# Strategic Plan

*for*

# Missouri Ozark Forest Ecosystem Project

**2006-2011**

**MOFEP**

**Missouri Ozark Forest Ecosystem Project**

**MOFEP Steering Committee**
**April 2006**

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# Executive summary

The MOFEP Steering Committee developed this 2006-2011 MOFEP Strategic Plan. The major objectives of the strategic plan are to:

- Identify new research areas important to MOFEP
- Prioritize on-going and new research areas
- Guide funding priorities for MOFEP studies
- Document MOFEP coordination mechanisms
- Accelerate research information transfer to resource managers and other interested stakeholders.

The following are identified as core research areas within MOFEP:

1) Forest interior birds
2) Overstory vegetation
3) Ground flora
4) Small mammals
5) Herpetofauna
6) Experimental design, data analysis and data management

Core research areas are identified as those research areas that are critical information needs for MOFEP. The core research areas are those that are absolutely needed for MOFEP to continue and will receive priority funding consideration.

The following are identified as on-going priority research areas:

1) Stump sprout response
2) Coarse woody debris
3) Harvest damage assessment
4) Economic comparisons of harvest practices and tree grading
5) *Armillaria* and forest management (harvest damage and stump sprouts)
6) Synthesis and integration studies
7) Oak herbivore fauna (time-series analysis, insect-bird interactions)
8) Carbon flux and storage
9) Canopy mapping

The following six new research areas are identified as priority future needs for MOFEP:

1) Nutrient cycling
2) Rare species studies and associated sampling methods
3) Management effects on socially and environmentally sensitive species
4) Invasive species effects
5) Logging roads effects on soil erosion and sediment loading of streams

Core, new and on-going research areas were reviewed and prioritized based on how critical the information needs are for addressing MOFEP objectives. All high priority research needs currently identified are outlined in this document. All proposals submitted for funding through MDC will follow the MDC Resource Science Division's internal review process. One-page proposals submitted will be ranked by the MOFEP Steering Committee and the highest ranking ones will be developed to the full budget stage for further review and ranking. Investigators are strongly encouraged to seek full or partial outside funding to enhance chances of being approved for implementation.

Three commitments are necessary for MOFEP to succeed in providing the scientific information necessary for future forest managers: 1) a commitment to continuation through multiple harvest rotations, 2) a commitment from forest managers to maintain the randomly assigned treatment protocols on each MOFEP site, and 3) a commitment of financial resources to data collection at critical times during the life of MOFEP.

# Introduction

Forest management practices in North America have been controversial since the days of Gifford Pinchot. Much of the debate has focused on how timber is managed. In the modern era, this controversy caught the public's attention when the debate focused on the impacts of timber harvest on northern spotted owls and fisheries habitat in the Pacific Northwest. Timber harvesting in large blocks was seen as a detriment to fish and wildlife (Salwasser and Tappeiner 1981). Territorial habitat for the northern spotted owl was perceived to be heavily impacted by clear-cutting of old-growth forests. Hillsides where clear-cutting had occurred were highly susceptible to erosion and landslides, which silted in spawning beds and clogged streams. These issues received national attention beginning in the late 1960s, which eventually prompted congressional action (Salwasser and Tappeiner 1981).

Congress forced the US Forest Service to adopt a multiple use philosophy and develop forest management plans for each of the national forests (Salwasser and Tappeiner 1981; Kirkman et al. 1986). This action brought the forest management controversy to the forefront in Missouri. The US Forest Service developed their plan for the Mark Twain National Forest, which included the option of using even-aged management, including clearcutting, as a harvest method in managing oak-hickory forests. This plan called for clearcutting as being optimal for oak-hickory reproduction. This option was challenged by several special interest groups and individuals.

The perceived decline of Neotropical migrant birds in the Midwest and Missouri due to forest fragmentation (Thompson et al. 1992; Wenny et al. 1993; Robinson et al. 1995) also added to the concerns for how forests were managed (Robinson 1993). In the late 1980s and early 1990s, there were concerns about possible declines in populations of Neotropical migrant birds that led to various symposia on the subject, and to the eventual development of the Neotropical Migratory Bird Conservation Program (Partners in Flight). The major factors thought to be responsible for these purported declines were: winter habitat limitation, stopover habitat limitation during migration, and habitat loss and fragmentation in the breeding grounds (Clawson et al. 1997).

Numerous studies have shown that fragmented breeding habitats have lower species diversity and reduced breeding success among species that still occur in those habitats (Clawson et al. 1997). If the Missouri Ozarks are critical to maintaining populations of migrant birds across the Midwest, we need to understand the effects of forest management practices on migrant birds in this region. Most fragmentation studies have been executed in forests already heavily fragmented (Robinson et al. 1995; Clawson et al. 2002), unlike the heavily forested Ozarks of southern Missouri, which is not influenced by great amounts of edge or small forested tracts surrounded by open lands. The Missouri Ozark Forest Ecosystem Project (MOFEP) would allow us to understand the effects of Missouri Department of Conservation (MDC) management practices on a landscape that is 80% forested.

The issue of how an oak-hickory forest can be regenerated continues to be a factor in establishing forest management guidelines in Missouri. Much of the oak-hickory forests on lands owned by MDC in the 1980s were 60-80 years of age. These second growth forests were rapidly reaching maturity with little diversity in their age structure. The older forest age classes were beneficial to wildlife requiring mature forest habitats, but a mature forest can not be maintained as a static environment. With little diversity in forest age, the question was how to regenerate forests, and how to manage also for wildlife species requiring habitats provided by younger age classes. Species, such as ruffed grouse, woodcock, and early succession forest birds, were not being benefited by these mature forest habitats.

The combined concerns about public perceptions regarding forest management methods (Palmer 1996; Kabrick et al. 2004), early forest succession habitat, and the impact of forest fragmentation upon wildlife lead MDC and others to recognize the need for improved science-based information in forest management decision making (Kabrick et al. 2004). It was during a wildlife research project review for a proposed study of how forest fragmentation might impact Neotropical migrant birds that MOFEP was born (Kurzejeski et al. 1993; Sheriff and He 1997; Kabrick et al. 2004). During this 1989 review, staff recognized the continual need for sound scientific information concerning the impact of forest management methods on the forest ecosystem. This science-based information would help ensure that the best forest management practices would be used in the decision-making process.

MOFEP provides this opportunity to learn about forest management, particularly as practiced by MDC. It was designed to understand how changes in forest management through time impact this oak-hickory forest ecosystem (Brookshire and Hauser 1993; Kurzejeski et al. 1993; Brookshire et al. 1997; Larsen et al. 1997; Sheriff and He 1997; Sheriff 2002; Kabrick et al. 2004). The information derived from MOFEP provides a scientific basis that will enhance forest and wildlife management in the oak-hickory forests of southeastern Missouri. Information from MOFEP also supplies evidence that is used in active forest management and revisions of practices. It builds a body of knowledge for the education of forest managers and decision makers.

MOFEP uses a manipulative experiment with replication and randomization to determine the effects of forest management methods (i.e. even-aged management, uneven-aged management, and no harvest management) upon the oak-hickory forest sites where the project is being conducted. The experimental design has the advantage over observational studies by being able to show cause and effect differences among various forest management methods as they impact the forest ecosystem (Kurzejeski et al. 1993; Sheriff and He 1997; Sheriff 2002). The specific regeneration and forest tending methods are applied in the same manner as practiced by MDC forest managers for even-aged and uneven-aged management. Presently, even-aged management includes clearcutting on a 100-year rotation for regenerating stands and thinning for improving stand quality and regulating growing space. Uneven-aged management includes a combination of group and single-tree selection harvests designed to create forest structures that are similar to those created by even-aged management at the compartment scale. Under both systems, a

15-year harvest interval is currently used and similar guidelines are applied for providing specific kinds of habitats through the regulation of reserve trees (e.g., den trees, snags, other "wildlife" trees; old growth reserves).

The even-aged and uneven-aged systems offer considerable flexibility in how they are implemented. With each system, different regeneration methods, harvest intervals, and residual stocking levels can be selected and different numbers and configurations of reserve trees can be retained for wildlife habitat. Other even-aged practices include regenerating stands with the shelterwood method, which can be applied with any number of residual densities, configurations, and durations (Nyland 1996). Similarly, uneven-aged methods offer considerable flexibility in how selection harvests are conducted. For example, single-tree selection and/or group selection for timber harvest and forest regeneration may be used. Under both systems, the methods can be applied to favor specific species groups or produce alternative forest structures.

Obviously, the no-harvest treatment provides the least flexibility for adjustment since harvesting is not done in this treatment. However, as presently and routinely done on most state-owned lands, wildfires are suppressed on the no-harvest sites and some preventative measures are taken to reduce the severity of damaging insect outbreaks adjacent to the no-harvest sites (Brookshire et al. 1997). Under MOFEP's objectives, these activities can be altered should the Department change these strategies for other state lands under a no-harvest regime.

What is necessary for MOFEP to succeed in providing the scientific information necessary for future forest managers is 1) a commitment to continuation through multiple harvest rotations, 2) a commitment from forest managers to maintain the randomly assigned treatment protocols on each MOFEP sites (Sheriff and He 1997; Sheriff 2002), and 3) a commitment of financial resources to data collection at critical times during the life of MOFEP. MOFEP can then provide not only insights as to the history of how MDC managed its oak-hickory forests in southeastern Missouri, but it will provide forest managers with information concerning how rotation length, small diameter tree harvesting, pine regeneration, and other future forest management options within the three methods affects this oak-hickory forest ecosystem. To add even greater benefits from MOFEP, the project can be expanded in terms of landscape and temporal scales by adding replicate blocks in other locations.

The latitude provided MDC researchers in program development established the climate necessary for the inception of long-term management experiments (Kurzejeski et al. 1993). MOFEP is well funded and supported through MDC's strategic plan and Forestry and Wildlife Divisions' operational plans which continue to stress the importance of broader, community/ecosystem level approaches to research and management. While some direction in plans is dynamic over time, the longer term direction provided by MDC's Mission Statement is strongly supportive of MOFEP's long-term nature and goals.

MOFEP seeks to address practical forest management problems facing land managers, in addition to providing information for evaluating forest management effects on the flora, fauna, and abiotic components of southeastern Missouri forests. MDC forest managers have continued to be interested in the progress of MOFEP, and have provided long-term support of this project in the agency. The project is particularly well suited to provide information to managers, because the implementation of harvest treatments can change over time in order to mimic the current inventory and forest management schedule and practices within MDC. Likewise, management practices and current ways of thinking can change as a reflection on what is learned from the project.

Many stakeholders have an investment or can benefit from the scientifically-based information that is derived from MOFEP (Table 1). This table of stakeholders should be dynamic as groups are more specifically defined. Through the addition and redefining of stakeholders, it should become obvious that MOFEP has wide interest and potential benefit. It will be these and future stakeholder groups that ensure MOFEP have a long and productive life.

Table 1. MOFEP Stakeholders.

| **Stakeholders with a Direct Investment** | **Stakeholders Who Should Benefit Indirectly** |
|---|---|
| Forestry Division – MDC | US Forest Service |
| Wildlife Division – MDC | Consulting Foresters |
| Private Lands Division – MDC | Missouri Forest Product Industry |
| Fisheries Division – MDC | Missouri Chapter of the Society of American Foresters and Missouri Chapter of The Wildlife Society |
| Resource Science Division – MDC | Farmers and Farm Organizations in Southeast Missouri |
| University of Missouri (and others universities involved in MOFEP – Several Institutions and Academic Departments) | Private Forestry Organizations and Associations |
| | Forest Industry Operating in the Oak-hickory Forests |
| | Academic Institutions with Natural Resource Departments or Centers |
| | Citizens of Missouri Concerned with the Impacts of Forest Management |

# Development of the plan

This 2006-2011 strategic plan was developed to identify MOFEP research needs and priorities. This is the second strategic plan, and it builds on the first plan developed in 1999. Like the previous plan, this one was developed by the MOFEP Steering Committee. The Steering Committee is composed of representatives of each major natural resource division within MDC and experts from other agencies and universities to provide overall vision, oversight and direction for MOFEP. The Steering Committee intends the plan to be used as a short-term planning tool for guiding MOFEP for the five-year period during 2006-2011. However, the research needs and priorities will evolve throughout MOFEP's course. Identifying and prioritizing research needs will require a continual effort by the Steering Committee, by other MDC employees, and by scientists from other agencies and universities.

# Objectives of the plan

The major objectives of the MOFEP strategic plan are to:

- identify new research emphasis areas
- identify priority research emphasis areas
- guide funding priorities
- document coordination mechanisms
- accelerate research information transfer to resource managers and other interested stakeholders.

Focusing research on priority questions and providing timely research information to agencies and managers will contribute significantly to the success of MOFEP.

# MOFEP Vision

### The Goal of MOFEP

MOFEP is a large-scale, long-term experiment to evaluate the effects of even-aged, uneven-aged, and no-harvest management on the flora and fauna in Missouri Ozark forests. However, MOFEP's purpose is not merely to gather information about how Ozark forests respond to a restrictive set of forest management practices. Rather, it was designed as an adaptive experiment that allows treatments to be modified, to some degree, based upon what is being learned though experimentation. This approach provides the mechanism for "learning while managing" that is so fundamental to the goal of adapting forest management practices for optimizing resource objectives (Sheriff and He 1997).

The vision for MOFEP was not to conduct a pure experiment implementing rigid treatment protocols to be evaluated at the end of the study. Rather, it was designed so that MDC managers could use the knowledge gained through experimentation to adjust and "improve" these management systems during the course of the project. As new information is generated about how the flora and fauna of the forest are responding to these management systems, the specific management actions can be modified to better meet the Department's conservation mission.

### The Role of Integration

Central to the mission of the MDC is conserving the state's biodiversity by managing land sustainably. Accordingly, management objectives within MDC are increasingly being set with broader consideration for the integrity of ecosystems rather than simply the abundances of a few plant or game species (Brookshire et al. 1997). This broader concern about ecosystems requires understanding how plant and animal species interact with each other as well as responding to management. It also requires understanding fundamental processes governing habitat dynamics and animals associated with the successional habitats created by management. This level of understanding cannot be derived by assembling information from a series of studies or independently evaluating faunal responses to habitat manipulations. Rather, it requires the simultaneous evaluation of multiple species responses to management actions over long periods of time to provide a more complete understanding. This is precisely what MOFEP seeks to accomplish this objective through the synthesis of findings from many studies being conducted. It is through this integration of component studies that MDC managers will develop a more comprehensive understanding about how forest systems in the Missouri Ozarks respond to even-aged, uneven-age, and no-harvest management.

**The Long-term Commitment**

Forest systems are dynamic. However, many of the successional changes in habitat structure and composition occur over long time periods. In forests managed with even-aged methods, the rotation age largely determines the full range over which succession takes place. In most central hardwood forests, rotation ages typically are about 100 years. With uneven-aged methods, there is no specified rotation age, but it may require several cutting cycles before the forest is fully regulated under an uneven-aged regime. In unmanaged forests, successional processes continue until interrupted by major disturbances, such as catastrophic wildfire or an extreme wind event. Although wildfires and tornados occur frequently, they seldom would affect a very large proportion of a forest at one time. Because understanding successional processes and responses to natural disturbances or harvesting requires long periods of time, MOFEP was purposely designed to extend for up to three even-aged rotations (300 years).

Although all research projects present difficulties, conducting a study for a century or more presents unique challenges. In particular, the project's duration will exceed the life spans of everyone who initiated the study as well as those who presently administer the project. For MOFEP to remain successful, all who are presently involved must inspire the new scientists, managers, and administrators to continue the commitment to this effort.

# MOFEP conceptual models

The overall planning strategy for MOFEP in this strategic plan has been to use conceptual models as a basis for:

- Visually identifying the key components of the system and demonstrating the linkages within the system.
- Identifying and prioritizing new MOFEP projects.
- Providing a way to identify areas for collaboration and integration.
- Facilitating communication between and among scientists, resource managers, and the public.
- Attracting outside funding.

The following models were developed by the MOFEP Steering Committee and MOFEP principal investigators:

**Coarse model** – This model depicts the relationships of the primary ecosystem components. Forest structure and composition is the component that is being changed by the treatments in MOFEP. Components that affect the forest structure and composition, and are in turn affected by forest structure and composition include physical environment, human impacts, site history and biotic community. The coarse model is illustrated in Figure 1 (Appendix 1). Boxes represent ecosystem components and arrows describe the relationships between components.

**Physical Environment sub-model** - The physical environment sub-model captures the feedbacks among the physical environment components and forest structure and composition. The components of the sub-model include soil, water, nutrients, decomposers, climate, geology, topography, and biotic community. These components interact with each other and time affects all components. The physical environment sub-model is shown in Figure 2 (Appendix 1).

**Human impact sub-model -** The structure of the human impacts sub-model captures the feedbacks among human impact components and forest structure and composition. Human impact components include management, policy, demand on the resource, land use, public values, external influences (economy, population growth, and climate change), researcher impacts, and site history. The sub-model is outlined in Figure 3 (Appendix 1).

**Flora sub-model** - The structure of the flora sub-model captures the feedbacks among flora components and forest structure and composition. The major floral components include woody vegetation (subclasses of tree overstory, understory, vines and shrubs), herbaceous vegetation (subclasses of forbs (dicots), grasses and allies (monocots), and vines), and soil/substrate (subclasses of bacteria, lichens, mycorrhiza, fungi). The sub-model is outlined in Figure 4 (Appendix 1).

**Fauna sub-model** - The structure of the fauna sub-model captures the feedbacks among fauna components and forest structure and composition. The major fauna components include insectivores, herbivores, carnivores, decomposers, pollinators and parasites. The fauna sub-model in outlined in Figure 5 (Appendix 1).

The models developed were a consensus of opinion among MOFEP partners on key ecosystem components and their linkages. They are a general reflection of the current state of our best available information. These models are flexible working tools that will be modified in an interactive process, as components and linkages are better understood in the coming years. The site history sub-model was not developed independently as all components of site history were considered and included in the other sub-models. Future research areas will be guided by the conceptual models.

## MOFEP research areas

Since MOFEP's inception, many studies have been completed (Appendix 2) and others are on-going (Appendix 3). This plan identifies core (high priority), on-going priority and future research needs. Core research areas are identified as those research areas that are critical information needs for MOFEP. The core research areas are those that are absolutely needed for MOFEP to continue and will receive priority funding.

Core, on-going and new research areas were critically reviewed and prioritized based on how critical the information needs are for addressing MOFEP objectives. All high priority research needs currently identified are outlined in this document. All proposals submitted for funding through MDC will follow the MDC Resource Science Division's internal review process. One-page proposals submitted will be ranked by the MOFEP Steering Committee and the highest ranking proposals will be invited to submit full budget proposals for further review and ranking. Investigators are encouraged to seek outside funding.

**Core research areas**

Six areas of study were identified as core projects by the MOFEP steering committee. The first five focus on the information requirements of resource managers. The experimental design, data analysis and data management studies focus on how the information can be obtained and analyzed in a more efficient and effective manner.

The six top priority studies are:

1) Forest interior birds,
2) Ground flora,
3) Oversory vegetation,
4) Small mammals,
5) Herpetofauna, and
6) Experimental design, data analysis and data management.

<u>Forest Interior Birds</u>

Understanding the relationships between forest management and bird populations is a top priority in MOFEP. Many bird species, including some Neotropical migrant species that are facing long-term population declines, depend on forest ecosystems that are routinely managed for timber resources. Identifying and understanding the mechanisms that link forest management to bird population processes will help scientists sustain species that use these ecosystems. The project directly monitors the impacts of forest management on avian demography and explores these relationships at expanded temporal and spatial scales. Other research into the impact of forest management on bird populations is frequently conducted at limited spatial and temporal scales that are not relevant to maintenance of bird populations or communities, and many studies lack rigorous experimental designs with adequate replication and randomization. Furthermore, many researchers measure only species' abundance and habitat use, but these patterns may not reflect reproductive success or habitat quality.

The overall, long-term objectives of the MOFEP bird study are:

- To determine differences in breeding densities of selected a) mature forest and b) early-successional forest songbirds in forests managed by even-aged, uneven-aged, and no-harvest methods.
- To determine rates of nest parasitism, nest predation, and reproductive success for these songbirds in forests managed by even-aged, uneven-aged, and no harvest methods.
- To provide an educational training ground in field biology for a diverse and talented group of students.

Ground flora

Ground flora is an important composition of any forested landscape. The composition and structure of the ground vegetation contributes greatly to the overall forest biodiversity, to wildlife habitat quality and to the character of future stands.

Fundamental knowledge of ground vegetation is needed in order to interpret wildlife responses and processes under investigation in other studies. For example, changes in composition and structure of herbaceous ground vegetation may affect the relative abundance of several wildlife species. Also, changes in ground flora may be interpreted relative to changes in overstory vegetation. Information on the effects of management practices on species diversity and regeneration is required to make decisions in forest management.

The objectives of the MOFEP ground flora study are:

- To determine effects of management practices on ground flora species richness and diversity.
- To determine the abundance and production of berry producing plants.

Overstory vegetation

Like ground flora, overstory vegetation is an important component of any forested landscape. The composition and structure of the overstory vegetation contributes greatly to overall wildlife habitat quality and to the character of future stands.

Fundamental knowledge of overstory vegetation is needed to interpret wildlife responses and processes under investigation in other studies. Also, changes in overstory vegetation may be interpreted relative to changes in ground flora. Information on the effects of management practices on forest structure, composition, succession and regeneration is required to make decisions in forest management.

The objectives of the MOFEP overstory vegetation project are:

- To quantify the effects of even-aged, uneven-aged, and no-harvest management systems on forest structure and reproduction.

- To quantify forest composition, regeneration, succession, and site quality in relation to environmental factors (e.g., site factors, elts, soils).

- To quantify factors governing the growth and dynamics of individual trees and their competitors in stands under different management systems.

- To quantify snags and tree cavity abundance, size and use.

- To use MOFEP data in part, or in its entirety, to examine important issues affecting Missouri Ozark forests (e.g., oak decline/red oak borer, evaluating the effectiveness of uneven-aged silviculture for perpetuating oak forests, historic role of disturbance, the ecology of Ozark forests, concern about impending gypsy moth infestation).

Herpetofaunal communities

Herpetofauna make up a significant proportion of biomass in forest ecosystems, are non-migratory or short-distance migrants and are sensitive to abiotic changes in the environment. In Missouri, information is available on the effects of management practices on game species, but there is a lack of information on the effects of forest management practices on herpetofauna.

The objectives of the herpetofauna project are:

- To determine effects of management practices on the species composition, species richness, and relative abundance of herpetofaunal communities.

- To determine if selected forest habitat characteristics and environmental factors are related to the presence and relative abundance of selected herpetofauna species.

Small mammals

Small mammals are integral components of the oak-hickory forests in Missouri. They are prey for a number of predator species, disperse plant seeds and mycorrhizal fungi spores, consume significant amounts of insects, including pest species, aerate and mix soil through tunneling activity, create refuge tunnels used by other wildlife and add to the organic content of forest soils. Abundance and composition of small mammal species may be affected differently by different management practices. As with herpetofauna, information is available on the effects of management practices on game species, but there is a lack of information on the effects of forest management practices on small mammals. Understanding the relationships between forest management and small mammal communities is a priority in MOFEP.

The objective of the MOFEP small mammals study is:

- To determine the effect even-aged, uneven-aged and no-harvest forest management have on the species composition, species richness, and relative abundance of small mammal communities.

Experimental design, data analysis and data management

MOFEP facilitates a better understanding of how forest management practices impact different components of the forest ecosystem. The mechanism that accelerates this learning process and makes MOFEP so valuable is that it is designed as an experiment that allows for the collection of data from a vast number of ecosystem components. The ecosystem components being studied, and those that may be studied in the future, do not act independently of each other nor independent of the management practices applied within and among sites. As the forest changes under the different management practices, so grows our understanding and the value of the data derived from MOFEP. To garner value-added information from the data collected, advanced statistical techniques need to be applied. Unfortunately, the statistical sciences are not static, but like a forest are highly dynamic with much growth and change. Therefore, to be able to derive as much value from the investment in these data and to better understand the reactions and interactions of ecosystem components under differing forest management practices, a continual need exists to develop and implement advanced statistical methods for gaining as much information from MOFEP as possible.

MOFEP has much potential for expansion, too. As other sites are included as temporal replicates or other ecosystem components currently not being studied are added to MOFEP, many statistical questions concerning study design and data analysis must be answered. By having an on-going emphasis in development and a continual knowledge base in the statistical design and analysis of MOFEP data, a foundation for communicating the information and knowledge learned from this experiment will be perpetual through future generations of foresters in the Missouri Ozarks. Statistical development associated with MOFEP is also required to enable efficient adjustments in study designs for data collection protocols (sample sizes, location, and methods) and schedules as the MDC changes their state-of-the-art forest management.

MOFEP is a long term and multi-disciplinary project. Thus, it is vital that all MOFEP data be archived in one central location and that it be well documented so that present and future scientists and managers can easily access the data, and understand it today and in the distant future. The ability to integrate data from many years of related studies can only be of great value to future researchers if the data is managed well. Well archived quality data will facilitate data exchange among scientists, and will ensure that data collected today will be useful to scientists that come after us, even in 300 years. Data need to be submitted on a regular basis.

Before integration and synthesis of MOFEP studies can begin in earnest the data need to be well-defined, error-free, and readily available. Although MOFEP currently supports a project to integrate component studies, the project leaders presently spend much of their time acquiring useable data sets. With adequate attention to database management and data integration beforehand, the project leaders' time can be spent integrating and synthesizing the different studies. Because database management and integration is absolutely critical to the success of a long-term, multi-disciplinary study, MOFEP needs a person who is dedicated (at least 50% time) to database management and integration. One of this person's responsibilities would be to directly contact principal investigators for their data. A database manager could also ensure that the data, where possible, were tied to a GIS.

The objectives of the experimental design, data analysis and data management studies are:

- To develop and implement advanced statistical methods.

- To archive all MOFEP data in one central location.

**On-going priority research areas**

The following on-going research areas are identified as priority for MOFEP:

Canopy Mapping

There is a lack of information on how fast a seedling will grow in a group opening versus a clearcut versus an uneven-aged treatment. This growth rate will determine if the reproduction will be recruited into the overstory or simply remain an understory tree. The canopy mapping project is addressing this question. Additionally, the canopy mapping data set is being used to determine if an overstory tree is thinned how long it takes to reoccupy the space made available during the thinning. Both of these are questions of importance to determining the intensity and type of treatments to impose on Missouri's forests.

The project objectives are:

- To determine how MOFEP treatments affect understory regeneration abundance.

- To determine the rate of overstory tree crown filling of available growing space after a partial removal of overstory trees.

Down wood coarse debris

Down coarse woody debris (CWD) is an important indicator of forest structure, fire risk, habitat quality, nutrient cycling, and carbon storage. For example, the volume of coarse woody debris of various sizes is indicative of fuel loading and ultimately of fire intensity if ignited.

The project objectives are:

- To quantify the magnitude and variability of the accumulation of CWD.

- To determine rates of decomposition for down wood.

Carbon Flux and Storage
Terrestrial ecosystems have been hypothesized to serve as a sink for atmospheric carbon. However, intensive timber harvesting, like clear-cutting, can offset carbon storage due to increases in decomposition. Quantifying carbon storage under different management regimes is important to inform managers of the capacity of the system to store carbon. Quantifying carbon storage and fluxes in our managed forests will establish a foundation for Missouri to enter the developing market of carbon credits.

The primary objective of the carbon flux project is:

- To quantify differences in carbon flux and storage within mixed oak forests of the southeast Missouri Ozarks resulting from alternative management practices, landscape form, and climate change.

Role of *Armillaria* in Forest Management
*Armillaria* is a ubiquitous genus of opportunistic, root-parasitic, white-rot wood decay fungi. *Armillaria* species often serve as pivotal contributing factors in stress-mediated forest declines, including oak decline. Stump creation, stem injury, and root damage are silvicultural disturbances which lead to elevated levels of *Armillaria* root disease. Forest managers need to know the extent to which forest decline and associated *Armillaria* root disease are responses to silvicultural disturbances *vs*. other stand and/or environmental dynamics. Forest managers also need to know the impact of various classes of tree injury on long-term tree and stand health. This project is monitoring and explaining the relationships between *Armillaria* and forest management operations.

The project objectives are:

- To document tree wound closure and explain *Armillaria* species interactions with each other, with forest stand composition and structure, and with anthropogenic disturbances, in the context of site factors.

- To evaluate of the role of *Armillaria* spp. in stump sprout development and survival.

Economics
The goal of the project is to inform land managers or landowners of the results of management alternatives, as well as to reinforce the need to consider aesthetics, non-traditional forest products, and other non-market values in their decision matrix. Various measures of harvest quality and quantity are made and simulations are made of tree growth, regeneration and harvest into the future. Cost/benefits analyses of even and uneven-aged silvicultural management systems are estimated, and compared to that of the control treatment. Using data on trees 1.5" DBH and larger from MOFEP, the project adapted the widely available Landscape Management System (LMS) and Forest

Vegetation Simulator (FVS) software to make long-term simulations using even and uneven-aged silvicultural management systems. To simulate the economic outcomes of even-aged, uneven-aged and control treatments, the project uses both standard algorithms and new LMS algorithms which simulate the effects of uneven-aged harvesting.

The objective of the economics project is:

- To determine the long-term economic sustainability of the even-aged, uneven-aged and control treatments on the MOFEP research sites.

<u>Oak Herbivore Fauna</u>

Insect herbivores are major components of Ozark forest communities, both in terms of their ecological and economic role, and their diversity. Because oaks dominate Ozark forests, leaf damage by insects that feed on oaks potentially could affect forest productivity. Furthermore, these insects are important components of forest food webs, providing food resources for birds, small mammals, and parasitic insects and nematodes. Characterizing the impacts of logging treatments on these insects, therefore, is essential to developing mechanistic explanations for treatment effects on plant productivity, vertebrate abundance, as well as nutrient cycling and forest regeneration.

The objectives of the oak herbivore fauna project are:

- To document the impacts of the forest management treatments on the abundance, richness, and community structure of leaf-chewing herbivores feeding on black and white oak in the canopy and the understory.

- To determine interactions between birds and insect herbivores on white oak.

<u>Stump Sprouting</u>

Oak stump sprouts are important in obtaining adequate oak regeneration. In young stands, stump sprouting may account for the majority of the reproduction. In older stands, stump sprouts can supplement advance reproduction populations to ensure the adequacy of oak in the new forest. Managers need to be able to predict the contribution of stump sprouts to the overall population of oak reproduction to judge whether (1) reproduction is adequate, (2) artificial regeneration by planting or direct seeding is needed to supplement natural reproduction, (3) competition control is needed to maintain oak in a free-to-grow state, or (4) harvesting should be delayed to give time for the development of large advance reproduction. The contribution of oak stump sprouts to oak regeneration potential is predictable and estimates based on tree, stand and site characteristics can be made before harvesting.

The objective of this project is:

- To determine the effect of overstory density, forest canopy crown cover, and individual tree characteristics on the sprouting potential and growth performance of sprouts arising from stems cut by chainsaw in timber harvesting operations.

Harvest impacts
Tree injuries resulting from harvest activity affect: tree health, levels of forest pest activity contributing to tree- and stand-level forest decline, and future value of residual injured trees. Tree injuries ultimately constrain forest management activities from marking to harvest planning.

The primary objective of this project is:

- To quantify postharvest damage.

- To determine the effects skidding and felling activities on the different silvicultural treatments.

Integration study
To rigorously evaluate the effectiveness of forest management treatments for Missouri Ozark forests, we must examine treatment effects at a variety of temporal, spatial, and ecological scales. Multidisciplinary analyses can potentially identify large-scale patterns among taxa and environmental characteristics that will help us understand how and why forest management treatments affect species. Integration of MOFEP data encourages collaboration among principal investigators which is likely to yield both additional insights into interpretation of results and novel ideas for future management and research activities. This integration also helps identify shortcomings in data collection and scale-issues for the MOFEP community to address as research continues.

The main objective of this study is:

- To integrate MOFEP data from multiple MOFEP studies across different spatial and temporal scales to evaluate the effects of the experimental treatments.

**Future research needs**

Future research directions are guided by the conceptual models. The following research areas were identified as priority future needs for MOFEP:

Nutrient cycling
The balance between nutrient acquisition and loss as well as cycling of nutrients is important for sustaining long-term forest productivity. Nitrogen is acquired slowly into soil primarily by fixation from the atmosphere. Most nutrients such as calcium, magnesium, potassium, and phosphorus are weathered from a finite supply of primary minerals in the soil. Nutrient losses are primarily incurred during tree removal. Studies elsewhere show that nutrient losses result from rapid organic matter mineralization and nutrient leaching during the first year or two following harvesting. Long-term nutrient losses are exacerbated by (1) increasing the quantity of biomass removed during harvesting (e.g., saw log harvests vs. whole tree harvests) and (2) shortening harvest rotations. Some soils on MOFEP have a low nutrient supply and may become nutrient

deficient after only a few rotations. To date, MOFEP includes one study on the effects of timber harvests on sulfur cycling and correlations among organic sulfur and carbon, potassium and magnesium levels (Spratt 1997). This work alone is not sufficiently comprehensive to address MOFEP's needs. An understanding of nutrient pools, additions by atmospheric deposition, mineralization rates and nutrient dynamics following harvesting at MOFEP will help MDC scientists and managers understand how management affects the long-term productivity of Missouri's forests.

A variety of invertebrates participates in the break down and incorporation of organic material in soil and participates in nutrient cycling. These range from wood-inhabiting species that reside in dead or dying woody plants to a wide array of soil invertebrates. Presently, MOFEP includes a study investigating leaf litter invertebrate populations (Weaver and Heyman 1997).

<u>Studies of rare species abundance and sampling methodology</u>

MOFEP was designed as a long-term, landscape-scale, replicated experiment to be analyzed with statistical procedures. This approach gives MOFEP scientists the ability to experimentally test effects of management practices on various flora and fauna. Thus, the experimental design has many advantages over descriptive or correlational studies that only provide the ability to generate, rather than test hypotheses. However, there are limitations to applying experimental designs to natural systems. Many statistical procedures do not work well with rare species (Thompson 2004) because rare species may not be present on all MOFEP sites or can not be adequately surveyed using MOFEP's design. Some rare species may be more sensitive to environmental changes and therefore are better indicators of forest ecosystem condition than abundant species.

<u>Effects of even- and uneven-age management on social and environmentally sensitive species</u>

Recent national discussion has focused on the effects of forest management practices on foraging habitat for bats. Two important issues are: how do different forest management practices affect insect food sources and availability to bats, and how are bat numbers and distributions affected by forest management practices?

Bat surveys from the Riparian Ecosystem Assessment and Management (REAM) project may provide some information regarding the second issue. The effects of bottomland forest management on bat populations can be evaluated with post-harvest surveys on REAM sites. Bat surveys on MOFEP can provide a similar assessment for upland forests.

The Steering Committee shall monitor progress in studies being conducted by MDC, Mark Twain National Forest, and University of Missouri-Columbia on bats, and use the information to determine if further studies are required.

<u>Invasive Species Impacts</u>

Introductions of invasive species of plants, fungi, animals, and other organisms are an increasing threat to biodiversity. Potential impacts on forest ecosystems are enormous.

Introductions of some invasive species could also seriously affect how MOFEP is managed. For example, the inevitable arrival of the gypsy moth in Missouri (probably within the next 25 years) is expected to cause a major, long-term ecological disturbance and significant shifts in forest species composition. Assessments are needed of current and potential impacts from invasive species. Such assessments could yield insights into additional investigations needed to document impacts or provide baseline data prior to arrival of a particular invasive species, and may also have consequences for long-term planning and management of MOFEP activities.

Effect of logging roads on soil erosion and sediment loading of streams
New or improved logging roads and skid trails on MOFEP that were used to remove harvested timber potentially increase soil erosion. MOFEP provides an opportunity to test the impact of logging roads, built to Department standards, on sedimentation and erosion.

## Implementation of the plan

This section provides information on the existing coordination strategies to support MOFEP. The implementation component of our Strategic Plan consists of four implementation strategies:

- Partnerships — Work in partnership with universities, federal and state agencies interested in ecosystem research. Also, work closely with forestry and wildlife resource managers – users of research results.
- Coordination – Ensure there are structures in place to manage MOFEP activities.
- Dissemination— Ensure timely and effective dissemination of research findings.

**Partnerships**

MOFEP has extensive collaborations with universities, such as University of Missouri-Columbia, University of Missouri-St. Louis, University of Toledo, Central Methodist University, Washington University, and University of Tennessee, with many through cooperative agreements. MOFEP also works in cooperation with Federal and other state agencies, and with resource managers. These partnerships will continue to be improved, because they enhance and extend the research capability of MDC.

**Coordination**

MOFEP Steering Committee
The role of the Steering Committee is to provide overall vision, guidance, oversight and direction for MOFEP. In addition the committee provides scientific and administrative advice on MOFEP to the MDC. The purpose of the committee is to:

- Maintain MOFEP direction
- Identify new research projects
- Prioritize research projects

- Facilitate collaboration among scientists
- Review proposals
- Review research reports
- Arrange conferences and workshops
- Promote dissemination and the application of research results
- Develop and revise the 5-year strategic plan
- Facilitate funding for projects that address priorities in the MOFEP plan
- Promote MOFEP vision to MDC and other agencies

The committee meets once a year to review progress on all projects and to review MOFEP's strategic direction. In addition, periodic meetings are held to review proposals or to review any changes in direction of existing projects.

*Membership*

The MOFEP Steering Committee consists of 12 members, 10 of which represent the major resource divisions within MDC: Forestry, Wildlife, and Resource Science. Members represent concerns and opinions of their divisions and sections within MDC. In addition two experts outside MDC representing public institutions and academia were appointed to provide independent opinion on the project.

Current members are:

- David Gwaze (Chair), Silviculturist, Resource Science Division, MDC
- Vicki Heidy, Supervisor, Resource Science Division, MDC
- DeeCee Darrow, Forest Management Chief, Forestry Division, MDC
- Larry Rieken, Regional Supervisor, Wildlife Division, MDC
- Steve Sheriff, Biometrician, Resource Science Division, MDC
- Mike Roell, Supervisor, Resource Science Division, MDC
- Tom Nichols, Supervisor, Resource Science Division, MDC
- Tom Draper, Regional Supervisor, Forestry Division, MDC
- Rob Lawrence, Entomologist, Resource Science Division, MDC
- Randy Jensen, Resource Staff Scientist, Resource Science Division, MDC
- John Kabrick, Research Forester, USDA Forest Service NCRS
- David Larsen, Associate Professor, University of Missouri-Columbia

<u>Data manager</u>

The data manager is responsible for data management, quality control and archiving all MOFEP metadata and data in one central location. Data management is critical to the success of long-term and multi-disciplinary studies, such as MOFEP. Good data management will facilitate integration and synthesis of MOFEP studies, and will ensure that scientists can find and understand the data today and in the future. The data manager is working on three areas to ensure that the value of the information collected on MOFEP is preserved for future use:

- Timely submission of data and metadata by the principal investigators
- Revise guidelines for access to MOFEP data as appropriate

- Continue to improve the metadata/data upload process

The current data manager is Julie Fleming.

Coordinator

The MOFEP coordinator provides the:

- Liaison between the principle investigators, project leaders and the MDC Resource Science administration
- Serves as the information clearinghouse on MOFEP issues
- Works with the field coordination team
- Assists in coordinating MOFEP activities with the field coordination team
- Facilitates the annual principal investigators meetings to discuss status and future plans for MOFEP studies
- Chairs the MOFEP Steering Committee

The current MOFEP coordinator is David Gwaze.

Field Coordination

The field coordination team assists the principal investigators with field measurements and visits, and coordinates harvest activities with Forestry Division. Currently the Field Coordination team consists of Tom Nichols and Randy Jensen

Administrative Oversight

Administrative oversight and coordination is currently being conducted by Vicki Heidy, Resource Science Division Supervisor.

**Dissemination of information**

MOFEP is committed to improving the processes and mechanisms through which research information and technology are shared with fellow scientists and resource managers. The implementation strategies which allow for distribution of research products include:

- Scientific publications
- Publications of notes for resource managers
- Study tours
- Website (http://mofep.mdc.mo.gov/)
- Conference presentations
- Conference proceedings dedicated to MOFEP such as the USDA Forest Service General Technical Reports (GTRs)

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Appendix 1: MOFEP Conceptual models

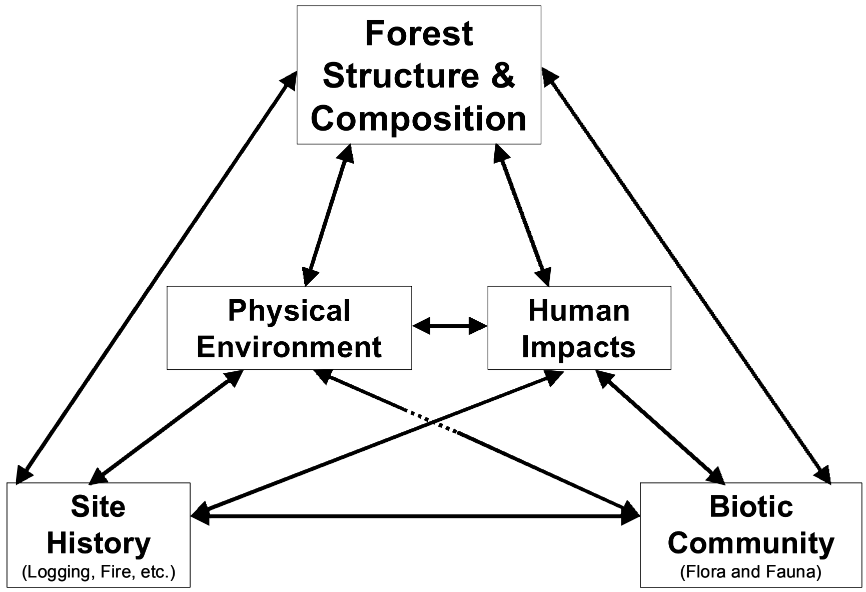


Figure 1. The MOFEP coarse model.

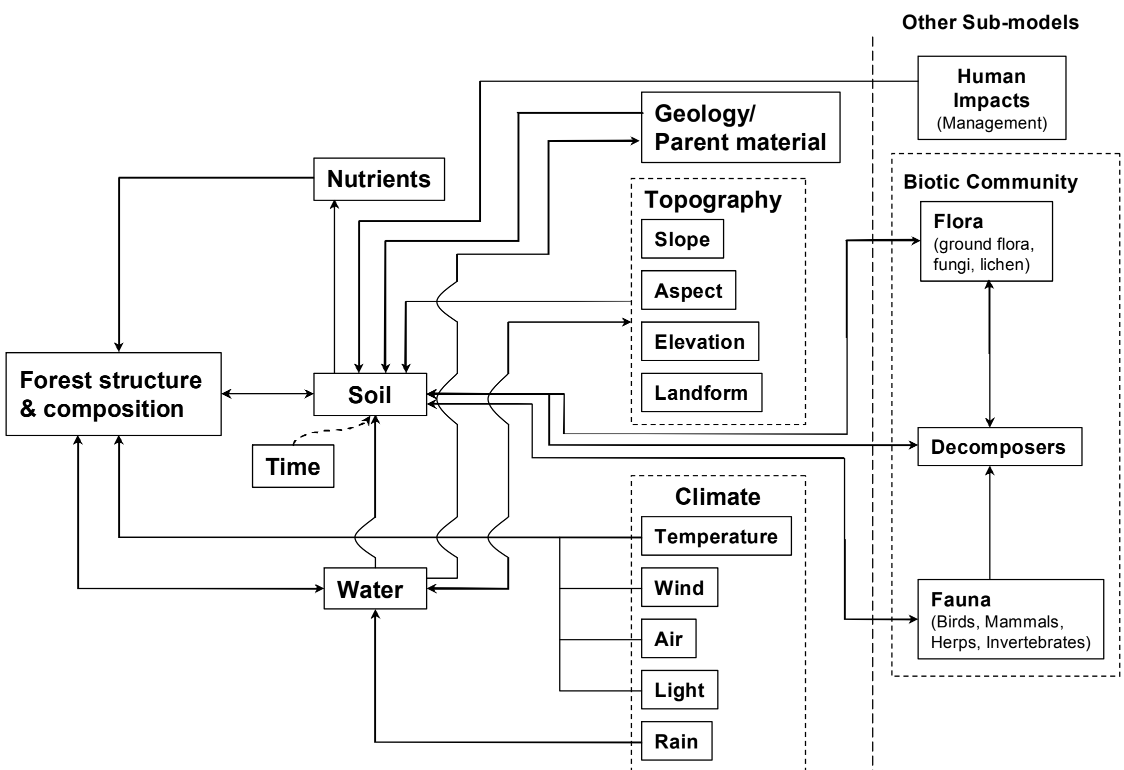


Figure 2. The MOFEP Physical Environment sub-model.

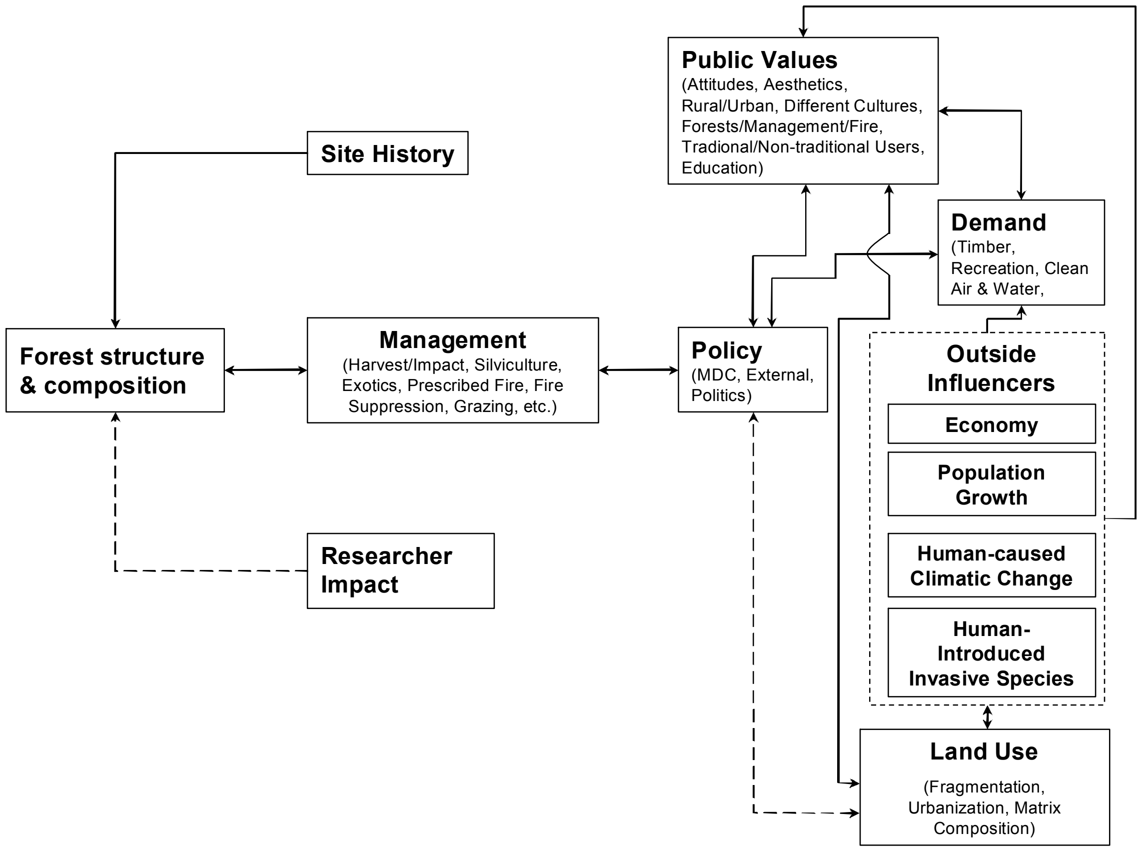


Figure 3. The MOFEP Human Impacts sub-model.

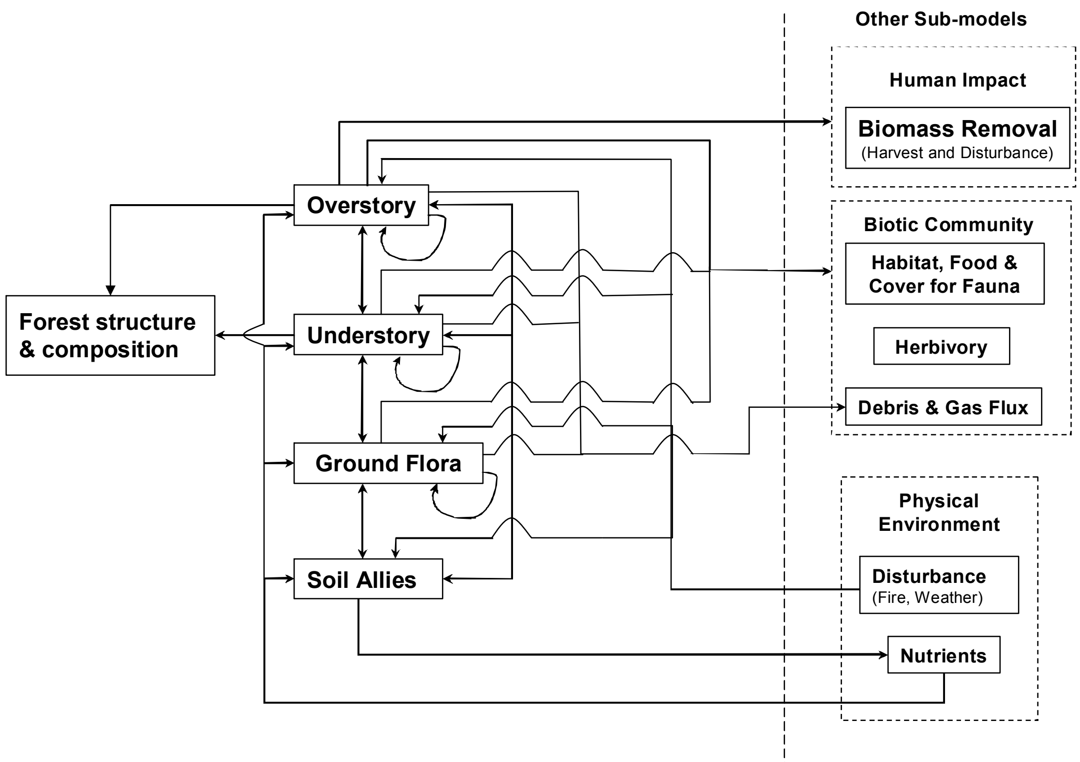


Figure 4. The MOFEP Flora sub-model.

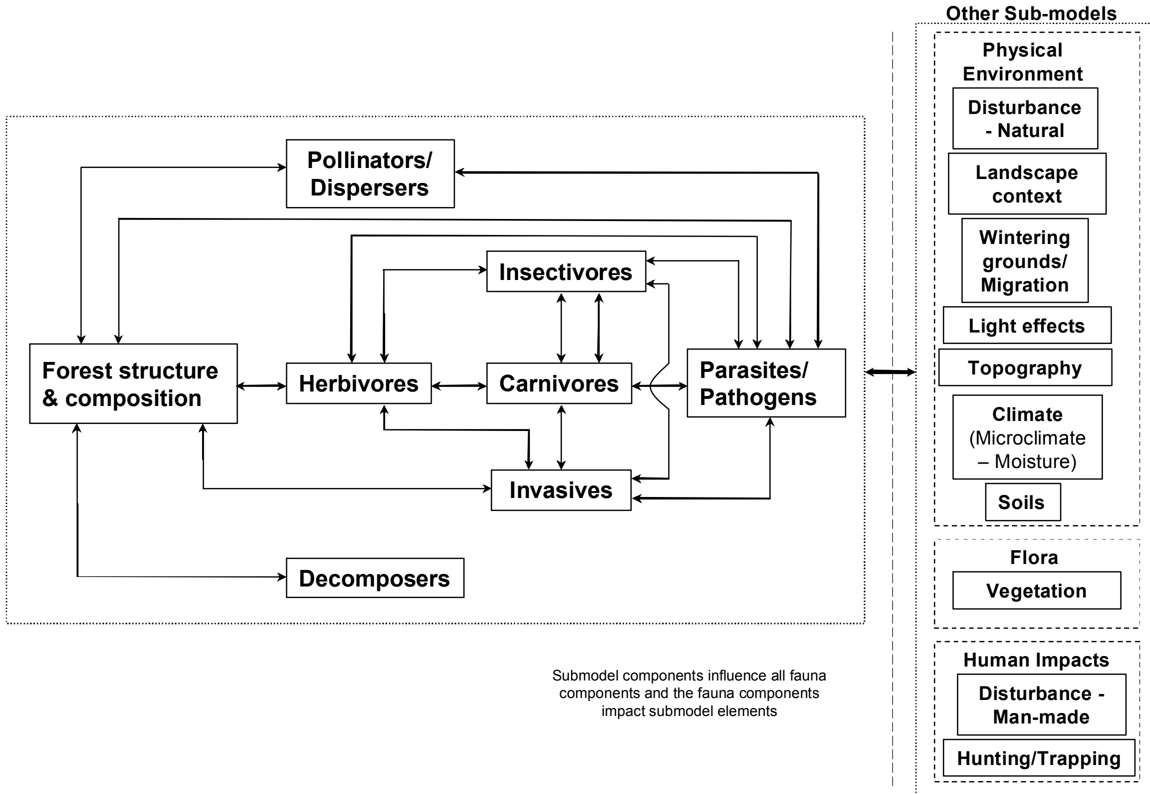


Figure 5. The MOFEP Fauna sub-model.

**Appendix 2: Completed MOFEP Projects – March 2006**

| No. | Project Title | Principal Investigator |
|---|---|---|
| 1 | Mechanical Damage to Residual Stem Root Systems Associated with Forest Operations | J. Bruhn |
| 2 | White Oak Acorn Production Along a Slope Transect | R. Cecich |
| 3 | Microclimatic Characteristics in Southeastern Missouri's Ozarks | J. Chen |
| 4 | Ecological Interactions of Vegetation and Plethodontid Salamanders | L. Herbeck, D. Larsen |
| 5 | Profiling MOFEP Lichen Vegetation | D. Ladd |
| 6 | Simulated Long-Term Effects of the MOFEP Cutting Treatments + Statistical Analyses | D. Larsen |
| 7 | Vegetation Analysis, Environmental Relationships, and Potential Successional Trends | S. Pallardy |
| 8 | Patterns of Genetic Variation in Woody Plant Species | V. Sork |
| 9 | Aspects of Carbon and Sulfur Transformations | H. Spratt, D. Larsen |
| 10 | Soils, Geology and Landforms | D. Meinert |
| 11 | Physical and Vegetation Responses to Stand and Landscape Structure: A synthesis | J. Chen |
| 12 | Development of Ecological Landtypes and Phases, and their responses to management | T. Nigh |
| 13 | Impacts of timber extraction on dung beetles | R. Marquis |
| 14 | Forest history | R. Guyette |
| 15 | Impacts of timber extraction on oak chemistry | R. Marquis |

**Appendix 3: On-going MOFEP Projects – March 2006**

| No. | Project Title | Principal Investigators |
|---|---|---|
| 1 | Forest interior birds | R. Clawson |
| 2 | Woody vegetation | J. Kabrick, R. Jensen |
| 3 | Ground flora | R. Jensen; J. Grabner |
| 4 | Small mammal communities | R. Renken |
| 5 | The herpetofaunal communities | R. Renken |
| 6 | Stump sprout response | D. Dey, R. Jensen |
| 7 | Economic comparisons of harvest practices and tree grading | T. Treiman, J. Dwyer |
| 8 | Documenting harvest damage | J. Dwyer |
| 9 | Abundance and production of berry producing plants | D. Hamilton |
| 10 | Ecology and geographic distribution of *Armillaria* species | J. Bruhn |
| 11 | Synthesis and integration studies | W. Gram |
| 12 | The oak herbivore fauna | R. Marquis |
| 13 | The experimental design and data management | S. Sheriff, J. Fleming |
| 14 | Down wood coarse debris on upland oak sites | S. Shifley, R. Jensen |
| 15 | Acorn production | C. Steen |
| 16 | Distribution and abundance of leaf litter arthropods | J. Weaver |
| 17 | Carbon flux and storage | J. Chen |
| 18 | Canopy mapping | D. Larsen |
| 19 | A comprehensive statistical model for MOFEP | C. He |
| 20 | Forestry practices and human risk of tick-borne disease | B. Allan, J. Chase |