Chapter 6: Threats and Their Sources

OVERVIEW

Threats are processes and events that may cause harmful ecological or physiological impacts on an ecosystem. *Sources of threats* are actions that cause the threat itself (adapted from The Nature Conservancy, The Five-S Framework, 2000). For example, ecological fragmentation is a threat because it often alters natural hydrological flows and harms certain populations of species. Frequent sources of ecological disruption include incompatible logging and residential development. This chapter combines aspects of the team's social, political and ecological analysis with additional research to inventory, analyze, and map the area's threats and sources of threats. The team feels that this is an essential component of any conservation plan that aims to protect an area's ecological integrity.

IDENTIFICATION OF THREATS AND SOURCES

Table 6.1 shows the study area's key threats, the sources of threats, and the relationships between the two. Note that any one threat may have multiple sources and vice versa. For example, one threat – landscape fragmentation – may have various sources including residential development, oil and gas drilling, and incompatible logging. Alternatively, one source – ORV use – can influence multiple threats such as altered composition/structure and landscape fragmentation.

DESCRIPTION OF THREATS

The six most severe threats in the study area are outlined below, listed in order of severity according to the analysis presented in Table 6.1.

Altered biotic composition/structure of ecosystems

Alteration of ecosystem structure can occur whenever an action changes the species composition of an area. A wetland that changes from eight percent to 20 percent cattails serves as an example of a change in ecosystem composition and structure. Because of the interwoven relationships between structure and function, the ecological functions will also be affected by changes in composition and structure. In the wetland example, an increased number of cattails may change hydrologic patterns. Such alterations of structure may vary widely in how they impact a given ecosystem, from relatively low impact associated with cattail growth to high impact if the wetland is drained and filled for development. Evaluating both the direct effects of altered structure, such as loss of wetland ecosystems, and the indirect effects, such as increased erosion due to faster surface water flows, is also critical to understand the complete ecological impacts of this threat.

Table 6.1: Threats and sources of threats arranged by severity[1]

This table depicts the threats, sources of the threats, and the total estimated numbers of each. Because each threat and source has a different likelihood of impacting the study area, the team assigned one of three severity rankings to each threat and source:

(red)	Severe
(yellow)	Moderate
(teal)	Minimal

These rankings were assigned primarily based on the team's subjective assessment of potential impact, but also on the total number of threats and sources. For example, development is ranked as severe because it is a source to a high number of threats (nine) and is also expected to have significantly impact the study area based on the team's research. Invasive and alien species provide a different example of a source that is ranked as severe, in that the number of threats to which this source contributes is fairly low (four), but the team is aware of an ever-increasing prevalence of invasive and alien species that threaten the ecological health of the entire study area.

	Sources of Threats										
Threats	Development	Oil and gas drilling	Incompatible logging	Invasive and alien species	Road development	ORV Use	Incompatible agriculture/grazing	Dams	Fire suppression	Contamination	**Total estimated sources of threats for each threat**
Altered composition/structure	X	X	X	X	X	X	X	X	X		**9**
Alteration of natural fire regimes	X	X	X	X	X	X	X		X		**8**
Ecological destruction or conversion	X	X	X	X	X	X	X	X			**8**
Landscape fragmentation	X	X	X		X	X	X	X			**7**
Extraordinary predation/competition/disease	X		X	X	X		X		X		**6**
Erosion	X	X	X		X	X	X				**6**
Sedimentation			X		X	X	X	X			**5**
Alteration of hydrology	X	X	X		X		X	X			**6**
Resource depletion	X	X	X		X						**4**
Thermal alteration	X		X		X			X			**4**
Nutrient loading	X						X	X			**3**
Toxins/contaminants		X				X				X	**3**
Total estimated threats for each source of threat	**10**	**8**	**10**	**4**	**10**	**7**	**9**	**7**	**3**	**1**	**69**

[1] The categories of threats and sources of threats were selected from The Nature Conservancy's "Illustrative list of stresses and sources" as documented in the 5-S Methodology. The project team did not list all the threats and sources that TNC lists but displayed only those threats and sources believed to be prevalent in the study area. For example, the team did not include sources such as excessive groundwater withdrawal and landfill construction.

Alteration of natural fire regimes

Changes in the frequency, intensity, and timing of fire in natural ecosystems can alter ecological structure and function. Under the common practice of fire suppression, ecosystems that depend on fire for survival and reproduction change dramatically. Understanding that some effects of fire can harm certain ecosystems, it is necessary to determine how the alteration of the natural fire regime by such sources as road and residential development, oil and gas drilling, and silviculture may affect the composition, structure, and function of the ecosystems across the landscape.

Ecological destruction or conversion

Ecological destruction occurs when natural areas are degraded to the point that ecological structures and functions are severely disturbed or eliminated. An example of ecological destruction is forest clearcutting. Ecological conversion is a type of ecological destruction in that the original covertype is converted to a non-natural covertype, thus altering normal ecosystem processes. Replacing a mixed hardwood forest with a pine plantation is an example of ecological conversion. The primary effect of ecological conversion and destruction is the loss of ecosystems. Species dependent on the ecosystem may fail to reproduce, die, or move elsewhere because they are no longer able to find the resources they need for survival. Ecological processes are also degraded and fragmented causing negative effects even to ecosystems outside of the immediate area.

Landscape fragmentation

Landscape fragmentation is the dissection of expansive ecosystems into small, isolated patches that are too limited in size to maintain their original structure and function into the indefinite future (Meffe, 1997). Landscape fragmentation is generally considered to have two components. The first is the reduction of the total amount of an ecosystem type in the natural landscape and the second is the apportionment of the remaining ecosystem into smaller, more isolated patches. The result is a patchwork of small, isolated natural areas in a sea of developed land (Noss, 1987).

Fragmentation can disrupt several ecological processes that affect biodiversity and ecosystem integrity. Fragmentation can increase nutrient loss through erosion, due in part to increased water transport resulting from vegetation lose. Fragmentation also alters the impacts of all natural disturbances, including fires, windstorms, landslides, and floods (Noss and Cooperrider, 1994). In addition to its effects on ecosystem processes, fragmentation degrades ecosystem structure by removing biota, reducing patch size, and increasing edge habitat. Many conservation biologists agree that conservation strategies can be evaluated on the basis of how well they counter the effects of fragmentation in real landscapes (Meffe, 1997).

Extraordinary predation/competition/disease

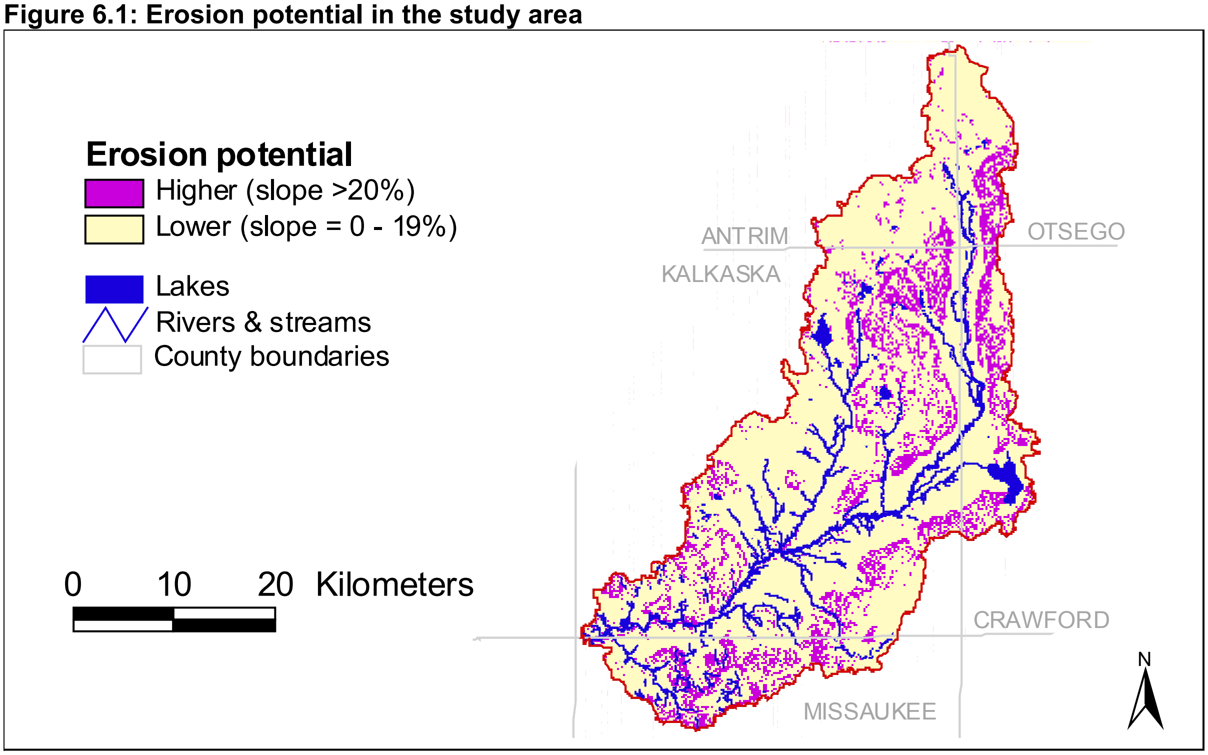
Extraordinary predation and disease typically changes an ecosystem's functions. Sources include invasive species that establish and proliferate beyond their natural ranges, typically replacing native flora and fauna through competition or predation (Meffe, 1997). These invasive species are primary signs of ecological stress from other threats in the ecosystem. For example, pine bark beetles are invasive insects that attack weakened pine trees.

Erosion potential

Erosion is a natural process that is not a concern in and of itself. Erosion becomes an issue when human activities either directly erode the landscape or leave terrain more susceptible to naturally-occurring erosion. For example, the use of off-road vehicles on slopes or along ridges can dislodge soil, thus directly contributing to erosion. Other activities such as incompatible logging do not directly remove soil from an area, but remove vegetation so that the soil is more exposed to the eroding effects of wind and water. General effects of erosion include sedimentation of surface water, soil nutrient loss (Gimeno-Garcia *et al.*, 2000), and decreased likelihood of reestablishing vegetation.

Several characteristics of the landscape influence its erosion potential, including slope, vegetation, soil texture, and soil moisture. With regard to soil texture, sand is more erodible than silt, which, in turn, is more erodible than clay. Steep slopes and sparse vegetation both lead to greater susceptibility to erosion.

Figure 6.1: Erosion potential in the study area



Compounding the problem, many individuals are interested in living in areas that are highly susceptible to erosion. Hilltops and shorelines provide favorable viewsheds to homeowners. These areas are particularly attractive to home construction and are thus vulnerable to erosion. Figure 6.1 displays the erosion potential for the study area, assuming that areas of high slope (>20 percent) will have the greatest erosion potential.

DESCRIPTION OF SOURCES

This section describes in detail the sources of ecological threats that are found in the study area. The sources are described roughly in order of their ecological impact. For each source, the team provides a description of the general ecological effects and study-area specific considerations.

Development

Ecological effects

For the purposes of this report, development refers to the conversion of land to residential, industrial or commercial uses. The effects of development on ecological integrity are numerous and can be quite severe. Of all the threats, development is the most damaging to ecosystems because it almost always permanently converts natural areas to non-natural uses. In theory, it is possible to move a home or tear up a parking lot and restore the areas. However, the ecosystem can be so altered that full-scale restoration is rarely successful, even when the costs are not so prohibitive as to discourage restoration efforts altogether.

Aside from overall conversion of the landscape, development also effectively fragments natural areas. Road construction and development go hand in hand because development often both prompts and follows infrastructure development.

Pollution is often a direct result of development. Though certain types of development are more likely to contaminate air, soil, groundwater, and surface water than others, even the smallest home with the most environmentally-conscious landowners can contribute some level of contamination to the surrounding area. For example, a woodstove releases pollutants into the air and a faulty septic system can contaminate groundwater.

Developments can be designed and constructed to minimize ecological impacts. Identifying the most ecologically valuable areas can help guide future development toward less sensitive locales. For example, clustering homes to leave a larger intact natural area is a more ecologically friendly site design than scattering homes across the entire tract. Similarly, incorporating green building techniques can reduce energy use and contamination potential (US Green Building Council, 2000). Regardless of the site or building design, however, there is little question that virtually all development affects an area’s ecology to a certain degree.

Study area specifics

The team asserts that residential development poses one of the greatest sources of threats to the ecological health of the study area. Residential construction is far more prevalent in the study area than industrial or commercial development, although some additional businesses may enter the area as the population expands. As explained in the demographics section (see Chapter 4), the nominal increases in housing units and population are not particularly alarming, but the percentage increases are quite significant. Population in the study area's counties grew 23 percent from 1990 to 2000, while the state's increased only seven percent. Similarly, housing units in the study area's counties increased 19 percent from 1990 to 2000, while the state's increased just 10 percent. Tables 6.2 and 6.3 provide details on these increases in housing units and population from 1990 to 2000.

Table 6.2: Housing units authorized by building permits (1990-2000) for counties within the study area and Michigan

	1990	2000	Increase, 1990-2000	Percent change, 1990-2000
Antrim Co.	13,145	15,090	1,945	15%
Crawford Co.	8,727	10,042	1,315	15%
Kalkaska Co.	9,151	10,822	1,671	18%
Missaukee Co.	7,112	8,621	1,509	21%
Otsego Co.	10,669	13,375	2,706	25%
Average for all counties	48,804	57,950	9,146	19%
State of Michigan	3,847,926	4,234,279	386,353	10%

Table 6.3: Population change (1990-2000) for counties within the study area and Michigan

	1990	2000	Increase, 1990-2000	Percent change, 1990-2000
Antrim Co.	18,185	23,110	4,925	27%
Crawford Co.	12,260	14,273	2,013	16%
Kalkaska Co.	13,497	16,571	3,074	23%
Missaukee Co.	12,147	14,478	2,331	19%
Otsego Co.	17,957	23,301	5,344	30%
Average for all counties	74,046	91,733	17,687	23%
State of Michigan	9,295,297	9,938,444	643,147	7%

Numbers aside, the pattern of most housing construction contributes greatly to the severity of development's impact on ecological health. The greatest concentrations of development include the Wilderness Valley subdivision in southwestern Otsego County and the Lakes of the North subdivision in southeastern Antrim County. While the size and density of these developments attracts attention, even more significant are the numerous smaller subdivisions and individual homes scattered throughout the study area. According to the Springfield Township Clerk (Kalkaska Co.), "Houses are sprouting up all over like mushrooms" (Ingersol, 2002).

The scattered development pattern is expected to continue indefinitely. Land splits have been particularly common over the last five to ten years (Riley, 2002 and Ingersol, 2002), as farmers or other elderly landowners retire and sell off all or part of their land (Pratt, 2002), or as new landowners purchase large tracts and sell off smaller portions to other buyers (Bucklin, 2002). Zoning ordinances permit home construction virtually anywhere in the study area except on public land and in areas zoned as commercial or industrial (see Chapter 4). In addition, people continue to move to the study area for its rural character, selecting isolated properties for added seclusion (Bidle, 2002; Leach, 2002). Residents appreciate having "as much land as they want," asserted the Zoning Administrator for Kalkaska County (Leach, 2002).

Certain landscape characteristics attract more development than others. Not surprisingly, waterfront property entices many homebuyers. Rolling hills and forested lands are also desirable. In some areas where saturated soils prevent easy home construction, growth is likely to occur "anyplace where there's high ground" (Ingersol, 2002).

Planning and zoning officials expect slight to moderate growth in the future. When asked about the ten-year outlook for land use, the Zoning Administrator for Garfield Township (Kalkaska Co.) replied that the township would look "pretty much the way it does now," and stressed the rural location of the area (Bidle, 2002). A different perspective was offered by Bill Riley, the Zoning Administrator for Blue Lake Township (Kalkaksa Co.). Riley expects that many more houses will be built (primarily new and large single family homes) and that parcels will be further subdivided over the next 10 years. At the same time, however, he mentioned that building permits in Blue Lake have been decreasing over time, from approximately 75 permits per year in 1994, to 55 per year from 1995-1999, to 35 per year in 2000 and 2001 (Riley, 2002). Similarly, the Springfield Township Clerk acknowledged that Kalkaska County has experienced a huge growth spurt in recent years, but that 2001 did not follow recent growth trends, with a significant reduction in construction compared with the three previous years (Ingersol, 2002). When considering the comments from all interviewees, it appears that residents definitely expect future growth, though at a slower pace than in the past.

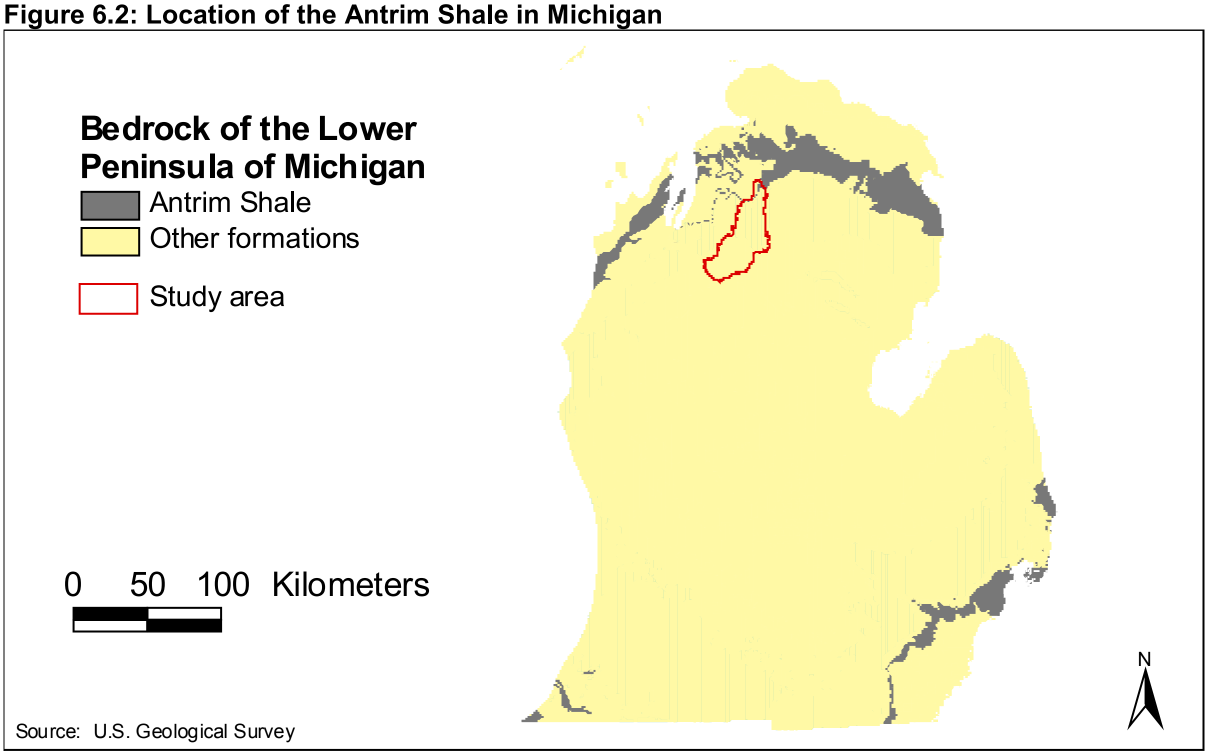
Oil and Gas Drilling

<u>Background</u>

Oil and gas development in Michigan began in the late 1960s with the discovery of the Niagaran Reef, a deep-layer shale that runs throughout the northern portion of the Lower Peninsula from Manistee to Rogers City. In response to the discovery, oil companies scoured the region for leases from public as well as private landowners. In the summer of 1968, the Michigan Department of Natural Resources (MDNR) leased nearly 550,000 acres of public land in northern Michigan for oil and gas development. This sale generated more than $1 million in revenue and prompted the most intensive oil and gas exploration in the continental United States in the 1970s, exceeded nationwide only by exploration in Alaska's North Slope (Michigan Land Use Institute, 2002).

In the late 1980s, Michigan's oil and gas industry began tapping the Antrim Shale, a new energy reserve that grew into the most important hydrocarbon development in state history and the third largest natural gas field in the United States. The Antrim Shale is a shallow late-Devonian formation occurring at depths of less than 1,800 feet in most places. This layer of gas-saturated rock covers about 33,000 square miles under the northern half of Michigan's Lower Peninsula and stretches in a 50-mile wide arc from Lake Michigan to Lake Huron (Figure 6.2).

Figure 6.2: Location of the Antrim Shale in Michigan



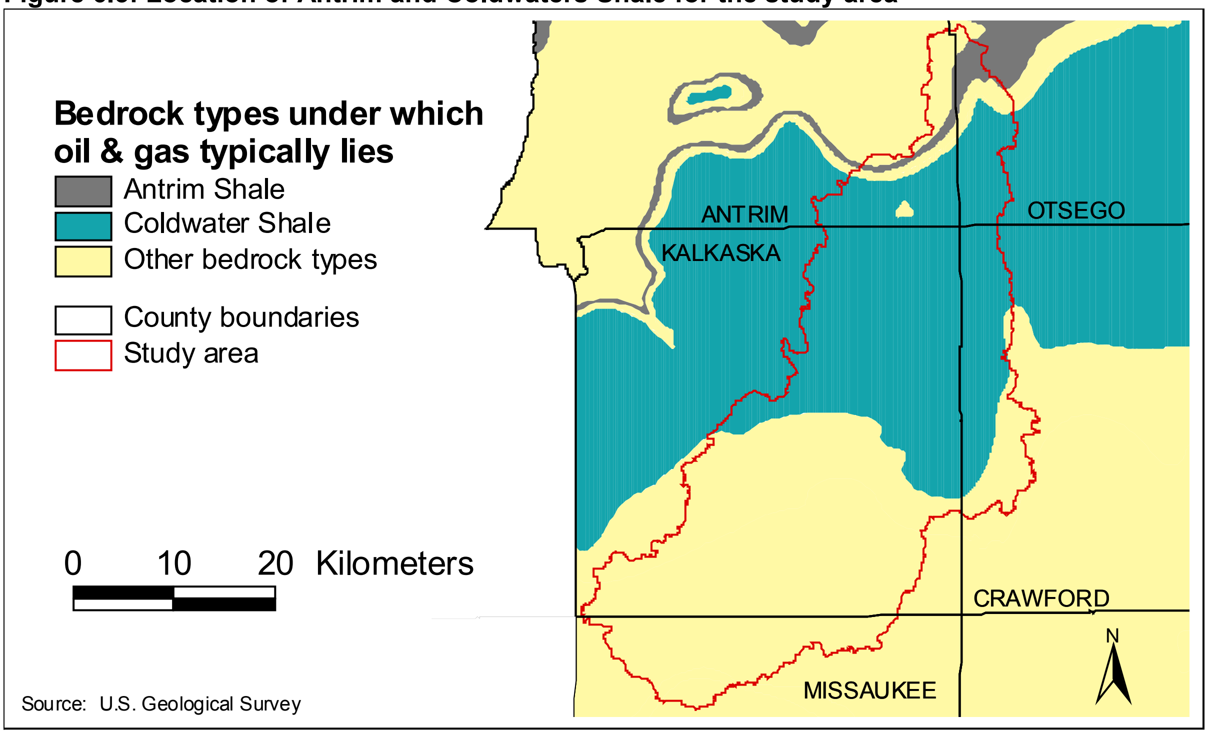
Since 1989, more than 6,000 wells have been drilled into the shallow but highly productive Antrim Shale. The State estimates that between 2,200 and 3,000 wells exist on public lands and, at minimum, another 3,000 wells are found on private lands (Michigan Land Use Institute, 2002). While more than 500 trillion cubic feet of natural gas permeate the Antrim Shale formation, less than one percent has been developed as proven reserves. Thus, the

Antrim Shale remains one of the most actively drilled gas fields in the United States (Corbley, 1995). The shale's productivity, boosted by a generous federal tax credit and a significant state subsidy, has enabled Michigan to produce more than 25 percent of the natural gas it uses, an increase from roughly five percent a decade ago. At current market prices and production levels, energy companies are earning gross revenues of more than $500 million annually from Antrim Shale gas. Furthermore, production is increasing around five to eight percent annually (Michigan Land Use Institute, 2002).

Study Area Specifics

The potential for continued Antrim Shale gas development exists throughout the study area, centered mainly in the southeast corner of Antrim County and central Otsego County. Extraction from the deep-layer Niagaran Reef also continues below the Coldwater Shale formation in Kalkaska, Antrim, Otsego and Crawford counties (Figure 6.3).

Figure 6.3: Location of Antrim and Coldwaters Shale for the study area



Any party can submit applications to lease state lands for five-year periods for oil and gas exploration, and this lease can be extended indefinitely for as long as oil and gas are produced. Therefore, many areas of public lands in the study area are likely to be auctioned for leasing, at prices ranging from $13 per acre to $1,000 per acre (MDNR - Forest, Mineral, and Fire Management Division, 2002). While the Department of Natural Resources restricts some lands from development, large areas of state land are open for potential oil and gas activity.

The Michigan Department of Natural Resources continues to lease thousands of acres within Pere Marquette State Forest, Mackinaw State Forest, and Au Sable State Forest, located mainly in Otsego, Crawford, and Kalkaska counties. With more than 2,000 more Antrim Shale gas wells expected in the next five years and an unknown number expected in the long-term, the potential for oil and gas development to harm ecosystems in the study area is immense (Michigan Land Use Institute, 2002). Since the inception of Antrim Shale gas exploration in the late 1980s, the most intensive drilling in the area has centered on Otsego County. Now, energy companies are expanding from Otsego County into Crawford and Antrim Counties. Currently, more oil and gas wells exist in Frederic Township in Crawford County than any other township in the state (Pratt, 2002). The study area contains two of the five most actively drilled counties in Michigan – Otsego County and Antrim County (Michigan Land Use Institute, 2002).

Groups in the watershed and throughout Michigan have formed to combat the threat of oil and gas development. In 1995, six grassroots conservation groups and a Manistee County township formed the Michigan Energy Reform Coalition, a statewide alliance to gain greater public oversight of Antrim Shale natural gas development. The coalition, managed by the Michigan Land Use Institute, has grown to 24 organizations and township governments representing more than 200,000 state residents. Involved organizations include Trout Unlimited, Michigan Environmental Council, Friends of the Jordan River Watershed, Center for Wildland Conservation, Tip of the Mitt Watershed Counsel, Michigan Communities Land Use Coalition, Citizens for Alternatives to Chemical Contamination, and the Pigeon River Country Association (Michigan Land Use Institute, 2002).

Incompatible agriculture/grazing

Ecological effects

Agricultural activities can degrade the environment in a variety of ways. Farming can increase soil erosion and create disturbed ground areas, which promote the establishment of invasive species on the edges of fields. Use of fertilizer and pesticides harms some native insect and plant species and the runoff of such chemicals increases water pollution. The monocultural characteristic of crop farms changes the natural composition of the ecosystem, destroying habitat for wildlife and degrading sites for native plants. However, farms typically have much less severe impacts than other development, including residential, commercial and industrial uses. The team also recognizes that farms and agricultural crops can provide a number of positive ecological services including the creation of migration corridors and habitats for some species.

Grazing affects the environment by compacting soil and decreasing native plant species. Most grazing sites are pastures planted with non-native grasses, thereby reducing the abundance and diversity of native plants and associated wildlife populations. Soil compaction can hinder water infiltration and make it difficult for plants to take root. Excessive grazing increases erosion as the soil is left exposed to wind and water. In addition, grazers can disperse seeds of non-native species across large ranges, through both their hooves and manure.

Study Area Specifics

Agriculture is not as extensive in the study as in other areas of Michigan. In Kalkaska County, farms are not abundant due to the sandy, infertile soils of the area. Most of the farms in Kalkaska County are potato farms located in Orange and Oliver townships and tend to use abundant amounts of chemicals and irrigation (Bromelmeier, 2002). Corn, hay, and oats make up other common crops farmed in Kalkaska, Otsego, Antrim, and Missaukee counties. However, the actual number of acres farmed in the study area is unknown. Some farmers in Kalkaska County are actually starting to take their land out of production as they near retirement. This trend indicates that incompatible agriculture will be less of a threat to the area in the future but may open more areas to the far greater threat of development (Bromelmeier, 2002).

Cattle are the main grazing animals in the study area. While Missaukee County boasts the largest number of cattle (22,000 head) of the five counties, Antrim (5,000 head), Otsego (2,300 head), and Kalkaska (1,000 head) counties also support cattle (U.S. Department of Agriculture, National Agricultural Statistics Service, 2002). The geographic extent of grazing lands in the study area is not known.

Incompatible logging

Ecological effects

Logging can impact ecological health in many ways. Perhaps most significantly, it can fragment natural areas by removing trees and constructing roads to transport logs and equipment. This fragmentation creates more edge area and leaves the remaining core areas more susceptible to disturbances such as wind and invasion of exotic or nuisance species. Logging can reduce ecosystem diversity, which in turn reduces biological diversity, by reducing the available area in which species can survive. Logging can also affect hydrology, as the removal of vegetation from slopes reduces infiltration and increases runoff and erosion to nearby surface waters. Logging in riparian ecosystems can dramatically increase surface water temperatures, especially in headwaters areas. Microclimate can change as well – temperatures increase when removing trees from the overstory increases the amount of sunlight that reaches the groundcover and understory layers.

The relative impacts of timber harvesting in a given area are largely determined by (1) the intensity of logging, (2) the scale of operations, (3) the logging techniques used, and (4) the sensitivity of different ecosystems to disturbance. In terms of intensity, logging 10 trees within a 10 acre site is less intense (and thus less damaging) than clearcutting on that same 10 acres. In terms of scale of operations, the larger the extent of the logging, the greater the impacts to ecosystem health. For example, logging 10 acres at a given intensity is less damaging than logging 100 acres at the same intensity. With regard to logging techniques, clearcut logging can severely affect ecosystems, whereas careful, selective logging of uneven-aged stands can be quite sustainable if done appropriately. And finally, in terms of ecosystem sensitivity, logging may differentially impact different ecosystems. For example, logging aspen trees may have less of an ecological impact than logging late successional hardwoods, because it is easier to reestablish aspens than hardwoods.

While logging can reduce ecological vitality, it is generally less damaging to the landscape than residential development at a comparable scale. Unlike most development, even clearcut sites can be restored to a more natural state, given adequate time and effort. Although most logging reduces ecosystem diversity, the county forester for Antrim and Kalkaska Counties asserts that plantations are also not the "biological desert" that many claim. He believes that plantation stands that are at least three years old and receive some active management offer a diversity of structure that provides wildlife values (Merriweather, 2002). For example, planting uneven-aged stands or more than one type of tree species in a plot provides a more diverse habitat for wildlife than even-aged monocultures.

Study area specifics

During the 18th and 19th centuries, European settlers clearcut and slash burned almost the entire state of Michigan, including the study area. These activities contributed to widespread and dramatic erosion, and the slash burning left fire scars that are still present today.[2] Since that time, trees have regenerated naturally or have been planted. Today, silviculture is highly prevalent throughout the study area. Plantations (typically even-aged stands planted and harvested on a regular basis) comprise roughly 90 percent of red pine in the study area, and approximately 100,000 pines are replanted every year in Kalkaska County alone (Merriweather, 2002). Other commonly logged trees include aspens and northern hardwoods (including beech, sugar maple, and hemlock). Much of the once prime hardwood forest is currently managed as plantations, but ample opportunity still exists to harvest hardwoods from naturally regenerating forests (Merriweather, 2002). In general, hardwoods are concentrated on moraines and ice contact terrain (Merriweather, 2002).

As outlined in Chapter 4, three types of woodlots occur in the study area. *Christmas tree farms* are generally planted in the even-aged and straight rows associated with plantations, and are intensely managed (Bromelmeier, 2002). The abundance of Christmas tree farms has decreased because many smaller farmers are losing the market. Despite this decline, roughly 4,000 acres of these plantations still exist in Kalkaska County. *Industrial tree farms* vary greatly in structure and size, ranging from 40 acres to over 2,000 acres. Corporations place more of an emphasis on timber harvest for profit than do owners of private woodlots. *Private woodlots* generally take the form of naturally-regenerating forests (and are therefore generally not plantations) on which the landowner may permit occasional timber harvesting, perhaps every 10 years. Private woodlots are generally 40 to 80 acres in size (MI Tree Farm System, 2000). These farms are more common throughout the study area than Christmas tree farms (Stone, 2002). Erickson *et al*. (2001) estimate that roughly 35 percent of all Michigan forests are owned by private and nonindustrial landowners.

[2] Fire scars are areas where the fire intensity was so great as to consume all organic soils and soil organisms.

Regardless of woodlot type, the intensity of logging operations is still an issue in the study area. While land managers increasingly recognize the importance of sustainable logging practices, clearcut logging remains a major threat to some areas. For example, forest product companies recently contacted MDNR to clearcut a large amount of state land in Crawford County's Graying Township. Public opposition successfully halted these plans (Wright, 2002). A Frederic Township (Crawford County) representative expressed greater dissatisfaction with many of the successful clearcutting ventures on state lands, explaining that MDNR has permitted clearcutting without always adequately informing the public or seeking its input (Pratt, 2002).

Another challenge regarding logging intensity is that multiple logging companies operate in the study area. At least two major companies – Weyerhauser and Georgia Pacific – harvest timber in the area. To their credit, logging companies are less interested in logging individual properties than they are in managing the tracts as a total system (Bucklin, 2002). However, unless the companies coordinate logging plans with each other and consciously attempt to limit impacts to any one region, the patchwork operations of multiple companies can result in intense logging throughout the region. Logging on private lands complicates cohesive management efforts, as companies must work with more landowners than if they primarily logged on state lands.

Though the intensity and scale of logging is a concern in the study area, several factors limit the potential extent of future logging operations. One forester mentioned that parcels of less than 10 acres are too small for timber management (Merriweather, 2002). Therefore, as landowners increasingly split lots in the study area, the opportunities for logging will decrease. Landowner interests also influence logging potential. According to one forester, more than 90 percent of the landowners with whom he works are interested in maintaining or enhancing property for wildlife habitat, aesthetic purposes, or hunting. These goals are not compatible with intense logging practices. The interviewee also mentioned that few landowners are motivated by profit, and for properties on which harvesting occurs, profits are often reinvested in other land improvements (Bucklin, 2002). Erickson's study (2001) offers support for landowners' non-economic management motivations for Michigan woodlots.

Invasive Species

Ecological Effects

Also known as "exotic" or "alien species," invasive species are flora or fauna that are introduced beyond their native ranges and proliferate, spread, and persist to the detriment of the environment (Mack *et al.*, 2000). The introduction of invasive species ranks as one of the leading causes of loss of biological diversity (Meffe, 1997).

Invasive species serve a primary source of threat to the environment by replacing native species through competition, predation, or disease. Such changes in species composition can alter the dynamics of ecosystem functions (Meffe, 1997). Vacant or underutilized niches within ecosystems promote the establishment and growth of invasive species. Niche vacancies may result from ecological disturbances such as road construction in which native species were destroyed and unable to re-establish in a short time frame due to changes in the ecosystem. Once established, invasive species often grow and spread quickly because the new environment lacks natural competitors, predators, grazers, and parasites (Mack *et al.,* 2000). Invasive species fall into three main groups – flora, fauna, and fungi.

<u>Study Area Specifics</u>

I. Invasive flora

- Spotted knapweed

Carried by wind or vehicles, spotted knapweed (*Centaurea maculosa)* invades open and disturbed areas. These areas include housing development sites and grazing fields as well as along highways, waterways, railroad tracks, pipelines, and recently installed utility lines. It produces 1,000 or more seeds per plant, and the seeds remain viable in the soil over five years, allowing infestations to occur a number of years after vegetative plants have been eliminated (Lym *et al*., 1992). In addition to prolific reproduction, spotted knapweed often releases a chemical compound that reduces the growth of competitor species (Center for Environmental and Regulatory Information Systems, 2002). By rapidly spreading in the disturbed area and inhibiting growth of other plants, spotted knapweed reduces the native floral diversity.

- Purple loosestrife

A plant of European origin, purple loosestrife (*Lythrum salicaria*), has degraded temperate North American wetlands since the early nineteenth century (Blossey, 2002). Purple loosestrife succeeds as an invasive plant mainly because it can survive in a wide range of physical and chemical conditions characteristic of disturbed areas. Conditions such as water drawdown or exposed soil accelerate purple loosestrife invasions by providing ideal conditions for seed germination. Its ability to reproduce prolifically by both seed dispersal and vegetative propagation also contributes to its success. A single stalk can produce from 100,000 to 300,000 seeds per year, with a 60 to 70 percent survival rate (Wisconsin Department of Natural Resources, 2002). These seeds are dispersed by water and in mud that adheres to aquatic wildlife, livestock, and people. Because seeds can remain viable in the soil for many years, eliminating purple loosestrife is extremely difficult.

Any sunny or partly shaded wetland is susceptible to purple loosestrife invasion including marshes, stream margins, alluvial floodplains, sedge meadows, and wet prairies. The plants tend to create monotypic stands that displace native wetland vegetation and degrade wildlife habitat. These impenetrable stands are unsuitable as cover, food, or nesting sites for native wetland animals including geese, ducks, rails, muskrats, frogs, toads, and turtles (Great Lakes Information Network, 2002).

Since 1996, purple loosestrife has been found in all contiguous states except Florida (Blossey, 2002). All counties of Michigan are infested with this invasive plant, including the study area.

- Kentucky bluegrass

Kentucky bluegrass (*Poa pratensis*) is a common exotic plant in oak-pine barrens in the study area. Since its growth and reproduction rates increase in nitrogen-rich and moist environments, Kentucky bluegrass proliferates in the absence of fire to form impenetrable areas that impede growth of native plants through competition for space, water, and nitrogen (Michigan Natural Features Inventory, 2002).

- Sheep sorrel

Sheep sorrel (*Rumex acetosella*) is another non-native species common to oak-pine barrens in the study area, as well as in fields, pastures, meadows, riparian areas, and along roadsides. Generally found in open, unshaded areas on disturbed sites, it thrives on acidic soils with low fertility but can adapt to a variety of soil types (U.S. Department of Agriculture, Fire Effects Information System, 2002). Reproducing from creeping roots and rhizomes, as well as through seed dispersal, sheep sorrel spreads rapidly through natural areas in the absence of fire and with the prevalence of off-road vehicles (Michigan Natural Features Inventory, 2002). The seeds generally remain viable in the soil long enough to provide a source of new infestations when the soil is disturbed.

II. Invasive fauna

A. Defoliating insects

Defoliating insects comprise the most threatening invasive animal species in the study area, because of its extensive forest cover. In addition, according to Michigan Department of Natural Resources, the introduction of exotic defoliators is perhaps the most serious threat to the state's native forest ecosystems (National Forest Health Monitoring System, 2002). Table 6.4 displays the occurrences of defoliators by type within the study area.

- Gypsy moth

Tree mortality increased in Michigan during the 1990s, due in part to gypsy moth (*Lymantria dispar*) defoliation. In 1992, the gypsy moth caused the largest known extent of defoliation in Michigan history. Currently, the gypsy moth exists in every county of the Lower Peninsula. While gypsy moths prefer oak tree leaves, they feed on more than 600 species of trees, shrubs, and vines (Michigan's Gypsy Moth Education Program, 2002). Since the study area abounds with oak, aspen, birch, willow, crabapple, maple, and other susceptible tree species, the gypsy moth is an increasing threat to the area's forest health (National Forest Health Monitoring System, 2002).

- Jackpine budworm

The jackpine budworm (*Choristoneura pinus pinus*) is a major threat to the area's pine forests. While it prefers jack pines located in mixed stands, damage to white and red pines also occurs. This damage results from larvae defoliation that leads to the deformation of the upper crown. Affected trees most commonly experience growth reduction, though tree mortality often occurs after repeated attacks. Within the study area, the jackpine budworm occurred in 12,471 areas in 2000 and 37,700 areas in 2001 (Table 6.4).

Table 6.4: Defoliation occurrences in the study area in 2000 and 2001

	Gypsy Moth	Jack Pine Budworm	Large Aspen Tortrix	Unknown Defoliant	TOTAL
Year 2000					
Antrim	0	0	0	0	**461**
Crawford	0	11,759	0	0	**12,043**
Kalkaska	15	409	0	392	**895**
Missaukee	27	0	0	2,827	**2,854**
Otsego	2,620	303	0	67	**2,990**
2000 TOTAL	**2,662**	**12,471**	**0**	**3,286**	**19,242**
Year 2001					
Antrim	0	0	0	63	**63**
Crawford	0	35,048	915	0	**35,964**
Kalkaska	0	1,426	5,578	0	**7,396**
Missaukee	0	1,296	13,640	0	**14,935**
Otsego	0	0	0	637	**637**
2001 TOTAL	**0**	**37,770**	**20,133**	**700**	**58,603**

Adapted from Michigan Forest Pest Infestation Statistics (Michigan Department of Natural Resources, 2002)

- Large aspen tortrix

Large aspen tortrix (*Choristoneura conflictana*) prefers aspen trees but also invades secondary hosts such as white birch, balsam poplar, and various willow species. Larvae feed on the tree buds and, in most cases, completely devour them so that no foliage is produced. Massive defoliation reduces annual incremental growth and inhibits twig growth but rarely results in tree mortality (National Resources Canada, 2002). Large aspen tortrix defoliated numerous acres of aspen and mixed aspen stands in the Lower Peninsula in 2001.

B. Other insects

- Pine bark beetle

Pine bark beetles (*Coleoptera: Scolytidae*) tunnel into pine trees and feed on the soft inner bark. Adult bark beetles are first attracted to weakened or stressed trees and lay eggs. During serious outbreaks, however, seemingly healthy trees are also susceptible to beetle infestation. Upon hatching, the larvae bore through the tree's nutrient transport system and feed on live tissue below the bark, eventually killing the tree. Since 1997, pine bark beetle populations have been increasing in the Lower Peninsula, including the study area (National Forest Health Monitoring System, 2002).

- Pine shoot beetle

Pine shoot beetles (*Tomicus piniperda*) attack new shoots of pine trees and may attack stressed pine trees by breeding under the bark at the base of the tree. Such activities stunt tree growth and may cause tree death when high populations exist. Known to be established in most counties of the Lower Peninsula, including the five counties in the study area (National Forest Health Monitoring System, 2002), pine shoot beetles inhabit mature pine stands as well as Christmas tree farms and pine nurseries (U.S. Department of Agriculture, 2002).

C. Non-native animals

- Zebra mussels

Zebra mussels (*Dreissena polymorpha*) are one of the most well-known invasive species in the Great Lakes region. Brought to the United States from Europe through ship ballast waters, zebra mussels were first found in Lake Erie in 1988. In the past 15 years, they have expanded rapidly into all of the Great Lakes as well as inland rivers and tributaries (National Atlas, 2002).

These small mollusks spread rapidly due to their high reproductive rate and early maturation. A fully mature female mussel can produce several hundred thousand eggs per season. The larvae travel large distances as plankton following the water currents until attaching to hard surfaces to develop into an adult. Within a year, a zebra mussel becomes sexually mature. Zebra mussels also flourish because they can tolerate a wide range of depths, light intensity, and temperatures extremes (Minnesota Sea Grant, Zebra Mussels, 2002). In addition, their known predators – some diving ducks, freshwater drum, carp, and sturgeon – are not numerous enough to have a major effect on the zebra mussel populations in the Great Lakes (National Atlas, 2002).

With each zebra mussel filtering about one liter of water per day, this invasive species causes significant impact on native animals. Filtering out large amounts of plankton from the water column, zebra mussels decrease the food supply available for small fish. Zebra mussels also harm native mussel species through encrustation (Minnesota Sea Grant, Zebra mussels, 2002).

Zebra mussels are expanding their range into many Michigan rivers, including the Manistee River and its tributaries in the study area.

III. Invasive fungi

- Oak wilt

Oak wilt is a lethal vascular disease caused by a fungus (*Ceratocystis fagacearum*) that lives and grows in the water conducting tissues (xylem) of oak trees. The trees attempt to stop the spread of the fungus by producing gummy substances called tyloses. The combination of the fungus and tyloses disrupts the water flow to the canopy and results in leaf wilting and defoliation. Root grafts between trees of the same species in close proximity are the most common method for spreading oak wilt since the interconnection of vascular tissue allows the fungus to travel from an infected tree to a healthy tree. Bark beetles also spread the disease. Although various oak species are hosts to the fungus, red oaks (*Quercus rubra*) are most susceptible and usually die within four to six weeks, while white oaks (*Quercus alba*) are more resistant to the disease (Rexrode and Brown, 2002).

- Dutch elm disease

The fungi (*Ophiostoma novo-ulmi* and *Ophiostoma ulmi*) that cause Dutch elm disease infect a tree the same way that oak wilt fungus infects oak trees – through the bodies of elm bark beetles and through grafted roots. Elm bark beetles breed in dead or dying elms and their larvae feed exclusively on elm tissue. If the tree dies because of Dutch elm disease, every beetle that hatches from that tree carries the fungus. Adult beetles, which prefer to feed on healthy elm trees, pass the fungus to healthy elms. Once infected, the fungi live in the xylem of the trees, which die in several months to several years (Stack *et al*., 2002). Dutch elm disease occurs within most counties in the Lower Peninsula, including the five counties in the study area.

Road Development

Ecological Effects

For the purposes of this report, roads include all primary roads such as federal and state highways and secondary roads, such as county and private roads. Some consider off-road vehicle trails as a type of road in that they cause ecological effects similar to paved roadways, but the team addresses these trails independently of roads.

The primary ecological damage caused by roads is the fragmentation of the landscape and disruption of ecological processes. By fragmenting natural areas, roads restrict the movement of species that are unwilling to cross open areas and create disturbed areas that encourages invasion by non-native and colonial species. Furthermore, automobiles travelling the roads serve as direct sources of mortality to many animals (Noss, 1987).

Roads also provide access that tends to increase activities such as logging, mining, housing development, and recreation. These activities often lead to additional fragmentation of natural areas as land is cleared for housing, mining development, recreational trails, or logging. They can also lead to increased pollution in the form of air and noise pollution from vehicle traffic, as well as water pollution from road salts and automobile fluids.

Study Area Specifics

Two major state highways, M-72 and M-66, are found in the study area. Primary county roads include C-42, C-38, C-597, C-612, and C-571. At present no new major roads are slated for construction. However, a passing relief lane program will take effect in the area by 2003, effectively widening roads. This program will add symmetrical passing relief lanes on stretches of M-72 where one passing lane already exists. This extension will occur on the segment of M-72 that runs from M-66 on the western side of Kalkaska County to the eastern Kalkaska County line (Michigan Department of Transportation, 2002). This road development will likely increase tourism traffic and vacation home development in areas served by M-72.

Overall, development and extension of major highways is not a major source of threat in the study area. Instead, with an increase in residential development in the area, secondary road construction is the dominant type of road development. For example, in Blue Lake Township in Kalkaska County, a trend of splitting large parcels into smaller lots creates the need for more roads to access additional lots (Riley, 2002). Depending on township regulations, road construction may occur after houses are built or may be a required precursor to home construction.

Off-Road Vehicle Use

Ecological Effects

The Michigan Department of Natural Resources defines off-road vehicles (ORVs) as “any motor vehicle that can be operated cross-country without benefit of a road or trail over land, snow and other natural terrain” (MDNR, Michigan’s off-road vehicle guide, 2000). Examples of ORVs include four-wheelers, dirt bikes, and other all-terrain vehicles.

In 1979, the White House Council on Environmental Quality released a powerful statement on the impacts of ORV use: “Off-road vehicles have damaged every kind of ecosystem found in the United States. In some cases the wounds will heal naturally; in others they will not, at least not for millennia” (National Off-Road Vehicle Coalition, 2000). Impacts of ORV use include soil erosion; disruption of wildlife mating and foraging patterns; spread of invasive species; and noise, water and air pollution. Many ORVs have two-stroke engines, which produce far more emissions than standard automobiles (Watzman, 2001). Fragmentation is also a concern -- ORVs create and use narrower trails than roads designed for automobile use, but these trails can still effectively perforate natural areas. While snowmobiles impact natural areas, they impact them less severely than ORVs that operate on bare ground.

To limit the negative impacts of ORVs, federal and state agencies attempt to regulate ORV use on public lands. For example, the agencies promulgate various regulations and require licensing and registration of ORVs. However, efforts to control ORV use have achieved limited success for two reasons. First, the very design of ORVs permits and encourages their use both on and off established trails. Second, monitoring and enforcement is a daunting task for officials that patrol thousands of acres of land with multiple access points. Regulations may help curb negative ecological effects, but it is extremely difficult to control ORV use entirely.

Study Area Specifics

ORV use is popular enough in the study area to warrant its classification as a significant threat. The Michigan DNR provides thousands of kilometers of trails for ORV use in the study area, and residents use ORVs on public and private lands year-round (Hopkin, 2002).

It is expected that ORVs impact private and public lands equally. On private lands, ORV users are not subject to regulations. On state lands, various rules limit the ecological impact of ORVs in theory, but fail to control it in practice. The Michigan DNR requires ORVs to stay on designated trails, forbids their operation in such a way that may create erosion, and prohibits users to drive them in streams, rivers, marshes, or other water features (Michigan Department of Natural Resources, 2000). To help enforce the use guidelines, the DNR patrols the public lands and can fine violators up to $500. Despite these regulations and the potential of fines, rules are frequently ignored and enforcement is limited.

Fire Suppression

Ecological Effects

Most forest ecosystems around the world have been burned at varying frequencies for many thousands of years. In Michigan, fire has been an important component in determining the composition and structure of natural vegetation for nearly 10,000 years (Barnes, 1998). Both natural and human-made fires greatly influence ecosystem health. Fires inhibit the growth of dense shrubs, while leaving relatively fire-resistant canopy trees intact. Limiting the development of woody vegetation helps maintain a high diversity of grasses and forbs and the associated habitats for many kinds of animals (Michigan Natural Features Inventory, 2002). Fire adapted species rely on fire to reduce competition from less fire-tolerant species that otherwise may dominate the site. For some animal species, less dense underbrush allows them to increase hunting, migration, and nesting activity.

In fire-dependent communities, fires promote regeneration and reproduction. Fire initiates sprouting in asexually reproducing species such as fire-dependent angiosperms. For sexually reproducing species, fire promotes fertility in pines by opening cones for seed dispersal and encourages wind-blown seed dispersal in other trees. Fire also enhances seedling establishment by exposing mineral soil, increasing sun penetration to the forest floor, and reducing competition by burning away understory vegetation. In addition, fire limits outbreaks of defoliators such as bark beetles and budworms.

Fire increases soil fertility in a number of ways. It improves site fertility temporarily by burning the organic matter on the forest floor, which increases nitrogen levels in the soil. Burning organic matter also increase the soil's pH, which stimulates an increase in microbial activity in the soils. The increased microbial activity releases additional nitrogen and other scarce nutrients into the ecosystem. Nitrogen-fixing legume species and free-living nitrogen-fixing bacteria have a good chance of surviving the fire beneath the surface and, in turn, increase the nitrogen-fixing potential of the area for a longer amount of time (Barnes, 1998).

Given the many ecological benefits that fire provides, fire suppression can threaten the natural structure and functions of ecosystems. Fire suppression leads to a build-up of fuel and a general increase in insect and disease attack as the proportion of mature forest increases. As late-successional species replace the mosaic of forest species characteristic of mid-successional stages, wildlife habitat declines and both plant and animal diversity decreases (Barnes, 1998). For example, animals that depend on fire-adapted trees may lose habitats and food sources as those tree species are replaced by more shade-tolerant species whose saplings can survive in the undergrowth.

The growing use of prescribed burns as a tool in silviculture, fire hazard reduction, and ecosystem management has caused a reevaluation of the effect of fire on natural areas. Many mangers now realize that fire's effects on forests are complex and often beneficial (Barnes, 1998). Prescribed burning entails setting fires according to a predetermined plan that describes the acceptable weather and fuel conditions in which a fire can be safely set to accomplish land management objectives. Prairies are one ecosystem commonly maintained by prescribed burns. Prescribed fire also helps maintain large openings characteristic of oak savannas. In addition, prescribed burns often aid wetland restoration. Because cattails can out compete other plants over time and fill in open water needed by waterfowl, burning cattails during the winters can help restore these open areas (MDNR, Wildland fire in Michigan, 2002).

Study Area Specifics

Fire suppression in the study area is a particularly great threat to many acres of jack pine, which support the federally endangered Kirkland's Warbler (*Dendroica kirtlandii*). Jack pines depend on fire for reproduction because their seed-bearing cones only open under intense heat. Without fire, the Kirkland's Warbler would lose its critical habitat.

The few remaining lands that continue to support pine barren plant associations in the study area are dependent on fire as an essential ecosystem process. Many former pine barren sites were logged or succeeded to closed-canopy forests as a result of fire suppression. Fire suppression also allowed Kentucky bluegrass, a common exotic grass that thrives in the absence of fire, to flourish in the pine barrens. Fewer than five high quality pine barren sites exist in Michigan, totaling only a few hundred acres (Michigan Natural Features Inventory, 2002).

Dams

Ecological Effects

Dams inflict several detrimental effects on riverine ecosystems. First, dams stop the transport of sediment and woody debris. When water is discharged from or overflows the dam without its normal sediment load, the river scours the downstream channel and picks up more sediment. This process can increase erosion on both riverbanks as well as the riverbed, which in turn can change the width and the depth of the river. In addition, a decreased amount of instream woody debris reduces the amount of habitat and food available for fish and other aquatic organisms (Rozich, 1998).

Second, dams can block the passage of fish and other aquatic organisms. Dams block upstream tributaries that would normally serve as spawning grounds for anadromous fish such as salmon and brown trout (Rozich, 1998). Other drifting aquatic organisms such as plankton, micro-invertebrates, or juvenile fish species often require the natural river flow to carry them to adult feeding and spawning areas downstream. While these problems are usually associated with larger dams, small dams can hinder such migrations as well. It is worth noting that while these blockages harm native fish populations, dams can also benefit the river system by blocking the passage of non-native aquatic species such as the sea lamprey *(Petromyzon marinus*) from Lake Michigan to upstream tributaries.

Third, dams can change river temperatures by slowing the natural flow regime. These undesirable warming or cooling effects create water temperatures unfavorable for native fish species. Finally, species associated with floodplain ecosystems depend on periodic flooding that is often restricted by both large and small dams.

Study Area Specifics

There are currently 63 dams in the Manistee River watershed. The majority of these dams are relatively small. Over half have a head of five feet or less and only five have a head greater than 20 feet.[3] The storage capacity of most of the dams in the Manistee River watershed is also very small. Forty-two dams, or roughly two thirds of the total number of dams, have impoundments less than 10 acre feet (Rozich, 1998). The two largest dams on the Manistee River do not occur in the study area. Built in the lower reaches of the river, Hodenpyl Dam stands 68 feet with a 60,700 acre-feet impoundment and Tippy Dam rises 56 feet in front of a 3,950 acre feet impoundment (Rozich, 1998).

Nineteen dams are found in the project study area (Table 6.5). These dams have heads ranging in height from two to 20 feet. Only four dams have more than five feet of head. Five of the 19 dams support measurable impoundment areas, which range from one to 135 acre-feet. While the majority of the dams in the study area are relatively small, they still threaten the river's ecology. Since most of the dams on the Manistee River are shallow, their main degrading effects on water quality and the aquatic ecosystems are warming of the water

[3] The head of a dam is the difference between the upstream and downstream water level at the dam site

column and conversion of nutrients from particulate to dissolved form (Rozich, 1998). These effects can harm aquatic species and hinder nutrient cycling in the Manistee River ecosystem.

Table 6.5: Dams within the study area

County	Dam	River	Head (ft)
Crawford	Lake Margrethe	Portage Creek	3
Kalkaska	Lutz Dam	Trib. Maple Creek	
	Gray Dam	Waterhole Creek	2
	Goulait Dam	Little Silver Creek	20
	Simmons Dam	Trib. Manistee River	8
	Gould Dam	Springfed trib. to Gould Creek	2
	Vantol Dam	Bourne Creek	3
	Williams Dam	Trib. Manistee River	3
	Condon Dam	Trib. Manistee River	
	Ash Dam	Fife Lake Outlet	2
	Skinner Dam	Inlet Creek	
	Goose Creek Imp. Dam	Goose Creek	
	Cotton Dam	Collar Creek	2
Missaukee	Cannon Creek Dam #1	Big Cannon Creek	
	Cannon Creek Dam #2	Big Cannon Creek	4
	Horseshoe Lake Dam	Big Cannon Creek	11
	Missaukee Walleye Rearing Pond Dam	Trib. Morrisy Creek	5
	Hamm Creek Dam	Trib. Hamm Creek	3
	Jenkins Dam	Trib. Morrisy Creek	11

Source: Adapted from Manistee River Assessment (Rozich, 1998)
* Blank boxes denote that information was not available.