among these herbivores influence their population levels and affect distribution and abundance of vegetation. Physiological requirements of white-tailed deer limit its food consumption to plants low in fiber that are easily digestible. As such, diet of white-tailed deer is limited to two forage classes, forbs and browse. Because of this narrow diet, white-tailed deer are an
inherently inferior competitor, and will be the first species to suffer under intensive competition with exotic ungulates. Livestock and exotics are much more flexible in their diets and are able to alternate between all three forage classes on both herb-dominated and browse-dominated ranges (Figs. 1 and 2; Stuth and Sheffield 1981).

In addition, domestic ungulates also are more flexible in their diet than native ungulates (Figs. 1 and 2). Dietary patterns are exacerbated by environmental conditions, such as temperature and rainfall that also influence amount and quality of vegetation available to these herbivores and may indirectly affect intensity of competition (e.g., seasonal patterns; Fig. 3 and 4; McMahan 1964).

Under competition, white-tailed deer show the most obvious signs of malnutrition. In addition, effects of competition on white-tailed deer will be more severe during seasons, particularly summer, in which forage conditions are less than optimal because vegetative growth is limited by environmental factors such as high temperature, low rainfall, and

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**Fig. 1.** Feeding habits (estimated relative percentage of forage classes consumed) for exotic game species, domestic species, and white tailed deer on an herb-dominated range of Edwards Plateau (data from Stuth and Sheffield 1981).

**Fig. 2.** Feeding habits (estimated relative percentage of forage classes consumed) for exotic game species, domestic species, and white tailed deer a browse-dominated range of Edwards Plateau (data from Stuth and Sheffield 1981).
occasional drought. If the range has already been depleted by livestock and exotic ungulates, whitetailed deer can suffer extensive nutritional damage during stressful seasons. Additional nutritional requirements of bearing and nursing fawns and growing antlers make these environmental conditions even more difficult for white-tailed deer (McMahan 1964). Exotic species may be classed together with livestock animals as generalist feeders. When their preferred forage is unavailable they readily switch to whatever class of forage is available. Such flexibility in diet gives exotics an advantage over white-tailed deer and, thereby, increases susceptibility of deer to competition and poor range conditions. Such stresses are not felt to the same degree by livestock or exotic species because they are able to switch to forage that is most available, that adequately meets their nutritional needs, and that allows them to fulfill normal physiological and developmental processes.

Fig. 3. Comparison of feeding preferences (percentage of each forage class consumed; g = grass, f = forb, b: browse) between white tailed deer and domestic herbivores in different seasons of the year on an ungrazed pasture (data from McMahan, 1964).

Fig. 4. Comparison of feeding preferences (percentage of each forage class consumed; g = grass, f = forb, b: browse) between white tailed deer and domestic herbivores in different seasons of the year on a heavilygrazed pasture (data from McMahan, 1964).
Only a few studies have examined directly effects of competition between white-tailed deer and exotic ungulates. One study described by Armstrong (1981) was conducted at the Kerr Wildlife Management Area, near Hunt, Texas. This study focused on the interaction between sika deer and white-tailed deer on an enclosed 39 ha pasture with no hunting or predation. Before competition for food became severe, sika deer increased from 6 to 27 individuals and white-tailed deer increased from 6 to 18 individuals. When availability of forbs and browse declined, intense competition reduced white-tailed deer population to 6 individuals, but sika deer continued to expand to 32 individuals because they switched to remaining types of vegetation. After 9 years there were 59 sika deer and no white-tailed deer in the pasture. In a parallel study with axis deer and white-tailed deer, similar results were obtained. These studies indicated that exotic game species were superior competitors to white-tailed deer and will displace them on overgrazed ranges.

In terms of conservation, it is necessary to question the desirability of displacement of native species by exotic species. With the goal of preserving the Texas Hill Country ecosystem, including its native plants and animals, it becomes a matter of priorities when determining an appropriate management plan for exotic species. There is not only the issue of displacement of native white-tailed deer by exotic game animals, but also the related issue of preserving endemic plant or animal species which may be deleteriously affected by presence or uncontrolled growth of exotic species. The paucity of knowledge about possible impact of exotic animals on native flora and fauna leaves the future of the Texas Hill Country ecosystem unpredictable.

**Predation of exotic, native and domestic ungulates**

Exotics could be exposed to the same predators as native or domestic ungulates such as lynx, foxes, coyotes, mountain lions, bears, eagles or even domestic dogs. For example, in Texas ranching areas axis deer will be hunted by coyotes and bobcats, but axis deer have a good alarm system. They bark and stamp their feet if a coyote is sighted. This is the same defense strategy that is used in India when axis deer sight a tiger, giving a higher pitched bark rather than the usual alarm call (Mungall and Sheffield 1994).

Leopards and wolves are chief predators of native ibex. In Texas ibex females and kids are killed by coyotes lynx and wolverine. Bears, foxes and probably jackals add Ibex to their diets (Mungall and Sheffield 1994).

In Texas, ranches report that domestic dogs sometimes kill aoudad sheep. In unsettled parts of California, mountain lions kill grown aoudad sheep (Mungall and Sheffield 1994).

**Parasites and Diseases**

Exotics in the Texas Hill Country have been free of diseases and parasites and they do not play a major role in spread of pathogenic organisms in wildlife or livestock. The most serious parasites and diseases isolated include catarrhal fever in axis deer, the nematode *Elaeophora schneideri* in aoudad sheep, stomach worms in ranch aoudad sheep, and coccidiosis in blackbuck antelope. Animals actually developing these symptoms are likely to die.

Internal parasites like flukes (trematodes), flatworms (cestodes), and roundworms (nematodes) have been found in several species of Texas exotics. The same parasite can affect different hosts in different ways. For example, *Elaeophora schneideri* that has devastated aoudad sheep produces no apparent effect in white-tailed deer or in its definitive host, the mule deer. Elk in Colorado, Arizona, and New Mexico lose up to half their calves to this parasite in bad years in addition to suffering blindness, gangrene and antler deformities among older individuals.

In general Texas exotics have a low incidence of disease and usually a light parasite burden. United States quarantine laws require that animals imported from foreign countries are confined for observation before they are released. If it is clear that the potential of infections of diseases and parasites exist, today’s regulations have greatly reduced the risk, but they cannot be eliminated (Mungall and Sheffield 1994). A very important factor is that disease and parasite outbreaks are more apt to occur where animal densities are high and are spread where animal become free-ranging.
Hypotheses for the Expansion of Game Ranching in Texas

Economic Motivations. Gray and Fowler (1981) provide an outlook on the future of ranching in Texas. They explain that costs and fees will increase and ranchers on private lands will find that game ranching exceeds the profitability of range livestock operations, particularly after 1985. Exotic game ranching provides a means of diversification of their ranch economy and thus allows them greater opportunity to achieve a profit.

Many authors have discussed economic benefits of exotic game ranching (Matzke 1983; Mellink 1991; Parkes et al. 1996; Van der Waal and Dekker 2000). Many works suggest that game ranching is a good alternative for conservation of natural areas and it involves human communities around those areas or natural parks. A lot of these studies have been conducted in Africa but, many of these principles could be applied to areas like the Texas Hill country, New Mexico or the North of Mexico.

In other countries it has been proved that game ranching will produce a great socio-economic impact. For example, in the northern province of South Africa game ranching contributes significantly to the economy especially through hunting and live game trade. Hunting makes the largest contribution to annual turnover of the game-ranching industry followed by live game trade and ecotourism (Van der Waal and Dekker 2000).

In other cases commercial exploitation as a pest control mechanism has been an option. In New Zealand commercial harvesting of red deer for game meat and by-products has culled over 2 million deer since 1960 and reduced the national population from over 1 million to a current population size of ca 250 000 deer, a 75 % reduction overall (Parkes et al. 1996).

Venison Sales. In many countries in Africa meat sales from game ranching have been successful for those communities involved (McRae 1998; Prins et al. 2000). For example in Nigeria over 90% of both urban and rural Nigerians accept bush meat as food and game ranching is justified because of rapid reproduction, biological efficiency, and adaptation to harsh environments (Akosim et al. 1999).

Prospect for a strong venison market in the near future provides an incentive for many ranchers to enter into exotic game ranching. The marketing strategy for exotic game venison is aimed at the increasing health-consciousness of the general public and its desire for a low-fat, low-cholesterol alternative to beef (Texas Department of Agriculture 1989). In addition, the currently existing demand for venison is being met by venison imported primarily from New Zealand. The opportunity for ranchers in Texas to fulfill this current and likely expanding demand is tremendous. Advantages of exotic game venison over sheep and cattle ranching include: (1) exotics convert forage to meat more efficiently; (2) deer mature earlier and continue reproducing longer, (3) venison yields a higher proportion of meat/animal; (4) demand currently exceeds world supply; and, (5) deer produce better quality and quantity of meat on land that is less productive for other types of agricultural production (Texas Department of Agriculture 1989).

Agricultural Tax Exemptions. An advantage to harvesting exotic game animals for venison as opposed to other economic activities associated with exotic game ranching is qualification for agricultural tax exemptions. Ranchers who demonstrate that primary use of their land is raising exotic animals for harvest and commercial sale have their land appraised on the basis of its productivity value rather than its market value, thereby significantly lowering their taxes (State Property Tax Board 1990). The goal of tax exemption is to encourage ranchers to raise exotic game for venison and to facilitate this aspect of the exotic game industry. Thus, ranchers raising exotics for the primary purpose of trophy hunting or the sale of broodstock do not qualify for this tax exemption.

Trophy Hunting. Many ranchers have built the entire income for their ranch around the practice of hunting exotic game animals as trophies. Such ranchers may not only provide exotic animals to be hunted but may also provide guides, housing, accommodations, and many other amenities to entice hunters to their property. However, trophy hunting only harvests males and leaves the possibility of over-population by remaining females. Highest prices are paid for largest males with greatest antler spread and most beautiful coat color. Consequently, ranchers must bear the financial burden of supporting animals until they reach this age that depends on their health and the health of the rangeland. There is less likelihood that the market for trophy hunting of exotic game animals will approach the market po-
potential of harvesting meat for venison because of limitation of interested hunters who can afford such a hunt.

**Sale of Broodstock.** The market for exotic game broodstock is limited in the sense that exotic game ranching in Texas has certain definite boundaries. There are a limited number of areas in the state where exotic game will survive and reproduce successfully. Many ranchers without their own populations of exotic species may turn increasingly toward businesses that provide broodstock. Finally, there may be an increase in regulation of sale and transport of exotics among ranchers as exotic game becomes more viable in the economy of Texas that could limit financial advantages of providing broodstock.

**Non-Economic Motivations.** Exotic game ranching requires a substantial initial investment of capital by landowners to purchase exotic animals and prepare their property to contain them by installing high, deer-proof fences. Landowners would not make such an investment if it were not going to benefit them economically in the long term. Non-economic motivations, such as aesthetic value and conservation efforts may outweigh other consideration for some landowners. A significant proportion of ranchers feel that their ranches serve the purpose, although not necessarily exclusively, of providing protection for exotic game threatened in their native habitat (Texas Parks and Wildlife 1989; Fig. 5). While primary motivating factors for exotic game ranching may be economic, it is clear that there are also non-economic motivating factors.

**Exotic Game Ranching: Pros and Cons**

Specific goals of organizations like The Nature Conservancy with respect to the Texas Hill Country are to: (1) protect and preserve all of the ecosystem’s key elements and functions, (2) recognize and incorporate the diverse needs of the central Texas people, and (3) coordinate the work of numerous groups and individuals. These goals may be understood in a broader context as aims of any conservation organization committed to preserving biodiversity. The accomplishment of these goals often is viewed as diametrically opposed to management of natural resources for economic gain. However, this view ignores the fact that the economy and ecology of a region may be inextricably linked. The short-term perspective of economic growth and the long-term perspective of ecological conservation must be merged into an alternative and more encompassing vision of natural resource management and protection.

There is strong opposition to the introduction of exotic artiodactyls (Courtnay 1978; Morrison 1988; Dietrich 1989) and a debate as to how to maintain ecosystem integrity with the introduction of exotics. Some authors report serious alterations in the habitat after the introduction of exotics (Ebenhard 1988),

![Percentage of ranches which participate in different ranching activities involving exotic game species in the Texas Hill Country (source: TPWD, 1989).](image-url)
but this damage had been observed only in islands or in large continental masses like Australia or New Zealand where plants and animals have been isolated for many years and they have not developed defenses against large herbivores.

Some authors defend the introduction of exotics by using an argument concerning the paleoecological history of prairie ecosystems of North America (Mellink 1991). Paleocological history shows that humans colonized the American continent in the late Pleistocene (11 000 years ago). It is believed that as a consequence 70% of the megaherbivores went extinct (Martin and Klein 1984). Many ecological niches remained empty in American prairies, and plant and animal dispersal was modified without the presence of megaherbivores. The best example is mesquite which has no native herbivores who consume it. In the last 2000 years these plants developed a defense against herbivory (Janzen and Martyn 1982). Planned introduction of exotics may help to restore megaherbivores richness and some of the ecological process lost in the Pleistocene (Mellink 1991).

Intensive, hands-on management of ranches must be attained for exotic game ranching to be compatible with goals of preserving ecological integrity and encouraging economic growth of the Texas Hill Country ecosystem. Game ranching may be compatible with these goals of conservation when (1) ranches contain poor quality or overgrazed rangeland, (2) economic diversification provides income to ranchers, and (3) marketable venison is produced by harvesting exotic game (sale of broodstock and trophy hunting are less economically viable; see flow-diagram below). Such intensive management and formulation of a land-use plan would support conservation goals but would require landowners to improve their property and manage herds of exotic animals. Under these conditions, exotic game ranching would allow conservation strategies to be implemented and also would encourage an ecologically sensitive, sustainable form of economic growth and development.

In assessing undesirable conditions of exotic game ranching, it is necessary to perform a conservation cost-benefit analysis and to weigh effects of a particular course of action on both ecology and economy of the Texas Hill Country (see flow-chart below). The most significant factor that contributes to conditions of exotic game ranching not being compatible with conservation goals is a lack of management. Poor or indifferent management produces effects that interfere with efforts to preserve

**Conditions when exotic game ranching is compatible with conservation goals**

- Ability of exotic game animals to utilize low quality, but generally abundant forage makes them desirable grazing animals in poor-quality or overgrazed rangeland
- Exotic game species provide economic diversification. Exotic game may be harvested for venison
- Domestication of exotic game provides benefits to ranchers and conservation interests, as well as to the average meat consumer. In terms of environmental impact, exotic game pose a milder threat than cattle
- Exotic game ranching based on intensive management and the formulation of a specific land-use plan would support the goals of conservation groups
- Landowner activities
  - Census populations periodically during the year. Monitor the range quality in terms of availability of plant species relative to the dietary needs. Good knowledge of the dietary preferences of all herbivores. This monitoring would detect signs of competition
Conditions when exotic game ranching is not compatible with conservation goals

- Displacement of native species
- Possibility to displace native species, such as native white-tailed deer in Texas Hill Country, that are either inferior competitors or low in abundance
- Exotics may influence vegetation patterns of the Texas Hill Country decreasing availability of preferred forage of white-tailed deer (Huston 1981)
  - Palatable species will be replaced by unpalatable species and the rate of vegetative productivity will decline (Pieper 1981)
- Introduction of exotic game animals poses several potential problems
  - The establishment of free-ranging populations of exotic game animals is a direct result of improper management
- Aesthetics; individuals and organizations whose goal is to maintain the unique ecology of this region oppose exotic species
  - Propose establishing a bioreserve in the Texas Hill Country with the premise that this region hosts a unique native ecology

Actions conservation organizations may employ

Information Database:
- Establishment of a single source of information on exotic game ranching is crucial to preservation of the Texas Hill Country ecosystem. Information would be provided on biology of particular exotic species, ecological conditions to which they are best adapted, effects of competition and dietary overlap between exotics, white-tailed deer, and domestic livestock, economic aspects of game ranching, census data on exotics, and long-term conservation-based management techniques.
  - An Information Center would provide ranchers interested in exotic game with the opportunity to educate themselves about different facets of exotic game ranching before making the necessary initial capital investment.
  - Contributions from ecologists, range managers, agriculture economists, ranchers, conservation organization, state agencies, and private citizens would be crucial.

Consulting Services
- Conservation organizations could provide a consulting service for ranchers interested in exotic game that would assist landowners with specific problems. This service would work in conjunc-
tion with the Information Database to ensure that landowners were aware of different options that exotic game provide as well as consequences of exotic game ranching with respect to other ranching activities.

- A comprehensive consulting service would provide landowners with the opportunity to establish specific goals for land use with the assistance of a diversity of valuable resources.

**Promotion of Venison Industry**

- To encourage intensive management of exotic animals, it may be desirable for conservation organizations to form partnerships with key individuals or groups who may be influential in establishment of the venison industry. Conservation groups could form partnerships with private companies to encourage harvesting practices based on sustainable use of land.
- Conservation groups may be a liaison between businesses and landowners to promote systematic harvesting of exotic animals for venison and to encourage creation of additional harvesting companies as supply of harvestable exotic game grows.
- Conservation groups could work cooperatively with government agencies to promote consumption of venison from exotic game and could play an important role in marketing of this venison.

**Scientific Research**

- Lack of scientific knowledge concerning exotic game species and the effects that their presence may have on the Texas Hill Country restricts efforts to establish widespread protection of the area to a superficial level. Conservation groups could initiate further scientific research as well as collaborate with universities and government agencies to establish firm empirical bases upon which management decisions may be made.
- Additional data are needed on impact of competition between native and exotic ungulates, impact of ungulates upon quality of rangeland and other plants and animals, and direction that vegetation of the region is developing.
- Models should be constructed to forecast the ecological future of the Texas Hill Country based on current and future patterns of use by landowners.

**Censusing**

- Censuses of exotic game populations have been inadequate to provide comprehensive knowledge of the number of exotics ungulates in Texas.
- TPWD has conducted some censuses with voluntary surveys that are sent only to ranches that are known to have populations of exotic game. This method only detects growth of know exotic game herds and does not take into account the spread of free-ranging exotics into new areas.
- Conservation agencies could improve these censuses and extend them to lands inadequately covered.
- Reliable population censuses of free-ranging animals are vital to conservation plans because they are not subject to any form of management or population control.

**Economic Models**

- Conservation groups could assist in analysis of economics of exotic game ranching through formation of economic models based on principles of ecologically sustainable growth and development. Will short-term economic benefits of exotic game ranching be sustainable?
- Economic analyses would incorporate findings from scientific research and results from current exotic game ranching ventures. In-depth analyses of, for example the venison industry, would facilitate formation of comprehensive, long-term management plans.

**Education**

- Educating and establishing lines of communication between different people involved in exotic game ranching and in conservation organizations will be significant. This is, arguably, the most important strategy that agencies may use to achieve the dual goals of preserving the unique ecology of the Texas Hill Country and supporting economic growth and development in the area. Including all constituencies in a frequent and open dialogue is critical to achieve conservation goals.
- Such an educational process will be reciprocal and will provide both conservation groups and ranchers with a more thorough understanding of each other’s goals and rationale.
Parasite control

- Avoid keeping high densities to ensure adequate nutrition.
- Review life cycles of parasites to identify the vulnerable stage and establish the best treatment.
- Isolate new arrivals in settling pastures before release into the range.
- Check animals frequently to aid early detection of abnormalities.
- Treatment for internal parasites by providing feed mixed with a vermicide has its best application for animals routinely fed commercial ration and keep in enclosures separately by species.
- Controlled burning can destroy ticks and reduce their cover.

Conclusions

- Exotic game ranching provides conservation organizations with the opportunity to demonstrate the ability of conservation principles to meet needs of both the biological and human components of an ecosystem.
- Identification of conditions under which exotic game ranching may or may not be compatible with conservation goals will help concentrate efforts on providing support for the more positive aspects of exotic game ranching in the Texas Hill Country.
- Establishment of a positive relationship between exotic game ranchers in the area and increased dialogue between conservation groups and landowners will facilitate cooperation between conservation and economic interests.
- A well planned management of exotics could contribute to reestablishing the richness of megaherbivores and ecological process of the Pleistocene before human colonization of the American continent.

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### Annex 1. Biological characteristics of exotic ungulates in Texas (Ransey 1969; Butts et al. 1982).

<table>
<thead>
<tr>
<th>Origin</th>
<th>Physical</th>
<th>Habitat</th>
<th>Social</th>
<th>Reproduction</th>
<th>Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Axis deer</strong></td>
<td>India</td>
<td>Bright reddish-tan coat with white spots in roughly longitudinal rows, a dark dorsal stripe, underparts, innerlegs and undertail are white. The average weight for a male 175 pounds, for a female 120 pounds.</td>
<td>Open country at low elevations in forested region. Often associated with mixed deciduous forest. The native habitat in India is an open deciduous forest with grades into thorn scrub. Their movements are influenced by temperature, food and water availability</td>
<td>Matriarchal family group</td>
<td>1 fawn per breeding attempt. Breeding season May to August. Gestation: 7.5 months</td>
</tr>
<tr>
<td><strong>Fallow deer</strong></td>
<td>Mediterranean, Southern Europe and Asia Minor</td>
<td>Many color variations, the most common coat colors are black, white albino, and the typical fallow with spots in the summer and a uniform greyish brown. Weight: 150 pounds male and 100 pounds female. Plains, non-mountains or hilly country with dense grass coves, sparse woods or bushy areas. In Texas they are found in woodlands, scrublands, and savanna habitats.</td>
<td>Gregarious. Small herds females with their young. Males separate groups. Join with females in mating season.</td>
<td>Monoestrous, mating season October-November, fawning season June-July. Gestation, 230 days.</td>
<td>Browsers, they eat grass in summer, chestnuts in the fall, young shoots, dried leaves, mosses and lichens in the winter. 53% browse, 39% grass, 5 % forbs and 3 % others (Kerr Wild. Manag 1982)</td>
</tr>
<tr>
<td><strong>Sika deer</strong></td>
<td>Southern half of eastern Asia</td>
<td>There are several races in Texas. Japanese sika the most common, has a brownish-olive winter fur. The rump patch is white sharply bordered by black. Female are usually lighter colored than the males. Belt of broad-leafed and mixed forest with moderate winters south of the tropical zone, excluding the coniferous forest of the northern type with deep snow cover.</td>
<td>Gregarious and herds consist of dozens of animals at certain periods. In winter they disperse throughout the forest in small family groups and in spring they move into the grass open area.</td>
<td>Polyestrous female, a single fawn. Breeding period: September-November, fawning period May-June. Gestation: 220 days</td>
<td>Browsers, in summer they prefer grass-like plants as well as leaves and small shoots of trees and bushes. 52% browse, 37% grasses 12 % forbs (Kerr Wild. Manag 1982)</td>
</tr>
</tbody>
</table>
Annex 1. Biological characteristics of exotic ungulates in Texas (Ransey 1969; Butts et al. 1982) (Continue)

<table>
<thead>
<tr>
<th>Origin</th>
<th>Physical</th>
<th>Habitat</th>
<th>Social</th>
<th>Reproduction</th>
<th>Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blackbuck antelope</td>
<td>Weight: male, 80-90 pounds and females 70-80 pounds. Mature males have a black coat color, females and young males have an orange tan color. All have a sharply defined white patch around each eye.</td>
<td>In India they encompasses the northern, central, and southern plains and open woodlands. Well adapted to plains areas, may also be found in areas that are relatively dry, flat, and have an open canopy. In Texas, the majority of the blackbuck antelope inhabit the Edwards Plateau region.</td>
<td>Gregarious, Males and Females may be together in mixed groups, pseudo harems or in separate single-sex groups or some may be solitary.</td>
<td>Give birth to a single fawn after a gestation of 5 months, and the interval between fawns is generally 6 months.</td>
<td>Grazers, more succulent growth and short-mid grasses as well as more xerophytic browse plants, such as <em>Acacia</em> sp. In Texas they are grazers and only in summer does browse consumption equal or surpass that of grass.</td>
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<tr>
<td>Aoudad sheep</td>
<td>Aoudad sheep are tawny brown with dark brown areas around the head and forequarters. Males and females retain the same coat coloration year around. Weight: males 300 pounds and female 150 pounds.</td>
<td>It is found in desert and semidesert regions, preferring rough and rocky terrain.</td>
<td>Gregarious, usually live in small family groups consisting of an adult male and female with their offspring.</td>
<td>Females give birth to a single lamb. The gestation period is about 154-161 days.</td>
<td>Grazers, grass made up a substantial portion of the aoudad sheep diet throughout the year. Consumption of browse species was inversely related to the availability of herbaceous forage and seemed to be a less preferred forage class (Kerr Wild. Manag 1982).</td>
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</table>
### Annex 2. Biology of White-Tailed Deer and diet of domestic livestock

<table>
<thead>
<tr>
<th></th>
<th>Origin</th>
<th>Physical</th>
<th>Habitat</th>
<th>Social</th>
<th>Reproduction</th>
<th>Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>White-tailed</td>
<td>Native to</td>
<td>The summer coat is a reddish brown with a white patch on the throat, inside the ear, on the stomach, inside thighs, and on the underside of</td>
<td>Area relatively open. In particular “edges” where there is an abundance of new plant growth. On the Edwards Plateau it is in relatively</td>
<td>Gregarious and from matriarchal family groups. During fawning the adult separate themselves from the group and move alone to give birth. Adult males groups of 2-4 individuals from February –August but become solitary from September-January as the breeding season nears.</td>
<td>Breeding season in October to early December. Gestation period about 200 days. Commonly give birth to twins and occasionally even triplets.</td>
<td>Browsers. Hosely (1956) gives a list of the plants utilized by white tailed deer: 1) sprout growth of trees and shrubs, ii) seedlings of trees and shrubs, iii) weeds and iv) grasses.</td>
</tr>
<tr>
<td>deer</td>
<td>America</td>
<td>the tail. In winter the coat is gray or grayish brown.</td>
<td>open woodland-savanna vegetation where browse species are common.</td>
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<tr>
<td>Cattle</td>
<td>DIET</td>
<td>Cattle are grazers, they are less selective in the forage they consume, quantity rather than quality of forage seems to be the determining factor in their dietary patterns. Cattle have a highly varied diet and will consume some browse during the winter and some forbs during the summer, but grass forms the bulk of their diet.</td>
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<tr>
<td>Sheep</td>
<td>DIET</td>
<td>Sheep are grazers and their diet overlaps with that of cattle. Grass is the bulk of their diet but sheep also use forbs year-around.</td>
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<tr>
<td>Goats</td>
<td>DIET</td>
<td>Goats are browsers and will consume significant amounts of grass only under those circumstances in which their preferred browse species are unavailable.</td>
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