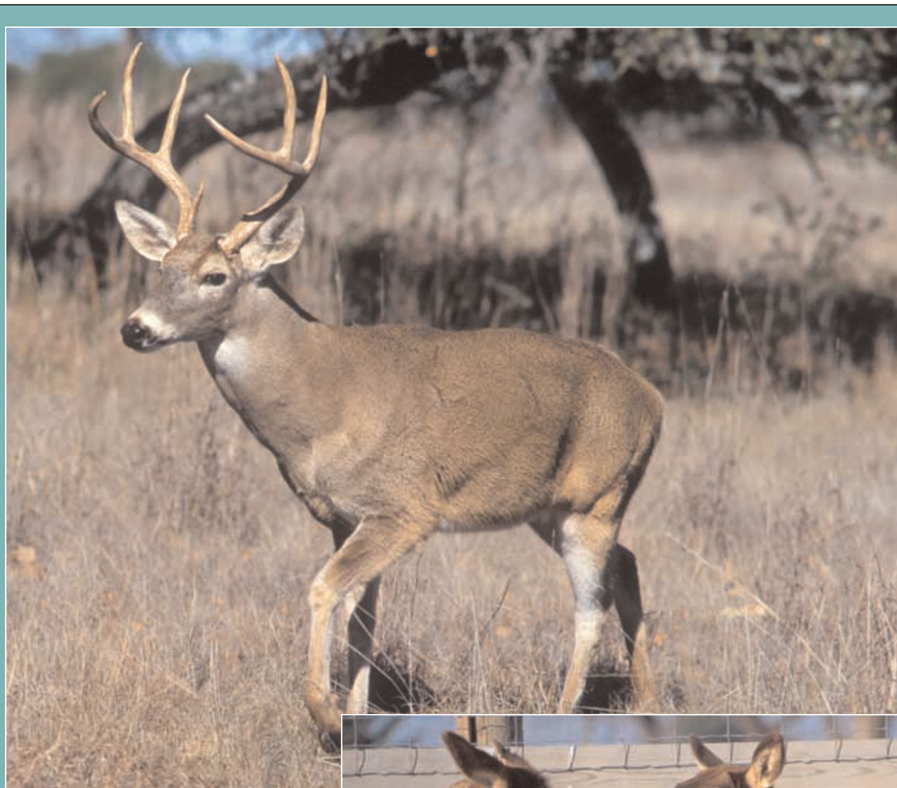
RESEARCH REPORT

Michigan Agricultural Experiment Station
Michigan State University

Farming Captive Cervids in Michigan:

A Review of Social, Economic, Ecological and Agricultural Opportunities and Risks



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A Review of Social, Economic, Ecological and Agricultural Opportunities and Risks

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Executive Summary

The husbandry and sale of captive deer and elk have grown in Michigan and throughout North America over the past 30 years. Because these species belong to the mammalian family Cervidae, the industry is referred to as farming, ranching or agriculture of captive cervids. In Michigan, this industry is regulated in part by the Michigan Department of Natural Resources and in part by the Michigan Department of Agriculture. Proponents of this industry anticipate that the industry is likely to grow dramatically in Michigan if the regulatory process is not prohibitive. This paper reviews of what is known about the captive cervid industry in Michigan and beyond, and identifies issues that may interfere with further development of the industry or may affect the free-ranging herd of white-tailed deer, elk or other wildlife species in Michigan. The paper is divided into five sections which review what is known about and what needs to be determined regarding economic issues, facility management issues, ecosystem management issues, health management issues and social issues associated with captive cervid agriculture.

Economic issues

Captive cervid agriculture in Michigan and in North America has grown dramatically over the past decade. Currently, Michigan citizens hold 640 permits to keep captive white-tailed deer and elk. The number of captive white-tailed deer is more than 21,000 head, and the number of captive elk is about 2,600. These numbers represent a doubling of the captive herd sizes since 1994. The total value of these herds is about $30 million. Little information is available on the number of non-native cervids (i.e., species that do not naturally occur in Michigan) that are kept in captivity because no permits are needed to keep and raise these animals. The captive cervid industry is distributed throughout the state, with the greatest concentrations occurring in central and southeastern lower Michigan. Many of the captive cervid operations are small, with 76 percent less than 20 acres in area. Some larger operations offer fee hunting opportunities within their enclosed areas. Other products from these herds include venison, hides and leather, velvet antlers, hard antlers and trophy males for fee hunting. Currently, much of the economic activity among Michigan captive cervid growers is in sale of breeding animals and semen. This is a common attribute of a developing animal agricultural industry. For this industry to realize continued growth and development, it will be important for domestic and international markets to increase demand for other cervid products.

Facilities management issues

Captive cervids require similar facilities to those needed for other hooved livestock. One of the key differences between captive cervid facilities and those for other livestock is the need for high, strong fencing. Captive cervids are capable of escaping over or under conventional livestock fencing. The most commonly recommended fencing for captive cervids is at least 8 feet tall (for elk) or 10 feet tall (for white-tailed deer) and made of strong woven wire. These specifications overcome the leaping abilities of most cervids and guard against fence failure due to impact of the animals with the fencing. Some recommend use of two lines of fencing to prevent escape in the event of fence failure and to prevent direct contact between captive and free-ranging cervids. As with all fenced livestock operations, frequent fence maintenance is necessary to prevent escape or ingress of animals through the barrier.

Ecosystem management issues

It is well documented that captive herds of cervids alter the composition and distribution of vegetation within the area occupied by the captive herd. The existence of captive cervid facilities and the animals within them are likely to alter ecosystem processes inside and outside the captive compound, and they have the potential to alter species relationships, movement patterns and the genetic composition of free-ranging species. Most of the potential negative impacts of captive cervids can be minimized by use of effective fencing systems that minimize escape from or ingress into captive cervid facilities. Effective fencing also has the potential to limit movement of free-ranging cervids, but this is likely to occur only if the area that is fenced for captive cervids becomes extremely large. Other land use practices may have greater, lesser or different impacts on ecosystem attributes than captive cervid facilities, but we did not find information that would assist in comparing the risks associated with captive cervids to those associated with other land use practices on private property. Conclusions here are based on inferences made from a diversity of articles because we were not able to find published studies that evaluate the direct relationships between individual captive cervid facilities and ecosystem attributes.

Health management issues

Efforts to raise wild species of cervids in captivity have encountered health management needs that pose challenges to growers and potentially to wild cervid populations in Michigan. There is a great need for more information and expertise on captive cervid health management to enable growers to keep their herds healthy and to minimize the risk of disease transmission between wild and captive animals. The potential risk of disease transmission between wild and captive herds differs from the risk of transmission of the same diseases between captive domesticated livestock and wild cervid populations. Diseases are more difficult to diagnose or treat in wild animals, whether captive or free-ranging, though new methods are under development and testing. Furthermore, an escaped deer is virtually indistinguishable from a wild one and is much harder to recapture than an escaped steer or cow. As a result, if an escaped deer transmits a disease agent to wild deer, it is much more challenging to eradicate the disease than it would be in a captive herd of domestic livestock. One example of this is the present problem of bovine tuberculosis in wild white-tailed deer in Michigan and the challenge of eliminating this problem. It is not clear how the disease was introduced into the free-ranging deer herd, but its eradication from the free-ranging population is one of the most challenging issues that wildlife managers have ever faced in Michigan. Even though the problem appears to be manageable in cattle and captive cervids in the area, the costs are great, and it remains to be seen if the problems can be eliminated in the free-ranging herd. To date, only one captive herd has been discovered to have deer infected with bovine tuberculosis, and this was likely a result of one or more infected free-ranging deer that were incorporated into the herd when the herd was enclosed by fencing.

Social issues

Game farming and ranching provide a number of benefits (e.g., local economy, recreation, food) and could potentially provide others not yet clearly proven (e.g., health products). Also, this industry may provide another alternative economic activity to rural landowners either in place of traditional agricultural practices or in place of non-agricultural development. They also pose a number of potential costs or risks that raise social issues. This paradox is not unique to game farming/ranching, but many of these issues are unique because of the wild nature of the species involved — white-tailed deer and elk — which also exist as a common property resource in the state. Although the rearing and marketing of these cervids is an agricultural activity, the process and potential consequences are inextricably linked to their wild counterparts, the wildlife management system and the ecosystem upon which wildlife species depend. The social issues identified here include the following:

1) There is potential for game farming/ranching to impede the effective administration of wildlife conservation methods.

2) Recreational shooting opportunities on game ranches could reduce public acceptance of recreational hunting and its role in wildlife management.

3) The chance of animal escapes poses a number of ecological risks and associated issues, including concerns that there is a greater risk of disease being introduced into wild herds and into domesticated livestock.

4) In addition to potential impacts on wildlife and its management, the wild nature of these captives also raises humane issues of animal welfare beyond those associated with traditional domesticated livestock production.

These risks and their associated issues suggest a need to carefully consider regulations for the captive cervid industry. Indeed, the captive cervid industry in Michigan has supported legislation to require disease testing and to establish guidelines for raising animals humanely.

Introduction

Michigan's agricultural economy is one of the most diverse agricultural economies in the United States. One sector of the economy that has attracted recent attention because of its growth is the culture of captive deer and elk. Deer and elk belong to the taxonomic group of animals called the family Cervidae. Farming and ranching of these animals is henceforth referred to in this document as captive cervid agriculture.

Raising wild species of animals in captivity poses similar challenges and opportunities as raising domesticated species but also generates concerns, challenges and opportunities different from those encountered with domesticated livestock. For example, white-tailed deer, elk and moose are native wildlife species in Michigan. Therefore, their wild populations are the common property of the citizens of Michigan, and their use and protection are managed in trust by the state government, particularly by the Natural Resources Commission and the Department of Natural Resources.

The white-tailed deer herd in Michigan varies between 1 million and 2 million head and ranges over the entire state. The elk herd is much smaller in number (1,100 head) and is restricted to the northern region of lower Michigan. It is difficult to establish a value for this public resource. In economic terms, the elk and deer herds generate at least $407 million each year in hunting trip and equipment expenditures (U.S. Dep. Interior, 1998). The herds generate additional but unquantified revenues in wildlife viewing and feeding activities, as well as non-market values associated with wildlife encounters.

Any confinement of these species to an individual's private property represents a taking of common property from the citizens of Michigan, and Michigan's game laws protect against such takings. Ownership of animals of these species under confinement is allowed by Michigan's game laws but only by issuance of a special permit granted by the Department of Natural

Resources. The permitting mechanism allows for private ownership of these three species for use in agricultural or other commercial or recreational enterprises, provided the owner keeps the animals confined within a specially fenced area.

Other cervid species also are farmed in Michigan, including sika deer, fallow deer, reindeer and red deer. None of these species are native to Michigan, and because they are non-native, there is less potential confusion of these privately owned livestock with publicly owned wildlife, though red deer are a different subspecies in the same species as elk and look similar to elk. Accordingly, regulation of agriculture involving these non-native species has been the responsibility of the Michigan Department of Agriculture, as it is for all domesticated livestock species.

The captive cervid industry in itself is quite diverse and promises unique opportunities for development. Two native and at least four non-native species are grown by Michigan farmers. Operations range from small pens on farms of several acres to game ranches that cover thousands of acres. Deer and elk are grown to produce products ranging from venison to trophy antlers, velvet antler, urine (as a hunting lure), and mature bulls or bucks for trophy hunting. Much of the industry is currently involved in developing breeding stock for increasing the size and number of captive herds in anticipation of growing demand for deer and elk products in North American and global markets.

In Michigan, smaller operations or game farms keep animals in pens and paddocks for production of venison, antler and velvet antler, and breeding or shooting stock. The larger operations are primarily engaged in game ranching, in which one of the primary economic activities is selling the opportunity to hunt for one of the captive animals, usually a bull or buck. The large operations also produce venison and other products from culled animals. In all cases, what distinguishes game farms and game ranches from other fee hunting or fee shooting enterprises is that, in game farms and ranches, the animals are confined in a fenced area. With a Michigan captive wildlife permit, the property owner determines when animals can be taken, under what conditions and with what methods. In other operations that charge a fee for hunting free-ranging (i.e., not enclosed by fences) wild cervids, the animals do not belong to the landowner and can be pursued and harvested only as prescribed by current state hunting regulations and seasons.

Because captive cervid agriculture involves farming and ranching species that are also free-ranging in Michigan, two state agencies are involved in regulating this industry. In addition to issuing permits to keep captive elk, moose and white-tailed deer, the Department of Natural Resources also regulates the type and height of fencing that must be used on captive cervid operations and requires detailed record keeping of any losses, sales or acquisitions of animals in captive herds. These records must be reported monthly to the Department of Natural Resources. The DNR also has the authority to enforce all regulations regarding captive cervids through the Law Enforcement Division. The Michigan Department of Agriculture is involved in regulating other aspects of the captive cervid industry, particularly with regard to animal health management. For example, recent regulations stipulate that entire herds of captive elk or white-tailed deer must be tested every year for three years for bovine tuberculosis to achieve accredited-free herd status, and that records of these tests must be filed with the Department of Agriculture (Appendix 1). Lower herd status is available to herds with lesser testing programs.

Representatives of the captive cervid industry in Michigan have requested some revision in the way their industry is regulated. As legislation and policy relating to captive cervid agriculture develop, it is important to have a full accounting of what is known about the benefits and risks associated with captive cervid agriculture and products so as to develop laws and policies that protect the public interest in natural resource management and public health while also minimizing undue restrictions on and optimizing economic development in private enterprise. For these reasons, the Wildlife Bureau of the Michigan Department of Natural Resources and the Michigan Department of Agriculture requested Michigan State University to prepare an analysis of captive cervid agriculture that would document the full extent of scientific information on captive cervids and the potential opportunities and potential impacts of this form of agriculture on Michigan's natural resources and agricultural economies.

A committee of faculty and staff members at Michigan State University completed the analysis and prepared the report. The committee included representatives from the College of Agriculture and Natural Resources and the College of Veterinary Medicine. Five departments were represented on the committee: Agricultural Economics, Animal Science, Fisheries and Wildlife, Large Animal Clinical Sciences and Small Animal Clinical Sciences. The committee began by identifying five key areas for investigation: economic issues, facility management issues, ecosystem issues, health management issues and social issues. Committee members then gathered information on captive cervid agriculture in these five areas by searching for and reviewing peer-reviewed scientific publications, collecting non-peer-reviewed literature (printed and electronic) from agencies and industry representatives, interviewing representatives of agencies in and outside of Michigan, interviewing representatives of industry advocacy groups, and interviewing holders of elk and deer permits in Michigan. The committee met biweekly during March, April and May 1999 to share information, discuss the material and identify further information needs.

The paper that follows was prepared for the Michigan Department of Natural Resources Wildlife Bureau and the Michigan Department of Agriculture. It reviews what is known about captive cervid agriculture and summarizes issues that need to be addressed in the management of captive cervid agriculture in Michigan. This review focuses on white-tailed deer and elk but also includes information on non-native cervid species where information was available and seems relevant to farming of native cervid species. Previous drafts were reviewed by staff members of both agencies, and the authors have included or addressed the suggestions provided with these reviews. The purpose for having agency review of the draft was to ensure that the breadth of addressed issues is complete and that the sources of information are thorough. The document was reviewed next by experts in the field of captive cervid agriculture and cervid wildlife management, practitioners of captive cervid agriculture and groups interested in the management of Michigan's wild deer and elk herds. The review process was managed in cooperation with the staff of the Wildlife Bureau, Michigan Department of Natural Resources and Michigan Department of Agriculture, and with input from the captive cervid industry and non-governmental organizations interested in wildlife management in Michigan. The purpose of this additional review was to assure the accuracy and completeness of the review. Ultimately, it is anticipated that policy-makers, agency leaders, regulators and legislators will use this report as they decide on the appropriate regulation and promotion of captive cervid agriculture in Michigan. It is important that all parties interested in and affected by these decisions have a role in making the ultimate decisions about how this industry is managed.

The paper is organized around the five key areas identified previously and is meant to address two key objectives within each of these areas. The first objective is to summarize what is known and documented about captive cervid agriculture in Michigan. The second is to identify what issues in captive cervid agriculture need to be addressed in policy, law and management. A third objective, how the key issues should be addressed in law and policy, will be pursued by the responsible agencies and the Michigan Legislature. It is not the purpose of this process to make recommendations about policy, law and regulation to either the Natural Resources Commission, the Commission of Agriculture or the Michigan Legislature. The paper begins with a summary description of the captive cervid industry in Michigan. The description is based on existing information; it was not intended to generate new data on the industry. It is clear, however, that additional information is needed if this industry is to be managed carefully and fairly. The Michigan description is followed by a more global description of the captive cervid industry and its recent history, particularly in North America.

The third section of the paper includes a description of the unique facility requirements of captive cervid operations, and this is followed by a discussion of the interactions between captive cervid agriculture and Michigan's natural ecosystems. The fifth section of the paper describes the health management concerns associated with captive cervid agriculture, and this is followed by a discussion of the social issues associated with captive cervid agriculture. In the course of gathering the information presented in this paper, the committee identified areas in which more information is needed to develop effective public policy and law regarding captive cervid agriculture. We have summarized these in the final section of the paper.

This industry is dynamic. The information gathered in this paper is current but is likely to become outdated within a matter of months to years. The purpose of this paper is to gather what is known about this industry now, so that policies and laws can be developed that improve the regulation and health of the industry.

The Captive Cervidae Industry in Michigan

This section draws on several primary data sources for information on the numbers, locations and values for captive white-tailed deer and elk in Michigan.

Michigan Agricultural Statistics Service data

In February 1998, the Michigan Agricultural Statistics Service (MASS), in conjunction with the Michigan Department of Agriculture (MDA), conducted a survey of Michigan captive deer and elk operations (MASS, 1998). The Michigan Department of Natural Resources (MDNR) registration list was used as the sampling frame. All large operations were surveyed, and random samples of medium and small herds were taken. The MASS reported a survey response rate of nearly 90 percent. The survey requested an inventory and value (grower's stated market value) for animals by age and type. The MASS report estimated that there were 16,800 captive deer and 2,000 captive elk in Michigan in 1998 (Tables 1 and 2). The weighted mean values for deer and elk were $1,095 and $5,500, respectively. The total value of the captive herd was estimated to be $29.4 million ($18.4 million for deer and $11 million for elk). This value represents what the herd is worth as an inventory; it does not refer to the cash receipts for products produced by the industry. No data were available to quantify cash receipts associated with Michigan's captive deer and elk operations. In comparison, the MASS estimated the state cattle (dairy and beef) herd to be 1.1 million head in January 1998 (MASS, 1998), with an inventory value of $748 million and cash receipts of $732 million for milk production and $218 million for cattle and calf marketings. Other livestock herds number 6,190,000 poultry, 1,030,000 hogs and pigs, and 90,000 sheep and lambs. The MASS does not report the inventory value for these other herds.

Table 1. Captive white-tailed deer inventory and value in 1998 (MASS, Table 12.1).

Item	**Inventory number**	**Mean value** $/head	**Total value** $
Mature bucks 5 years +	750	3,500	2,625,000
Mature bucks 3-4 years	2,000	2,600	5,200,000
Young bucks 1-2 years	3,600	1,400	5,040,000
Breeding does	5,100	650	3,315,000
Cull does	550	300	165,000
Buck fawns	2,400	500	1,200,000
Doe fawns	2,400	350	840,000
Total deer	**16,800**	**(weighted) 1,095**	**18,385,000**

Table 2. Captive elk inventory and value in 1998 (MASS, Table 12.2).

Item	**Inventory number**	**Mean value** $/head	**Total value** $
Breeding bulls	180	8,500	1,530,000
Trophy bulls	120	3,600	432,000
Velvet bulls	390	3,400	1,326,000
Breeding cows	880	7,100	6,248,000
Bull calves	210	2,100	441,000
Heifer calves	220	4,800	1,056,000
Total elk	**2,000**	**(weighted) 5,520**	**11,033,000**

Data on number of operations in Michigan from the MDNR

Another source of information on the status of the captive deer and elk herds is the information provided to the MDNR by permit holders (see Appendix 5 for information on permit requirements and fees). According to the latest MDNR data, there were 630 white-tailed deer and elk enclosures with captive wildlife permits in Michigan as of May 1999 (MDNR, unpublished data). The breakdown of these enclosures is 448 enclosures with white-tailed deer only, 79 enclosures with elk only, and 103 enclosures with white-tailed deer and elk combined (Table 3). The number of captive deer in Michigan grew 50 percent from 1994 to 1998 with numbers reaching about 21,000 in 1998. The annualized growth rate over this period was just over 10 percent. The number of captive elk doubled in the 1994-98 period, rising to about 2,600 elk in 1998. The annualized growth rate over this period was almost 19 percent. The number of permits listing elk in 1998 was more than four times larger than it was in 1992. The number of permits listing white-tailed deer in 1998 was 50 percent larger than it was in 1992. Because some operations include both white-tailed deer and elk, the numbers in the respective white-tailed deer and elk rows of Table 3 include some combined enclosures in each row. In 1997, the DNR inventory reports about 3,000 more white-tailed deer (18 percent larger) than are reported in the MASS survey for the same year. Similarly for elk, the 1997 DNR inventory numbers suggest a herd size that is about 260 elk larger (13 percent more) than the MASS survey for the same year.

Producers of other livestock species number 17,500 for all cattle (beef and dairy), 4,100 dairy producers, 4,100 hog and pig producers, and 2,100 sheep and lamb producers (MASS, 1998). No estimates of the number of poultry farms are available.

Table 3. Number of Michigan captive wildlife permittees listing deer and/or elk.

Year	Deer/elk	Total permits	Commercial*	Non-commercial	*Enclosures> 39 acres	Number of animals
1992	Deer	363	293	70	49	n/a
	Elk	42	39	3		n/a
1993	Deer	425	323	101	58	n/a
	Elk	52	50	2		n/a
1994	Deer	458	303	155	65	13,858
	Elk	78	67	11		1,330
1995	Deer	503	316	186	79	n/a
	Elk	116	96	20		n/a
1996	Deer	531	348	182	86	17,505
	Elk	141	122	19		1,924
1997	Deer	561	379	182	101	19,812
	Elk	170	149	21		2,258
1998	Deer	540	357	183	107	20,961
	Elk	179	157	22		2,582

Information and table provided by Jim S. Janson, Wildlife Bureau, MDNR.

* The commercial/non-commercial distinction merely signifies which permit holders desire to have their names placed on a list of commercial breeders that is made available to the public and is intended to facilitate the buying and selling of wildlife and their products. There is no legal distinction between the two categories.

Location of enclosures

With 43 enclosures, Genesee County has more permitted captive cervid facilities than any other county in Michigan (Figure 1). Some reports indicate that this is the highest number of facilities in any county in the United States (Bill DeMarz, Michigan elk producer, personal correspondence, May 1999). Kent and Newaygo counties have the next most enclosures, with 22 each. With 30 enclosures, the Upper Peninsula contains about 5 percent of all permits listing deer or elk. There are elk enclosures in the vicinity of Michigan's wild herd, but most of the elk operations are more distant from the wild elk herd (Table 4).

Figure 1. Number of captive wildlife permits listing white-tailed deer, elk, and white-tailed deer or elk per county in Michigan as of January 1999.

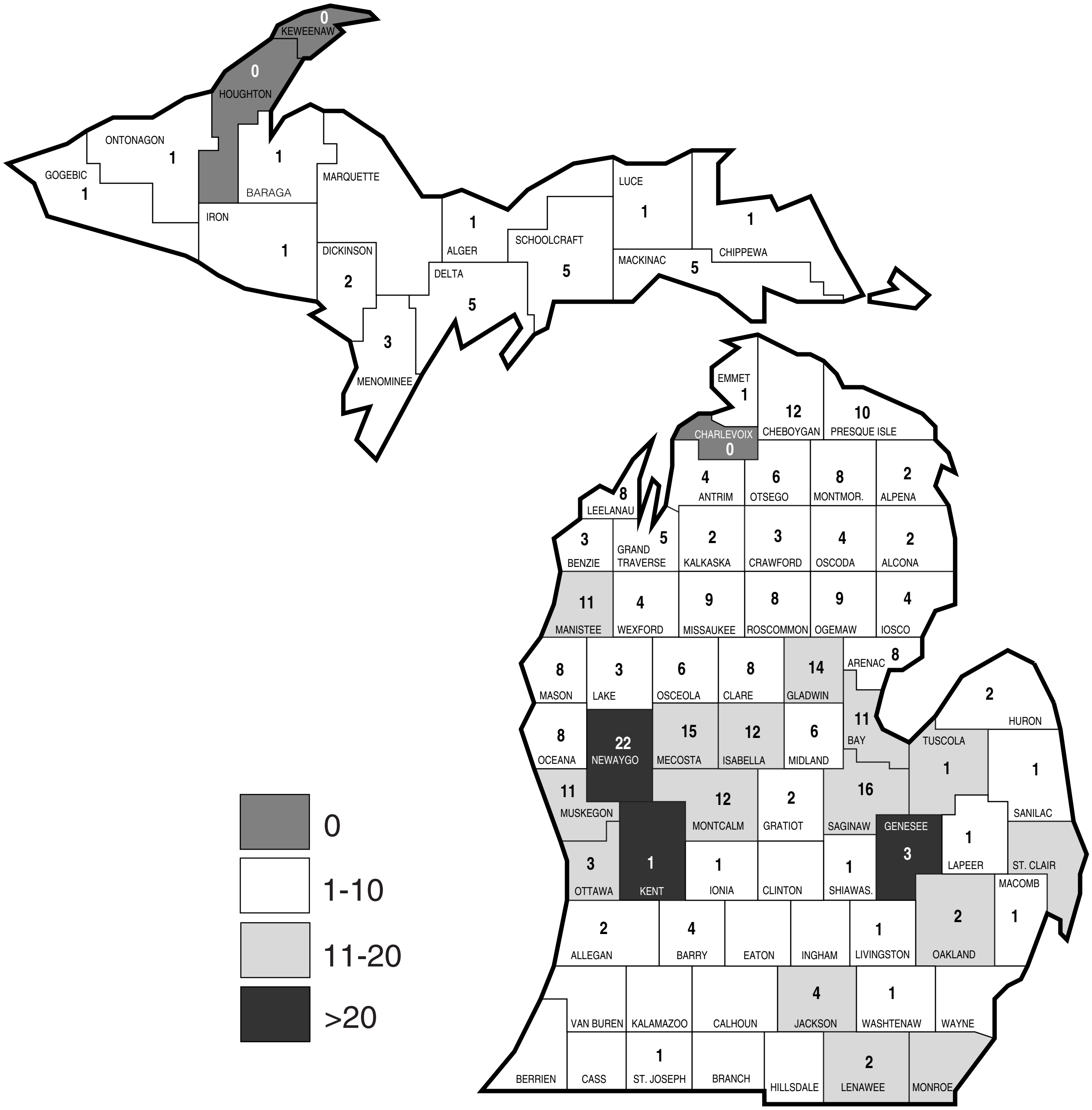


Table 4. Number of captive wildlife permits listing white-tailed deer and/or elk in Michigan counties as of January 1999, with county breakdown for white-tailed deer only, elk only, and white-tailed deer and elk combined.

County	Number and type of permit			Total
	Deer	Elk	Both	
Alcona	2		1	3
Alger	1			1
Allegan	2	4	2	8
Alpena	2			2
Antrim	4			4
Arenac	6		2	8
Baraga			1	1
Barry	3	6		9
Bay	8	1	2	11
Benzie	1	2		3
Berrien	2	1		3
Branch	3			3
Calhoun	5	1	2	8
Cass	8		1	9
Charlevoix	-	No permits	-	0
Cheboygan	7	3	2	12
Chippewa			1	1
Clare	7	1		8
Clinton	4	1		5
Crawford	2		1	3
Delta	3	2		5
Dickinson	1		1	2
Eaton	5	1	1	7
Emmet	1			1
Genesee	23	8	12	43
Gladwin	12	1	1	14
Gogebic		1		1
Grand Traverse	5			5
Gratiot	2			2
Hillsdale	5	2	1	8
Houghton	-	No permits	-	0
Huron	2			2
Ingham	9	1		10
Ionia	5	1	2	8
Iosco	4			4
Iron			1	1
Isabella	11	1		12
Jackson	11	1	4	16
Kalamazoo		1		1
Kalkaska	2			2
Kent	18	1	3	22
Keweenaw	-	No permits	-	0

County	Number and type of permit			Total
	Deer	Elk	Both	
Lake	3			3
Lapeer	5	2	2	9
Leelanau	3	3	2	8
Lenawee	12	2		14
Livingston	3	1		4
Luce	1			1
Mackinac	5			5
Macomb	5			5
Manistee	5		6	11
Marquette	3			3
Mason	6	1	1	8
Mecosta	11	1	3	15
Menominee	1	2		3
Midland	5	1		6
Missaukee	5	2	2	9
Monroe	11		3	14
Montcalm	8	2	2	12
Montmorency	5	1	2	8
Muskegon	9		2	11
Newaygo	12		10	22
Oakland	8	2	1	11
Oceana	6	1	1	8
Ogemaw	6	1	2	9
Ontonagon		1		1
Osceola	4		2	6
Oscoda	3		1	4
Otsego	5		1	6
Ottawa	8	1	4	13
Presque Isle	7	1	2	10
Roscommon	4		4	8
Saginaw	12	2	2	16
Sanilac	4	2		6
Schoolcraft	5			5
Shiawassee	6	2		8
St. Clair	11	2		13
St. Joseph	4		1	5
Tuscola	16	1	1	18
Van Buren	2	1		3
Washtenaw	9			9
Wayne	6			6
Wexford	3		1	4
Total	**433**	**76**	**100**	**609**

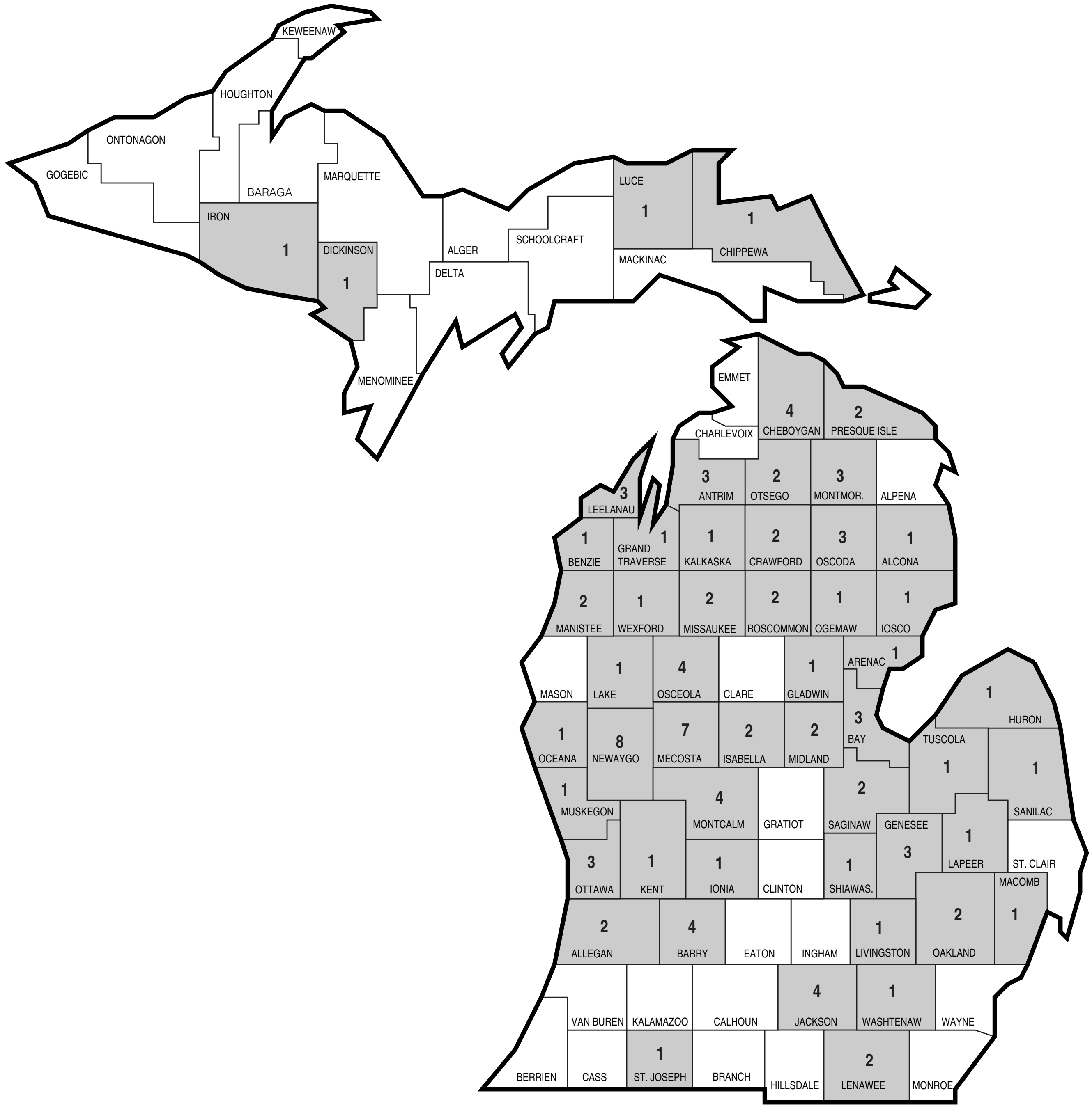
The majority of the enclosures are relatively small: 76 percent are 20 acres or less (Table 5; data as of May 1999). Seventeen percent (107) of all white-tailed deer or elk enclosures exceed 39 acres, and 90 percent are less than 150 acres. Four of the 30 enclosures in the Upper Peninsula exceed 39 acres (Figure 2). Most of the captive white-tailed deer are on larger farms: about two-thirds of the captive white-tailed deer are on farms

Table 5. Size distribution of captive deer and/or elk enclosures in Michigan.

Acres	Number of enclosures	Cum. %	No. white-tailed deer	Cum. %	No. elk in in enclosures	Cum.% enclosures
< 5	337	53.5	2,273	11.6	311	12.5
5-10	92	68.1	1,754	20.5	353	26.7
11-20	49	75.9	913	25.2	240	36.3
21-30	18	78.7	419	27.3	223	45.3
31-40	27	83.0	983	32.2	353	59.5
41-50	3	83.5	48	32.6	15	60.1
51-60	8	84.8	355	34.4	93	63.8
61-70	9	86.2	947	39.2	157	70.1
71-80	4	86.8	274	40.6	5	70.3
81-90	0	86.8	0	40.6	0	70.3
91-100	2	87.1	115	41.2	7	77.6
101-150	16	89.7	874	45.7	175	77.7
151-200	15	92.1	828	49.9	232	87.0
201-250	6	93.0	824	54.1	2	87.1
251-300	5	93.8	553	56.9	7	87.3
301-350	4	94.4	202	57.9	0	87.3
351-400	4	95.1	432	60.1	62	89.8
401-450	2	95.4	249	61.4	9	90.2
451-500	4	96.0	381	63.4	0	90.2
501-550	3	96.5	511	66.0	0	90.2
551-600	4	97.1	795	70.0	22	91.1
601-650	2	97.5	279	71.4	0	91.1
651-700	1	97.6	75	71.8	2	91.2
701-750	1	97.8	642	75.1	0	91.2
751-800	0	97.8	0	75.1	0	95.5
801-850	2	98.1	792	79.1	109	96.0
851-900	2	98.4	822	83.3	11	96.0
901-950	0	98.4	0	83.3	0	96.0
951-1000	1	98.6	656	86.7	0	96.0
1001-1050	1	98.7	574	89.6	0	96.0
1051-1100	1	98.9	110	90.2	0	96.0
1101-1150	1	99.0	1,182	96.2	0	96.0
1400-1500	3	99.5	579	99.1	0	96.0
3500-5500	3	100.0	168	100.0	100	100.0
Total	**630**		**19,609**		**2,489**	

Information provided by Jim S. Janson, Wildlife Bureau, MDNR.

Figure 2. Number of white-tailed deer and/or elk enclosures per county that are 40 acres or larger (shaded counties) in Michigan as of January 1999.



larger than 40 acres, and about one-third of the deer are on farms larger than 550 acres. Moreover, 10 percent of the captive white-tailed deer are in enclosures that exceed 1,000 acres. Most of the elk are on smaller farms: about 60 percent are in enclosures that are 40 acres or smaller, and about 90 percent are in enclosures that are 400 acres or less.

Operations offering hunting within enclosures

Some of the operations listed in Table 5 offer opportunities to hunt for pay within the enclosure, but no direct data identifying such operations are available. Nevertheless, most of the captive white-tailed deer and elk permit holders operate on fewer than 40 acres (Tables 3 and 5; Figure 2). In 1998, 107 permittees out of 540 operated on greater than 39 acres, and it is very likely that some of these also offer hunting within enclosures as part of their business (J. Janson, MDNR Wildlife Bureau, personal correspondence, May 1999). As noted in the footnote to Table 3, there is no legal distinction between the commercial and non-commercial designations. The non-commercial permittees are likely to be hobbyists who do not sell stock or products (J. Janson, MDNR Wildlife Bureau, personal correspondence, May 1999).

Interstate sales of captive cervids in Michigan

The number of elk and white-tailed deer from Michigan since 1997 is more than twice the number imported (Table 6). These data summarize the official interstate health certificates maintained by the Michigan Department of Agriculture. Interstate transport of live captive cervidae requires a health certificate (Appendix 2). Table 6 also reports data for sika deer, fallow deer and reindeer for comparison. Relative to herd sizes, the number of interstate sales of live animals reported (Michigan imports and exports) is smaller for white-tailed deer than for elk.

Missouri figures prominently as a point of origin for both elk and white-tailed deer imported into Michigan, according to the MDA health certificates database (Figures 3 and 4; Tables 7 and 8). California was the origin of a substantial share of the elk imports (in part because of a large number in 1996). In addition, a small share of the elk (3.1 percent) and white-tailed deer (1.9 percent) imports are from Canada.

Table 6. Imports and exports of live white-tailed deer and elk into and out of Michigan.

	Imports				Exports		
	1996	1997	1998	1999*	1997	1998	1999*
Elk	191	157	69	12	238	225	57
White-tailed deer	50	47	54	8	152	132	132
Fallow deer	9	16	17	0	70	8	0
Reindeer	0	2	16	15	42	58	0
Sika deer	17	2	9	7	18	5	0

*as of 6/16/99.

Data provided by the Michigan Department of Agriculture and based on a summation of interstate health certificates.

Table 7: Origin of elk imports into Michigan.

Origin of imported elk	1996	1997	1998	1999*	3.5 yr total	% of total
Canada		7	1		8	1.9%
California	95	14			109	25.4%
Colorado		4			4	0.9%
Idaho		7			7	1.6%
Illinois	11			1	12	2.8%
Indiana		5	1	2	8	1.9%
Iowa	10	1	3		14	3.3%
Kansas			3		3	0.7%
Minnesota	3	7		3	13	3.0%
Missouri	32	50	42		124	28.9%
Montana	7	18	2		27	6.3%
North Dakota	2		1		3	0.7%
Ohio	12	4	6	6	28	6.5%
Pennsylvania		7	1		8	1.9%
Texas		7			7	1.6%
Wisconsin	19	26	9		54	12.6%
Total	**191**	**157**	**69**	**12**	**429**	

Figure 3. Origin of elk imported into Michigan, 1996 to June 1999.

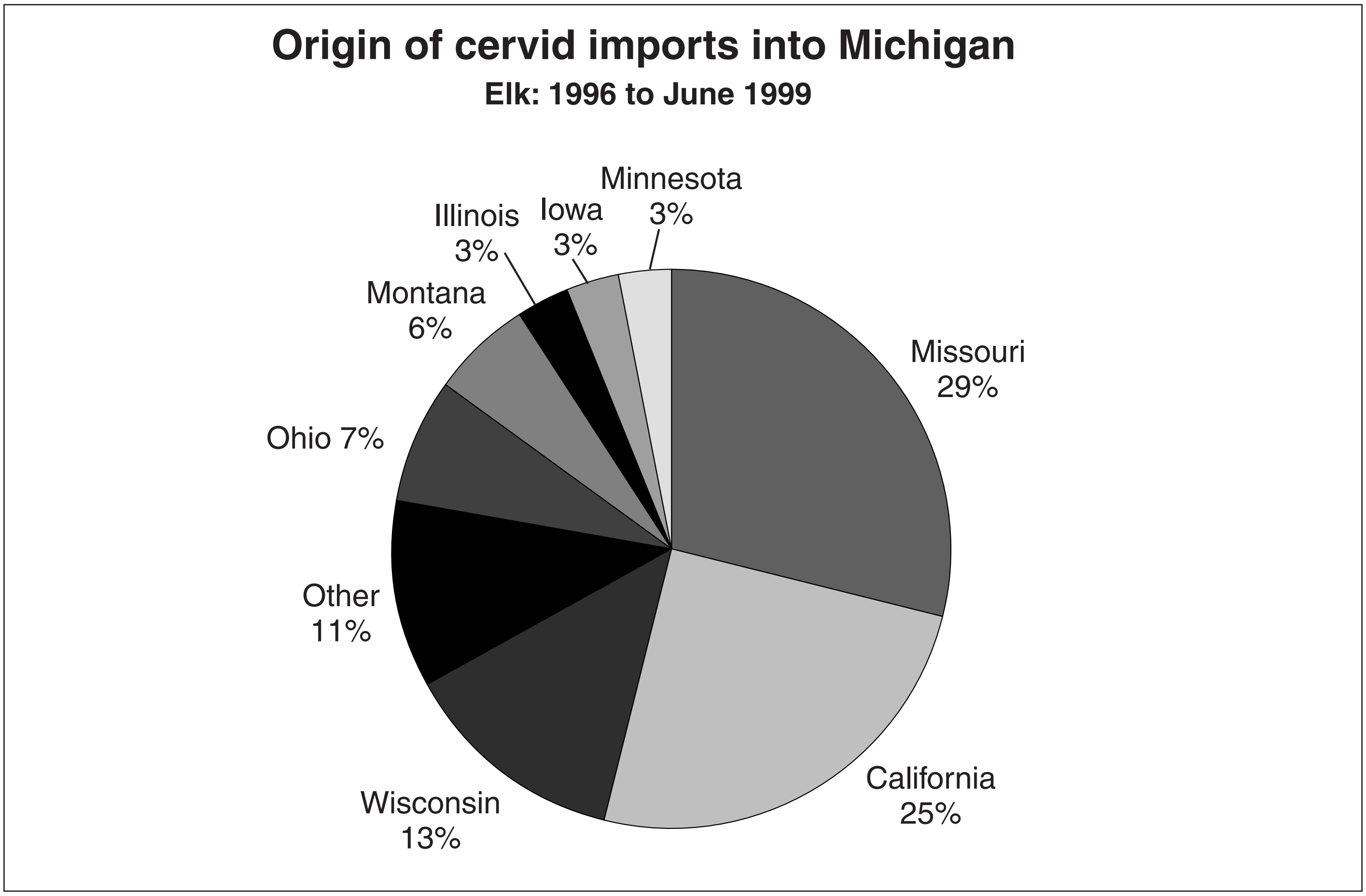
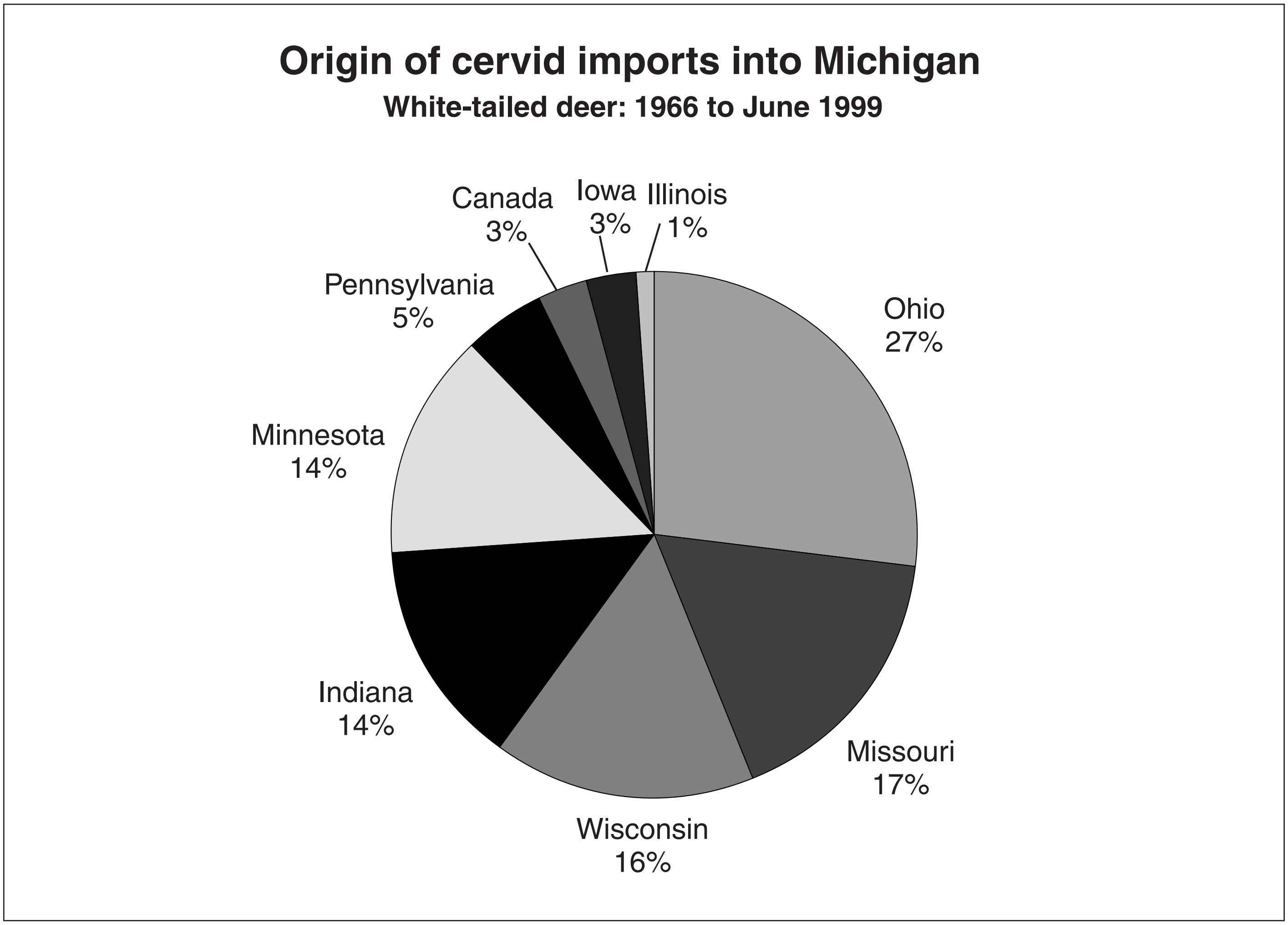


Table 8. Origin of white-tailed deer imports into Michigan.

Origin of imported white-tailed deer	1996	1997	1998	1999	3.5 yr total	% of total
Canada		5			5	3.1%
Illinois		2			2	1.3%
Indiana	5	12	6		23	14.5%
Iowa				4	4	2.5%
Minnesota		2	21		23	14.5%
Missouri	27				27	17.0%
Ohio	16	13	8	4	41	25.8%
Pennsylvania	1		7		8	5.0%
Wisconsin	1	13	12		26	16.4%
Total	**50**	**47**	**54**	**8**	**159**	

Figure 4. Origin of white-tailed deer imported into Michigan, 1996 to June 1999.



Economics and Status of Captive Cervid Agriculture

The basic approach and purpose of this section is to provide economic information on captive deer and elk operations. To this end, we summarize and relay available information to characterize the number and types of operations both nationally and, where possible, internationally. This information bears on the potential markets for the products of captive cervid farms. In addition, data are presented on the primary markets for key products of the captive cervid industry. It is important to note that this study has not collected primary data with which to assess the economic viability of deer and elk farming in Michigan. Unlike the data provided in the previous section, the data in the following section are rarely based on independently verifiable sources (i.e., permit data, survey data or health certificate data). Rather, most of the material originated from one of three sources of information: personal correspondence, articles from the deer and elk industry trade journals, and reports from the agricultural agencies for Alberta and Saskatchewan. We were unable to locate any peer-reviewed journal articles on the economics of deer or elk farming. With this in mind, we feel that the information is a useful start for providing some idea of the scope and extent of the industry.

Number of captive deer and elk

The global captive deer population is estimated "to be in excess of 5 million, with the largest producers being New Zealand, Russia, and China" (Saskatchewan Agriculture and Food [SAF], 1996). In 1998, New Zealand industry representatives estimated they had a herd size of about 1.4 million animals (Hobart, 1998), though that number may better reflect New Zealand conditions around 1996 (L. Renecker, Ph.D., personal communication, October 1999). The current number of captive cervids in New Zealand is probably closer to 2.5 million and may have been as high as 4 million in 1998 (L. Renecker, Ph.D., personal communication, October 1999). Significant production also occurs in Poland, Hungary and other eastern European countries (SAF, 1996). The single largest exporter of farm-raised venison is New Zealand; Russia is the largest total exporter of venison (SAF, 1996). Countries with the largest consumption of venison are Russia, China and Eastern European countries (SAF, 1996). Asia, especially Korea, consumes the most velvet antler (Luxmoore, 1989).

Estimates of captive elk numbers range from 40,000 to 100,000 in North America. Greaser et al. (1996) state that the number of elk in North America is 40,000. The Canadian herd expanded from almost no animals in 1976 to more than 24,000 animals in 1996 (SAF, 1996). In Alberta, Canada, the number of captive elk rose from 3,100 in 1990 to almost 15,000 in 1997, and in the same time period, captive white-tailed deer numbers rose from 287 to 3,544 (Alberta Agriculture, 1997). Another estimate of the number of captive elk in North America in 1999 is 100,000 (rough estimate provided by North American Elk Breeders Association, NAEBA, and cited in Haigh, 1999). Haigh (1999) adjusts this for the 44,000 captive elk in Canada in 1999 to derive an estimate of 55,000 elk in the United States in 1999. If these numbers are accurate, the captive elk herds in Michigan contain approximately 2 percent of the North American herd and approximately 4 percent of the U.S. herd. The exact number of operations with captive elk is unclear, but the NAEBA has just over 1,500 members (Paula Whiting, NAEBA, personal correspondence, May 1999). Estimates of the mean values of elk inventories nationally are $8,000 for breeding cows, $4,000 for heifer calves and $5,000 for trophy bulls, though this is variable from $4,000 to $20,000 for the top of the line (R. Murphy, American Elk Products Board, personal communication, October 1999).

In recent years, the number of deer held by members of the North American Deer Farmers Association (NADeFA) grew steadily from about 26,000 in 1992 to about 83,000 in 1997 (Table 9). NADeFA members grow a variety of deer species and some elk (Table 10). NADeFA members include about 80 percent of major deer farmers in the United States and Canada. An estimated 8,000 operations in the U.S. that have captive deer are not members of NADeFA, and most of these operations are small or non-commercial (Barbara Ramey Fox, cited by Haigh, 1999). Discrepancies between the NADeFA data and others — e.g., the 1997 data show fewer captive white-tailed deer among all NADeFA members (13,287) than are reported in Michigan (Tables 10 and 1) — are likely a result of comparisons of data from different years and the preponderance of white-tailed deer breeders in Michigan who are not NADeFA members (B. Ramey Fox, personal communication, October 1999). For white-tailed deer, some estimates place the Canadian herd at more than 10,000 in 1997 and about 4,600 in 1993 (Alberta Agriculture, 1997).

Table 9. Herd size and value of captive deer herds in the United States reported by North American Deer Farmers Association members,1992-1997.

	1992	1993	1994	1995	1996	1997
National herd	26,062	41,654	54,964	63,200	72,832	83,270
Venison revenue		$71,000	$1,450,000			$1,921,000
Velvet revenue		$130,000	$347,000			$910,000
Breedstock rev.	$337,000	$837,000	$2,051,000			$3,010,000
Livestock value		$26,485,000		$50,213,950	$63,372,000	$56,416,475

(Source: Table is based on NADeFA correspondence provided by Dr. Mike Vanderklok, MDA.)

Table 10. Breakdown of North American Deer Farmers Association members' herds by species, numbers and value, 1997.

Species	Number	Value each	Total herd values
Axis	9,051	$700	$6,335,700
Fallow	30,027	$350	$10,509,450
Red	21,532	$800	$17,225,600
White-tailed	13,287	$1,000	$13,287,000
Sika	2,979	$600	$1,787,400
Elk	2,513	$2,500	$6,282,500
Other (unspecified)	3,479	$500	$1,739,500
Totals	**82,868**	**$57,167,150**	

(Source: Table is based on NADeFA correspondence provided by Dr. Mike Vanderklok, MDA.)

Products and prices

Captive deer and elk producers range in intensity from hobbyists to operations that perform artificial insemination and genetically register their breeding stock. The major products for deer and elk farms and ranches are:

Elk: Major products are breeding stock, semen, velvet antler, meat (venison) and hunt bulls. According to Greaser et al. (1996), some specialty markets exist for elk byproducts, including hides, tails, leg sinews, antler buttons and ivories (canine teeth).

Deer: Major products are breeding stock, meat (venison) and hunt bucks. Minor products with specialty markets include: hard antlers — e.g., for decorations or furniture (Cashion, 1998-99) — deer urine, which is sold as a hunting aid (e.g., <http://www.outdoor-products.com>), velvet antler (Cashion, 1998-99), hides, tails, leg sinews and antler buttons (Alberta Agriculture, 1997).

Artificial insemination is used by farmed deer and/or elk operations, though it is more commonly used in the elk operations. Therefore, the breeding stock market includes sales of semen straws for elk and, to a lesser extent, deer. In addition, tourism associated with animal viewing is also a potential source of income, though we were unable to document its extent.

Velvet antler

Velvet antler is marketed as a dietary supplement. Research conducted by the industry proposes the following abilities of velvet antler: reduce inflammation, influence body metabolism, support immune function, protect damaged tissues, and improve blood, liver and kidney function (Nutrinfo, 1998 and 1999; McNeary, undated).

Velvet antler is harvested annually from bull elk. The quantity harvested per animal depends on the genetics and the age of the animal, as well as the timing of the harvest. Elk typically produce 16 or more pounds of velvet antler annually, while red deer produce only about 4 pounds (Greaser et al., 1996). Mature bull elk that are 4 or more years old can generally produce 20 or more pounds per year (L. Renecker, Ph.D., personal communication, October 1999), and some produce more than 40 pounds (Whittlesey, 1999). The highest prices are received for velvet antler that is harvested before the calcification or hardening process becomes advanced. The velvetting season runs from about the last week in May until early July (for 2-year-old bulls). Antlers are generally harvested for the first time in the second year of a bull's life and annually thereafter. Harvest requires that the animals be restrained, so velvet operations require handling facilities (Haigh and Hudson, 1993; Alberta Agriculture, 1997).

White-tailed deer also produce velvet antler. However, there is not much current production of deer velvet antler because deer do not produce as much velvet antler and are more sensitive to handling than elk (Dean Skinner, president Velvet Independent Processors [VIP], personal correspondence, May 1999). Also, it has been suggested that the buyers in Korea prefer the larger sized antlers of elk (Alberta Agriculture, 1997). In addition, white-tailed deer antlers have not historically been used and are not recognized by the Korean Pharmaceutical Industry Association as having medicinal properties (L. Renecker, Ph.D., personal communication, October 1999). As a consequence, the potential for velvet from farm-raised white-tailed deer appears to be limited.

Korea has traditionally been the largest purchaser of velvet antler (Alberta Agriculture, 1997). It is estimated that in Korea, with a population of 44 million, some 8 million people are committed to using velvet antler in traditional medicines (Alberta Agriculture, 1997). Other significant purchasers include China, Taiwan, Japan, Thailand and Russia (Luxmoore, 1989). Some have suggested that China may become the world's largest importer of velvet antler in the near future (Alberta Agriculture, 1997).

The Korean velvet antler market is "a more complex market that requires considerable producer effort to ensure that the highest price possible is received" (SAF, 1996). The market is dominated by a small number of large Korean pharmaceutical companies (SAF, 1996), and operates under import quotas that restrict the amount of velvet antler allowed into the country (Alberta Agriculture, 1997). As a result, the market has been characterized by a small number of velvet antler buyers that act like a cartel, and producers have essentially become "price-takers" (SAF, 1996) — that is, the Korean buyers can set prices (Alberta Agriculture, 1997). Traditionally, the velvet antler buyer travels to the farms and negotiates the purchase of velvet with individual producers (SAF, 1996). Recently, the trend has been toward farms coordinating their marketing activities to create larger lots and achieve more favorable bargaining positions (SAF, 1996).

In 1996, 125,000 pounds of velvet antler was processed in North America, of which 85,000 pounds was processed in Canada (Alberta Agriculture, 1997). The amount of velvet antler produced in Canada in 1996 is estimated at about 60,000 pounds. This is less than the amount processed because the Canadian processing includes imports from the United States (Alberta Agriculture, 1997). New Zealand, China and Russia are the world's major producers of velvet antler. In 1996, Canada produced an estimated 6 percent of the world antler production (Alberta Agriculture, 1997).

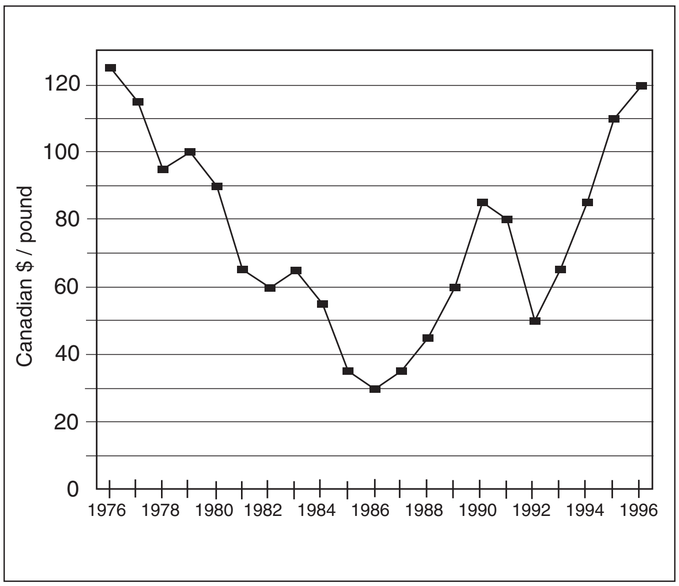
Greaser et al. (1996) stated that the market for velvet antler often "is unstable and currently is dominated by countries that produce large amounts of velvet antler (such as Russia and New Zealand)". The price of velvet antler has been extremely volatile over the past 15 years (SAF, 1996). In that time, prices ranged from $35 to $110/lb (Paula Whiting, NAEBA, personal correspondence, May 1999). Prices for velvet antler have fallen recently following the Asian economic crises in combination with high production levels in New Zealand. Velvet antler prices were particularly depressed in the late 1990s, and ranged from $15 to $45/lb, with the highest prices going to the best quality antlers and the producers and processors with good contacts (Paula Whiting, NAEBA, personal correspondence, May 1999). In a recent interview, one velvet processor suggested that, in 1998, 60 percent of the velvet produced in North America was not sold or processed (Dean Skinner, as quoted by Graham, 1999). Though others feel that prices may occasionally fluctuate above the $100/lb level, prices are more likely to stabilize in the range of $50 to $65/lb (L. Renecker, Ph.D., personal communication, October 1999).

A Saskatchewan Agriculture and Food report on elk production (SAF, 1996) indicates that industry price quotes place the average price for frozen velvet antler to be $55/lb (Canadian) in 1993 and $85/lb (Canadian) in 1996 (SAF 1996). Historic Saskatchewan prices for top quality frozen velvet antler ranged from $30/lb to $125/lb between 1976 and 1996 (Figure 5; SAF, 1996).

Markets for velvet antler are also emerging in other areas of the world, including North America, as people begin to examine possible non-traditional/natural health aids. Approximately 25 percent of the velvet antler produced in North America is consumed in North America. A 1996 Saskatchewan report listed only four velvet processors in Canada (SAF, 1996). The dietary supplement industry is one of the most rapidly growing consumer markets in North America and was predicted by the industry to increase greatly in 1999. Potential for product growth in the North American market exists. New nutraceutical companies in the United States and Canada are developing the U.S. market for antler products in both liquid and capsule form, and given the available supplies in North

America, some are considering importing antler (R. Murphy, American Elk Products Board, personal communication, October 1999). Recently a contract was secured by Canadian processors with General Nutrition Centers (GNC) of Canada to sell a velvet antler product that is combined with ginseng (Dan Marsh, Michigan Elk Breeders Association, personal correspondence, April 1999). According to Craig Stefanko, a Michigan elk producer, the GNC contract is expected to use all of the velvet antler that Canada currently produces (C. Stefanko, personal correspondence, May 1999).

Figure 5: Prices per pound for top quality frozen velvet antler in Saskatchewan, 1976-1996 (Canadian $ per pound).



Nationally, the natural products industry is growing at double-digit annual rates (Batie, 1998; Adelaja and Schilling, 1999) and is currently valued at $14.8 billion. Natural products encompass fresh and organic foods and beverages, nutraceuticals, vitamins and dietary supplements. Nutraceuticals include so-called "functional foods" and dietary supplements that provide benefits beyond basic nutrition and may prevent disease or promote health. Functional foods are foods that consumers eat for specific medical purposes (Batie, 1998). Thus, if velvet antler were to capture a small share of this market, it could mean substantial growth in domestic velvet antler sales.

Velvet antler brands

Below are examples of velvet antler product brands, along with the health benefits claimed by the manufacturers. Independent scientific tests of these benefits have not been reported, and natural products such as this are not regulated by the U.S. Food and Drug Administration. Velvet antler products are sold in health food stores and through the Internet. Velvet antler products are sold in capsule and liquid form. Products contain velvet antler and some also contain herbs such as ginseng.

Natural Velvet: The elk industry association's (NAEBA's) trade-marked brand name for describing and promoting dietary supplements and other products containing velvet antler (McNeary, undated).

Qeva: Relieves the symptoms of arthritis, raises testosterone levels, reduces inflammation, lubricates the joints, increases muscle performance.

Vital-Ex: Original, athlete's, women's and men's formulas for: arthritis, osteoporosis, anemia, athletic performance, anti-aging, energy and mental acuity, gonadotropic disorders, gynecological disorders, skin conditions, and tissue and bone rejuvenation.

Velvet Independent Processors (VIP), Saskatchewan: products offered by VIP range from naturally dried capsules to freeze-dried extracts (Dean Skinner, president VIP, personal correspondence, May 1999).

Venison

The venison market consists of both deer and elk meat from farmed animals. Hunter-harvested venison cannot legally be sold in Michigan. In addition to white-tailed deer, the venison market includes species such as fallow, sika and red deer. Industry information promotes venison as lower in fat, cholesterol and calories than many other meats (SAF, 1997; Alberta Agriculture, 1998).[1] For this reason, many people expect that there is potential for increased demand for venison among health-conscious consumers (SAF, 1997; Alberta Agriculture, 1998; Renecker, 1999). Venison consumption in the United States has more than doubled since 1992 (Table 11). The global market is currently dominated by New Zealand (Alberta Agriculture, 1997), which supplies about 80 percent of the venison consumed in the U.S. market (Table 11). Canadian consumption of venison in 1995 was estimated by industry analysts at less than 400,000 pounds (or about 0.13 pound per capita) as compared to 2 billion, 1.8 billion and 1.6 billion pounds for beef, pork and chicken, respectively (SAF, 1996). Similarly, U.S. consumption of venison is a small fraction of that for other meats. By assuming that venison can capture up to 3.5 percent of the beef market, Harpur (1998) has estimated that domestic U.S. venison consumption may reach as much as eight times its present level. We were unable to locate any detailed market analysis of the potential for growth of venison sales either domestically or internationally, and we find no basis for evaluating Harpur's (1998) assumption about inroads into the beef market.

[1]However, as tabulated in Appendices 3 and 4, there seems to be some discrepancy in the nutritional data. Several sources indicate that while venison is lower in total fat than beef, pork or chicken, it is higher in cholesterol. Elk appears to be lower in both fat and cholesterol than deer meat. However, the nutritional data is somewhat limited. For example, in one of the most comprehensive databases available (USDA, 1998), there is only one entry for elk and one entry for deer (species unknown), yet for beef there are about 100 entries for various cuts and cooking methods.

Table 11. Estimated venison consumption in the United States and production in North America (imports from New Zealand account for almost all of the difference).

1992	1993	1994	1995	1996	1997
Estimated U.S. consumption: 3,120,000 lbs.	1,200,000	1,650,000	2,000,000	2,734,000	2,560,000
Estimated North American production: 640,300 lbs.	200,000	260,000	393,400	510,900	n/a

(Data are based on NADeFA correspondence provided by Dr. Mike Vanderklok, MDA.)

Elk and deer venison is sold either to wholesalers as a farmgate product, by mail order, or into specialty markets such as gourmet restaurants, delicatessens and health food stores. Individual producers have received higher profit margins in specialty markets (SAF, 1997).

Table 12. Average retail white-tailed deer meat prices in Saskatchewan in 1997.

Item	Price (Canadian $/lb)
Venison racks	$18.90
Strip loin	$19.60
Saddle (bone in)	$9.80
Denver leg (restaurants)	$11.30
Front shoulder (bone in)	$3.75
Hamburger patties	$4.25
Trim (no processing)	$2
Jerky ($2.88/100g)	$13.06

(Source: Saskatchewan Agriculture and Food, 1997.)

In Canada, larger markets are not being pursued because of the current limited supply of venison (SAF, 1997). On the retail side, prices for venison are two to three times the price of beef (SAF, 1997, Table 12). It is believed that some U.S. consumers will pay $15 per pound for high-end cuts of elk meat (Renecker, 1999).

Potential food and product safety issues could affect demand for venison and even velvet antler. For example, concerns could arise over the use of tranquilizers and other drugs during the process of velvet antler removal, the use of drug/hormone enhancement to obtain increased velvet antler growth, weights and color by some producers, and/or antibiotic use in the production of the elk meat and products (Renecker, 1998). Some elk producers advocate practices that would result in a product which could find a market niche as a meat free of growth hormones, antibiotics, etc., and believe that continued price premiums depend on elk meat maintaining an image as a natural product, and that means producers should not use antibiotics and growth hormones (Renecker, 1999). To address potential food and product safety concerns, elk producers, through the American Elk Products Board, are designing a "quality seal" program. The goal behind the "quality seal" program is to assure the quality of elk velvet, venison and byproducts from "pasture to plate" (S. Richards, Michigan elk producer, personal communication, May 1999). However, some note that without a quality assurance protocol and scientific data to back it up, the quality seal lacks meaning (L. Renecker, Ph.D., personal communication, October 1999).

Some producers directly market venison cuts through the World Wide Web. For example, Venison World of Eden, Texas, sells ground venison at $4.99/lb and venison burgers at $6.99/1.4 lb. In addition, Butcher Boy in Warren, Michigan, sells game meat including deer and elk venison. Prices that Butcher Boy pays to Michigan producers were requested but were not made available.

Average prices that wholesalers were paying Canadian farmers for white-tailed deer venison in 1997 were $3.50 (Canadian) per pound for young carcasses (18 months, 77 to 95 pounds) and $3.20 (Canadian) per pound for cull carcasses (just over $2/lb [U.S.] at an exchange rate of 1.45) (SAF, 1997; Alberta Agriculture, 1998). Elk meat experiences much lower sales volume than deer meat and sold in the mid-1990s at a wholesale price of approximately $4 (Can.)/lb (SAF, 1996) and more recently for about $6.50 (Can.)/lb (L. Renecker, personal communication, October 1999).

In Michigan, it is estimated that producers would need to receive $4 to $5/lb wholesale for an operation that relied on venison production to be profitable (Alex Draper, Michigan Deer Farmers Association, personal correspondence, May 1999). For example, it takes about $120 (for feed, veterinary care and other expenses) to raise a doe to 2 years of age. At this age, the carcass weight of deer is approximately 65 pounds, and the venison market for carcasses is $2/lb. (Alex Draper, Michigan Deer Farmers Association, personal correspondence, May 1999). Some specialty markets pay higher prices (e.g., direct sales to local restaurants), but these opportunities are few and can be unstable (Alex Draper, Michigan Deer Farmers Association, personal correspondence, May 1999). Michigan venison suppliers face competition from New Zealand and Australia (Alex Draper, Michigan Deer Farmers Association, personal correspondence, May 1999).

A branded venison product that ensures product quality could command price premiums and/or capture a greater market share away from existing venison suppliers. For example, New Zealand developed a venison brand called Cervena. Some in the venison industry believe that the Cervena brand allowed New Zealand to export more venison into the United States in recent years. However, others have pointed out that marketed brands such as Cervena have had problems with quality because they advertise higher quality without a consistent guarantee (L. Renecker, personal communication, October 1999).

Paid hunting on preserves/ranches

Elk bulls and white-tailed deer bucks are also potential products of captive elk and deer operations. Bulls or bucks that are top quality and mature, with large antlers — i.e., "shooter bulls/bucks"— can be sold to game and hunting preserves/ranches. However, Greaser et al. (1996) stated that "limited opportunities are available to sell [elk] bulls as trophy animals to game and hunting preserves."

Exact numbers of facilities offering paid hunting opportunities within enclosures were not available for Michigan or the United States. However, a general idea for Michigan can be gleaned by referring to the data on Michigan permittees (Table 3). The enterprises larger than 39 acres are more likely to offer hunting as part of their business than are the smaller facilities (J. Janson, Michigan DNR Wildlife Bureau, personal correspondence, May 1999). Moreover, since 1992, larger operations have more than doubled in number. This may suggest that the number of hunting operations has increased since 1992, though no data exist to indicate whether these new operations do offer hunting services. Most hunt ranches in Michigan (except for the very new or small ones) sell out every year (Terry Thompson, Michigan Deer Farmers Association, personal correspondence, May 1999). Because the demand for shooter bucks is currently strong, mature bucks with good pedigrees are easy to sell in Michigan (Alex Draper, Michigan Deer Farmers Association, personal correspondence, May 1999). In addition, most shooter bucks that are sold from Michigan farms remain in the state (Terry Thompson, Michigan Deer Farmers Association, personal correspondence, May 1999).

Game hunting ranches throughout the United States provide opportunities for paid hunting within enclosures for trophy deer and elk. Statistics on the number of such operations and the value of paid hunting are not readily available. Also, because some of these ranches maintain their own herds, the overall demand for trophy deer is unclear. For example, the Sanctuary in Stanwood, Michigan, has an enclosure with native white-tailed deer and practices intensive management of this herd. The Sanctuary does not have any breeding pens and does not buy or sell deer (Michael Hine, Michigan Deer Farmers Association, personal correspondence, May 1999).

Hunt elk bulls with antlers of superior size can command prices as high as $20,000 (Canadian) per animal (SAF, 1996). A typical elk hunt in Colorado sells for $8,000 (Hemmert, 1999). Prices for some hunt ranches are listed below:

- Sanctuary ranch, <http://www.sanctuaryranch.com>, Stanwood Michigan, advertises hunts for white-tailed deer in a herd that averages Boone and Crockett (antler trophy rating) scores over 160 points.

  •Management fun hunts: $2,500, six- to seven-point bucks (three days/four nights).

  •Trophy/management hunts: $3,500, seven- to eight-point bucks (three days/four nights).

  •Trophy hunts: $14,500 for slots in early part of 1999 season to $8,000 for slots later in the season (four days/five nights).

- Buckpole Archery and Deer Ranch, <http://www.buckpole.com>, Marion, Michigan.

  •Enclosure deer hunting rates: $1,000 for a 2-day hunt; $250/day for additional days. Harvest charge of $1,000 to $5,000, depending on quality of animal and antler size.

  •Private land deer hunting rates: $500 for a 2-day hunt ; $100/day for additional days. Harvest charge of up to $1,000, depending on quality of animal and antler size.

- Valhalla Game and Guest Ranch, <http://www.whitetailhunts.com>, Lovells, Michigan.

  •Prices for three days/nights start at $4,500 for white-tails with Boone and Crockett scores in the 100 to 125 range and increase by $500 for every 10-point increment in the Boone and Crockett score. Prices for elk start at $4,500.

- Red Oak Deer and Fence, <http://www.redoakdeer.com>, Rusk, Texas.

  •Trophy hunt rates: $50 per person per day; harvest rates for white-tailed deer — those under eight points — are $999, and those eight points and over are $1,499.

In Michigan, most opportunities to engage in paid hunting within an enclosure are for white-tailed deer rather than elk.

A recent trade magazine article by Hemmert (1999), based on a senior thesis, examined the profitability of an elk-hunting operation in Colorado. It is estimated that 50 elk hunts are sold each year for $8,000 each. Ranch operator interviews were conducted to verify cost assumptions. The study concluded that the profitability of this operation depended on what was paid for the land and how much land was necessary for providing a fair chase and a natural habitat (Hemmert, 1999). At Colorado mountain land prices of $1,100 an acre and an assumed 1,500 acres of land, the operation did not generate a positive cash flow. As with any land-based enterprise, operations are not profitable if they cannot generate enough income to cover rental payments on land (or the annualized cost of owning the land). An editor's note that accompanies the article suggests that a fair chase need not require 1,500 acres. In addition, some of the ranchers interviewed stated that the price of a good bull elk hunt is continually rising, and selling 50 hunts a year at $8,000 each should not be a problem. Yet they also noted that competition is increasing, so they expect sales will become more difficult in the future (Hemmert, 1999). The cost of land and cost of hunting in Michigan are likely to differ from these data from Colorado, and the applicability of Hemmert's conclusions to Michigan is not certain.

Breeder markets

Weaners, yearlings and older breeders can be sold. Many customers are looking for bulls (males) with high weight gains and high velvet antler yields and for cows (females) with high weight gains and good fertility (Greaser et al., 1996). In Canada, bred cow prices rose from an average of $6,000 per bred cow in 1993 to an average of $19,000 per bred cow in 1996 (SAF, 1996).

Some elk producers use artificial insemination. For top bloodlines, bull semen is another product that can be sold for prices that range from $200 to $3,000 per straw. At the 1999 Colorado Select Elk Sale, eight lots of semen sold at prices that ranged from $450 to $1,150 per straw (Whitlessey, 1999).

Top bloodlines that have demonstrated large velvet production have commanded prices that rival those of top bison and cattle (Whitlessey, 1999). For example, Starburst, the yearling son of Starbuck, sold along with 100 straws of semen for $56,000 at the 1999 Colorado Select Elk Sale (Whitlessey, 1999). Starbuck held North American velvet antler records by producing almost 48 pounds of velvet antler as a 6-year-old. Another top bloodline is that of Korean Gold, the first bull in North America to produce more than 50 pounds of velvet antler. The NAEBA has established a registry for all North American captive elk that uses genetic testing to indicate possible cross-breeding and to clarify parentage information (Alberta Agriculture, 1997). This system can help to enhance the reliability of breeder and semen sales, which may help to stabilize this market.

The U.S. market for breeding elk stock

The elk breeding stock market experienced substantial growth in the 1990s. In this section, we summarize a recent description of the market for elk breeding stock (Watson, 1998). Watson noted that in the early 1990s, the market for breeding stock focused more on heifer calves than on bred females. In addition, there was not much discrimination among genetic lines. The advent of certified antler competitions and the identification of genetic lines that consistently performed well in these competitions fueled a growth in the high-end market. Good velvet prices through the mid-1990s helped fuel demand for breeding stock. As Watson (1998) notes, growth was strong in 1994 and 1995, but "1996 can probably be best described as explosive". Very high-end bulls sold for record prices.[2] These high-priced sales "separated the high-end market distinctly from the rest and established a trend that would continue throughout the year. Demand for velvet antler continued to be very strong, and the thirst for breeding stock was insatiable."

The strong demand for breeding stock affected elk prices at all quality levels. Watson (1998) notes that demand and prices continued to be strong through 1997. However, the market started to change in 1998. Again, quoting Watson (1998):

"Several events in 1997 brought about some changes in the elk industry. The Asian financial collapse severely restricted demand for velvet antler — this in combination with a market now glutted with velvet antler. (Anticipation of lucrative velvet antler sales had been a prime driver of breeding stock prices.) The laws of supply and demand in a free market system were also coming to bear. Extremely high prices for breeding stock certainly diminished the demand.

"The select sales in early 1998 began to reflect the changes that had occurred in 1997. Prices for the high-end animals could best be described as steady to weak.

"For animals in the mid- to lower range of our intermediate group, prices dropped by as much as 40 to 50 percent. By the fall of 1998, prices for the entire intermediate group had declined by 40 to 50 percent from the highs of '96 and '97, and the commercial group prices had declined by 50 to 60 percent" [Watson, 1998].

[2]Watson's (1998) categories are defined as follows: "high end" — individual animals or bloodlines that consistently place high or win in sanctioned antler competitions; "intermediate" — a rather large grouping including somewhat above-average animals with some pedigree and/or limited performance documentation; "Commercial" — animals of unknown origin, no performance data and obviously less "eye appeal" than the above groups.

Watson (1998) reported select sale prices from several auctions in 1998 and early 1999 (Table 13). By comparing the results of these recent sales with prices and qualities at earlier auctions, Watson (1998) concluded that overall elk breeding stock prices "are down 35 to 60 percent from the highs posted in '96 and '97". As pointed out in the above quote, the lower classes of breeding stock suffered the largest price declines relative to the 1996-7 period. This led Watson to conclude: "The old days of 'an elk is an elk' are gone. Performance and pedigree are now the factors that determine elk prices."

A comparison of Watson's table (Table 13) with the MASS data for Michigan (Table 2) suggests that Michigan elk producers' inventories are also likely to have declined in value (provided that the average quality level of the Michigan captive elk herds does not fall in the high-end category).

Example budget

Saskatchewan Agriculture and Food developed sample enterprise budgets for elk and white-tailed deer operations (Table 14 and Table 15; SAF, 1996). These enterprise budgets and variants produced by Alberta Agriculture are among the only well developed enterprise budgets for captive deer and elk operations and are referenced in the trade articles about the industry. Tables 14 and 15 are presented to facilitate comparisons between values for Michigan herds (see MASS results presented in Tables 1 and 2).

Table 13. Summary of auction prices for elk breeding stock at five recent sales.*

Categories[1]	Summary of five recent elk sales[2]
Top-selling bred cows	$9,500 - $16,000
High-end bred cows	$6,000 -$10,500
Intermediate bred cows	$3,500 - $7,000
Commercial bred cows	$2,000 - $4,000
Herd sire prospects (calves-spikers)	$4,500 - $15,500
High-end heifer calves	$7,300 - $9,200
Intermediate heifer calves	$2,900 - $4,900
Commercial heifer calves	$1,800 - $2,500

*Data and table reproduced from Dennis Watson, Tracking Elk Prices.

[1]The categories are defined as follows: High end — individual animals or bloodlines that consistently place high or win in sanctioned antler competitions; intermediate — a rather large grouping including somewhat above-average animals with some pedigree and/or limited performance documentation; commercial — animals of unknown origin, no performance data, and obviously less "eye appeal" than the above groups.

[2] The select sales are: North Dakota sale in December 1998, Kansas sale in January 1999, two Colorado sales in late January 1999, and an Indiana sale in 1999.

Table 14. Saskatchewan elk price ranges used to derive prices in elk production budget documents produced by Saskatchewan Agriculture and Food (all prices in Canadian dollars).

	1994 price range	1996 price range
Bull calves	$1,000 - $1,500	$3,000 - $4,000
Heifer calves	$3,000 - $4,500	$10,000 - $13,500
Yearling exposed heifers	$4,500 - $7,000	$17,000 - $26,000
Exposed cows	$5,000 - $8,000	$17,000 - $21,000
Yearling velvet bulls	$1,200 - $2,000	$4,000 - $6,000
Two-year+ velvet bulls	$1,500 - $3,000	$5,500 - $7,000
Hunt bulls	$2,000 - $4,000	$5,000 - $10,000
Mature breeding bulls	$5,000 - $10,000	$8,000++
Velvet price used in budgets	$55/lb	$90/lb

(Source: Table adapted from Table 7 of the 1994 and 1996 versions of SAF publication "Elk Production: Economic and Production Information for Saskatchewan Farmers.")

Table 15. Saskatchewan white-tailed deer estimated price list, March 1997.

	Age	Price range (dollars Canadian)*	Mean price, (dollars U.S.)***
Hunt bucks	3.5+years	$2,000-$3,000	$1,724
Mature breeding bucks	2.5+years	$4,000-$6,000	$3,448
2.5-year buck (breeding)	2.5 years	$3,000-$5,000	$2,759
Yearling buck (meat)**	18 months	$330	$228
Buck fawns	5-7 months	$700-$1,000	$586
Cull bucks (meat)**	6.5 years	$400	$276
Mature breeding doe	2.5 years	$7,000-$9,000	$5,517
Yearling doe (open)	7-15 months	$5,000-$6,000	$3,793
Yearling doe (bred)	1.5 years	$7,000-$9,000	$5,517
Yearling doe (meat)**	1.5 years	$270	$186
Doe fawn	5-7 months	$4,000-$5,000	$3,103
Cull doe (meat)**	12.5 years	$280	$193

Table adapted from Table 7 from SAF (1997).
* Source: Saskatchewan Whitetail and Mule Deer Producers Association.
** The meat price is based on $3.50/lb for yearlings and $3.20/lb for cull breeding stock.
*** The mean price in U.S. dollars was computed by taking the midpoint of the range of prices and then converting to U.S. dollars using an exchange rate of 1.45.

A complete financial analysis of cervid operations is beyond the scope of this paper and, to our knowledge, has not been produced in Michigan. Even though there are important differences between Michigan and Canada, the enterprise budgets for Saskatchewan (Table 16) illustrate important features about a typical cervid operation.[3] Note that in year 10, the model operation generates a positive and substantial net income. This income is received in the 10th year of an operation with 100 bred does. Breeding stock was required to bring the herd to 100 bred does. It starts with 20 does (10 purchased in each of the first two years) and grows to 100 bred does by the ninth year. Another point is that in this scenario, cash flow becomes positive in the ninth year. Thus, these investments require significant cash reserves. Finally, note that in the 10th year, about 88 percent of the revenues generated are derived from the sale of breeding stock, not from the sale of end-products such as venison or hunt bucks.

The Canadian enterprise budget (and similar budgets produced by Greaser et al. [1996] for Pennsylvania elk operations) points to the importance that breeding stock currently plays in determining the future financial viability of these operations. In contrast to the large share of revenue due to breeding stock in Table 16, sales of breeding livestock in the Michigan swine operations reported in Nott (1997) accounted for about 3.5 percent of cash incomes. These low percentages are typical for mature livestock industries (Christopher A. Wolf, Department of Agricultural Economics, MSU, personal correspondence, April 1999). In addition, in a mature livestock industry, only a fraction of the producers are involved in marketing breeding stock. For example, less than 10 percent of the dairy operations are involved in the production and supply of breeding stock (and semen) for sale to other producers (Steven Harsh, Department of Agricultural Economics, MSU, personal correspondence, April 1999). The experience of other livestock industries suggests that, as the captive cervid industry matures, the majority of producers cannot rely on sales of breeding stock as their primary income source. Rather, in the long run, most producers would need to rely on the sale of end products to generate income.

[3]For example, breeding stock is less readily available in Canada than it is in Michigan, and this is reflected in the relative prices listed in the table. Nevertheless, examining the Canadian budgets is warranted because none are available for Michigan and because these budgets are often used to illustrate the profitability of captive cervid operations. Also note that the Canadian elk budgets are not substantially different from the elk budgets of Greaser et al. (1996).

Table 16. Projected annual revenues for an established 100-doe white-tailed deer enterprise (year 10).

Description	Number of animals	Price per animal	Revenues/ head	Percent of total revenues
Yearling does (breeding)	42	$5,333	$233,986	75.1%
Yearling bucks (breeding)	12	$2,667	$32,004	10.3%
Yearling does (meat)	8	$270	$2,160	0.7%
Yearling bucks (meat)	33	$330	$10,890	3.5%
Hunt bucks (2.5 years)	19	$1,667	$31,673	10.2%
Mature bucks (breeding)	2	$3,333	$6,666	2.1%
Cull does	10	$280	$2,800	0.9%
Cull bucks	2	$400	$800	0.3%
Total revenue	128	$311,640		
Net income of business	$201,534			

Table adapted from Table 8 from SAF (1997).

Export potential

The potential for the export of breeding stock to Canada appears to be limited by very strict import rules in some of the provinces. For example, a moratorium on importing deer into Alberta was established in 1988 to protect both domestic and wildlife stocks from disease and parasites (Alberta Agriculture, 1997). Export markets for elk meat are limited (SAF, 1996), though more recently, Canadian producers have established export markets for elk meat as far away as South America. Some see the critical factor for export markets as supply coupled with quality assurance and marketing (L. Renecker, Ph.D., personal communication, October 1999). Nevertheless, venison export potential applies mainly to deer. There is a market for venison in Europe, but the U.S. export is likely limited by the large supplies and production potential in Russia, New Zealand, Australia and Europe (Greaser et al., 1996). Because of annual culling, most venison production occurs in North American herds when production from New Zealand is low. Thus North American production may be able to find an export market by supplying fresh venison at times when other producers are not able to meet demand (Twiss et al., 1996; Hobart, 1998).

In 1998, New Zealand industry representatives estimated they had a herd size of about 1.4 million deer (Hobart, 1998). The same representatives indicated that they expected to top 2 million in 2000 and believed that the most potential for marketing is in the United States (Hobart, 1998). One would expect that such increases in supply would depress venison and velvet prices unless demand were to grow accordingly or consumer demand were to shift to North American-grown venison and velvet.

Potential for continued growth of the captive cervid industry

In this section, we draw on the information provided above to provide some analysis of the potential economic future for Michigan captive white-tailed deer and elk operations. We briefly address the potential for growth in key product areas — venison, shooter bucks/bulls, velvet antler and breeding stock. Bear in mind that this section represents the analysis of the authors.

Venison: Venison consumption, though currently very limited in comparison with other meats consumed in North America, showed a trend of increasing consumption from 1992 to 1997 (Table 11). Even so, domestic producers are providing only about 20 percent of the venison consumed in the United States. This may indicate that it is unprofitable for domestic producers to supply the market at or below current prices. The lack of domestic supply is likely attributable to the relatively higher prices paid for breeding stock and the relative profitability of increasing herd sizes. Though the large share of imported venison suggests there is room to increase domestic venison production and sales, another factor that will affect the domestic venison market is the ability of domestic producers to compete with imports. For example, given the already large venison supplies from New Zealand and their planned growth, it will be difficult for the domestic venison market to provide substantial growth opportunities for domestic producers. For the same reasons, the potential for exporting venison to countries with higher consumption rates than the United States also appears to be limited. If the demand for breeding stock were to fall, the venison market might become more attractive to domestic producers, especially if producers can cultivate specialty outlets for venison. Long-run growth in domestic venison production will depend on the development of higher valued venison markets and/or on domestic producers' ability to compete profitably with imports from volume producers such as New Zealand. Alternatively, if North American producers can generate and certify a higher quality product, they may be able to outcompete New Zealand and other nations in a high-end segment of the U.S. and foreign venison markets.

Shooter bucks/bulls: The hunt/trophy buck market has the potential to be a steady market for white-tailed deer farmers. Demand for these opportunities seems to be strong, and some anticipate fourfold growth in these operations. However, improved hunting opportunities on public and private lands resulting from efforts such as quality deer management could reduce the demand for private hunt ranches to the extent that the two are equivalent for some individuals. However, an assessment of the demand for this market is hampered by a lack of data on the extent of this market and about the market segment of hunters who engage in paid hunting within enclosures.

Velvet antler: The North American nutraceutical market is experiencing dramatic growth. If velvet antler can find a place in this market, it would have a substantial effect on the demand for velvet antler. However, any increased demand by U.S. consumers will also attract the attention of large international suppliers such as New Zealand. The ability of these importers to compete with North American producers will affect the market shares that domestic producers can garner. Moreover, the potential continued growth and presence of velvet antler as a nutraceutical will depend on the future of the nutraceutical industry and, to some extent, on the efficacy of the product, as well as any future regulations of dietary supplements and nutraceuticals.

Breeding stock: All evidence gathered indicates that much of the current profitability of captive cervidae is attributable to the production and sale of breeding stock. As long as prices for breeding stock rise, current producers can continue to operate profitably. However, in the long run, the industry cannot sustain itself on only the sales of breeding stock. Only those producers able to supply genetically superior animals will be competitive in the breeding stock markets, and one would expect that a small share of producers would be participating in this market. Moreover, the values for breeding stock are tied to the expected values associated with the products provided by those animals. Ultimately, markets for end products such as venison, velvet antler and shooter bulls/bucks must grow and be sufficient to support the demand for (and prices being paid for) breeding stock.

Our analysis suggests that the short-run viability of the industry depends on continued support of prices and markets for breeding stock, and the long-run viability of the industry depends on adequate development of markets for end products. Other alternative agricultural enterprises have failed because markets did not adequately develop for their products. For example, breeding stock for emus and ostriches were once highly valued. When markets failed to develop, however, the value of breeding stock dropped accordingly. Alternatively, bison enterprises seem to have found a niche market for their products and remain viable. If the captive cervid industry can follow the bison example — and its product diversity and recognition suggest that it may — it has the potential for substantial economic growth.

Facilities Issues

Captive cervid agriculture requires facilities similar to those of other livestock operations, including fencing, corrals, chutes and restraint systems, feeding systems, health management systems and some protective cover from severe weather conditions. The facilities issues unique to captive cervid farming are particular design features that accommodate the size and behavior of these species and differences in their nutritional needs (Michigan Agriculture, 1997; Thorleifson et al., 1998). Cervids are less easy to tame than domesticated species. Handling deer, particularly for health management practices, requires care and caution to minimize extraneous noise and activity. Michigan Agriculture (1997) recommends infrequent handling to minimize stress, which requires coordination of multiple health management actions (e.g., vaccinations, weighing, anthelmintic treatments, identification) for simultaneous administration.

In general, the design of captive cervid farming facilities should include accommodations for fenced pastures, raceways, gates, paddocks, yards, chutes and restraining systems (Thorleifson et al., 1998). Design should accommodate site features including topography, type of fencing and layout (Haigh, 1987). For example, in hilly areas, fencing may need to be reinforced or buried to account for possible erosion beneath the fence in low areas. Also, animals may be able to use hillsides to jump over downslope fencing that otherwise would be high enough to prevent escape.

Animals may be fed from pasture or from feed bunks or troughs. It is important to keep feed troughs simple to avoid animals becoming entangled in the structures (Wallace, 1994). As with other livestock, one disadvantage to the use of feed troughs or placing feed in concentrations on the ground is that it brings animals in close proximity to one another and leads to higher parasite loads. This can facilitate transmission of diseases and parasites from one animal to another. Also, sufficient numbers of troughs are needed to minimize aggression between animals and associated trauma (D. Davis, Ph.D., Texas A&M University, personal communication, October 1999). Each cervid species has unique nutritional requirements (e.g., grasses vs. forbs), but all require access to fresh drinking water (Michigan Agriculture, 1997).

Diagnosis and treatment of cervids for some common diseases of ruminant livestock are less reliable than for domesticated livestock (Thorleifson et al., 1998; CWF, 1992; Lanka et al., 1992). One reason is that wild species tend to mask clinical signs in early stages of disease etiology (Thorleifson et al., 1998). Captive cervid species are more vulnerable to some diseases than domestic livestock because efficient prophylaxis options, such as vaccines for some diseases, are not available or are not as reliable for cervid species (Morley and Hugh-Jones, 1989; Thorleifson et al., 1998). These challenges increase the need for frequent monitoring of animal health as well as expanded research and expertise in health management of captive cervids. The current stringent requirements (Appendices 1 and 2) for testing all deer and elk herds in Michigan in response to the presence of bovine tuberculosis in the wild white-tailed deer herd reflects this need.

Fencing

One of the primary differences between facility requirements for captive cervids and domesticated livestock is the need for strong, high fencing. Fencing is needed not only to protect the captive herd from ingress by wild cervids but also to guard against loss of captive animals to the wild herd. Both white-tailed deer and elk are capable of passing through fencing typically used for large domesticated livestock such as cattle and horses. They penetrate fences either by going under, through or over the fence (Palmer et al., 1985). Kirkpatrick and Scanlon (1984) recommend that fencing for white-tailed deer (in enclosures 0.1 hectare [0.25 acre] or larger) should be "woven wire or chain link fencing...and should reach a height of approximately 3m (10 ft). Woven wire should be at least 11 gauge, otherwise it will rust and weaken within a few years." [More recent information recommends 12 gauge or higher — S. Wolcott, NAEBA Animal Health Committee Chairman, personal communication, October 1999). Fencing must be strong enough to withstand animal impacts and tall enough and of sufficiently fine mesh to prevent escapes and ingress (Bryant et al., 1993). Palmer et al. (1985) evaluated five fencing designs that had been proposed for preventing passage of white-tailed deer and found none were reliable in preventing deer passage. As a result, more stringent standards have been applied to captive cervid permit requirements in Michigan and other states.

Specifications for fencing required of captive cervid facilities in Michigan are detailed in Appendix 5. In summary, fencing must be constructed of woven wire and must be at least 10 feet high for white-tailed deer and at least 8 feet high for elk. These standards are more restrictive than those tested in Palmer et al. (1985) and are based on the results of more recent studies such as Bryant et al. (1993).

Bryant et al. (1993) discussed the use of a 12.5-gauge, high-tensile woven wire deer fence that was 8 feet high with a strand of smooth, high-tensile wire at the bottom to discourage animals from crawling under. In addition, the researchers also placed two strands of smooth wire above the woven wire fence. The construction of this fence was to enclose elk and mule deer. Bryant et al. (1993) commented that 14 elk have escaped from the enclosure and all known escapes occurred during moving and handling operations. These researchers felt that "under normal conditions" deer and elk would probably not attempt to jump the fence unless snow pack made the fence less of a barrier.

Several materials have been developed to address the need for greater strength of fencing for captive cervids. High-tensile wire like that tested by Bryant et al. (1993) is especially favored for fence construction (Wells and Dougherty, 1998) because it absorbs the impact of deer or elk, as well as fallen trees, limbs or equipment without stretching or breaking (Palmer et al., 1985).

The high-tensile woven wire provides unique tension curves that flex upon impact, thereby minimizing severe body injuries to animals caused by impact with the fence (Bryant, 1993). This type of deer fence was selected for the 25,000-acre Starkey enclosure near LaGrande, Oregon, containing 300 mule deer and 560 elk, because of its strength, durability in variable weather conditions and cost effectiveness (Bryant et al., 1993). Life expectancy of the high-tensile woven wire deer fence is 30 years or more with minimal maintenance (Bryant et al., 1993). Brand names of high-tensile fence include Tightlock, Solidlock, Baechart, Langley, Stelco and Wiremakers (L. Renecker, Renecker & Associates Inc., personal communication, October 1999; J.C. Haigh, University of Saskatchewan, personal communication, September 1999).

Electric wires also have been shown to be effective in preventing animal contact with the fence (Palmer et al., 1985) and may be useful on fences between bulls in adjacent paddocks (Haigh, 1987). In Michigan, electric wires would represent a supplemental effort to enhance the effectiveness of the required 8- or 10- foot-high fencing. Their usefulness in this application has not been tested and documented in Michigan or with Michigan fencing requirements. Electric wire above the woven wire fence may be particularly effective in preventing escape when deep or drifting snow allows deer or elk to surmount the 10-or 8-foot woven wire fence. Also, electric fence can be equipped to provide an alarm if fencing is compromised by a break or tree fall (L. Renecker, personal communications, October 1999). Fencepost materials differ for captive cervids as well. For example, alternate steel and wooden posts were used every 12 feet at the Starkey enclosure in Oregon to ensure that the fence remains upright, even with heavy snow accumulation. Others suggest using wider spacing to allow greater shock absorption by the fence when animals run into it (L. Renecker, personal communication, October 1999). The reason for alternating between steel and wooden posts was to ensure that the fence would not fail in case of a fire (Bryant, 1993). There are, however, no specific regulatory requirements for fenceposts in Michigan (M. VanderKlok, MDA Animal Industry Bureau, personal correspondence, August 1999), nor have any studies tested fencepost materials in Michigan conditions.

Many factors affect the cost of fence construction (Bryant et al., 1993), including the supplier of material, the size of the order, the distance required for material transport, labor costs, topography, the type of posts used, whether electrified fencing is used, the mesh and height of the woven wire, and the number of gates. The cost for construction of 1 mile of New Zealand elk-proof fence at Starkey Forest and Range in northeastern Oregon totaled $10,434.26 (Bryant et al., 1993). Other sources cite similar costs of approximately $10,000 per mile (Hemmert, 1999) and $7,900 per mile (Renecker, 1992), but no studies specific to Michigan are available for price comparisons.Though the cost of fencing is high for captive cervid facilities (Haigh, 1987), the cost of losing animals (representing a substantial investment of time and money) justifies building the best available game-proof fence (Bryant et al., 1993). Furthermore, higher initial fence construction costs may reduce long-term maintenance costs and lower the risk of injury to animals (Bryant et al., 1993).

Fence maintenance is critically important to minimize loss or ingress in captive herds. Normally, the fence line should be surveyed weekly, but during the mating and hunting season, it should be checked more often because animals are more active during this time of year (Bryant et al., 1993). Frequent monitoring of the fence ensures that few fence-related injuries to animals are overlooked and problems can be identified and fixed quickly (Bryant et al., 1993). Requirements for producers to include fencing inspection and maintenance in their farm development plan would help to reinforce the importance of this to growers.

Wild cervid collisions with newly constructed fences are inevitable and sometimes result in mortality. For example, within 5 years after completion of the Starkey enclosure, one elk and 15 deer died as a result of collisions with the perimeter fence (Bryant et al., 1993). No data are available on mortalities of captive or wild animals after colliding with 8- foot or 10-foot fences in Michigan, so it is not possible to assess the overall risk this presents to livestock or wildlife in Michigan, or to compare these risks with those associated with other causes of mortality in wild deer and elk herds.

Other species such as coyotes may pass under perimeter fencing, and bears may climb over the fences (Bryant et al., 1993). This suggests that movement of these wild species may not be impaired by standard approved fences used for captive cervids in Michigan.

One alternative to the use of specialized fencing materials is to use two lines of fencing — a perimeter fence and an interior fence. The interior fencing may be used to enclose paddocks and holding facilities or may be offset a short distance (8 to 15 feet) inside the perimeter fence. One advantage of double fencing is that it provides an extra level of protection against escape or ingress in the case of damage to the perimeter fence. In addition, double fencing prevents close contact between captive and wild animals, further reducing the potential for disease transmission in either direction between the captive and wild herds. This is a practice commonly used in zoological parks and preserves, but its expense makes it prohibitive for many captive cervid farms and ranches (J.C. Haigh, University of Saskatchewan, personal communication, September 1999).

Ecosystem Management Issues

The relationship between captive cervid herds and surrounding ecosystems may be affected by the presence of the captive animals as well as the existence of the facilities needed to enclose these animals, especially if the facility is relatively large and/or encloses unique vegetation types used by free-ranging wildlife. Though any livestock operation is likely to have effects on ecosystems both within and outside the operation, there are two fundamental differences between captive cervid operations and other livestock operations. First, captive cervid operations, by definition in Michigan, involve livestock that are of the same species as wild animals that are the property of the people of Michigan. Second, captive cervid operations are required to use fencing that may restrict movement of publicly owned wildlife (cervids and others), and other livestock operations typically use fencing that is passable for most wildlife species.

Issues/concerns associated with captive cervid animals

There are primarily five issues associated with cervids documented in the literature that have potential implications for various components of natural ecosystems. These issues are: direct ecological interactions, potentials for escapes, ingress of native wildlife into licensed captive wildlife facilities, movement of escaped animals into adjacent areas where they are not wanted, and the illegal taking of wildlife.

Direct ecological interactions

The direct ecological interactions of captive cervids (especially non-native or exotic species, i.e., "species that become established artificially outside of their historic ranges...through some method other than natural dispersal" [Campa and Hanaburgh, 1999) poses a concern to natural resource managers (Feldhamer and Armstrong, 1993). This concern stems from the fact that cervids — native and exotic species — have been documented to cause impacts at the ecosystem level (e.g., altering successional trajectories of habitat types through herbivory [Schmitz and Sinclair, 1997] that may affect the quality of habitat for wildlife species other than cervids [Raymer, 1996], browsing altering the density, coverage and species composition of forest types [Campa et al., 1993; Jones et al., 1997]); at the species level (e.g., direct competition with native species, disease transmission — see the health management section of this report); and at the genetic level (e.g., hybridization [Harrington, 1985]).

The potential for direct ecological interactions of captive cervids with native fauna results from two aspects of cervid husbandry: impacts on wildlife habitat within the fenced area of a captive cervid farm or ranch, and impacts on wildlife habitat outside the fenced areas that result from the escape of captive cervids or from free-ranging deer or elk being restricted to localized areas by ungulate-proof fences. Within the fenced area, the effects may be qualitatively different from those that would result from establishing domesticated livestock in the fenced area because of preferred forage species of wildlife species and the types of fences used to contain domestic species. However, because the impacts are confined primarily to the private property of the captive cervid permittee, impacts on public resources are likely to be limited to those wildlife species that can move into and out of the fenced area, such as birds and small mammals. These impacts are considered in the section on ecosystem-level responses. Outside the fenced area, captive cervid operations may affect public resources and neighboring private properties. Impacts on public and private resources outside of the fenced area are discussed in the species- and genetics- level sections.

Ecosystem level — succession and habitat quality

Schmitz and Sinclair (1997) discussed that, in the absence of deer, northern hardwood forests undergo a successional trajectory (after timber harvesting) from vegetation types dominated by grass-herbaceous species to those dominated by shade-intolerant species (e.g., aspen) to ones dominated by shade-tolerant species (e.g., maple). The environment created by shade-tolerant species promotes the growth of other shade-tolerant species as well as the recruitment of shade-tolerant seedlings into taller height classes while suppressing shade-intolerant species. However, with deer browsing — even at a relatively low deer density — a more open forest overstory may be maintained that encourages the development of shade-intolerant species.

In the above scenario, deer and elk have the potential to change the composition (reduce abundance of preferred browse species), structure (lack of overstory development) and successional development (maintained in earlier vegetation growth stages-dominated by shade-intolerant species) of forest vegetation types. These ecological changes have been documented by Tilghman (1987), who investigated the effects of various white-tailed deer densities in enclosures on forest regeneration, and Healy and Lyons (1987:3), who investigated deer herbivory-forest dynamics on a 50-year-old unfenced wildlife "sanctuary". The specific effects of herbivory on forest ecosystems described below, however, are more likely to affect non-cervid wildlife in large captive cervid facilities (ranches) such as those that that promote hunting within enclosures rather than small facilities that function more like a livestock farm.

Other authors have also documented that white-tailed deer browsing can have a negative impact on forest regeneration (Stoeckeler et al., 1957; Anderson and Loucks, 1979; Frelich and Lorimer, 1985; Campa et al., 1992). Frelich and Lorimer (1985) suggested that in sugar maple-hemlock forests in Michigan, overbrowsing by deer may alter overstory species composition through gradual replacement of hemlock with hardwoods and may create gaps in the progression of size classes within a stand. In areas without intensive browsing, hemlock appears capable of regenerating and maintaining itself (Anderson and Loucks, 1979; Frelich and Lorimer, 1985). Campa et al. (1992) documented that browsing intensities greater than 50 percent on regenerating aspen stands in multiple years can alter some stand characteristics and nutritional qualities of browse.

Change in the forest structure or composition caused by ungulate browsing has several implications. First, cover provided by coniferous trees may be one of the most important factors for winter survival of deer in the hemlock-hardwood forests of Michigan (Graham, 1954). Decreased conifer regeneration may reduce amounts of winter cover in the long term, subsequently resulting in higher winter mortality of deer.

In addition, increased browsing may damage endangered plants. For example, if deer traditionally browsed in an area that later became unavailable because of the construction of high fences, they would have to find an alternate area in which to forage, perhaps on a nearby nature preserve. DeCalista (1994) investigated the effects of four densities (3.7, 7.9, 14.9 and 24.9 deer/km^2) of white-tailed deer within enclosures on songbird community and habitat attributes. He observed that "threshold deer densities" (7.9 and 14.9 deer/km^2) resulted in changes in species composition of ground cover; he noted a decrease in the number of flowering plants and an increase in grasses and ferns in managed forests within deer enclosures. Forests, as well as small ecological reserves set aside to protect rare plants such as members of families Liliaceae and Orchidaceae, can suffer from heavy browsing by ungulates (Geist, 1985; Miller et al., 1992). This situation may also occur if land use practices cause animals to shift normal movement or migration patterns. Several plant species disturbed by white-tailed deer within the Liliaceae and Orchidaceae families are found in Michigan and are listed as endangered, threatened or species of special concern (e.g., *Cypripedium canididum*, threatened; *Isotria verticillata*, threatened; *Platanthera ciliaria*, threatened; *P. leucophaea*, endangered; *Spiranthes ochroleuca*, special concern) (MDNR 1992).

Third, by affecting forest structure, deer browsing might alter the composition of the breeding bird community (Casey and Hein, 1983; DeCalista, 1994). Casey and Hein (1983) noted that in a nature preserve in Pennsylvania with high densities (100 browsing animals/km^2) of ungulates (5 percent mouflon sheep, 10 percent elk and 85 percent white-tailed deer), the habitat after 27 years of heavy browsing had decreased understory and more dead standing timber than habitat outside the preserve with lower ungulate densities (10 to 20/km^2). Bird species found exclusively or in greater abundance outside the preserve were associated with undergrowth or lower canopy layers (e.g., warblers, black-capped chickadee, rufous-sided towhee). Bark-foraging birds (woodpeckers and nuthatches) occurred in greater abundance inside the preserve because of the open understory and the abundance of large trees and dead timber (Casey and Hein, 1983).

DeCalista (1994) found that ungulate browsing within enclosures negatively affected songbird populations, particularly in the intermediate canopy layer (greater than 0 to 7.5 m) by decreasing height of woody vegetation in the intermediate layer. Bird species richness (i.e., number of species) of intermediate canopy-nesting songbirds decreased 27 percent and abundance decreased 37 percent between lowest and highest deer densities (3.7 and 24.9 deer/km^2). By altering vegetation composition and structure, especially in fragmented forests, deer densities greater than 7.9 deer/km^2 could decrease habitat availability and quality for vulnerable intermediate canopy-nesting species (DeCalista, 1994). Furthermore, if habitat changes have altered habitat structure and composition for some birds, then potentially other vertebrate and invertebrate species (e.g., herpetofauna, small mammals, insects) could also be affected (E. Wiggers, Nemours Plantation Wildlife Foundation, personal communication).

Species level — competition from escaped exotic species

If animals from captive herds escape to surrounding public or private property, they may become mixed with the wild herd of deer and/or elk and thereby may pose ecological risks to the wild herd. Such an escape would be a violation of current requirements for keeping captive white-tailed deer or elk. However, under current Michigan regulations, exotic species of cervids are treated differently than native species. Furthermore, escape of elk from captive facilities outside the current range of wild elk could have effects similar to the escape of an exotic species on the white-tailed deer population. If an escape of substantial numbers were to occur, the escaped animals may become established as a self-sustaining population, and removal of these animals would be difficult. These risks have also been discussed by some western states (e.g., Montana and Idaho) in a review of elk farming (Utah DWR, 1996). Because these risks exist, it merits review of the possible ecological impacts these might have on the native herds. Challies (1985) discusses the impact of intentional releases of exotic deer species, and Harrington (1985) described how hybrids escaped and may have outcompeted or even mated with native species.

Though numerous authors have reviewed the positive (e.g., aesthetic and sport values) and negative attributes of free-ranging exotic species (e.g., Craighead and Dasmann, 1966; Demarais et al., 1990; U.S. Congress, Office of Technology Assessment, 1993) and their potential impacts on ecosystems (e.g., Campa and Hanaburgh, 1999), wildlife agencies consider exotics as competitors with native species (Ervin et al., 1992). Examples of exotic species in the United States that have caused ecological problems for natural resource managers include the zebra mussel (*Dreissena polymorpha*) (Nalepa and Schloesser, 1993), Austrian pine (*Pinus nigra*) (Leege, 1997), red fire ants (*Solenopisis invicta*) (Pedersen et al., 1996), purple loosestrife (*Lythrum salicaria*), European starling (*Sturnus vulgaris*) and house sparrow (*Passer domesticus*) (Ehrenfeld, 1970). Feldhamer and Armstrong (1993) stated that, perhaps because of the problems of declines in habitat quality and quantity and limited financial resources for natural resource agencies, the existence of free-ranging exotics (large herbivores) is not in the best interest of public wildlife management programs because they may outcompete native species for habitat and forage.

Davidson et al. (1987) investigated the parasites, diseases and general health of sambar deer (*Cervus unicolor*) in relation to sympatric, native white-tailed deer in Florida. In general, the researchers concluded the general health and overall physical condition of sambar deer appeared to be better than that of white-tailed deer, primarily because of differences in food utilization, nutritional ecology, and parasitism and disease.

Davidson et al. (1987) concluded that the sambar deer utilized food resources that were unavailable or unacceptable to white-tailed deer and that there was an absence/lower frequency of certain pathogens on sambar deer. Also, they noted that the sambar deer have a competitive advantage over the white-tailed deer by being able to sustain body condition and health status in situations that were nutritionally deficient for white-tailed deer. For example, sambar deer had fewer species of parasites (13) than white-tailed deer (19 species). In general, sambar deer appeared to be in better physical condition and had less evidence of infectious diseases than white-tailed deer.

Davidson et al. (1985) also found the overall physical condition of fallow deer to be greater than that of white-tailed deer in Kentucky. Fallow deer may develop an immunity to reinfection of meningeal worm (*Parelaphostrongylus tenuis*), and white-tailed deer harbored more parasites than the fallow deer.

Feldhamer and Armstrong (1993) reviewed research on the interspecific competition between native artiodactyls in the United States and exotic, sympatric free-ranging species. One of the exotic species discussed by Feldhamer and Armstrong (1993), the sika deer, was found to compose an increasingly larger percentage of the harvest in Dorchester County, Maryland, than the native white-tailed deer between 1973 and 1991. In 1973, sika deer made up 24.8 percent of the total number of deer harvested in the county (white-tailed deer made up 75.2 percent). In 1991, sika deer made up 65.5 percent of the total harvest (white-tailed deer made up only 34.5 percent). The authors stated that these data suggest that the sika deer has the competitive advantage over the white-tailed deer if one accepts the assumption that harvest data reflect relative changes in population characteristics. The competitive advantage of the sika deer over the white-tailed deer may be explained by the digestive anatomy, feeding behavior (Hofmann, 1985) and nutritional needs of the sika deer — it is more adaptable in the selection of forages (i.e., more opportunistic).

Feldhamer and Armstrong (1993) reviewed an experimental case in Texas with sika deer that showed results similar to those observed in Maryland — in essence, that sika deer can outcompete the native white-tailed deer. In the Texas example, experimental projects were conducted at the Edwards Plateau within enclosures. These research projects are described by Harmel (1980) (cited in Feldhamer and Armstrong). In one project, six adults of each species were placed in enclosures and population numbers were monitored for eight years. In this project, Harmel (1980) also used a similar enclosure with 15 white-tailed deer as a control. After eight years, in the experimental enclosure, the number of sika deer increased to 62 while the white-tailed deer became extinct. The number of white-tailed deer in the control enclosure remained stable at 14.

Feldhamer and Armstrong (1993) concluded that sika deer, axis deer and possibly fallow deer have a competitive advantage over sympatric white-tailed deer or other native species. Sika deer (e.g., in Maryland, Texas, Virginia), axis deer (e.g., in California, Florida and Texas) and fallow deer have been successful in maintaining population density and distribution in a variety of regions and habitat types. Because of the results of the studies reviewed by Feldhamer and Armstrong (1993), they felt that "...introductions are ill-advised, with fiscal resources and personnel efforts better spent on native species...".

Genetic issues — hybridization

Hybridization between captive animals and wild animals can occur only if captive animals escape captivity (a violation of current state regulations) and mate with wild deer or if wild deer enter captive facilities and mate with captives. In the event of escaped white-tailed deer and elk, it would be difficult to distinguish the captive animals (private property) from wild deer (public property). Dratch (1993) discussed the development and use of genetic markers to distinguish farmed animals from wild animals with the caution that it is important to maintain the "genetic integrity of native deer populations...". Better tests may be available in the near future (L. Renecker, personal communication, October 1999).

The implications and long-term effects of hybridization are not fully known (Stubblefield et al., 1986). Several states, however — Colorado, Oregon, Utah, Washington, Wyoming — have expressed concern about the risk to the genetic integrity of native wildlife as a result of hybridization between wild animals and escapees from captive cervid operations (Utah DWR, 1996). Ontario also noted a concern about the potential loss of genetic integrity that may result if exotic red deer that escaped from facilities were to interbreed with elk in the wild (OFAH, 1991). In both references, the concern over hybridization is that introduction of genetic material from outside the native genome of wild cervids in the region — either from non-native species or from non-native populations of native species — may reduce the fitness of animals in the wild population. We did not find any documented cases of genetic improvement of wild cervid herds by the introduction of foreign genetic material into the population. There is also no known documentation of loss of fitness due to such introduction into wild populations. Nevertheless, hybridization is a cause for general concern (Jacobson and Lukefahr, 1998).

The deleterious effects of hybridization may be manifested in reduced resistance to disease, reduced digestive efficiency, altered growth and maturation patterns, or ultimately reduced reproductive potential. Just as excessive inbreeding can be detrimental to captive or wild populations of animals, outbreeding also can diminish the adaptive fitness between a wild population and its environment (Avise and Hamrick, 1996).

Free-ranging hybrids of white-tailed deer and mule deer have been documented in Texas (Stubblefield et al., 1986; Derr, 1991) and Canada (Wishart, 1980). In addition, interbreeding may occur between red deer and elk (Challis, 1985; Dratch, 1993; Abernethy, 1994). Some researchers have reported that hybrid animals may contribute little, if any, to a herd's productivity (Stubblefield et al., 1986). Upon studying mule deer and white-tailed deer hybrids in Texas, Derr (1991) suggested that the genetic structure of local populations may be altered by hybridization, but overall it does not appear to present a significant challenge to the genetic integrity of either parent species in Texas. Other reports indicate that hybridization between exotic and native species may affect the genetic integrity of the native species. For example, Ratcliffe (1987) documented a basis for concern over the genetic impact of non-native sika deer on native red deer in Great Britain.

The overall effects of hybridization between escapees and free-ranging wildlife depend on the extent of the problem (i.e., frequency of escapes), the size of the free-ranging population, and the amount of genetic difference between the escaped animal and the native free-ranging species (K. Scribner, MSU Department of Fisheries and Wildlife, personal correspondence, May 1999). In a relatively large population, for instance, effects of hybridization may be lost within a few generations; however, the genetic structure of smaller populations may be disrupted. Michigan's free-ranging elk population (fewer than 1,500 animals) may be more sensitive to the effects of hybridization than the much larger white-tailed deer population (K. Scribner, MSU Department of Fisheries and Wildlife, personal correspondence, May 1999). Hybridization between an escaped farm-bred white-tailed deer whose genetic origin may have been from outside of Michigan or the Great Lakes region or mule deer or black-tailed deer with free-ranging white-tailed deer in Michigan might not have a great impact on the native population because it is so large. Hybridization between red deer and elk in Michigan, however, might present more serious consequences because the elk population is much smaller than the white-tailed deer population and because red deer and elk are more genetically different than farm-bred white-tailed deer and free-ranging white-tailed deer.

The social, behavioral and ecological factors that would establish and maintain hybridization between species are largely unknown (Carr et al., 1996). For example, natural selection may quickly eliminate any introduced traits not fit for the environment. On the other hand, the full impact of hybridization may not be realized until a population is under some stress (OFAH, 1991; Avise and Hamrick, 1996). Nevertheless, the potential of hybridization to jeopardize the genetics of wild animals is a serious concern (Jacobson and Lukefahr, 1998). These risks can be minimized or avoided by careful management by captive cervid owners to prevent escapes of captive animals into the wild or regulations that specify farming of only native species (L. Renecker, Renecker and Associates Inc., personal communication).

Potential for escape

Massey (1986) and Rennie (1986) stated that escapes from game farms or ranches are rarely documented and that data are limited (Massey, 1986; Rennie, 1986). This may be because: escapes are rare, owners may be unaware of escapes, the number of escapees may be considered minimal by the facility owner, owners may be unwilling to report escape incidents, or because it is difficult to determine if an "escape" was accidental or intentional (U.S. Congress, Office of Technology Assessment, 1993). In general, the overall magnitude of problems associated with escaped animals is poorly quantified, especially before the early 1980s (Miller and Thorne, 1993). The U.S. Congress Office of Technology and Assessment (1993) reported that some exotic game animals in captivity do escape. Lanka et al. (1990) reported that 12 out of 16 U.S. states or Canadian provinces surveyed had documented cases of escapes of game animals. If escapes occur more or less frequently than is documented, the effects of escaped, captive cervids on free-ranging wildlife species, whether genetic, ecological or disease-related, also may be greater or lower than currently documented (Miller and Thorne, 1993). Cervid owners, however, have observed that escaped animals generally remain in the vicinity of the fence and attempt to reenter to rejoin the herd (L. Renecker, Renecker and Associates Inc., personal communication).

Wheaton et al. (1993) emphasized that fencing standards exist to minimize or eliminate cervid escapes. Lanka et al. (1990) and Kahn (1993) concluded that escapes will inevitably occur in the game farming industry. For example, Kahn (1993) reported that during the 1980s, the Colorado Division of Wildlife documented five populations of exotic wildlife occurring in the wild, all resulting from escapes from private facilities. As a result, stricter fencing regulations were enacted in Colorado in 1989 and went into effect in 1990. Even so, Kahn (1993) cited the Colorado Division of Wildlife as having documented "33 incidences of captive wildlife escaping or being released" from captivity since 1988, and half of these involved captive cervidae. Over 75 percent of these documented escapes occurred despite the adoption of uniform fencing regulations in 1990. During these escape incidents, 518 animals escaped from 1988 to 1992 and only 252 (49 percent) were recovered. Of the 173 elk and 40 red deer that escaped, 89 percent (154) and 20 percent (eight) were recaptured, respectively. Recovered animals were found as far as 144 kilometers from the facility of origin.

The Canadian Wildlife Federation (1992) documented another example of captive cervids escaping, despite control measures in which the escape could have affected free-ranging wildlife species. In this case, 91 red deer infected with tissue worm (*Elaphostrongylus cervi*) escaped while being shipped from New Brunswick to Ontario for slaughter. Conservation officers captured or killed all of them, but the deer could have dropped larvae into the environment before they were recovered, and it would be nearly impossible to determine if this had occurred or to determine if suitable intermediate or terminal hosts were present in the area occupied by the escaped deer. Whether the specifics of this case apply to Michigan conditions, it illustrates that infected animals can escape and pose a reasonable but unknown risk of infecting the wild population.

Lanka et al. (1990), in a review of the literature and a survey of exotic species, including cervidae, and game ranching of western states and provinces, documented incidences of escape from facilities in eight states and four Canadian provinces. Five of the states and all four of the provinces had fencing stipulations. Escapes were attributed to "poor fence maintenance", "inadequate fencing", "jumped over fence" or "crawled under fence".

There are primarily eight methods of escape for captive cervids documented in the literature (Bryant et al., 1993): poor fence maintenance; inadequate fence height; environmental factors such as floods, storms and fallen trees destroying or damaging fences; vandalism; animals destroying fences; animals crawling under fences; snow creating bridges; and poor fence construction.

Ingress of wildlife

The third area of concern about the effects of captive cervids on ecosystems is the ingress of native wildlife into licensed captive wildlife facilities. Kahn (1993) described "incidents of native wildlife entering licensed [captive wildlife] facilities." Between 1989 and 1992, the Colorado Division of Wildlife documented 32 incidents involving 317 wildlife animals (mule deer, elk, pronghorn antelope, bighorn sheep) entering captive wildlife facilities (Kahn, 1993). Of the 317 animals, 97 percent (308) were mule deer and elk. These incidents can pose a risk to the captive herd and represent a loss or taking of a public resource. For the captive herd, ingress by wild cervids can introduce disease or parasites. Additionally, a well-documented genetic history increases an animal's value. Ingress of wild cervids may negatively affect the genealogy of a captive herd. Ingress by predatory wildlife can pose a risk of animal mortality to the captive herd, and ingress by large animals such as bears and coyotes can damage perimeter fencing and lead to escape of captive animals. The movement of wild white-tailed deer and black bear into the white-tailed deer enclosure at the Cusino Wildlife Research Station in Michigan was described by J. Ozoga (Michigan Department of Natural Resources-Wildlife Bureau, personal correspondence to H. Campa III, 1987). Bryant et al. (1993) also documented black bear climbing over and crawling under their fence, as well as coyotes moving under the fence.

Movement of escaped wildlife

Because captive cervids have escaped, even from facilities with required fencing, a fourth issue of captive cervid management is the potential for animals to escape into adjacent areas where they are not wanted (urban and rural areas). In instances where this may occur, escaped animals may remain nearby , increasing the local density of cervids and potentially causing local ecological (e.g., herbivory), economic (e.g., crop damage complaints in orchards or row crops) and/or wildlife-human conflict (e.g., ungulate-vehicle accidents) problems. Davis (1985) concluded that fawns and calves born in enclosures are not likely to have the migratory nature of their parents. They also noted that this lack of migratory behavior may also make them less likely to escape.

Illegal Taking of Wildlife

The fifth topic is illegal taking of wildlife. As stated in a report by the Ontario Federation of Anglers and Hunters (1991:40): "Game farming and ranching has been argued to provide poachers with the golden opportunity to market illegal animals and parts through the convenience of a legal market — a means of increasing reward while reducing risks." Bunnage and Church (1991) commented that illegal taking might occur for three primary reasons: selling meat, live animal breeding stock and velvet antlers. These authors stated that in Alberta, it would be very difficult to harvest wild animals illegally for these products because game farm animals must carry registration tags that are read by government inspectors prior to slaughter, live animals on game farms must be identified with tamper-proof tags, and velvet antlers removed must carry a tag. Little information exists to document the existence or frequency of illegal harvest that occurs in association with captive cervid operations. By its nature, poaching is difficult to document (CWF, 1992), though state agencies have reported instances of wild cervids being taken into captive herds illegally in Colorado, Idaho and Oregon (Utah DWR, 1996).

In Canada, the Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act was developed to curtail this type of activity (Twiss et al., 1996). Further information is needed to determine whether this is a problem in Michigan and if enforcement is adequate to prevent it from becoming a significant problem. Additional studies are needed to ascertain the degree to which a legal and regulated farmed cervid industry reduces the demand for venison obtained by illegal hunting. Careful regulation that requires thorough record keeping and verification of animal acquisition and uses genetic and biochemical monitoring can help to offset any benefits that may tempt growers to take wild animals into their herds illegally (Renecker and Kozak, 1987).

Issues/concerns associated with the existence of facilities

The existence of facilities with high fences that restrict cervid movement also poses some ecological concerns, including issues related to migration routes or wintering areas and habitat loss. Research data are scarce, however, and documentation of the effects of high fences on habitat use and migration patterns of free-ranging wildlife is difficult to substantiate (from an informal survey by Shellenbarger, personal communication, 1999). Nonetheless, the fact that wildlife agencies in five other states — California, Minnesota, Texas, Utah and Wyoming — expressed concerns about the potential for negative ecological effects of high fenced enclosures indicates that more information is needed to determine if these effects are potentially important to Michigan wildlife.

High 3-meter, restrictive fences associated with game farms have the potential to disrupt migration patterns of free-ranging wildlife (Kahn, 1993). Because white-tailed deer traditionally use the same seasonal ranges (VanDeelan et al., 1998), a high fence may present a barrier to deer migration patterns. Nielson et al. (1997) demonstrated that a partial enclosure (319-hectare fenced area with five openings 10 to 50 meters wide) reduced overall male deer migration and delayed migration in some males. It is unknown whether the fence affected female migration. In Wyoming, courts ruled that fences constructed on private lands were restrictive to migrating antelope and had to be removed (Shellenbarger, 1999).

Because the area within game farms and ranches is unavailable to free-ranging cervids, these animals may be forced into a more crowded habitat (Canadian Wildlife Federation, 1992). The number, size and geographic distribution of the high fenced operations determine the amount of functional habitat lost through fencing (Shellenbarger, 1999). In addition, high fences have altered migratory behavior in white-tailed deer (Nielson et al., 1997). If migration is impeded or access to seasonal yards is restricted, deer may utilize areas throughout the year where they otherwise would not remain. Year-round herbivory in one area can lead to browse depletion and affect forest regeneration (VanDeelan et al., 1996). Ultimately, the number, size and location of facilities relative to migration patterns and seasonal yards will determine the degree to which high fences affect free-ranging cervids or potentially other wildlife species by restricting movement or decreasing the amount of functional habitat. However, the effects of such perturbations as fence building on wildlife demographics are not well documented in the scientific literature. Similar ecological conditions (i.e., blocking of migration routes and crowded wildlife) may also be created by other shifts in land use such as road construction and housing and business developments.

Health Management Issues

Properly managed wild and captive cervid populations are generally healthy and free from significant disease problems. They are, however, susceptible to a variety of infections and parasitic diseases (Miller and Thorne, 1993). For example, parasites, tuberculosis, brucellosis and Johne's disease have been found in wild cervid populations (Davidson et al., 1987; Tessaro, 1986; and Doster, 1998) (Appendix 6). When a wild population becomes infected with a significant disease agent (e.g., brucellosis in elk in Yellowstone National Park, tuberculosis in white-tailed deer in Michigan), it is difficult and costly to control, and it poses a threat to other wildlife and livestock.

Implications of disease prevalence or transmission in captive cervid herds are important because some diseases in cervids are difficult to diagnose and control (Appendix 6). Efforts to domesticate deer species have caused the emergence of diseases that are either uncommon or non-existent in wild deer in New Zealand, where deer are exotic and both captive and feral (Mackintosh, 1990). As with other livestock, many of these diseases arise because of crowded conditions within facilities, exposure of some species to new pathogens, and higher or increased levels of stress associated with crowded conditions, capture and shipment (Mackintosh, 1990; Hunter, 1996). Because interactions between captive or escaped cervids and free-ranging cervids offer the greatest potential avenue for introducing disease from affected facilities into native wildlife populations and for introducing disease from native wildlife into captive herds , it is important to minimize contact between captive and wild cervids (Miller and Thorne, 1993).

In 1993, Miller and Thorne noted: "To date, there has been no documented case where a novel disease has been transmitted from captive to free-ranging cervids in North America." Transmission of diseases between captive and free-ranging wildlife, however, has been documented. For example, in Montana, *Mycobacterium bovis* was cultured from a free-ranging coyote and a free-ranging mule deer collected near an *M. bovis*-infected captive elk herd where evidence suggested that coyotes had penetrated the fence surrounding the elk facility (Rhyan, 1995). Whipple et al. (1997) used genetic analysis to determine that the isolates from the coyote and the mule deer were indistinguishable from *M. bovis* isolated from the nearby captive elk facility. Though it was not stated which animal (i.e., free-ranging or captive) was the underlying cause of the spread of *M. bovis*, epidemiological evidence suggests that the captive elk (originally infected from domesticated livestock) were the source of the *M. bovis* that infected the free-ranging wildlife (Rhyan, 1995; Whipple et al., 1997). In addition, it is thought that coyotes in Michigan do not serve as reservoirs for tuberculosis (Bruning-Fann et al., 1998). Nevertheless, it is obvious that disease transmission has occurred between captive and free-ranging populations and from livestock to wildlife (D. Davis, Texas Veterinary Medical Center, personal communication). For example, bison in Wood Buffalo National Park in Canada carry brucellosis, anthrax and tuberculosis, and pose a threat of infection to livestock (including captive cervids) in the area (Broughton, 1992; Meyer and Meagher, 1995; Forbes and Tessaro, 1996; Canadian Food Inspection Agency, 1999).

The level at which diseases affect the cervid industry (i.e., local, national or international) depends on the nature of the disease and the degree to which it is perceived as a threat (Haigh and Hudson, 1993). For instance, a single case of foot rot may affect only one farm; tuberculosis, however, may affect the cervid industry at the local, statewide, the national or international levels (Haigh and Hudson, 1993). Some advocate that management of the industry must work to develop measures that decrease disease prevalence and, ultimately, reduce the cost at all levels (Alderink, 1985). Brown (1993) suggested that vaccination, careful testing, record keeping and health certification should be mandatory and rigorously enforced. Enforcement of identification, record keeping and regulation of translocation of animals helps to ensure success of programs that manage activities of captive cervid industries. Testing, however, is often unreliable, and pharmaceutical therapy for many diseases is currently ineffective (Appendix 6).

The North American Elk Breeders Association has aggressively pursued enhanced disease prevention, diagnosis and treatment as an industry policy. The current test used for detecting bovine tuberculosis in elk was developed shortly after bovine TB was documented in domestic elk herds in 1991. The NAEBA advocated establishing a TB program for elk with the USDA and was successful in 1994. The initial efforts led to identification and quarantine of more than 20 infected elk herds in the United States. These herds were either depopulated or went through a test-and-slaughter program until they were free from tuberculosis. Surveillance continues, and the prevalence of TB in captive cervids is now less than that in cattle. Furthermore, the cattle TB program was modified to more closely resemble the protocols used in the captive cervid program (S. Wolcott, NAEBA Animal Health Committee, personal communication, October 1999). The NAEBA also advocated establishing brucellosis in captive cervids as a USDA program disease, though it is not known to exist in captive herds.

The Elk Research Council, funded by the farmed elk industry, has funded the development of a blood test for Johne's disease in elk and a blood test for meningeal worm. Both were undergoing verification and projected to be available for herd screening within a year (S. Wolcott, personal communication, October 1999).

The Elk Research Council also has spent more than $130,000 in efforts to develop a live animal test for chronic wasting disease (CWD) in captive cervids and has advocated establishment of this as another USDA program disease.

Disease transmission via captive animals

The possibility of density-dependent disease transmission is greater among animals in captivity than in free-ranging wildlife for several reasons. First, because animals are held at higher than natural densities under an intense farming system (Hunter, 1996; Twiss et al., 1996), there is a greater possibility for animals to spread disease through direct contact. For example, close confinement contributes to the transmission of tuberculosis (*M. bovis*) and brucellosis (*Brucella abortus* and *B. suis*) (Tessaro, 1986). In addition, sick animals in an enclosed game farm have lower energy demands, experience less predation pressure and so may survive longer than a free-ranging animal with the same disease (Samuel et al., 1992). Therefore, there is an increased chance of disease transmission within enclosures (Hunter, 1996) than in the wild.

Tests for detecting some diseases in living game farm animals are unreliable (Kuttler, 1981; Haigh, 1989; Welch et al., 1991; Lanka et al., 1992; Hunter, 1996; and Burt, 1998; Zebarth, 1998). Regulations for disease testing have failed to prevent shipment of diseased animals, even though the animals had been certified as disease-free (Lanka et al., 1992). Similar problems occur with traditional livestock. For example, cervids brought into New Zealand game farms introduced muscle worm, nasal bot and warble fly into the country (Massey, 1987) and cattle introduced tuberculosis and brucellosis to the country. Similarly, Montana elk infected with tuberculosis were found on an Alberta farm in 1990 (CWF, 1992). In Colorado, two game ranches tested positive for tuberculosis as a result of transport of animals from herds in which *M. bovis* infections had been confirmed (Miller and Thorne, 1993). Another tuberculosis infection was imported in elk from Nebraska that had tested negative for the disease (Miller and Thorne, 1993). In this case, the caudal fold test had been used, and this is now known to be unreliable in cervid species. If the appropriate test had been used (i.e., cervical skin test), perhaps this disease transmission could have been prevented. Further improvements are needed to increase the reliability of disease testing in cervid species, and the industry has been investing in new techniques to address this need (S. Wolcott, personal communication; L. Renecker, personal communication).

Animals that show no sign of disease when tested may develop clinical diseases after stress (Beatson, 1985; Mackintosh and Henderson, 1985; Aiello and Mays, 1998), particularly after capture (DeNicola and Swihart, 1997), transport (Waas et al., 1997), handling, social stress at high densities, climatic stress and nutritional stress (Mackintosh and Beatson, 1985). These stresses make farmed animals more susceptible to diseases (Mackintosh and Beatson, 1985). For example, a disease that has caused mortality of animals in stressful situations is malignant catarrhal fever (MCF). MCF caused deaths of red deer on 12 of 34 (35 percent) of the intensively farmed properties in New Zealand but only one of the 11 (9 percent) extensive properties (Beatson, 1985). Beatson's (1985) data suggest that MCF is a disease of intensification, and farmed deer may develop clinical signs after episodes of severe stress (Aiello and Mays, 1998).

MCF is just one example of disease that could affect cervids if they were to be exposed to it (Haigh, 1989; Fritz et al., 1992). White-tailed deer are particularly susceptible to this disease (Haigh, 1989) and contract it from exposure to asymptomatic but infected sheep or certain exotic antelope (subfamily Alcelaphanae — wildebeest). There is no evidence of MCF being transmitted to white-tailed deer from other deer. Though farmed deer are most likely to be exposed to MCF by comingling with infected and asymptomatic domestic sheep, it is also possible for them to be exposed to MCF by comingling with infected and asymptomatic exotic antelope — for example, during auction or shipping when many stressed hoofstock are comingled for handling and shipping through a common facility. Stress increases the susceptibility of deer to this pathogen (Haigh, 1989).

Species and even individuals vary in response to animal diseases. For example, white-tailed deer in Texas appear to be resistant to MCF (D. Davis, Texas A&M University, personal communication, October 1999). In addition, little is known about the epidemiology of many diseases in different wildlife species that may become hosts or reservoirs. Potential exposure to exotic foreign animal diseases or parasites is greater for farmed deer with contact through the fence or escape being a realistic source of exposure to free-ranging cervidae. This potential exists with other livestock, but the ability to diagnose these diseases by observation of clinical signs and testing is more likely in domestic livestock. Furthermore, methods for treatment and facilities for handling are much more common for cattle and other domestic livestock. Recent improvements in the captive cervid industry are closing the gap on disease testing and treatment to the extent that testing of certain diseases (tuberculosis and brucellosis) is more common in domestic elk herds than in cattle herds nationwide, and methods for treatment have been developed for captive cervid species (S. Wolcott, NAEBA Animal Health Committee chairman, personal communication, October 1999). In some areas, appropriate handling facilities are more common for domestic elk herds than for cattle herds. Finally, escaped cattle are easily distinguished from native wildlife, but distinguishing escaped cervids from free-ranging cervids of the same species is much more difficult. Escaped animals that are infected with a disease may serve as vectors or carriers of infectious agents.

Furthermore, in the United States, there are no USDA-licensed biologics for use in deer or elk (Dr. Morgan, USDA-APHIS, Veterinary Biologics, personal correspondence, 1999).

Finally, the quarantine period may not be long enough to guarantee that all infected animals are identified prior to translocation (CWF, 1992). In Michigan, for instance, the Animal Industry Act of 1987 (MDA, 1995) states: "Captive cervidae 6 months of age or older, except those consigned directly to a state or federally inspected slaughter facility premises, imported into this state shall test negative to an official test for brucellosis within 30 days before importation." Animals that test negative for brucellosis may, however, have a latent infection that may become evident at first calving (Currier, 1995). Brucella organisms can also survive for 3 to 4 months in the environment under favorable conditions (Currier, 1995). A documented case of this occurred in Colorado after a farmer purchased 20 cattle from a South Dakota livestock market. These animals tested negative for brucellosis 30 days prior to purchase. One year later, the infection showed up in his cattle and, after being exposed to aborted fetuses, the farmer also became sick with brucellosis (Currier, 1995).

Other diseases have long incubation periods, and infected animals may not be identified prior to translocation. For example, eggs of the giant liver fluke (*Fascioloides magna*) would not be detectable in feces of infected animals (either cervids or bovids) during the prepatent period, which may be as long as 30 to 32 weeks (Haigh, 1991). In addition, the long incubation period for malignant catarrhal fever, 3 weeks to 6 months, may result in exposure of susceptible animals to this disease (Fritz et al., 1992; Aiello and Mays, 1998). Data indicate that chronic wasting disease (spongiform encephalopathy) also has a long incubation period, up to 22 months (Fraser et al., 1991).

Some diseases already known to occur in cervids that may be transmitted between captive and wild populations in either direction include the following: anaplasmosis (*Anaplasma marginale*), brucellosis (*Brucella abortus*), chronic wasting disease (*spongiform encephalopathy*), epizootic hemorrhagic disease/blue tongue (hemorrhagic disease of deer), giant liver fluke (*Fascioloides magna*), Johne's disease (*Mycobacterium paratuberculosis*), malignant catarrhal fever, meningeal worm (*Parelaphostrongylus tenius*) and bovine tuberculosis (*Mycobacterium bovis*) (Mackintosh, 1990; Lanka et al., 1992; Wheaton et al., 1993) (Appendix 6).

Disease transmission via free-ranging wildlife

Free-ranging wildlife can also potentially transmit diseases to captive animals if they share the same environment (Mackintosh and Beatson, 1985). For example, white-tailed deer in eastern North America carry meningeal worm without having clinical signs. The parasite can cycle through the slug or snail intermediate host and back into the white-tailed deer, causing little damage to the deer (Haigh, 1989; Samuel et al., 1992). Western white-tailed deer currently do not carry this parasite, but it could potentially be translocated to western areas. To date, no occurrences have been documented from western states or provinces (D. Davis, Texas A&M University, personal communication, October 1999). In addition, meningeal worm can be fatal to most species of cervids, including elk, caribou, moose and many bovids, including bighorn sheep, mountain goats, antelope and many exotics (Samuel et al., 1992). There were no definitive tests to detect the presence of this parasite in live animals (Kocan, 1985) until recently. A new method developed by the Elk Research Council was expected to become commercially available in 2000 (S. Wolcott, NAEBA Animal Health Committee Chairman, personal communication, October 1999). Treatment with IvermectinTM very early in the infection is effective against third-stage larvae, but after the 10th day of infection, treatment is ineffective (Haigh, 1989). If the parasite is translocated into an enclosure by an infected deer or via a slug or snail and consumed by a susceptible animal (Appendix 6), meningeal worm could spread within the captive population and result in infection or fatality of several animals. Also, in the northeastern Lower Peninsula of Michigan where tuberculosis exists in free-ranging white-tailed deer, captive white-tailed deer may be at higher risk than other livestock for contracting tuberculosis from the wild deer because of social contact at the fence or ingress and egress (USDA, 1996).

Transmission routes

Possible disease transmission routes in either direction between captive cervids and free-ranging wildlife include the following: social contact at a fence, ingress and egress of free-ranging wildlife, environmental contamination of pathogens (i.e., through feces or aerosols), snail or slug intermediate hosts, invertebrate vectors (ticks, flies, mosquitoes) or escape of infected individuals from facilities (Mackintosh and Beatson, 1985; Miller and Thorne, 1993). Small wild mammal populations may also contribute to the spread of diseases in either direction between captive and free-ranging populations. In New Zealand, for example, the brush-tailed possum is a reservoir for *M. bovis* (Bruning-Fann et al., 1998). In Montana, a coyote caught in the vicinity of a tuberculosis-infected deer farm tested positive for *M. bovis* (Rhyan 1995). Coyote, raccoon, bobcat, red fox and bear in northeast Michigan (Deer Management Unit 452) also have been documented to test positive for *M. bovis* (Bruning-Fann et al., 1998, and Bruning-Fann et al., [in press]). Whether these were infected from contact with infected wild or captive cervids cannot be determined, but these cases demonstrate that the disease can be transmitted between species. No evidence exists to indicate whether these non-cervid species may serve as vectors of this disease, but this possibility must be considered seriously and evaluated. Though domesticated livestock such as cattle and swine can also contract disease through invertebrate vectors and other infected wildlife, diseases are more easily and accurately diagnosed and treated in cattle and swine than in cervids. Subsequently, the possibility of the establishment of diseases in cervid populations because of the difficulty of diagnosis, the possibility of latent infections and the unreliability of tests may complicate disease eradication strategies within the state.

Social Issues

Potential benefits

Economic benefits

Many of the potential benefits that could be provided by a captive cervid industry in Michigan are economic. These are only briefly mentioned here and are detailed in a special section on economic considerations (see economics section). Game farming has been proposed as diversification of traditional livestock operations that are experiencing a decline in returns (OFAH, 1991; Ruark, 1993; Von Kercherinck zar Borg, 1998). Production of venison from North American herds occurs during a season when production from the large New Zealand industry is low. Subsequently, North America may be able to fill a market niche supplying fresh venison to Europe when other producers are not able to meet the demand (Twiss et al., 1996; Hobart, 1998). Game farming and ranching also may offer opportunities for landowners to realize profit from lands considered marginal for other types of agriculture (Twiss et al., 1996).

Recreational benefits

The opportunity to participate in game farming may provide recreational value to participating landowners. A majority of respondents to a 1994 survey of Michigan captive cervid operators indicated that they kept cervids primarily for fun (55.2 percent, n = 220) (Shank and Bruning-Fann, 1993).

Viewing recreation is provided to members of the public who enjoy seeing these species in captivity. Nationally, some game farms on privately owned land annually receive hundreds of visitors (school children, elderly, families, interested citizens) who want to see elk and deer and have greater access to game animals in enclosures than in the wild (Bunnage and Church, 1991).

Some forms of game ranching offer recreational shooting for a fee (Schneider, 1990; Twiss et al., 1996). Often an added attraction is the ease of access to or the trophy quality of harvested animals. In Michigan, harvesting of captive cervids is not restricted by the same regulations that apply to hunting of free-ranging deer and elk (permits, season, etc.). For legal and other reasons to be discussed in the section on societal costs and risk, harvesting game animals in enclosures is differentiated from recreational hunting of free-ranging wildlife. Participation in game ranch recreation involves expenses beyond those associated with recreational hunting on publicly owned lands during the legal hunting seasons (Schneider, 1990; Geist, 1994; Twiss et al., 1996). Examples of the fees involved are provided in the economics section.

Public health benefits

Consumption of game ranch venison could provide health benefits. Some studies report that meat of free-ranging wild cervids is lower in fat and cholesterol than beef, pork, lamb or poultry (Twiss et al., 1996). For example, meat from free-ranging elk has one seventh the fat of lean roast beef, one third the fat of salmon, and one half the fat of chicken breast without the skin (Wolcott, 1999). Publicizing these potential benefits has increased demand for venison in Europe (Saskatchewan Agriculture and Food, 1993; Hobart, 1998). Producers also claim that their venison products are "natural and chemical free," which also increases appeal and could provide health benefits (Saskatchewan Agriculture and Food, 1993). However, no system is currently in place to certify which venison products meet this standard. A meat inspection program has been established by USDA APHIS VS that is equivalent to inspection programs for other livestock, but this does not address the "chemical-free" standard. Industry efforts to standardize testing and implement quality assurance and grading protocols would help to increase the reliability of these claims and are proposed or being developed within the industry (L. Renecker, personal communication, October 1999).

One product of game ranching is velvet antler, which has been used for more than 2000 years as a major animal ingredient in traditional Chinese medicines (Wolcott, 1999). The wide range of health benefits claimed to be provided by velvet antler have not been established through scientific research. These include increased energy and mental alertness, increased stamina, decreased cholesterol levels (Sim and Sunwoo, 1999), and anti-inflammatory effects (Zhang et al., 1994;

Sim and Sunwoo, 1999) for treatment of arthritis. In addition, it is used as an aphrodisiac and used in combination with herbs to strengthen bones and tendons, fortify the stomach, nourish the blood and disperse swelling (Burgio, undated). One product from velvet antler (Vital-Ex) is combined with ginseng and other herbal ingredients and sold worldwide as a means of decreasing stiffness and joint pain, offsetting loss of bone, enhancing athletic performance and slowing aging processes (http://www.vital-ex.com/basics.htm). The NAEBA and other industry organizations are involved in current studies intended to evaluate these claims objectively.

Potential societal costs and risks

The existence of any major land use activity presents some actual costs and/or risks to individuals beyond the immediate landowner and to society. Game ranching is no exception. For example, reliable methods for disease testing, prevention and treatment are not as widely available for captive cervids as they are for species such as cattle, which have been domesticated for centuries, though the captive cervid industry is developing new procedures (see health management section). For these and other reasons, raising wild cervids in captivity poses potential disease problems that are unique to this industry, and this unique risk is associated with potential costs to society, either in the form of infecting the free-ranging herds of cervids or in the form of increased monitoring and eradication programs funded by state and federal tax revenues. The expense associated with the occurrence and spread of bovine TB in the free-ranging white-tailed deer herd of Michigan has been enormous. Though likely the outbreak did not originate from a captive cervid herd, this experience points out the need for vigilance in disease testing, prevention and treatment in domesticated livestock as well. Other unique risks presented to free-ranging wildlife by captive cervids are discussed elsewhere in this document, and include the potential for genetic mixing between captive and free-ranging cervids and impairment of wildlife movements and access to habitat.

Risks such as these have potential social as well as economic consequences. Important social values include the values placed on healthy and natural ecosystems, well-being of free-ranging wildlife populations and recreational opportunities. Deer hunting is an important form of recreation for more than 700,000 deer hunters in the state. Wildlife viewing, including viewing of wild cervids, is an integral part of outdoor recreation in the state and it depends on healthy and adequate population sizes. The outbreak of bovine TB among wild deer in the northeastern lower peninsula of Michigan has demonstrated the costs in human resources, recreational opportunity and conflict that can be associated with risks to the wild deer herd. Though there is no evidence linking this problem to captive cervid agriculture, similar effects could result from an accidental escape of captive cervids that carry this or other diseases.

Conservative estimates of the economic benefits of recreational deer hunting in Michigan, representing the amount of money spent by hunters for hunting supplies and trip expenses, are more than $400 million per year (U.S. Dept. of the Interior, Fish and Wildlife Service, and U.S. Dept. of Commerce, Bureau of the Census, 1998). These economic benefits could be affected by risks such as those posed by the captive cervid industry for wildlife health, wildlife habitat or public acceptance of recreational hunting.

Issues: game ranching vs. wildlife as a common property resource

Game ranching has been criticized because it defies traditional conservation values and policies that have allowed wildlife to flourish (CWF, 1992). For example, Michigan's recent policy to allow landowners to compensate the state when they enclose free-ranging deer transferred wildlife ownership from all citizens to individual landowners and encroached on public ownership of that wildlife. Other objections to game ranching are raised by those who believe wildlife has an intrinsic right to live in its natural setting (Schneider, 1990; Hobart, 1998) and by those who value the undisturbed quality of wilderness (Hobart, 1998).

Strong views are held on both sides of the issue of private ownership of wildlife. Private ownership of wildlife is currently permitted under Michigan law and has been for some time. Yet, little information is available on public attitudes about private ownership of wildlife. Wildlife traditionally is public property and accessible to all (Posewitz, 1994; Twiss et al., 1996). In the United States, wildlife has traditionally been a common property resource (Lueck, 1998). One of the dilemmas of wildlife management in the United States is that much of the habitat occupied by this public resource is privately owned land. Thus managers have been challenged to enlist the efforts of private landowners in enhancing habitat for a public good. In addition, managers depend on individual hunters to help control expanding populations. Private ownership of wildlife on private property changes the fundamental basis of this tradition, which some view as an undesirable outcome (Geist, 1994; Schneider, 1990) and others view as a desirable trend for the future (C. Stefanko, Michigan elk farmer, personal communication). Wildlife policies based upon public ownership of wildlife have conserved wildlife species and created a successful, economically productive system of wildlife conservation (Geist, 1989). The money spent by people who hunt or fish in North America provides the primary source of funds for wildlife agencies to conduct wildlife management (Geist, 1994). It has been argued that traditional mechanisms for protecting and conserving wildlife cannot be effectively practiced when those same species can be held under private ownership and subjected to global markets for the purpose of creating wealth and employment (Geist, 1994). For example, it is likely to be more difficult to protect free-ranging elk calves from being stolen and marketed when the opportunity exists to integrate the calves into a legally owned herd. Brown's (1993) argument that there is no evidence that such illegal activity would occur as a result of captive cervid ranches/farms is disproven by documented cases (Utah DWR, 1996).

Little research exists on the Michigan public's views on private ownership of wildlife. This information would be beneficial in evaluating and promulgating public policy and law regarding captive cervid agriculture.

Issues: impact of game ranches on public attitudes

The recreational harvest of enclosed game animals was differentiated from recreational hunting of free-ranging wildlife earlier in this report. Game ranches provide unique shooting and recreational viewing opportunities, including an extended season for taking animals as well as accessibility for some who may benefit from facilities for disabled clients. Some opponents argue that these opportunities are fundamentally different from and do not substitute for current hunting recreation of free-ranging wildlife (Geist, 1989; Schneider, 1990).

Recreational hunting on lands adjacent to large captive cervid operations may be affected by limitations to the movement of free-ranging deer around the enclosed properties. Adjacent landowners also may lose esthetic and perhaps resale values of their property as well. These would be local effects, and the effects over time on both wildlife movement and land use values of adjacent properties are undocumented.

Differences between hunting free-ranging wildlife and harvesting in captive facilities may also affect public perceptions of recreational hunting. Recreational game facilities range in size from a few to thousands of acres. The size of the facility directly affects the ability of the enclosed animals to avoid hunters and may influence public perceptions of whether the hunt gives the animal a fair opportunity to escape from being shot (fair chase). The term "canned hunt" has been used to describe shooting of animals in small enclosures (Wrage, 1997). In a review of the failed federal Captive Exotic Animal Protection Act of 1995, Wrage (1997) discussed the need to clearly differentiate between the "canned hunt" and game ranch concepts. He proposed that a large facility (e.g., greater than 3,000 acres) simulates hunting of free-ranging animals and does not produce a 100 percent certainty of killing a particular animal (e.g., a trophy bull elk or white-tailed deer). However, customers expect and are given a much higher probability of success than is normally achieved during recreational hunting of free-ranging wildlife. The ability of the public to differentiate among various forms of hunting has been questioned (Peyton, 1998; Wrage, 1997). They may fail to distinguish clearly between the "canned hunts" in small enclosures, harvesting animals for a fee in large facilities which simulate hunting conditions and hunting of free-ranging wildlife.

More information is needed to determine how public perceptions of hunting are likely to be affected by increased numbers of captive cervid facilities that provide shooting opportunities and to determine how game ranches can avoid potentially costly negative public opinion. These information needs have public policy implications as well. Questions of fair chase have been the focus of a number of ballot initiatives in Michigan and elsewhere over the past decade (Posewitz, 1994). Any activity that escalates public concern over killing of animals or creates negative images of hunters may carry over to recreational hunting of free-ranging wildlife and its use as a means of wildlife population management.

The public's attitude toward hunting has been subjected to considerable research. Only 13.5 percent of respondents to a Michigan survey opposed all forms of hunting (Peyton and Grise, 1995). Duda and Young (1996) reported similar results in a national study. Yet the strength of approval varies with the motivation for hunting. Kellert found in 1979 that 80 percent of a U.S. national sample disapproved of hunting only for a trophy, such as horns or a mounted animal. Sixty-four percent, however, approved of hunting for recreational purposes if this hunting also included utilizing the animal. Such findings that the public believes hunting should be related to some practical use (for food) and not merely for the entertainment value (for trophy or recreation) further suggest that captive cervid operations offering opportunities to harvest trophy-sized animals, for example, may encounter opposition from the non-hunting public (Lanka et al., 1990), yet no definitive studies have evaluated this potential.

The issues associated with these enclosed game facilities could have serious implications for the future of hunting free-ranging wildlife. Given the role of recreational hunting in wildlife management, the state wildlife agency should have a strong interest in how such facilities are regulated. Some states, such as Minnesota and Oregon, do not allow any recreational harvest of enclosed wildlife. Others allow the recreational harvest of enclosed game but place a minimum size requirement on the enclosures (e.g., Louisiana requires at least 300 acres in size). In contrast, however, Texas is moving toward privatization of wildlife. Texas recently passed two legislative initiatives that gave landowners the right to ownership of animals behind their high fences and the right to capture animals from the wild and incorporate them into the captive herds (C. Adams, Department of Wildlife and Fisheries Sciences, Texas A&M University, personal communication, October 1999).

Issues: animal welfare

Animal welfare concerns will also have an increasing impact on the future of the game farming industry (Haigh, 1995). The public generally expects that the utilization of animals for human gain carries with it an obligation to have proper regard for their well-being (Pollard et al., 1992; Waas et al., 1997). A number of specific concerns have been expressed, but many are not unique to captive cervids and may occur with domesticated livestock, such as the use of ear tags in all livestock for identification purposes (Johnston and Edwards, 1996). To the extent that these concerns affect all animal agriculture, they also apply to captive cervid agriculture. However, other animal welfare concerns are unique to captive cervid agriculture and merit further discussion here. In general, these relate to the higher level of stress associated with captivity and handling for wild species than for domesticated species. Proper herd management practices can minimize the level of stress and the effects of stress on captive wild cervidae.

Some of the most serious challenges to the welfare of captive wildlife species may occur when an animal is being transported. In red deer, heart rate and concentrations of cortisol, lactate and sodium (all common measures of stress levels) increase during transport to a greater extent than they do in domesticated livestock (Waas et al., 1997).

Stress during velvet antler removal has been targeted as a concern by some welfare groups. It is essential that regional blocks be administered properly, especially with respect to their relatively thicker sheaths, to adequately block sensation in the larger nerves in the antler during velvet removal (Haigh, 1995). A ring block around the base of the pedicle is recommended for humane reasons (Haigh, 1995). Pollard et al. (1992) collected heart rate data that indicated that velvet antler removal was aversive to bulls, despite administration of local anesthesia. The heart rate was higher during the second antler removal, which occurred on a different day. Both rates were higher than the control (Pollard et al., 1992). Post-treatment behavior demonstrated that antler removal continued to affect bulls for several hours (Pollard et al., 1992). A pilot study in 1998 evaluated the efficacy of several analgesics on the stress response in cervids during velvet antler removal (N. Cook, Agriculture-Canada Lacombe Laboratory, personal communication, June 2000). Researchers used electrical analgesia, lidocaine and an organic treatment, and measured stress response by cortisol levels and infrared thermography. They found evidence that these analgesics may reduce stress. More thorough tests were to be completed in 2000.

Fletcher (1984) suggested that deer farming may actually reduce the amount of suffering that naturally occurs in the wild. He notes that young animals in captivity do not have to endure slow deaths by predation nor suffer from exposure and starvation in the winter. Also, injuries inflicted by rutting stags, which occur in the wild, can be prevented on game farms.

Properly managed deer farms can potentially provide four of the five basic freedoms that form the basis of animal welfare in Great Britain (no similar criteria exist for farming operations in the United States) and that are absent in the wild (Fletcher, 1984). The first of these freedoms is freedom from malnutrition. As is true with farming of domesticated species, game farmers must assume responsibility for providing adequate nutrition for the animals, since movements are restricted with fences (Haigh and Hudson, 1993).

The second freedom is freedom from thermal or physical discomfort. In the wild, deer appear resistant to summer heat and winter cold. In captivity, however, natural barriers to temperature fluctuation (i.e., thick vegetation for cover, shade or windbreaks) may not exist (Haigh and Hudson, 1993). Farmers must pay special attention to these needs to provide for them (Haigh and Hudson, 1993).

A third freedom is freedom from injury or disease, which has been more difficult to achieve with captive cervids than with traditional livestock. Design of handling facilities is important to decrease the risk of injury because deer can become caught in fences (Haigh and Hudson, 1993). In a 1996 survey of game farms in Michigan, injury accounted for 32.1 percent of all illness and 27.1 percent of all deaths. Injury and stress from handling and transport accounted for nearly 50 percent of all deaths observed in captive cervids (Bruning-Fann et al., 1997). More recent data are not available, but improvements in restraint systems are likely to reduce these causes of injury and stress. Michigan game farms in the survey consisted of white-tailed deer, elk, fallow deer, sika deer, red deer, axis deer, reindeer and caribou (Bruning-Fann et al., 1997). In the same survey, nearly one third of farms did not have a veterinarian to provide professional advice (Bruning-Fann et al., 1997). This study did not provide comparative data on farms with domesticated livestock. It is doubtful that one third of dairy or swine farms lack a veterinarian for professional consultation. It is likely that fewer veterinarians have familiarity and expertise with the health management needs of captive cervidae, and this may limit the ability of captive cervid farmers to provide optimal conditions for their livestock.

The fourth freedom — to express normal patterns of behavior — is also difficult to guarantee with captive cervids. Commercial farms may not allow natural social groupings to form; forced weaning may replace natural, gradual weaning; and normal battles between hard-antlered bulls are prevented (Haigh and Hudson, 1993).

Fletcher (1984) noted that the most problematic freedom to provide for captive wildlife is freedom from fear. Fear is an important source of physiological stress (Haigh and Hudson, 1993). Though captivity may reduce the frequency of contact between captive cervids and their natural predators, it also increases the frequency of contact with humans and limits the ability of the animals to escape from their perceived sources of fear.

Information Needs for Effective Management of Captive Cervidae

This review has identified needs for information that will assist policy-makers, regulators and decision makers as they develop policies, regulations and laws concerning the captive cervid industry in Michigan.

Effective regulation

The diversity of regulations and policies among states suggests that there would be some benefit to a thorough study of the differences in regulation of captive cervid agriculture between states. For example, an informal review conducted by the North American Deer Farmers Association in 1997 (unpublished) found that, in six states, captive cervid agriculture was regulated by the state wildlife agency. The state agriculture department had jurisdiction over captive cervidae in 20 states, and both agencies had regulatory responsibilities in 21 states. Jurisdiction was not determined for the remaining states. In 16 states, laws did not restrict which species of cervidae could be raised, but restrictions varied for other states. Even this informal survey suggests that most state regulations are not consistent or comprehensive, in spite of the recent growth in captive cervid enterprises. A more thorough and accurate survey of states on the status of regulations for captive species would be useful to evaluate the regulatory options and their impact on the industry as well as protection of public resources. It would also be helpful to document the various methods used to finance the regulatory system in other states and provinces.

Monitoring and enforcement

Data on the number and value of captive cervids raised and marketed in Michigan have been collected during only one year. These data were collected by the Michigan Agricultural Statistics Service for the Michigan Department of Agriculture in response to the current crisis involving bovine tuberculosis in cattle and wild and captive cervidae in the state. Given the importance of bovine tuberculosis and the potential risks identified in this review, these data should be monitored regularly. The system for collecting and handling this information is similar to that used for other livestock species.

Captive cervids present unique risks to the well-being of wildlife and agricultural livestock. It is important that movements of captive cervids within Michigan and between states continue to be recorded and monitored as they are currently. Feldhamer and Armstrong (1993) reported that the "lack of regulations" regarding transport of cervids increases the risk of transmitting diseases. Current regulations require that captive cervid owners in Michigan report the sale or purchase and transport of any white-tailed deer or elk, along with testing for brucellosis and bovine tuberculosis (Appendix 1). Rigorous record keeping and monitoring such as this help to minimize the risks of disease transmission and also provide important information that would be needed if a disease outbreak or other crisis occurred. These records also assist in monitoring escapes and evaluating risks posed by escape situations, help to reduce the opportunity for capturing free-ranging wildlife and integrating it into captive cervid operations, and facilitate improvements in quality control of animal products.

Currently, the MDNR requires captive cervid operators to make periodic reports on animals in captivity (births, sales, etc.). These are not routinely processed and monitored, because no funds are appropriated to the MDNR for that function and resources are limited. In addition, captive cervid operators who sell animals from their herds are required to have veterinarians test their herds for bovine tuberculosis and submit results to the MDA (Appendix 1). Better coordination of these record-keeping requirements and more direct interagency access to these records would help to reduce the confusion and frustration experienced by operators.

Health management

The disease transmission risks to agriculture and wildlife posed by captive cervids are still poorly understood. If the industry is to grow and prosper in Michigan, operators will need access to better diagnostic tests, better health management program and more expertise in the unique health management issues of captive cervid agriculture. In particular, a more responsive system is needed for educating veterinarians about the newest and most reliable health management practices for captive cervids. More research is needed to develop more reliable diagnostic tests and treatments for captive cervid diseases and to identify best management practices that can be implemented to enhance the health of captive cervids.

This report has documented potential risks of disease transmission associated with the captive cervid industry. Little information is available to evaluate the magnitude of these risks or the costs associated with either managing the risks or responding to their consequences. Further information is needed on the magnitude of these risks at all levels, including individual captive herds, the industry as a whole, health of publicly owned wild herds and human health (Haigh and Hudson, 1993; Lanka et al., 1992; Miller and Thorne, 1993). Further analysis is needed to assess the potential costs of these risks as well, including costs to captive cervid farmers, farmers with other livestock, communities and the people of the state of Michigan.

For example, humans can contract tuberculosis and brucellosis from coming in contact with infected animals or inhaling aerosol particles (Currier, 1995; Fanning and Edwards, 1991). Currently, the potential risk of humans contracting tuberculosis from free-ranging white-tailed deer in Michigan, as assessed by scientists, is low (USDA, 1996). In addition, the risk to humans is primarily related to occupational or recreational exposure (i.e., hunters, guides, taxidermists, abattoir workers, and laboratory or veterinary personnel, USDA, 1996). Cattle farmers or others who may come in contact with infected animals may perceive risk of tuberculosis transmission to livestock or humans differently than experts (Slovik, 1987).

Fencing standards and enforcement

The potential for escape of captive cervids, ingress by wild cervids into captive cervid herds or interaction between captive and wild cervids through the fences poses risks to both captive and wild herds. Other than height restrictions and a recent requirement (April 1999) to use woven wire fencing, few standards exist to regulate design, installation or maintenance of enclosures to minimize opportunities for escape. A clear need exists for a more thorough study of fence designs that will minimize contact between wild and captive cervids as well as a review of the regulations on fencing and confinement.

A system is needed that would document and quantify instances of cervid escapes from captive herds as well as ingress of wild cervids into captive facilities. A determination of the conditions that lead to escapes or ingress could help to minimize potential risks to wild or captive herds in the future.

Animal welfare

This report identified a number of potential animal welfare issues. It may be prudent to review animal welfare considerations to determine whether the current regulations are adequate for captive cervids and to evaluate enforcement of animal welfare regulations.

Regulation of recreational shooting on game ranches

Few regulations exist regarding the taking (harvest) of exotic or native species inside fenced facilities. The potential for issues and implications for recreational hunting might be reduced by a review to determine regulation and enforcement needs.

Criteria for evaluating proposed facilities

All applications for permits to establish game farming/ranching enclosures currently must be approved except for those in the region affected by the bovine tuberculosis outbreak. A number of potential issues and problems have been identified to suggest that not all proposals may be appropriate. Fences designed to contain cervids safely also inhibit movement of wild cervids to a much greater extent than fences designed for traditional livestock such as cattle. Placement of fences may have impacts on free-ranging wildlife such as blocking winter and spring migration routes of white-tailed deer. Fences may have an impact on adjacent landowners. Enclosures may not be of appropriate sizes to accommodate intended uses (e.g., recreational shooting). These land use decisions should be carefully considered. Current law does not allow for a process by which agencies may evaluate and approve or disapprove applications for captive cervid operations on the basis of the risks and benefits associated with each permit application. A study of these issues would help to inform the regulatory process so as to minimize conflicts as well as protect the rights of private landowners and the public.

Status of exotic species

The focus of this paper has been on captive white-tailed deer and elk, both of which exist as free-ranging species in the state. Similar, if not greater, risks and challenges are posed by the presence of other captive species of cervids as well as other hoofstock. It appears timely to consider policies, regulation and enforcement needs for exotic species during this current review process to minimize the opportunities for negative impacts in Michigan and to ensure a healthy and productive agricultural industry based on all cervid species.

References

Adelaja, A.O., and B.J. Schilling. 1999. Nutraceuticals: blurring the line between food and drugs in the twenty-first century. Choices: the Magazine of Food, Farm and Resource Issues, 4th quarter: 35-39.

Alberta Agriculture, Food and Rural Development. 1997. Commercial elk industry. (www.agric.gov.ab.ca/agdex/400/481_830-1.html).

Alberta Agriculture, Food and Rural Development. 1998. Preliminary market study of alternative livestock meats and other value-added products in domestic and international markets. (www.agric.gov.ab.ca/trade/market_research/livestock.html).

Abernathy, K. 1994. The establishment of a hybrid zone between red and sika deer (genus Cervus). Molec. Ecol. 3: 551-562.

Aiello, S.E., and A. Mays (eds.). 1998. The Merck veterinary manual (eighth ed.). Whitehouse Station, N.J.: Merck & Co., Inc.

Alderink, F.J. 1985. The National Animal Disease Surveillance Program: determining the cost of livestock disease. J. Vet. Med. Educ. 11: 109-110.

Anderson, R.C., and O.L. Loucks. 1979. White-tailed deer (Odocoileus virginianus) influence on structure and composition of Tsuga canadensis forests. J. Appl. Ecology 16: 855-861.

Avise, J.C., and J.L. Hamrick (eds.). 1996. Conservation genetics: case histories from nature. New York: Chapman and Hall.

Baier, B., and D. Kaliel. 1992. A consensus of costs and returns in north central Alberta. Alberta Agriculture, Food and Rural Development Report No. 281.

Batie, S.S., M. Schulz and D.B. Schweikhardt. 1998. Meet your new boss: the consumer. Michigan Farm News, June 15.

Beatson, N.S. 1985. Field observations of malignant catarrhal fever in red deer in New Zealand. Pages 135-138 in P.F. Fennessy and K.R. Drew (eds.), The biology of deer production. Bull. 22. Wellington, New Zealand: the Royal Soc.

Brown, R.D. 1993. Good fences make good neighbors — the industry perspective. North American Elk. Summer: 14-15.

Bruning-Fann, C.S., S.M. Schmitt, S.D. Fitzgerald, J.B. Payeur, D.L. Whipple, T.M. Cooley, T. Carlson and P. Friedrich. 1998. Mycobacterium bovis in coyotes from Michigan. J. Wildl. Dis. 34: 632-636.

Bruning-Fann, C.S., K.L. Shank and J.B. Kaneene. 1997. Descriptive epidemiology of captive cervid herds in Michigan. U.S.A. Vet. Res. 28: 295-302.

Broughton, E. 1992. Anthrax in bison in Wood Buffalo National Park. Canadian Veterinary Journal 33:134-135.

Bryant, L.D., J.W. Thomas and M.M. Rowland. 1993. Techniques to construct New Zealand elk-proof fence. General Technical Report PNW-GTR-313. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Buckpole Archery and Deer Ranch. 1999. White-tailed deer hunting (www.buckpole.com).

Bunnage, R.J., and T.L. Church. 1991. Is game farming really that bad? Can. Vet. J. 32:70-72.

Burgio, P.A. Undated. A literature review of velvet antler: the global market, chemical composition, health benefits and factors affecting growth. Elk Research Council.

Campa, H., III, and C. Hanaburgh. 1999. A management challenge now and in the future: What to do with exotic species. Pages 203-218 in R. K. Baydack, H. Campa, III, and J. B. Haufler (eds.), Practical approaches to the conservation of biological diversity. Washington, D.C.: Island Press.

Campa, H., III, J.B. Haufler and D.E. Beyer, Jr. 1992. Effects of simulated ungulate browsing on aspen characteristics and nutritional qualities. J. Wildl. Manage. 56:158-164.

Campa, H., III, J. B. Haufler and S.R. Winterstein. 1993. Effects of white-tailed deer and elk browsing on regenerating aspen: A ten-year evaluation. Pages 304-311 in I.D. Thompson (ed.), Proceedings of the XXI IUGB Congress International Union of Game Biologists, Volume 2. Chalk River, Ontario, Canada: Canadian Forest Service.

Canadian Wildlife Federation. 1992. Game farming in Canada: a threat to native wildlife and its habitat. Ottawa, Ontario: Canadian Wildlife Federation.

Canadian Food Inspection Agency. 1999. Risk assessment on bovine brucellosis and tuberculosis in Wood Buffalo National Park and area. CFIA Science Division (http://www.cfia-acia.agr.ca/english/ppc/science/ahra/docs/wbnp_e.html).

Carr, S.M., S.W. Ballinger, J.N. Derr, L.H. Blankenship and J.W. Bickham. 1986. Mitochondrial DNA analysis of hybridization between sympatric white-tailed deer and mule deer in west Texas. Proc. Natl. Acad. Sci. 83: 9576-9580.

Casey, D., and D. Hein. 1983. Effects of heavy browsing on a bird community in deciduous forest. J. Wildl. Manage. 47: 829-836.

Cashion, T.L. 1998-99. Marketing: the future of the deer industry. North American Deer Farmer (www.nadega.org).

Challies, C.N. 1985. Establishment, control and commercial exploitation in New Zealand. Pages 23-36 in P.F. Fennessy and K.R. Drew (eds.), The biology of deer production. Bull. 22. Wellington, New Zealand: The Royal Soc. New Zealand.

Craighead, F.C., Jr., and R.F. Dasmann. 1966. Exotic big game on public lands. Washington, D.C. U.S. Dep. of the Interior Bureau of Land Management.

Currier, R.W. 1995. Brucellosis. Pages 31-34 in Zoonosis, updates from the Journal of the American Veterinary Medical Association (2nd ed.)

Davis, D.S. 1985. Game-proof fences-my personal experience. In Roberson, S.F. (ed.), Deer-proof fencing—proceedings of a workshop; June 26, 1984, Kingsville, Texas. Kingsville, Texas: Caesar Kleberg Wildlife Research Institute.

Davidson, W.R., J.L. Blue, L.B. Flynn, S.M. Shea, R.L. Marchinton and J.A. Lewis. 1987. Parasites, diseases and health status of sympatric populations of sambar deer and white-tailed deer in Florida. J. Wildl. Diseases 23: 267-272.

Davidson, W.R., J.M. Crum, J.L. Blue, D.W. Sharp and J.H. Phillips. 1985. Parasites, diseases and health status of sympatric populations of fallow deer and white-tailed deer in Kentucky. J. Wildl. Diseases 21: 153-159.

DeCalista, D.S. 1994. Effect of white-tailed deer on songbirds within managed forests in Pennsylvania. J. Wildl. Manage. 58: 711-718.

Demarais, S., D.A. Osborn and J.J. Jackley. 1990. Exotic big game: A controversial resource. Rangelands 12: 121-125.

DeNicola, A.J., and R.K. Swihart. 1997. Capture-induced stress in white-tailed deer. Wildl. Soc. Bull. 25:500-503.

Derr, J.N. 1991. Genetic interactions between white-tailed and mule deer in the southwestern United States. J. Wildl. Manage. 55:228-237.

Dieterich, R.A. 1985. An overview of Alaskan reindeer diseases and current control methods. Pages 97-100 in P.F. Fennessy and K.R. Drew (eds.), The biology of deer production. Bull 22. Wellington, New Zealand: the Royal Soc. New Zealand.

Doster, G.L. (ed.). 1998. Southeastern cooperative wildlife disease study briefs. College of Veterinary Medicine, University of Georgia. 14(3):1-7.

Draper, A. Michigan white-tailed deer producer. Personal communication, May 1999.

Dratch, P.A. 1993. Genetic tests and game ranching: no simple solutions. Trans. 58th N.A. Wildl. & Natur. Resour. Conf. 58: 479-486.

Duda, M.D., and K.C. Young. 1996. Public opinion on hunting, fishing and endangered species. Responsive Management Report, Winter 1996, pp. 1-3.

Duffy, M.S., and M.D.B. Burt. 1998. Meningeal worm. N. Am. Elk. Fall.

Ehrenfield, D.W. 1970. Biological conservation. New York: Holt, Rinehart and Winston.

Ervin, R., S. Demarais and D.A. Osborne. 1992. Legal status of exotic deer throughout the United States. Pages 244-252 in R.D. Brown (ed.), The biology of deer. New York: Springer-Verlag.

Essey, M.A., and M.A. Koller. 1994. Status of bovine tuberculosis in North America. Vet. Microbiology 40: 15-22.

Fanning, A., and S. Edwards. 1991. Mycobacterium bovis infection in human beings in contact with elk (Cervus elaphus) in Alberta, Canada. The Lancet 338: 1253-1255.

Feldhamer, G.A., and Armstrong, W.E. 1993. Interspecific competition between 4 exotic species and native artiodactyls in the United States. Trans. 58th N.A. Wildl. & Natur. Resour. Conf. 58: 468-478.

Fletcher, J. 1984. Welfare considerations in the management of wild and farmed deer. Priorities in animal welfare: proceedings of a symposium.

Forbes, L.B., and S.V. Tessaro. 1996. Infection of cattle with Brucella abortus biovar 1 isolated from a bison in Wood Buffalo National Park. Canadian Veterinary Journal 37:415-419.

Foreyt, W.J., and R.L. Hunter. 1980. Clinical Fascioloides magna infection in sheep in Oregon on pasture shared by Columbian black-tailed deer. Amer. J. Vet. Res. 41:1531-1532.

Fraser, C.M., J.A. Bergeron, A. Mays and S.E. Aiello (eds.). 1991. The Merck veterinary manual (seventh ed.). Rahway, N.J.: Merck & Co., Inc.

Frelich, L.E., and C.G. Lorimer. 1985. Current and predicted long-term effects of deer browsing in hemlock forests in Michigan, U.S.A. Biol. Conserv. 34:99-120.

Friedel, B., and D. Kaliel. 1994. A Consensus of Costs and Returns in Northwest Alberta. Report No. 287. Alberta Agriculture, Food and Rural Development.

Fritz, D.L., M.S. Mostrom, L.E. Lillie and R.W. Coppock. 1992. Probable malignant catarrhal fever in a sika deer from an Alberta game farm. Can. Vet. J. 33:267- 269.

Geist, V. 1985. Game ranching: threat to wildlife conservation in North America. Wildl. Soc. Bull. 13:594-598.

Geist, V. 1989. Legal trafficking and paid hunting threaten conservation. Trans. 54th N.A. Wildl. & Natur. Resour. Conf. 54: 171-178.

Geist, V. 1994. Wildlife conservation as wealth. Nature 368: 491-492.

Graham, M.M. 1999. Seeing is believing! (http://www.naelk.org/Articles/Article000227.html).

Graham, S.A. 1954. Changes in northern Michigan forests from browsing by deer. Trans. N. Am. Wildl. Conf. 19: 526-533.

Greaser, G.L., J.K. Harper and R. Murphy. 1996. Agricultural Alternatives: Elk Production. State College: Pennsylvania State University.

Guiroy, D.C., E.S. Williams, R. Yanagihara and D.C. Gajdusek. 1991. Topographic distribution of scrapie amyloid-immunoreactive plaques in chronic wasting disease in captive mule deer (Odocoileus hemionus hemionus). Acta Neuropathologica 81: 475-478.

Haigh, J.C. 1987. Game farming practice: notes for the game farming industry. "Elk farm start-up." Publication GF-FS-2-01. University of Saskatchewan.

Haigh, J.C. 1989. Game farming practice: notes for the game farming industry. "Brain and muscle worms." Publication GF-S-2-01. University of Saskatchewan.

Haigh, J.C. 1991. Game farming practice: notes for the game farming industry. "Liver flukes." Publication GF-S-10-01. University of Saskatchewan.

Haigh, J.C. 1995. Velvet antler production: prediction of weights and correct anesthesia. Report 92000103. The Agriculture Development Fund.

Haigh, J.C. 1999. Affidavit fax transmittal as provided by Dan Marsh, North American Elk Breeders Association, April 12, 1999.

Haigh, J.C., and R.J. Hudson. 1993. Farming wapiti and red deer. St. Louis: Mosby-Year Book, Inc.

Hansen, T.J. 1999. North American Elk Breeders Association Achieves Claims for Velvet Antler and Collagen. North American Elk Breeders Association (www.naelk.org).

Harmel, D.E. 1980. The influence of exotic artiodactyls on white-tailed deer production and survival. Performance Rep. Job No. 20 Fed. Aid Proj. No. W-127-R-1.

Harpur, T.R.D. 1998. The potential market for venison in North America. The North American Deer Farmer, Summer, pp. 15-17.

Harrington, R. 1985. Evolution and distribution of the Cervidae. Pages 3-11 in P.F. Fennessy and K.R. Drew (eds.), The biology of deer production. Bull. 22. Wellington, New Zealand: the Royal Soc. New Zealand.

Harsh, S. 1999. Michigan State University, Department of Agricultural Economics. Personal communication, April 1999.

Healy, W.M., and P.J. Lyons. 1987. Deer and forests on Boston's municipal watershed after 50 years as a wildlife sanctuary. Pp. 3-21 in Deer, forestry, and agriculture: Interactions and strategies for management. Warren, Pennsylvania: Plateau and Northern Hardwood Chapters, Allegheny Society of American Foresters.

Hemmert, J. 1999. Is an elk hunting ranch profitable? North American Elk.

Hine, M. 1999. The Sanctuary in Stanwood, Michigan. Michigan Deer Farmers Association, personal communication. May 1999.

Hobart, D. 1998. World deer farming congress: the program. North American Deer Farmer, autumn: 25-26.

Hofmann, R.R. 1985. Digestive physiology of the deer — their morphophysiological specialization and adaptation. Pages 393-407 in P.F. Fennessy and K.R. Drew (eds.), Biology of deer production. Bull. 220. Wellington, New Zealand: Royal Soc. New Zealand.

Hunter, D.L. 1996. Tuberculosis in free-ranging, semi free-ranging and captive cervids. Rev. Sci. Tech. Off. Int. Epiz. 15: 171-181.

Jacobson, H.A., and S.D. Lukefahr. 1998. Case study: genetics research on captive white-tailed deer at Mississippi State University. Pages 47-60 K.A. Cearley and D. Rollins (eds.), Proceedings of a Symposium on the Role of Genetics in White-Tailed Deer Management. College Station, Texas: Department of Wildlife and Fisheries Science, Texas A&M University.

Janson, J. 1999. Wildlife Bureau, Michigan Department of Natural Resources. Personal communication, May 1999.

Johnston, A.M., and D.S. Edwards. 1996. Welfare implications of identification of cattle by ear tags. Vet. Rec. 138: 612-614.

Jolicoeur, H. 1994. Correspondence between H. Jolicoeur, Ministère du Loisir, de la Chasse er de la Peche, Quèbec, and J. Thompson-Delaney, Ontario Ministry of Natural Resources, March 18, 1994.

Jones, J.C., H.A. Jacobson and D.H. Arner. 1997. Plant community characteristics within an 18-year-old deer exclosure in southern Mississippi. Proceedings of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies 51:250-258.

Kahn, R. 1993. Wildlife management agency concerns about captive wildlife: the Colorado experience. Trans. 58th N. A. Wildl. & Natur. Resour. Conf. 58: 495-503.

Keel, M.K., W.L. Goff and W.R. Davidson. 1995. An assessment of the role of white-tailed deer in the epizootiology of anaplasmosis in the southeastern United States. J. Wildl. Dis. 31:378-385.

Kellert, S.T. 1979. Phase I: Public attitudes toward critical wildlife and natural habitat issues. U.S. Department of the Interior, Fish and Wildlife Service.

Kirkpatrick, R.L., and P.F. Scanlon. 1984. Care of captive white-tails. Pages 687-696 in L.K. Halls (ed.), White-tailed deer ecology and management. Harrisburg, Pa.: Wildlife Management Institute. Stackpole Books.

Kocan, A.A. 1985. The use of Ivermectin in the treatment and prevention of infection with Parelaphostrongylus tenuis (Dougherty) (Nematoda: Metastrongyloidea) in white-tailed deer (Odocoileus virginianus Zimmerman). J. Wildl. Dis. 21: 454-455.

Kocan, A.A., A.E. Castro, M.G. Shaw and S.J. Rogers. 1987. Bluetongue and epizootic hemorrhagic disease in white-tailed deer from Oklahoma: serologic evaluation and virus isolation. Am. J. Vet. Res. 48: 1048-1049.

Kuttler, K.L. 1981. Anaplasmosis. Pages 126-137 in W.R. Davidson, F.A. Hayes, V.F. Nettles and F.E. Kellog (eds.), Diseases and parasites of white-tailed deer. Misc. Publ. #7. Tallahassee, Fla.: Tall Timber Res. Station.

Lanka, R.P., R. Guenzel, G. Fralick and D. Thiele. 1990. Analysis and recommendations on the applications by Mr. John T. Dorrance III to import and possess native and exotic species. (A review of the literature and a survey of western states and provinces on the subject of exotic species and game ranching including a discussion on implications for wildlife in Wyoming.) Cheyenne, Wyo.: Game Division, Wyoming Game & Fish Dept.

Lanka, R.P., E.T. Thorne and R.J. Guenzel. 1992. Game farms, wild ungulates and disease in western North America. Western Wildlands, Spring: 2-7.

Leefers, L., J. Ferris and D. Propst. 1998. Economic consequences associated with bovine tuberculosis in northeastern Michigan, a report to Michigan Department of Agriculture, Michigan Department of Natural Resources and Michigan Department of Public Health. East Lansing, Mich.: Michigan State University.

Leege, L.M. 1997. The ecological impact of Austrian pine (Pinus nigra) on sand dunes of Lake Michigan: An introduced species becomes an invader. Ph.D. dissertation. Michigan State University.

Luxmoore, A. 1989. International trade. In R.J. Hudson, K.R. Drew and L.M. Baskin (eds.), Wildlife production systems: economic utilisation of wild ungulates. Cambridge: Cambridge University Press.

Mackintosh, C.G. 1990. Diseases of farmed deer in New Zealand. Pages 59-63 in C.S.G Grunsele and M.E. Raw (eds.), The Veterinary Annual [(30) Wright].

Mackintosh, C.G., and N.S. Beatson. 1985. Pages 77-82 in P.F. Fennessy and K.R. Drew (eds.), The biology of deer production. Bull. 22. Wellington, New Zealand: the Royal Soc. New Zealand.

Mackintosh, C.G., and T.G. Henderson. 1985. Pages 159-162 in P.F. Fennessy and K.R. Drew (eds.), The biology of deer production. Bull. 22. Wellington, New Zealand: the Royal Soc. New Zealand.

Marsh, D. 1999. Michigan Elk Breeders Association. Personal correspondence, April 1999.

MASS 1998. Michigan Agricultural Statistics 1997-98. 1997 Annual Report. Michigan Department of Agriculture.

Massey, W. 1986. Escape. The crisis faced by Robbie and Barbara Oldeman. The Deer Farmer, September: 6-10.

Massey, W. 1987. Embryo imports - the next wave. The Deer Farmer, June: 23.

McNeary, P.S. Undated. Velvet antler: science substantiates new hope for arthritis sufferers. Printed material describing Nature's Velvet. Platte City, Mo.: North American Elk Breeders Association.

Meyer, M.E., and M. Meagher. 1995. Brucellosis in free-ranging bison (Bison bison) in Yellowstone National Park, Grand Teton National Park and Wood Buffalo National Park — a review. Journal of Wildlife Diseases 31:579-598.

Michigan Department of Agriculture. 1997. Generally accepted agricultural and management practices for the care of farm animals. Lansing, Mich.: Michigan Commission of Agriculture.

Michigan Department of Agriculture. 1995. Animal industry act of 1987, Act 466. East Lansing, Mich.: Animal Industry Division.

Michigan Department of Natural Resources. 1992. Michigan's Endangered Plants. Lansing, Mich.: Endangered Species Program.

Michigan Department of Natural Resources. 1998. Information circular for permits to hold wildlife in captivity. Michigan Department of Natural Resources, Wildlife Bureau.

Miller, M.W., and E.T. Thorne. 1993. Captive cervids as potential sources of disease for North America's wild cervid populations: Avenues, implications and preventative management. Trans. 58th N.A. Wildl. & Natur. Resour. Conf. 58: 460-467.

Miller, M.W., J.M. Williams, T.J. Schiefer and J.W. Seidel. 1991. Bovine tuberculosis in a captive elk herd in Colorado: Epizootiology, diagnosis and management. Proc. U.S. Animal Health Assoc. 95: 533-542.

Miller, S.G., S.P. Bratton and J. Hadidian. 1992. Impacts of white-tailed deer on endangered and threatened vascular plants. Nat. Areas J. 12: 67-74.

Morley, R.S., and M.E. Hugh-Jones. 1989. Seroepidemiology of Anaplasma marginale in white-tailed deer (Odocoileus virginianus) from Louisiana. J. Wildl. Dis. 25:342-346.

Morton, J.K. 1985. Brucellosis in small mammals and predators associated with reindeer in Alaska. Pages 101-104 in P.F. Fennessy and K.R. Drew (eds.), The biology of deer production. Bull. 22. Wellington, New Zealand: the Royal Soc. New Zealand.

Nalepa, T.F., and D.W. Schloesser (eds.) 1993. Zebra mussels. Biology, impacts and control. Boca Raton, Fla.: CRC Press.

Nielson, C.K., S.J. Nelson and W.F. Porter. 1997. Emigration of deer from a partial enclosure. Wildl. Soc. Bull. 25: 282-290.

Nott, S.B. 1998. 1997 Business analysis summary for swine farms. Department of Agricultural Economics Staff Paper #98-23. East Lansing, Mich.: Michigan State University.

Nutrinfo. 1998. Tradeworks-North American Elk Breeders Association: claims for velvet antler and chondroitin sulfate. Watertown, Mass.: Nutrinfo (www.nutrinfo.com).

Nutrinfo. 1999. North American Elk Breeders Association: claims for velvet antler and collagen. Watertown, Mass.: Nutrinfo (www.nutrinfo.com).

Ontario Federation of Anglers and Hunters. 1991. Report and recommendations on game farming and ranching of big game in Ontario: implications for native wildlife and conservation.

Palmer, W.L., J.M. Payne, R.G. Wingard and J.L. George. 1985. A practical fence to reduce deer damage. Wildl. Soc. Bull. 13: 240-245.

Pedersen, E.K., W.E. Grant and M.T. Longnecker. 1996. Effects of red imported fire ants on newly hatched northern bobwhite. Journal of Wildlife Management 60:164-169.

Peyton, R.B. 1998. Defining management issues: dogs, hunting and society. Trans. No. Am. Wildl. and Natur. Resour. Conf. 63: 544-555.

Peyton, R.B., and C. Grise. 1995. A 1994 survey of Michigan public attitudes regarding bear management issues. Unpubl. report to the Wildlife Bureau. Michigan Department of Natural Resources.

Pollard, J.C., R.P. Littlejohn, P. Johnstone, F.J. Laas, L.D. Corson and J.M. Suttie. 1992. Behavioral and heart rate responses to velvet antler removal in red deer. New Zealand Vet. J. 40: 56-61.

Pope and Young Club. 1999. 21st big game awards statistical summary. Chatfield, Minn.: Pope and Young Club.

Posewitz, J. 1994. Beyond fair chase: the ethic and tradition of hunting. Helena and Billings, Mont.: Falcon Press Publishing Co., Inc.

Pout, D.D. 1977. The real cost of livestock disease. Livestock Farming 14: 56,58.

Pybus, M.J. 1990. Survey of hepatic and pulmonary helminths of wild cervids in Alberta. Canada. J. Wildl. Dis. 26: 453-459.

Qeva. 1999. Welcome to Qeva. Elk Tech International, Calgary, Canada. (www.qeva.com).

Qeva. 1999. What is velvet antler? (Product Information) Calgary, Alberta: Elk Tech International (www.qeva.com).

Ratcliffe, P.R. 1987. Distribution and current status of sika deer (Cervus nippon) in Great Britain. Mammal Review 17: 39-58.

Raymer, D.F. 1996. Current and long-term effects of ungulate browsing on aspen stand characteristics in northern lower Michigan. Master's thesis, Department of Fisheries and Wildlife, Michigan State University, East Lansing, Mich.

Red Oak Deer and Fence. 1999. Red Oak trophy hunts: 1998-1999 hunting prices (www.redoakdeer.com).

Renecker, L.A. 1992. Game farm management. Agroborealis 24:5-10.

Renecker, L.A., and H.M. Kozak. 1987. Game ranching in western Canada. Rangelands 9:213-216.

Renecker, T.A. 1998. Elk meat marketing: part I. Industry concerns as related to product perception and standardization. North American Elk, Spring.

Rennie, N. 1986. Good insurance deals are available. The Deer Farmer, Sept: 11-12.

Rhyan, J.C., K. Aune, B. Hood, R. Clarke, J. Payeur, J. Jarnagin and L. Stackhouse. 1995. Bovine tuberculosis in a free-ranging mule deer (Odocoileus hemionus) from Montana. J. Wildl. Dis. 31: 432-435.

Ruark, J. 1993. Elk "save" small farm. North American Elk, Fall.

Samuel, W.M., M.J. Pybus, D.A. Welch and C.J. Wilke. 1992. Elk as a potential host for meningeal worm: implications for translocation. J. Wildl. Manage. 56:629- 639.

Sanctuary. 1999. Welcome to the world of Sanctuary! (www.sanctuaryranch.com).

Saskatchewan Agriculture and Food (SAF). 1993. Venison and bison meat market: an overview. Regina, Saskatchewan: Marketing Development, Saskatchewan Agriculture and Food.

Saskatchewan Agriculture and Food (SAF). 1994. Elk production: economic and production information for Saskatchewan producers. Regina, Saskatchewan.

Saskatchewan Agriculture and Food (SAF). 1996. Elk production: economic and production information for Saskatchewan producers (http://www.agr.gov.sk.ca/saf/live/elkint.htm).

Saskatchewan Ag and Food (SAF). 1997. White-tailed deer financial and production information (http://www.agr.gov.sk.ca/saf/live/97wtd1.htm).

Schmitz, O.J., and A.R.E. Sinclair. 1997. Rethinking the role of deer in forest ecosystem dynamics. Pages 201-223 in W.J. McShea, H.B. Underwood and J. H. Rappole (eds.), The science of overabundance deer ecology and population management. Washington, D.C.: Smithsonian Institution Press.

Schneider, R. 1990. Concerns about game ranching. Can. Vet. J. 31: 479-480.

Shank, K.L., and C.S. Bruning-Fann. 1993. The Michigan captive Cervidae project. U.S. Department of Agriculture.

Shellenbarger, D. 1999. Background and discussion — fencing: an informal survey. Lansing, Mich.: Michigan Department of Natural Resources.

Sim, J.S., and H.H. Sunwoo. 1999. Canadian scientists study velvet antler for arthritis treatment. Canadian Elk and Deer Farmer, Winter: 28-29.

Skinner, D. 1999. President and general manager of Velvet Independent Processors Ltd. (VIP) of Wilkie, Saskatchewan, Canada. Personal correspondence, May 1999.

Slovik, P. 1987. Perception of risk. Science 236: 280-285.

Smith, K.E., and D.E. Stallknecht. 1996. Culicoides (Diptera: Ceratopogonidae) collected during epizootics of hemorrhagic disease among captive white-tailed deer. Journal of Medical Entomology 33: 507-510.

Spraker, T.R., M.W. Miller, E.S. Williams, D.M. Getzy, W.J. Adrian, G.G. Schooveld, R.A. Spowart, K.I. O'Rourke, J.M. Miller and P.A. Merz. 1997. Spongiform encephalopathy in free-ranging mule deer (Odocoileus hemionus) and white-tailed deer (Odocoileus virginianus) and Rocky Mountain elk (Cervus elaphus nelsoni) in north central Colorado. J. Wildl. Dis. 33: 1-6.

Stefanko, C. 1999. Michigan elk producer. Personal correspondence. May 1999.

Stoeckeler, J.H., R.O. Strothman and L.W. Krefting. 1957. Effect of deer browsing on reproduction in the northern hardwood-hemlock type in northeastern Wisconsin. J. Wildl. Manage. 21: 75-80.

Stubblefield, S.S., R.J. Warren and B.R. Murphy. 1986. Hybridization of free-ranging white-tailed and mule deer in Texas. J. Wildl. Manage. 50: 688-690.

Tessaro, S.V. 1986. The existing and potential importance of brucellosis and tuberculosis in Canadian wildlife: a review. Can. Vet. J. 27: 119-124.

Thompson, T. 1999. Michigan white-tailed deer producer, Michigan Deer Farmers Association. Personal communication, May 1999.

Thorleifson, I., T. Pearse and B. Friedel. 1998. Elk farming handbook. Saint John, New Brunswick: Abbott Richards Graphic Design, Inc.

Tilghman, N.G. 1987. Maximum deer populations compatible with forest regeneration — an estimate from deer enclosure studies in Pennsylvania. Page 71 in Deer, forestry and agriculture: Interactions and strategies for management. Warren, Pa.: Plateau and Northern Hardwood Chapters, Allegheny Society of American Foresters.

Twiss, M.P., V.G. Thomas and D.M. Lavigne. 1996. Sustainable game farming: considerations for Canadian policy-makers and legislation. J. Sustainable Agric. 9:81-98.

U.S. Congress, Office of Technology Assessment. 1993. Harmful non-indigenous species in the United States. OTA-F-565. Washington, D.C.: U.S. Government Printing Office.

U.S. Department of Agriculture. 1996. Assessing the risks associated with M. bovis in Michigan free-ranging white-tailed deer. Fort Collins, Colo.: Cadia Tech. Rep. No. 01-96. Centers for Epidemiology and Animal Health.

U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, Bureau of the Census. 1998. 1996 National Survey of Fishing, Hunting and Wildlife-Associated Recreation, Michigan results. FHW/96-MI.

Utah Division of Wildlife Resources. 1996. Alternative livestock (elk farming), position of the Division of Wildlife Resources (www.nr.state.ut.us/dwr/elkposi.htm).

VanDeelen, T.R., K.S. Pregitzer and J.B. Haufler. 1996. A comparison of presettlement and present-day forests in two northern Michigan deer yards. Am. Midl. Nat. 135:181-191.

VanDeelen, T.R., H. Campa, III, M. Hamady and J.B. Haufler. 1998. Migration and seasonal range dynamics of deer using adjacent deer yards in Northern Michigan. J. Wildl. Manage. 62: 205-213.

VanSchaik, G., C.H.J. Kalis, G. Benedictus, A.A. Dijkhuizen and R.B.M. Huirne. 1996. Cost-benefit analysis of vaccination against paratuberculosis in dairy cattle. Vet. Rec. 139: 624-627.

Von Kerckerinck zur Borg, J. 1998. Preserve hunting: protecting a market alternative. The North American Deer Farmer, Winter: 17.

Waas, J.R., J.R. Ingram and L.A. Matthews. 1997. Physiological responses of red deer (Cervus elaphus) to conditions experienced during road transport. Physiol. And Beh. 61: 931-938.

Wallace, L. 1994. Feed off the ground. North American Elk, Winter: 24-25.

Watson, D. 1998. Tracking elk prices. North American Elk Breeders Association (www.naelk.org).

Welch, D.A., M.J. Pybus, W.M. Samuel and C.J. Wilke. 1991. Reliability of fecal examinations for detecting infections of meningeal worm in elk. Wildl. Soc. Bull. 19: 326-330.

Wells, G., and B. Dougherty. 1998. Fencing the farm. North American Elk, Fall: 201 - 203.

Wheaton, C., M. Pybus and K. Blakely. 1993. Agency perspectives on private ownership of wildlife in the United States and Canada. Trans. 58th N.A. Wildl. & Natur. Resour. Conf. 58: 487-494.

Whipple, D.L., P.R. Clarke, J.L. Jarnagin and J.B. Payeur. 1997. Restriction fragment length polymorphism analysis of Mycobacterium bovis isolates from captive and free-ranging animals. J. Vet. Diagnostic Investigation 9: 381-386.

Whiting, P. 1999. North American Elk Breeders Association. Personal correspondence, May 1999.

Whittlesey, S. 1999. 1999 Colorado select elk sale a smashing success. North American Elk.

Williams, E.S., and S. Young. 1980. Chronic wasting disease of captive mule deer (Odocoileus hemionus hemionus): a spongiform encephalopathy. J. Wildl. Dis. 16:89-98.

Wishart, W.D. 1980. Hybrids of white-tailed and mule deer in Alberta. J. Mammal. 61:716-720.

Wolcott, S. 1999. Can elk ranching help save local agriculture? North American Elk, Winter: 149-151.

Wolf, C.A. 1999. Michigan State University Department of Agricultural Economics. Personal communication, April 1999.

Wrage, J.E. 1997. Taking aim at canned hunts without catching game ranches in the crossfire. Loyola of Los Angeles Law Review, 30: 893-922.

Zaiglin, B. 1998. What is fair chase? North American Deer Farmer, Autumn.

Zebarth, G. 1998. Controlling Johne’s disease in elk. North American Elk, Winter: 40.

Zhang, Z-Q, Y. Wang, H. Zhang, W. Zhang, Y. Zhang and B-X Wang. 1994. Anti-inflammatory effects of pilose antler peptide. Acta Pharmacologica Sinica 15:282-284.

Appendix 1. Captive White-Tailed Deer and Elk Farm Tuberculosis Surveillance Requirements.

A bulletin produced by the Michigan Department of Agriculture

January 25, 1999

Each owner of every herd in Michigan which possesses one or more captive white-tailed deer or elk must complete one of the following requirements:

Breeding farms or Hobby farms

All captive cervidae herds which possess one or more captive white-tailed deer or elk and does not have white-tailed deer or elk removed by the hunting method must have a single cervical tuberculosis test conducted on all captive cervidae in the herd 12 months of age or older, and all cattle and goats in contact with the herd 6 months of age or older, by July 25, 2000. All animals tested must be identified with an official identification, and be tested at owner expense by a private accredited veterinarian approved to perform single cervical testing on cervidae. Any herd which possessed official tuberculosis accredited or qualified herd status as of January 25, 1999, is exempt from this testing requirement.

If testing of the herd is completed within a 7 consecutive month time frame, the herd may be eligible for official tuberculosis qualified status. Contact the Michigan Department of Agriculture at (517) 373-1077 for more information.

Hunting Ranches

All captive cervidae herds which possess one or more captive white-tailed deer or elk and has white-tailed deer or elk removed by the hunting method (Captive cervidae ranch) must have captive cervidae removed from the ranch (harvested animals) examined for evidence of tuberculosis by a specially trained private accredited veterinarian at owner expense. The number to be tested will be based upon the average adult herd size, and equal to the amount necessary to establishing an official tuberculosis monitored herd. [A separate graph shows this: it requires testing of 60% of the animals for herds up to 200 animals and declining fractions for larger herds with a maximum of 178 animals to be tested from any one herd.] Inspection of the animals must be evenly spaced over a three consecutive year period, and must be completed by January 25, 2004.

Owners of captive cervidae ranches may elect to complete the tuberculosis testing requirements for breeding farms in lieu of the harvest surveillance. Live animals sold or removed for breeding farms which have not undergone the testing required for breeding farms (single cervical testing of animals 12 months of age and older) must meet additional tuberculosis test requirements prior to movement between premises within Michigan (see Requirements for movement of captive cervidae with Michigan).

Any new herds assembled must complete the appropriate tuberculosis surveillance testing within the above mentioned time frame following assembly of the herd (i.e., a breeding herd assembled in August, 2000, has 18 months from that date to complete the required tuberculosis testing).

Appendix 2. Requirements for Movement of Captive Cervidae within Michigan.

A bulletin produced by the Michigan Department of Agriculture

January 25, 1999

All captive cervidae moved between premises within Michigan must be identified with official identification, and this identification must be present on any required test reports or movement permits. In addition, movements of captive cervidae must be accompanied by copies of any official movement permits, official tuberculosis test charts, or official tuberculosis herd status letters during transport. These documents must be presented to representatives of the Michigan Department of Agriculture upon request.

Captive white-tailed deer or elk

The tuberculosis test requirements for movement of white-tailed deer or elk within Michigan are based upon the tuberculosis surveillance status of the herd of origin, and the age of the animal.

1. Captive white-tailed deer or elk less than 6 months of age must meet one of the following:

   A. Originate directly from an official tuberculosis accredited or qualified herd.

   or

   B. Originate from a herd that has received a negative tuberculosis test of all captive cervidae 12 months of age and older and all cattle and goats 6 months of age and older (and is not an official tuberculosis qualified herd) and receive an official Permit for Movement of Captive White-tailed Deer or Elk less than 6 months of age within Michigan from a private accredited veterinarian. The animals moved must then be tested for tuberculosis at the destination stated on the permit by a private accredited veterinarian when it becomes 6-8 months of age. Following testing, a copy of the movement permit and tuberculosis tests chart needs to be forwarded to the Michigan Department of Agriculture, Animal Industry Division, P.O. Box 30017, Lansing, Michigan 48909.

Captive white-tailed deer and elk less than 6 months of age which originate from herds which have not completed a negative tuberculosis test of all captive cervidae 12 months of age and older and all cattle and goats 6 months of age and older may not be moved to other premises within Michigan.

2. Captive white-tailed deer or elk 6 months of age or older must meet one of the following:

   A. Originate directly from an official tuberculosis accredited or qualified herd.

   or

   B. Originate from a herd which has received a negative tuberculosis test of all captive cervidae 12 months of age and older and all cattle or goats in contact with the herd 6 months of age and older (and is not an official tuberculosis qualified herd). The animal must also receive a negative tuberculosis test within 90 days prior to movement.

   or

   C. Be isolated from all other members of the herd and receive two negative tuberculosis tests 90-120 days apart prior to movement.

Captive cervidae other than white-tailed deer and elk

1. Captive cervidae other than white-tailed deer and elk which are less than 6 months of age or older may move without prior tuberculosis testing.
2. Captive cervidae other than white-tailed deer and elk which are 6 months of age or older must meet one of the following prior to movement within Michigan:

   A. Originate directly from an official tuberculosis accredited or qualified herd.

   or

   B. Receive a negative tuberculosis test within 90 days prior to movement.

Appendix 3. Selected Values from NIH'S Tables of Nutritional Values for Various Meat Cuts (Per 3-OZ Cooked Portion)*

Product (3 oz. cooked)		Saturated fat (grams)	Cholesterol (mgs)	Total fat (grams)	Total calories
Venison	Venison, roasted	1.1	95	2.7	134
Beef	Eye of round, roasted, 1/8" trim	2.9	60	7.7	171
Beef	Top round, roasted, 1/8" trim	4.0	70	10.6	195
Beef	Top sirloin, broiled, 1/8" trim	5.3	77	13.3	222
Beef	Short loin, tender loin, broiled, 1/8" trim	6.9	74	17.7	253
Beef	Ground beef, regular, broiled medium	7.8	76	17.6	246
Beef	Short loin, T-bone steak, broiled, 1/4" trim	8.6	70	18.0	253
Beef	Chuck, blade roast, braised, 1/8" trim	9.3	88	23.4	308
Beef	Rib, whole, roasted (6-12 ribs), 1/8" trim	10.3	72	25.5	313
Chicken	Chicken, roasting, light meat w/out skin	1.2	64	3.5	130
Chicken	Breast, w/out skin (1/2 a breast)	1.2	72	3.0	140
Chicken	Breast, with skin (1/2 a breast)	2.1	71	6.6	168
Chicken	Chicken, roasting, dark meat, w/out skin	2.6	63	7.4	152
Chicken	Thigh, w/ skin (1 1/2 thighs)	4.1	79	13.2	210
Chicken	Wing, w/ skin (2 1/2 wings)	5.1	71	16.6	247
Pork	Ham, cured, boneless, extra lean, roasted	1.7	45	4.7	123
Pork	Loin, tenderloin, roasted	2.2	67	5.1	147
Pork	Ham, cured, boneless, regular, roasted	3.0	50	7.7	151
Pork	Loin, sirloin roasts, boneless, roasted	3.4	73	8.0	176
Pork	Loin, sirloin, bone-in, roasted	5.6	74	13.6	222
Pork	Ground pork, cooked	7.3	80	17.7	252
Pork	Ribs, country-style, roasted	8.6	78	21.5	279
Pork	Spareribs, braised	10.6	103	25.8	338

*Source: National Institutes of Health, National Heart, Lung and Blood Institute home page: <http://www.nhlbi.nih.gov/health/public/heart/chol/sbs-chol/index.htm>, June 1999.

Appendix 4. Selected Values from USDA Nutritional Values for Selected Cuts of Meat (Per 100 Grams Edible Portion)*.

Variety	Description**	Total Fat	Cholesterol	Protein	Calories
Elk	Game meat, elk, cooked, roasted	1.90 g	73 mg	30.19 g	146 kcal
Deer***	Game meat, deer, cooked, roasted	3.19 g	112 mg	30.21 g	158 kcal
Bison	Game meat, bison, cooked, roasted	2.42 g	82 mg	28.44 g	143 kcal
Chicken	Chicken, broilers or fryers, breast, meat only, cooked, roasted	3.57 g	85 mg	31.02 g	165 kcal
Beef	Beef, round, eye of round, separable lean & fat, trimmed to 0" fat, all grades, cooked, roasted	5.36 g	69 mg	28.80 g	171 kcal
Beef	Beef, tenderloin, separable lean & fat, trimmed to 1/8" fat, all grades, cooked, roasted	24.60 g	85 mg	23.90 g	324 kcal

*Source: U.S. Department of Agriculture, Agricultural Research Service. 1998. USDA Nutrient Database for Standard Reference. Nutrient Data Laboratory home page: <http://www.nal.usda.gov/fnic/foodcomp>, June 1999.

**The description refers to the exact reference terms given by the USDA database. Note that for beef the database contains about 100 entries for various combinations of cuts and cooking methods, and the fat content varies substantially among these. Alternatively, the database contains only one entry for deer and only one entry for elk.

***The database does not indicate what species of deer was tested.

Appendix 5. Permits to Hold Wildlife in Captivity.

In Michigan, a permit is required to hold deer or elk in enclosures. The permits are issued by the Michigan Department of Natural Resources (MDNR) and must be renewed every three years. The information in this section is drawn from the MDNR information circular "Permits to hold wildlife in Captivity." Readers interested in the exact wording and the full procedures for obtaining a permit are referred to that circular.

Deer, moose or elk enclosures

New applicants wishing to construct deer, moose or elk enclosures or current permittees wishing to expand existing enclosures must own or lease the land to be enclosed. The following summarizes the procedures that must be followed before beginning any construction:

1. Written approval for the enclosures must first be obtained from the township or city.
2. A preapplication letter is sent to the Wildlife Division permit specialist providing personal information, total acreage, site location and a legal description of the site.
3. Any necessary construction permits for crossing inland lakes, streams, wetlands and floodplains must be obtained from Michigan Department of Environmental Quality.
4. Management unit supervisor will review the preapplication, determine if there is a threat of enclosing wild deer and, if so, approve a plan for driving deer out of the enclosure. Enclosure construction cannot begin without the approval of the management unit supervisor.
5. After completing the enclosure, if the management unit supervisor estimates that deer remain within the enclosure and there is no practical means of removing them, the deer are purchased from the state at $250 per deer.
6. At this point, the application for the new or amended permit is filed following the steps in the booklet for obtaining the respective permit type.

Specifications for white-tailed deer enclosures

1. Each deer shall be allowed at least 1,000 square feet of space with an exterior fence of no less than 10 feet in height.
2. An overhead shelter or protected area at least 8 feet by 12 feet will be provided within or attached to each pen.
3. After April 1, 1998, the department will not approve a deer enclosure unless the fence is constructed entirely of woven wire. Deer enclosures at least 10 feet in height approved prior to April 1, 1998, with strands of wire completing the top 2 feet, may continue to be approved. Deer enclosures at least 8 feet in height approved prior to June 30, 1990, may continue to be approved at that height.

Specifications for Elk or Moose Enclosures

1. Single animals require a minimum of 1,500 square feet of space, with an exterior fence of no less than 8 feet in height.
2. Each additional animal requires an additional 1,000 square feet of space.
3. An overhead shelter or protected area at least 8 feet by 12 feet shall be provided within or attached to each pen.

Application fee

The base fee for new or renewal applications is $45. In addition, if an applicant has more than 500 animals or more than 40 acres enclosed, the fee is increased by the larger of the following: $15 for each animal in excess of 500 or $15 for each acre in excess of 40. The maximum fee that can be charged for a single location is $150.

Deer or elk enclosures — prohibited area

As of February 11, 1998, no new permits to hold wildlife in captivity shall be issued for the possession of white-tailed deer or elk in an area including the whole of Alcona, Alpena, Montmorency, Oscoda and Presque Isle counties and also those portions of Cheboygan, Otsego, Crawford, Roscommon, Ogemaw and Iosco counties lying to the east of I-75 and to the north of M-55. Within this area, no expansion is allowed unless it has an approved bovine tuberculosis eradication plan.

This moratorium on the issuing of permits in this area is necessary because it has been determined that the prevalence of bovine tuberculosis in the deer populations in the northeastern Lower Peninsula poses a potential risk to public health and wildlife health and threatens USDA bovine tuberculosis-free accreditation and wildlife-related recreation and tourism. The Michigan departments of Agriculture, Community Health and Natural Resources are working jointly to develop management plans for eradicating bovine tuberculosis in Michigan. It is the collective judgment of those departments, as well as prevailing scientific opinion, that the opportunities for transmission of bovine tuberculosis are enhanced when deer and elk feed in concentrated, confined areas or over common feeding grounds.

Michigan captive cervidae industry regulation

The industry has a dual regulatory system — both the MDA and the MDNR have jurisdiction over parts of the operations. The Natural Resources and Environmental Protection Act (P.A. 451) defines elk and deer as game, granting regulatory jurisdiction to the MDNR. The Animal Industry Act (P.A. 466) includes captive white-tailed deer farms and captive elk farms as livestock for disease testing and transportation requirements under the regulatory auspices of the MDA.

Testing requirements for bovine TB (Federal Register)

The following definitions and material relate to bovine tuberculosis and captive cervids and were taken from the Federal Register, Vol. 63, No. 251, Thursday, December 31, 1998:

Accredited herd — A herd of captive cervids that has tested negative to at least three consecutive official tuberculosis tests of all eligible captive cervids. The tests must be conducted at 9- to 15-month intervals.

Qualified herd — A herd of captive cervids that has tested negative to at least one official tuberculosis test of all eligible captive cervids within the past 12 months, and that is not classified as an accredited herd.

Monitored herd — A herd on which identification records are maintained on captive cervids inspected for tuberculosis at an approved slaughtering establishment or an approved diagnostic laboratory and on captive cervids tested for tuberculosis in accordance with interstate movement requirements.

Single cervical tuberculin (SCT) test — The SCT test is the primary test to be used in individual captive cervids and in herds of unknown tuberculosis status.

Identification — Any captive cervid tested with an official tuberculosis test must bear official identification in the form of an official eartag or another approved identification device.

Movement — Except for movement from accredited herds, no captive cervid may be moved interstate unless it has been tested using an official tuberculosis test. A captive cervid from an accredited herd may be moved interstate without further tuberculosis testing if it is accompanied by a certificate. Testing of herds for classification must include all captive cervids 1 year of age or over and any captive cervids other than natural additions (captive cervids born into the herd) under 1 year of age.

Testing Requirements for bovine TB (Michigan Department of Agriculture)

The requirements for testing of captive cervidae for bovine tuberculosis and regulations associated with movement of captive cervidae as per Michigan's Public Act 552 (P.A. 552-Michigan) are provided in Appendices 1 and 2 of this document.

Appendix 6. Diseases Known to Occur in Cervid Populations That May be Transmitted Between Captive and Free-Ranging Animals

Disease	Susceptible animals	Documented cases	Source	Transmission	Control
Anaplasmosis *(Anaplasma marginale)*	Cattle, mule deer, b-t deer w-t deer (Keel et al., 1995)	In North America, it naturally occurs in mule deer and b-t deer. Low prevalence in w-t deer in Louisiana	Keel et al., 1995 Morley and Hugh-Jones, 1989	Transmitted biologically by ticks (genus dermacentor) and mechanically by biting flies (family Tabanidae) (Keel et al., 1995)	Incidence can be decreased by killing/ repelling vectors on host with chemical dusts and sprays (Fraser et al., 1991).
		In cattle in Louisiana	Morley and Hugh-Jones, 1989		
Brucellosis *(Brucella abortus)*	Humans, bison, elk, reindeer, caribou	In buffalo in Wood Buffalo Ntl. Park, Canada In free-ranging elk in Wyoming	Tessaro, 1986 Tessaro, 1986	Direct contact with infected animals, urine, feces, tissues, and by breathing airborne particles (Morton, 1985)	No reliable tests. Control by test and slaughter (Dieterich, 1985).
		In reindeer and caribou in Alaska	Dieterich, 1985		
		In humans from contact with infected elk	Currier, 1995		
Chronic wasting disease	Mule deer, w-t deer, elk,b-t deer (Guiroy et al., 1991; Doster, 1998)	In free-ranging elk, mule deer and w-t deer in Colorado and Wyoming	Spraker et al., 1997; Doster, 1998	Causal agent unknown; oral route of infection (Aiello and Mays,1998)	No tests for live animals; treatment ineffective (Aiello and Mays, 1998).
		In captive mule deer and b-t deer in Colorado and Wyoming	Williams and Young, 1980		Control by slaughter (Doster, 1998)
		In captive elk in South Dakota, Nebraska and Oklahoma	Doster, 1998		
Epizootic hemorrhagic disease/blue tongue	Cattle, goats, elk, sheep, deer (Kocan et al., 1987)	In cattle and w-t deer in Oklahoma	Kocan et al., 1987	Biting midges (genus Cullicoides) (Smith and Stallknecht, 1996)	Decrease insect bites by reducing insect populations in the area (Aiello and Mays, 1998)
		Free-ranging w-t deer mortality in Alabama, Arkansas, Illinois, Iowa, Kansas, Kentucky, Mississippi, Missouri and Tennessee	Doster, 1998		
Giant liver fluke (*Fascioloides magna*)	Elk, w-t deer, caribou, red deer, fallow deer, moose, sheep, goats, bison (Pybus, 1990; Haigh, 1991)	10% mortality due to *F. magna* in flock of sheep in Oregon when pasture was shared by b-t deer.	Foreyt and Hunter, 1980	By aquatic snails (Haigh, 1991)	Little info on control with effective anthelmintics or control snail intermediate host (Haigh, 1991)

Disease	Susceptible animals	Documented cases	Source	Transmission	Control
Johne's disease (*Mycobacterium*)	Elk, red deer, cattle, sheep, goats, w-t deer (Doster, 1998)	In key deer in Florida.	Doster, 1998	Contact with infected animals (Aiello and Mays, 1998)	No satisfactory treatment; incurable (vanSchaik et al., 1996)
Malignant catarrhal fever	Elk, red deer, sika deer, moose, mule deer, caribou, axis deer (Beatson, 1985); not reported in fallow deer (Fraser et al., 1991)	Cause of 48% of all deaths in Mid-Southern Canterbury area of New Zealand. In sika deer from game farm in Alberta.	Beatson, 1985 Fritz et al., 1992	Contact with infected animals (Mackintosh, 1990)	No effective treatment once signs show. Control by test and slaughter (Mackintosh, 1990).
Meningeal worm *(Parelaphostrongylus tenius)*	Elk, w-t deer, caribou, sheep, goats, fallow deer, moose, mule deer, b-t deer (Samuel et al., 1992; Twiss et al., 1996; Duffy and Burt, 1998)	In caribou in Nova Scotia. In elk in Michigan.	Haigh, 1989 Beyer, 1987	Snail intermediate host (Haigh, 1989; Lanka et al., 1992; Duffy and Burt, 1998)	No reliable tests for detection or treatment (Kocan 1985; Welch et al., 1991). Control by slaughter (Duffy and Burt, 1998).
Tuberculosis *(Mycobacterium bovis)*	Humans, elk, w-t deer, red deer, sika deer, fallow deer, cattle, opossums (Miller et al., 1991; Fanning and Edwards, 1991; Lanka et al., 1992)	In captive elk in Colorado. In humans from contact with elk in Alberta.	Miller et al., 1991 Fanning and Edwards, 1991	Aerosol particles; contact with infected animals (McKintosh 1990; Lanka et al., 1992)	No treatment or vaccine. Control by slaughter (Lanka et al., 1992).
		In red, sika, axis, and fallow deer, cattle and opossums in New Zealand.	Lanka et al., 1992		No reliable tests (Hunter, 1996).
		In free-ranging buffalo in Wood Buffalo Ntl. Park, Canada.	Tessaro, 1986		
		In 16 captive ungulate herds in 4 provinces in Canada.	Essey and Koller, 1994		
		In free-ranging w-t deer in Michigan.	USDA, 1996		