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Integrating Forest Management for Wildlife and Fish



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INTEGRATING FOREST MANAGEMENT FOR WILDLIFE AND FISH

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FOREWORD

People have always expected bountiful resources from their forested land. Today, the increasing demand for fish and wildlife is being reflected in forest resource management. On National Forests, many acres now are being managed primarily for fish and wildlife. To meet these management goals as well as those related to more traditional forest products, rich, diverse forest ecosystems are needed.

The shift to biotic diversity as a major criterion for good land management challenges us all. We must learn to plan habitat management proactively, not reactively. Integrated resource management addresses a richer set of purposes. Biologists and foresters must work as a team and increase their sense of partnership. The keys are integration, leadership, and creativity. The presentations in this session represent innovative approaches to integrated resource management and economic values. They offer ideas on how biologists can join foresters in leading the way.

CONTENTS

	<i>Page</i>
INTEGRATED RESOURCE MANAGEMENT - MAKING IT WORK ON THE GROUND Joel D. Holtrop	1
INTEGRATED RESOURCE MANAGEMENT MEANS FOR MANAGEMENT FOR FISH AND WILDLIFE TOO Floyd J. Marita	5
ASPEN MANAGEMENT FOR RUFFED GROUSE Gordon W. Gullion	9
WOODLAND LANDSCAPING FOR WILDLIFE Carrol L. Henderson	13
INTEGRATING HABITAT NEEDS OF MOOSE WITH TIMBER MANAGEMENT IN NORTHEASTERN MINNESOTA Peter A. Jordan, Elizabeth R. Kennedy, Scott D. Posner, and Gordon A. Weil	18
INTEGRATING WILDLIFE HABITAT OBJECTIVES WITH SILVICULTURAL PRESCRIPTIONS John E. Mathisen	23
KIRTLAND'S WARBLER BREEDING BIOLOGY AND HABITAT MANAGEMENT John R. Probst	28
MANAGING NORTHERN FORESTS FOR BLACK BEARS Lynn L. Rogers, Gregory A. Wilker, and Arthur W. Allen	36
RIVERS OF SAND; RESTORATION OF FISH HABITAT ON THE HIAWATHA NATIONAL FOREST Charles E. Bassett	43
AQUATIC HABITAT MANAGEMENT CONCEPT - A STREAMSIDE MANAGEMENT STRATEGY FOR NATIONAL FORESTS IN ALASKA Dave R. Gibbons	49
MANAGEMENT OF RIPARIAN ZONES AND STREAM CHANNELS TO BENEFIT FISHERIES Robert L. Hunt	54
ECONOMIC CONCEPTS RELATED TO THE COMPARISON OF RELATIVE VALUES OF TIMBER AND FISHERY RESOURCES David B. Rockland	59

INTEGRATED RESOURCE MANAGEMENT - MAKING IT WORK ON THE GROUND

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Presented at the SAF National Convention held in Minneapolis on October 20, 1987

INTRODUCTION

Integrated Resource Management is considering and planning for all resources in the same area at the same time, using an interdisciplinary approach. It is how the National Forest Plans were developed, and now how they are being implemented.

Integrated Resource Management (IRM) can be explained with buzz words and concepts, such as "Interdisciplinary Teams", "Management Areas", "Opportunity Areas", and "Desired Future Condition". But making IRM work on the ground requires more than words and concepts. It requires things like a champion for resources like fisheries, wildlife, and endangered plants. It requires real, meaningful public participation. It requires cooperative relationships, well-articulated objectives for all resources, and more.

Not that the words and concepts associated with IRM are not important. It is essential to have a common approach and consistent terminology. Basic concepts and an understanding of the value of an integrated approach are essential. However, I will concentrate on some of the other items necessary to make IRM work on the ground.

INTEGRATED RESOURCE MANAGEMENT

First of all, though, let me lay the ground work of what I mean by Integrated Resource Management. It is the Forest Service Eastern Region's approach to implementing our Forest Plans. The Forest Plans were developed by considering all the resources of the Forest at the same time using an interdisciplinary team. That is, the Forest Plans are integrated resource plans. Now, as we implement the Plans, as we get more site and project specific, we must continue to do so in an integrated fashion, to stay consistent with the Plan.

The IRM approach involves identifying and analyzing 5,000 to 20,000 acre sections of the Forest called Opportunity Areas. These Opportunity Areas are analyzed by an interdisciplinary team that considers all the resource opportunities and concerns of the area at the same time. Based on Forest Plan direction, a long-term Desired Future Condition forms the basis for what projects need to occur during the next 10 years to move us toward that desired condition. The projects have been planned at the same time for the Opportunity Area, so integration of the various projects occurs.

Integration like closing roads by planting wildlife supporting shrubs. And cutting aspen to encourage beaver activity to create wetland habitat, and locating a timber skid trail to provide access for a future fisheries project. This helps insure efficiency and avoids conflicts between projects.

In the past, we had individual plans for every resource. For instance, there were river plans for watershed and fisheries improvement, timber plans, recreation plans, and wildlife plans. Each of these tended to head in its own direction, with the result being conflict and inefficiency. Integrated Resource Management brings all of these together as one integrated plan.

We have some common concepts and terminology in IRM, and good professionals very capable of implementing resource technology. Now what does it take to make Integrated Resource Management really work on the ground? Based on experiences with things that have been successful, and others that have not been as successful, takes:

- Public participation
- A Champion for key resources
- Objectives for all resources
- An interdisciplinary team attitude
- Cooperative relationships

Now I will discuss each of these items.

PUBLIC PARTICIPATION

Making IRM work on the ground requires real, meaningful public participation. For truly integrated resource management to be implemented, all kinds of resource projects must occur. Not only popular projects, but also controversial ones. Public participation identifies sensitive issues, concerns, and opportunities. If done well, it insures the public will not be surprised. It helps develop public support for the integrated projects. And it provides a basis for better understanding of resource management. All this adds up to a better decision, as well as a better chance of being able to implement all of the integrated resource projects incorporated in that decision.

There are a few pitfalls to avoid in public participation. The first is seeking public input too late in the decision process. Get public participation throughout the decision making process. Many Ranger Districts in the Eastern Region have even used members of the public on their interdisciplinary teams.

The second pitfall to avoid is not talking to a wide enough range of publics. It may not be easy to get any public input, and this varies by geographic area and level of controversy, but generally it is easier to get local input, more difficult to get regional or national publics involved. It also tends to be easier to get input from the vocal extremes, but not the less vocal "middle of the road" publics.

The third pitfall is a tendency to try to sneak by sleeping dogs. There is a temptation to try to implement projects or plans before affected publics know or understand all the effects. In the long run, this strategy will not work.

We need the public's consent to manage the National Forests. Informed consent of the public is stable. It legitimizes what we do. It wins supporters for good resource management. Uninformed consent, on the other hand, is a time-bomb, threatening everything we do. It will lead to lack of trust, when unexpected negative effects occur. So, address your critics and potential critics throughout the public participation process.

As time allows, there is nothing like the personal touch. Go to an affected public's home or office, and one on one ask them their opinion on what should be done in a particular area. I have found people to be flattered, even honored by the opportunity to express their views in this context. These people have been able to understand and provide quality input on our 5,000 to 20,000 acre Opportunity Area analyses. Some have mentioned their relative comfort with input at this stage in relation to the overwhelming size and complexity of providing input into the Forest Plan.

Real, meaningful public participation leads to better, more informed decisions, and it produces public support so integrated resource management can be implemented on the ground.

A CHAMPION FOR KEY RESOURCES

For the management of an area to be truly integrated, the key resources need to be fully considered. This may seem to be as easy as having the appropriate resource specialist serving on the interdisciplinary team for that area. That certainly is a major step in the right direction.

But I want to highlight that role more than that. There needs to be a strong advocate for key resources that have historically received less attention. Someone who knows the resource well. Someone who can and will uphold the needs of that

resource. Someone I would call a champion for that resource.

Without a champion for these resources, they will fall by the way-side in the push for other things. Without a champion, they will not attain their rightful level of prominence in the integrated resource management of an area.

Let me illustrate with a couple of examples. Rare or sensitive plants are often overlooked in resource management. It takes a champion for these plants - for orchids, prairie grasses, ferns, whatever - to see they are adequately considered. On the Rapid River Ranger District we have a very few remnants of the big grass prairie species. An individual with botanical ability recognized the prairie grass species, recognized the potential significance of our remnant stands of these species, and articulated his knowledge and foresight. Thanks to that champion, where appropriate we have integrated the protection and expansion of native prairie grasses into our management scheme.

Another example of a champion making IRM work is the Forest Service fisheries initiative: Rise To The Future. I am proud to say the Hiawatha National Forest is one of the nation's leaders in fish habitat management and restoration. The reason for the Hiawatha's prominence is largely due to the tenacity of the Forest's first fisheries biologist. He recognized the tremendous potential for fisheries on the forest, and he championed the cause of fisheries until it is now fully integrated into our Forest Plan.

The entire fisheries initiative is the result of champions in all levels of the Forest Service and other groups. Its future depends on champions continuing to labor at all organizational levels.

OBJECTIVES FOR ALL RESOURCES

Integration implies all resources are considered at the same time in one area. For integration to really occur, all key resources need to have enhancement or improvement objectives, not just mitigation objectives.

A resource with clear objectives for outputs or improvement that relate to the Desired Future Condition is easily incorporated into an interdisciplinary analysis. A resource without stated objectives for the area being analyzed is in danger of only being considered in the realm of mitigation.

An objective like "improve fish habitat" is not precise enough when putting IRM to work in an Opportunity Area. If possible, the objectives should include things like desired species and amount of increased productivity. With objectives like that for all key resources, true integrated resource management can work on the ground. If only some of the key resources have well-stated, clear objectives, true integration is handicapped at the implementation phase.

AN INTERDISCIPLINARY TEAM ATTITUDE

The interdisciplinary team needs to have an interdisciplinary attitude to make IRM work on the ground. The team needs to be more than a collection of people representing different disciplines. The team members need to have a mind-set that encourages integrated resource management.

This can be difficult to attain. Selection of team members must consider personalities, leadership, and cooperativeness, as well as resource specialty.

Often, though, there is little choice in the team's make-up. To develop an interdisciplinary attitude on the team is certainly still possible, but it will not just happen.

The team needs to have the attitude of working toward a common goal. Each team member has personal interests and strengths. Hopefully, some are even champions for a key resource. But in the team concept, the emphasis is a common goal. The team needs to work together, with the common goal being managing the area as best as it can be.

Developing the proper attitude on an interdisciplinary team to make IRM work requires strong coaching and direction from the line officer. In the Forest Service, that means the District Ranger. Spend time with the team, emphasizing the need to be integrated.

A team in which all the members work on the entire integrated solution, not just their own resource, has what I call an interdisciplinary team attitude. That team will make IRM work on the ground.

COOPERATIVE RELATIONSHIPS

This might be the most powerful aspect of making integrated resource management work. Cooperative relationships are absolutely essential for they provide financial support, and form a basis of support for integrated resource management.

Particularly in fish and wildlife habitat management, a close cooperative relationship with the state agency is essential. On the Hiawatha National Forest, we enjoy an excellent partnership with the Michigan Department of Natural Resources. That partnership is a key ingredient in our successful fisheries restoration program.

But let me discuss cooperative relationships with other groups. Groups like Trout Unlimited, Ruffed Grouse Society, Ducks Unlimited, and Wildlife Unlimited. Groups like these are providing the funds necessary to make integrated resource management work on the ground. The Challenge Grant Program is allowing us to multiply their contributions with matching allocations from Congress. Another important spin-off of these partnerships is they provide us with contacts, supporters, and friends in key places. So the financial help and the grass-roots support allows us to make IRM work.

Let me tell you a little about an example, Wildlife Unlimited of Delta County. This group raises well over \$50,000 each year to put directly into fish and wildlife projects in Delta County, Michigan. We are talking here about a county whose population is around 39,000 people. In 1986, Wildlife Unlimited funded about \$30,000 for projects on the Rapid River Ranger District. What a pleasure it is to do that work, especially for such an appreciative public.

Let me discuss building a relationship with a group like Wildlife Unlimited or Ducks Unlimited. Five things I have found to be effective are:

1. Quality project proposals. When the call comes from an organization for project proposals, be ready to respond with well-planned, documented proposals. The IRM Opportunity Area analysis facilitates this by identifying project sets for the next 10 years. Take the time to document the project proposal in an attractive manner.

2. Be involved in the organization. Be a member, serve on the advisory board, or on a planning committee. It not only makes excellent contacts for funding, it makes excellent contacts with people who really care about the management of their forest resources. And it is enjoyable, too.

3. Provide feedback to the organization on projects completed, even without them asking for it.

4. Publicity for the organization. Always credit them when talking to the media. Never forget.

5. Thank them. I sent Wildlife Unlimited a copy of the U.S. House of Representatives' Committee Report on the Challenge Grant Program that listed organizations involved. I thanked Wildlife Unlimited for their support, and congratulated them on being recognized by the US Congress. A simple little thing, but it made one local organization very proud.

I can not emphasize enough how much cooperative relationships have to do with making integrated resource management work on the ground.

CONCLUSION

The overall results of integrated resource management are an appropriate balance of resource projects and outputs from a piece of land. The public better understands and supports the resource management and local economies benefit. There are multiple benefits, and efficiently coordinated projects.

It takes some effort to make it work on the ground. Perhaps a different kind of effort than we have made before. It is an effort that really embodies all of the basic principles underlaying the Eastern Region's IRM approach.

We need to recognize people as our most important resource, because we need them to be champions for their resource and to set resource objectives.

We must be good neighbors, to get real, meaningful public participation, and to develop cooperative relationships.

Finally, we need to work together as a team, so we have a true interdisciplinary team attitude, to result in integrated resource management.

Integrated Resource Management is an attitude, not a process. We have developed it into an approach that can work. But to make IRM really work on the ground, you have to want it to. It has to be your attitude, which will expand to be the attitude of those around you.

Integrated Resource Management Means Management for Fish and Wildlife Too

by Floyd J. Marita, Regional Forester,
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Good afternoon. I'm glad to be here today. There are some exciting things happening in the Eastern Region of the Forest Service and I'm anxious to tell you about them. During this year we have been working together as part of a Pilot Project. We call it Project Spirit. Project spirit is our way of trying better ways of accomplishing our work; looking for new ways to be more efficient. It involves everyone. Our Region thrives on teamwork. Integrated Resource Management, known as IRM, is teamwork in action. Let me tell you how IRM got started.

The Forest Service has been completing the first round of comprehensive land and resource management planning as congressionally mandated by the National Forest Management Act. As the Forest Plans in the Eastern Region were completed, several things became clear. I'm going to talk to you about two of them.

First of all, it was obvious to us that implementing the Forest Plans' goals and objectives would require an effort unlike any previously undertaken anywhere in the Forest Service.

Secondly, the public told us to achieve a better balance in resource management.

The Forest Service has a long history of habitat management. In the Eastern Region, we have 45 wildlife and 8 fisheries biologists. Our annual budget is 4.5 MM. That sounds like a sizeable program until you spread it over:

- 17 National Forests
- 11 million acres of land
- 960,000 acres of lakes, and
- over 13,000 miles of streams

The public's "program balance" message was uppermost in our minds when we confronted Plan implementation. Accordingly, we developed a process to implement Forest Plan goals and objectives in a way which will achieve that balance. We call this process Integrated Resource Management. We think it is a land management approach that can be used anywhere--not just on National Forests. It can be applied equally well to any private or public land where balanced resource management is a goal.

IRM departs from planning and implementing activities by individual resource as is done on nearly all other Federal, State and private lands. It is a systematic way to insure that all resources are taken into account. Let me give you some examples of traditional approaches:

--Opportunities to manage Industrial and State Forest lands for recreation, wildlife and fish habitat are usually considered secondarily.

--State fish and wildlife management areas are seldom sources of wood products, even when timber management could directly benefit many wildlife species.

--Park management emphasizes visual quality and general recreation, but seldom employs timber or wildlife habitat to enhance either one.

IRM, in contrast, coordinates all actions, such as the management of timber, recreation, wildlife and fish habitat and visual resources to achieve overall area goals and objectives. With IRM, management of all resources in an area is planned and scheduled over the next decade, using an interdisciplinary approach.

IRM is teamwork with the public:

--Pooling expertise to manage all resources in a planning area to meet public needs.

--Designed to unify people and manage resources in a coordinated manner.

--Each person knows his or her role, what is expected, when to do it.

The result of this team effort is not managing every acre for all interests, but an integration of resource management to achieve true balance in multiple use. We feel good about that.

IRM helps us to look at what we've done and make changes when we need to. Management costs are lower and public benefits are higher because IRM schedules work in a same-time/same-place manner.

IRM employs six simple steps to assure program balance in an area:

1. Units of land, usually 5,000 acres or more, which offer the best opportunities to implement Forest Plan goals and objectives are identified. These land units are called Opportunity Areas.

2. The desired future condition of an Opportunity Area is spatially arranged and integrated project sets meeting Forest Plan direction are identified.

3. Projects are scheduled and budgeted.

4. Projects are designed, considering needs of all resources and values.

5. Projects are executed as designed.

6. Resources and property values are protected and managed. This is how it works:

1. An interdisciplinary team with the needed expertise for the Opportunity Area works through Step 2. They spatially arrange integrated project sets to achieve the desired future condition.

2. Managers then schedule and budget these project sets.

3. Last, individual projects are designed and executed in an integrated manner.

State and other agency fish and wildlife biologists routinely provide consultation and review to National Forest IRM teams. Several State biologists have served as team members and some have taken IRM training given National Forest personnel. Biologists from at least three States have expressed a desire for their agency to adopt IRM or a similar process. I think that says a lot about IRM.

Participation by State biologists serves two purposes:

1. They provide needed expertise when it is not available, in-house.

2. They can do much to insure that wildlife and fish habitat management on National Forests is compatible with the goals of their own agency. Related project work may even be coordinated for greater efficiency.

IRM puts all resources on equal footing. Since management is based upon land capability, wildlife and fisheries become the driving forces in some cases. Where wildlife and fisheries are not primary concerns, they still benefit, because IRM emphasizes taking advantage of habitat improvement opportunities which are coincidental to managing other resources. IRM also emphasizes

preventing adverse impacts rather than mitigating them. Potential resource management conflicts are resolved equitably before implementation by the range of expertise integrated into the process. Fewer options are foreclosed to future management.

Further, when this range of expertise concentrates on a land unit, previously unrecognized opportunities emerge. IRM serves as a "discovery" process, improving the quality of land management by considering all opportunities and priorities within the umbrella of the Forest Plan direction. Program balance improves. This point may be best demonstrated by the fisheries resource.

The health of aquatic systems reflects the stability of terrestrial systems. Put another way, simply because water runs downhill, the quality of fish habitat reflects the quality of land management--or the lack of it.

As Edwin Miller, Professor of Forestry at Oklahoma State University, points out in a recent paper, aquatic systems are tightly tied to terrestrial systems for such things as:

1. Food energy.

2. Cover and habitat diversity as provided by large woody debris.

3. Temperature regime.

4. Bank stability.

5. Regulation of nutrient and sediment input.

6. Waterflow regime.

Forest management has the potential to effect all these factors positively or negatively. However, an added consideration makes this list especially important to Forest managers. By nature of their locations, National Forests have an abundance of headwater streams. Small streams, including intermittent or ephemeral waterways, are the most

sensitive or vulnerable to the effects of land use. They are the point of maximum interface between the aquatic and terrestrial systems. The health of small headwaters is reflected far downstream.

As we implement our Forest Plans, some examples show how we can address fisheries opportunities:

During road construction/reconstruction, simple guidelines such as bringing the roadbed down to grade well back from stream crossings can significantly reduce sediment input. There are also economical opportunities during reconstruction to re-set culverts which may block fish movement.

Vegetation management prescriptions promoting long-term accrual of dead and down large trees to riparian areas and shorelines enhance fish cover and habitat diversity at no direct cost. Long-term vegetation management can also promote or discourage beaver activity which is undesirable on low-gradient trout streams, but which may be desirable elsewhere.

Timber sales near lakes and streams can be sources of material for log cribs and brushpiles. Whole trees from sale areas can be anchored in littoral zones and stream channels. This avoids risking bank stability by using shoreline trees for fish cover. Trees can be positioned during frozen conditions to avoid disturbing riparian soils.

Direct fish habitat improvement can often be coordinated with other work such as construction of boat ramps, bridges and near-shore campsites. Sometimes the same crews and equipment can be used for both jobs.

All these examples require a high degree of coordination - a true integration of the management skills of fisheries biologists, engineers, transportation planners, wildlife biologists, foresters, and hydrologists. It also means that our partnership with the public involves all of the resources in our organization; our human resources at all levels, including our Older Americans.

Fish are not mobile in the sense that terrestrial wildlife is. We can't shift or extend their local ranges or distribution as we can with many wildlife species. However, we can avoid damaging existing habitat and we

can dramatically improve its productivity. Implementing our Forest Plans through IRM is a key element in helping us recognize and take advantage of opportunities to improve or restore fish habitat simply because it forces us to more fully consider the needs of all resources as we work on a given land unit. IRM will not let us simply hit the high points in one land area and move on to the next one. IRM forces land management in the fullest sense of resource stewardship.

In assuring program balance, IRM can turn critics into a support base. Fishermen and hunters constitute the biggest single public lands user group in the U.S. Further, nearly 110 million adult Americans participate in wildlife association activities other than fishing and hunting. These groups have tremendous untapped potential for volunteerism and funding support.

The Eastern Region's 1988 Challenge Grant Program has the potential to bring in over \$1,120,000 in outside funding and we are just beginning to market our wildlife and fisheries programs and opportunities.

The program includes projects with national organizations such as Trout Unlimited, The Ruffed Grouse Society, Ducks Unlimited and the Wild Turkey Federation.

Among our partners are state level organizations like the Michigan Steelheaders, the Wisconsin Waterfowler's Association and the Minnesota Deer Hunter's Association.

A particularly gratifying element in the Challenge Grant picture is strong participation by local clubs and organizations like the Island Run Sportsmen's Club and the Clarion Explorer Post, both in Northwest Pennsylvania, and Wildlife Unlimited of Delta County, Michigan.

Of course, our long-term partners, State fish and wildlife agencies, are also strong participants in the Challenge Grant program.

IRM is no different from anything else in that what you get out of it depends on the effort you put into it. IRM carries some challenges in this regard.

It challenges wildlife and fisheries biologists to channel increased program emphasis into efficient, productive work. To do this, they must acquire inventories, data bases, analytical tools and new habitat improvement

technology while continuing to implement sound projects on the ground in response to opportunities already identified.

IRM challenges all professional groups, biologists, foresters, engineers, and recreation managers alike to avoid turfism and participate openly in the IRM process. They must all adopt a wholistic view, answering as many resource management needs as possible in same-time/same-place fashion, recognizing special needs of sensitive resources and user groups.

IRM challenges the public, especially user groups and conservation organizations to participate in the process. Their input can be pivotal. The public is also challenged to participate in the management scenarios they help develop through volunteerism and cooperative funding. Perhaps nothing facilitates volunteerism as well as fish habitat improvement. It closes the public involvement loop as members of the public execute projects resulting from their earlier input to Forest plans.

The need to involve the public in funding natural resource management is gaining recognition. Gordon Guyer, Director of the Michigan Department of Natural Resources made this comment last October - "I think the greatest challenge we face, personally, is habitat; both the acquisition and management of it...We've gotta get people in there from the private sector."

With increasing demands on public lands, there may be no "right" answer to some management issues. Recreational tank driving and warhead testing probably cannot be accommodated by integrated resource management. But our experience with Forest Planning shows that it will provide the best answer to complex management issues because it considers the broadest possible range of opportunities to carry our Plan direction while facilitating the exchange of the other person's perspective, and that's the point natural resource managers must start from in any conflict resolution. Achieving program balance within the context of resource stewardship is what IRM is all about. Wildlife and fisheries resources are among the primary beneficiaries.

Integrated Resource Management means we are all members of a team . . . we all work together. I think that's something to be excited about!

ABSTRACT.--The aspens (*Populus tremuloides*; *P. grandidentata*) should be considered the primary or basic plant resource supporting ruffed grouse (*Bonasa umbellus*) populations across more than 95 percent of the latter's continental distribution. The habitat requirements of these forest game birds are best met by different stages in the successional development of aspen stands. The aspens and the ecosystem they dominate best provide for the food and cover needs of these grouse at all seasons of the year. Where these resources are in proper juxtaposition in time and space densities of about 24 breeding pairs of grouse/100 ha (10/100 ac) can be expected. Management of aspen to benefit ruffed grouse consists basically of treating aspen stands in the manner that best perpetuates aspen on the site. The maintenance of this ecosystem was dependent upon fire in the primeval forest and suffers when forests are effectively protected from severe disturbance for more than 40 to 60 years across most of its range. Commercial clearcut logging during the dormant season effectively substitutes for fire if done properly.

INTRODUCTION

The aspens provide the primary habitat resource for ruffed grouse across Canada and the northern United States, or more than 95% of this important game bird's native range (Gullion and Svoboda 1972).

The aspens have the widest geographical distribution of any North American tree, being

an important part of the forest composition on more than 172 million ha (425 million acres), or 26% of the forested area north of Mexico (Gullion 1985). Then it is not surprising that ruffed grouse enjoy the widest distribution of any resident game bird on this continent.

At some time during the growth of an aspen stand the highest quality cover or food resources are provided ruffed grouse at some stages in their life history.

Moderate density aspen sapling stands provide the highest quality of cover from fall through the winter and during the breeding season (Gullion 1977), and in summer the best cover for the growing brood (Kubisiak 1978).

The most secure nesting cover is in more open, park-like stands of mature aspen. These older aspen, especially those under some sort of physiological stress, provide the staminate flower buds that are the most valuable winter-long food for these grouse (Svoboda and Gullion 1972).

¹A paper presented at the Wildlife and Fish Ecology Working Group Technical Session, 1987 Society of American Foresters Convention, Minneapolis, Minnesota, October 21, 1987. This is Paper No. 2284 of the Miscellaneous Journal Series of the Minnesota Agricultural Experiment Station, reporting research conducted on Minnesota Project No. 83H.

²Professor, Department of Fisheries and Wildlife, College of Forestry, University of Minnesota, St. Paul, stationed at the Cloquet Forestry Center, 175 University Road, Cloquet, MN 55720.

The forest community or ecosystem that is most valuable to ruffed grouse is a system maintained by periodic catastrophic destruction, followed by secondary succession. This community is composed primarily of shade-intolerant trees and shrubs that regenerate rapidly following destruction by fire or windstorm.

LOGGING SUBSTITUTES FOR NATURAL DISTURBANCE

Clearcut logging produces many of the same ecological benefits, and provides some distinct advantages to mankind that may not result from the natural agents responsible for forest renewal.

Among the obvious advantages is the control over when, where and how extensive the disturbance may be, and usually a product usable by industry is produced.

Currently the harvest of aspen in Minnesota provides more employment, both in the woods and in the mills, than any other forest product. Even though it is less valuable than most other species on a per unit basis, the volume of the aspen harvest makes it Minnesota's most valuable timber crop. The 3.96 million m³ (1.52 million cords) of pulpwood delivered to mills in 1984 had a value of about 50 million dollars, and more than twice the value of all other species combined (Blyth and Smith 1986; Lothner unpubl. data).

On the other hand, aspen also requires less management effort and expertise than any other Minnesota forest tree. Clearcut harvesting at the proper age and season is usually all that is required to maintain vigorous, fully-stocked stands, ready for harvest every 40 years or so.

LOGGING PROVIDES HIGH QUALITY HABITAT

For ruffed grouse and other wildlife the advantages of regulated harvest are based on the control over age-class distribution, stand dispersal and the size of harvested parcels.

Proper interspersation of age-classes is necessary to assure that food and cover is in the proper spatial relationship, which in turn is determined by the behavior, or more specifically, the preferred mobility of the wildlife to be benefitted.

Based on the locations of the sites selected by the male ruffed grouse for their drumming logs, these birds prefer moderately dense shrub and/or sapling vegetation growth within 100 meters (100 yards) of the mature aspens providing a winter-long food resource. Shrub-sapling

densities acceptable for cover range from about 7,000 to 40,000 stems/ha (3,000 to 16,000/stems acre). The lower densities are in relatively pure aspen-hardwood sapling stands; the upper densities in thick hazel (*Corylus*) or other shrub cover. But in Minnesota, at least, ruffed grouse tend to be most abundant where aspen saplings constitute the highest percentage of the vegetation composition (Gullion 1983).

SCALE OF TREATMENT IMPORTANT

Aspen management for ruffed grouse consists of periodic harvesting of suitably-sized blocks in such a manner that there is old and young aspen in an acceptable juxtaposition throughout the harvest rotation (Gullion 1984).

Ideally this means clearcutting blocks about 4 ha (10 ac) in size, at 10- to 12-year intervals, in a 4-stage rotation around a central point.

Even smaller blocks, 1 ha (2.5 ac) in size are preferable where economic considerations are less important than providing the greatest amount of optimum ruffed grouse habitat.

Other configurations are possible and useful, but none are as easily delineated in the forest nor as satisfactory as a series of square blocks in providing proper spatial relationships at all stages in the rotation.

Current data indicate that benefits to ruffed grouse decline rapidly as the size of the clearcut exceeds the optimum.

Whereas a series of properly spaced 1 ha (2.5 ac) clearcuts will support 4 or 5 pairs of breeding grouse per 16 ha (40 ac), a series of 4 ha (10 ac) clearcuts will probably not support more than 2 pairs per 16 ha (40 ac). If size of the cutting is 8 ha (20 ac) the resulting grouse density is likely to be no more than one pair per 16 ha (40 ac), and as the size of clearcuts increases grouse benefits diminish in almost direct proportion.

The total area cut is less important than the size and interspersation of the individual cutting blocks. An optimum harvesting rotation should take one-quarter of the managed area in each rotation.

I should point out that these observations, based on over 20 years of observations of ruffed grouse response to habitat manipulation on the Mille Lacs Wildlife Area in central Minnesota, provide somewhat lower rates of response than we forecast earlier, based on data from the Cloquet Forestry Center farther north (Gullion 1984).

³Unpublished forest product price data provided by D. C. Lothner, North Central Forest Experiment Station, Duluth, Minnesota.

TIMING OF HARVEST CRITICAL

Since ruffed grouse respond quickest and at highest densities to the best aspen regeneration it is important to harvest at a time and in such a manner that this will occur.

Total removal of all standing aspen down to 2.5 - 5.0 cm (1 to 2 inch) saplings is important to assure dense, even, and rapidly growing sucker regeneration. Cutting during the dormant season when there is maximum storage of carbohydrates in the root system is preferable to harvesting at any other season. But this is not as critical in vigorous aspen stands on good sites as it is for decadent or sparse stands, or on poorer sites.

Post-cutting disturbance or grazing, especially once regeneration has begun sprouting, should be avoided. Virtually all of the regeneration occurs in the first and second season after cutting. Sucker density lost at this time is seldom recovered.

TIMING OF WILDLIFE RESPONSE VARIES

Of all the wildlife benefitting from aspen management ruffed grouse are second to beaver in being most dependent upon it, but are most demanding in their need for proper age class interspersions. On the other hand, these grouse are also one of the last species of wildlife to commence heavy use of this resource.

While deer, beaver, woodcock, snowshoe hares and a number of songbirds begin using cut-over aspen stands within the first or second year of regeneration, these dense sucker stands have to go through one or two natural thinnings before ruffed grouse make heavy use of them. Most aspen sapling stands need to have naturally thinned to one-quarter to one-half initial density before these grouse will use them. The rate at which this occurs depends upon several factors, but it usually means that use does not begin until the aspen is 6- to 12-years old.

On the Mille Lacs Wildlife Area in central Minnesota, on heavier soils and in a warmer climate ruffed grouse usually begin using the aspen saplings 6 to 8 years after harvesting; but at Cloquet on sandier soils and in a colder climate 145 km (90 miles) to the northeast, it is more often 10 to 12 years before the aspen stand develops the characteristics essential to be cover for these birds.

FREQUENT TREATMENT NECESSARY

On the more favorable Mille Lacs sites few stands of aspen regeneration remain acceptable to grouse longer than 15 years after cutting; at Cloquet use continues 20 to 25 years after cutting. The difference lies in the relative rates of natural thinning, and at Mille Lacs, the recovery and increasing dominance of the

other hardwoods (ash, maple, birch, basswood, and oak) that have little or no value to these birds.

At Mille Lacs we have found that aspen has remained dominant, and ruffed grouse use has continued several years longer on sites where a northern hardwood forest was uprooted by bulldozing as compared to nearby similar stands that were clearcut (Gullion 1983).

In any event, aspen stands must be treated in a continuing rotation to maintain ruffed grouse cover. When this is done, as one block of cover loses its value to these birds another nearby block harvested 6 to 10 years earlier becomes suitable for their use.

THE FUTURE IS BRIGHT

In closing it appears safe to predict that the current demand for aspen in Minnesota and the widespread acceptance of harvesting guidelines developed as the result of a quarter century of research involving ruffed grouse and aspen management will result in a marked increase in the abundance of this popular game bird in this region. There is every reason to expect that this increased abundance will extend well into the next century as the aspen stands being harvested now develop into prime quality ruffed grouse habitat over the next two decades.

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Carrol L. Henderson

ABSTRACT -- One comprehensive, ecological approach to the management of wildlife is a holistic strategy termed "Landscaping for Wildlife". Information from wildlife managers, foresters, agricultural extension specialists, horticulturists, botanists, nurserymen, and landscape architects has been collected to assimilate relevant information from their respective disciplines into one useful reference. "Landscaping for Wildlife" includes techniques for managing midwestern wildlife ranging from monarch butterflies to white-tailed deer. Comprehensive principles for landscaping for wildlife will be reviewed with special emphasis on woodlands. Involves the management of 16 components - eight living plant components and eight structural components.

"Landscaping for Wildlife" is a comprehensive, ecological approach to the management of wildlife that treats wildlife in a holistic manner. For the past three years I have collected information from wildlife managers, foresters, agricultural extension specialists, horticulturists, botanists, nurserymen, and landscape architects to assimilate relevant information into one useful reference - a book called "Landscaping for Wildlife". That book is now being printed and should be available from the Minnesota Department of Natural Resources by December 15, 1987. It will be approximately 150 pages long and include a variety of information useful throughout the Midwest.

I would like to share with you some information from the book, especially as it applies to woodland management.

"Landscaping for Wildlife" involves the management of 16 habitat components - eight living plant components and eight structural components: 1) Conifers, 2) Grasses and legumes, 3) Butterfly, bee, and moth plants, 4) Hummingbird plants, 5) Summer plants, 6) Fall plants, 7) Winter plants, 8) Nut and acorn plants, 9) Nest boxes, 10) Snags, 11) Brush piles and rock piles, 12) Cut banks, cliffs, caves, 13) Dust and grit, 14) Salt, 15) Water, and 16) Feeders.

Many landowners in the Midwest own woodlots of 40 to 80 acres for recreational, esthetic, or economic reasons. The first impulse of many of these citizens is to protect their woodland from disturbance, include cutting. However, successful forest management is complex science which frequently requires active manipulation in order to achieve the goals for which the property was purchased. The key to successful management lies in recognizing the features of the woodland upon which a management plan can be designed. An excellent reference for woodlot management is Decker et al (1983).

¹ A paper presented at the Society of American Foresters Convention held at Minneapolis, MN on October 20, 1987.

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As with other habitats, woodlands must provide food, water, shelter, and space for wildlife. The greater the vegetational diversity, structural diversity, and vertical diversity of the woodland, the greater will be the diversity of the wildlife populations present.

Food is provided by mast-producing trees, snags, fruit-bearing trees and shrubs, browse, buds, grasses, food plots, feeding stations, and salt licks.

Water is provided by ponds, beaver ponds, marshes, swamps, lakes, streams, springs, and gravel pits.

Shelter in woodlands is provided by conifer stands, tree cavities, brush and rock piles, thickets, unmowed grassy areas, caves, snags, south-facing slopes, riparian vegetation, ant mounds, cut banks, unbroken forest tracts, old growth, logs, old building sites, bridges, and nest boxes. (Abandoned ant mounds are used as wintering sites by small garter snakes, smooth green snakes, and red-bellied snakes). The DNR Private Forest Management (PFM) Program Specialist can identify your forest types and develop a plan for managing both timber and wildlife on your land. Contact your local DNR forester for more details.

Riparian Zones

A riparian zone is the area of vegetation adjacent to wetland or watering habitats. Riparian vegetation typically grows well in wet or moist soils and may include emergent aquatics, sedges, rushes, shrubs, deciduous trees, and conifers. Riparian zones support an abundance of plant and animal life and are an important source of diversity in forests (Thomas et al 1970).

Among birds found in riparian zones are the barred owl, great blue heron, broad-winged hawk, spotted sandpiper, pileated woodpecker, belted kingfisher, red-shouldered hawk, wood duck, common goldeneye and hooded merganser. Typical mammals are the black bear, fisher, otter, mink, beaver, raccoon, muskrat. Reptiles and amphibians typical of riparian zones are wood turtles, Blanding's turtles, leopard frogs and snapping turtles. These areas are especially important for cavity-nesting species.

Buffer zones 200 feet wide should be left around all wetlands over one acre in size and along streams and rivers. Buffer zones 100 feet wide should be left around wetlands smaller than one acre. Grasslands adjacent to wetlands should not be used as sites for dumping logging slash. Salvage wood cutting and fuelwood cutting should not be done in riparian zones because these trees, particularly dead trees and hollow trees, are so important for wildlife. If woodcutting is

necessary, single tree or small group selection is the recommended harvesting method. Riparian zones should be considered for preservation as "old growth" areas. Trail and road construction should be minimized in riparian areas because of the problems associated with increased erosion from roadways and human disturbances. Grazing should be minimized in riparian zones.

Wetlands

Wetlands are a vital part of a forest community — springs, small ponds, beaver ponds, lakes, streams, rivers, and wet lowlands. They should be preserved. There may be opportunities for creation or enhancement of wetlands where the topography and soils allow. Preservation of riparian zones as buffer strips is an integral part of a wetland preservation plan. The DNR area wildlife manager should be consulted for recommendations about wetland management in forest lands.

Old Growth

"Old growth" is comprised of forest areas that are generally one and a half times the age of traditional forest harvesting.

Wildlife species that benefit from the presence of old growth are the pileated woodpecker, gray treefrog, water shrew, heather vole, red-shouldered hawk, chorus frog, merlin, pine marten, yellow-billed cuckoo, barred owl, northern goshawk, fisher, lynx, wood warblers, and bald eagle. On the Chippewa National Forest, 145 wildlife species use old growth stands during at least some part of their life. The Chippewa National Forest has a goal of reserving five percent of its forest as old growth.

The element that makes old growth such a unique and important wildlife feature is decay. Old growth contains an abundance of hard and soft snags, fallen logs and natural cavities in mature trees. The structure of old growth is complex and is characterized by many species that are adapted to rather specific and narrow habitat niches. Many wood warblers and several woodpeckers live in old growth and feed on forest insect pests that periodically are characterized by large outbreaks. In fact, some studies have shown that commercial forests that lack tracts of old growth are more vulnerable to insect damage because of lack of insectivorous birds that help prevent or limit such outbreaks.

Most small private woodlots will not have extensive stands of old growth. On smaller parcels, however, several types of areas should be considered for old growth designations: 1) parcels isolated by swamps or water, 2) timber of low economic value, 3) eagle and osprey nest buffer zones, 4) riparian zones, and 5) areas where esthetics are important.

Northern hardwoods are characterized by about 50 to 75 percent maple and basswood mixed with oak, yellow birch, aspen, paper birch, elm and ash. They typically have many natural cavities and a diversity of wildlife, including pileated woodpeckers, flying squirrels, white-footed mice, screech-owls, oven-birds, black and white warblers, wood frogs, red-bellied snakes, black bears, chipmunks, American redstarts, chesnut-sided warblers, rose-breasted grosbeaks, gray tree frogs, and common garter snakes. Trees known to have cavities should normally be preserved. Oak stands are also especially valuable because they are long-lived and produce acorn crops. Unfortunately, too many people value oak stands more as firewood than as food for wildlife. These forest types should not be used extensively for firewood cutting or for type conversion to conifers. These types are frequently best designated for old growth status. Whenever oaks are cut, they should be cut during dormancy and low to the ground to encourage sprouting. Grazing should be avoided. When cutting trees in a predominately oak woodlot, consider leaving some relatively uncommon tree species for the unique benefits they provide. Examples would be white pine, hickory, or black cherry. Logging slash can be used to create brush piles.

The DNR PFM Specialist should be consulted for specific management guidelines.

Aspen Forest Type

Aspen forest types are vital to the survival of ruffed grouse, woodcock, snowshoe hare, and moose. White-tailed deer, black bears, and some songbirds also use this forest type.

Aspen is primarily of interest to people who wish to manage their woodlots for grouse and woodcock. Because of the difficulties of establishing aspen where it does not exist, people hoping to manage their woods for ruffed grouse or woodcock should buy woodlots that already have a good stand of aspen. Aspen management for grouse is discussed in detail by Gullion (1984).

However, an intensive tree harvest program designed to benefit ruffed grouse will not provide for the needs of many other forest wildlife species that require older aspen stands or non-aspen habitats. While some high-quality aspen stands may lend themselves to intensive grouse management as described, most forest tracts should be managed for a diversity of wildlife and not for the maximum number of grouse that can be produced. Riparian areas, coniferous woods, old growth, oak woods, bogs, cedar swamps, and snags do not lend themselves to intensive grouse management.

Some species of wildlife require extensive forest stands that are unbroken by openings or trails. An example would be many wood warblers, tanagers, thrushes, and flycatchers. The main reason is that cowbirds are typical of forest openings and have become more abundant. They lay their eggs in the nests of forest songbirds that are in or near forest openings, and the cowbird young prevent the forest songbird young from surviving. This problem threatens some forest interior species like the ovenbird. This is not a consideration for most small woodlot owners because small woodlots are already fragmented by roads and openings. This is mainly important for large forest holdings (Robbins 1984).

Forest Openings, Gravel Pits and Trails

A forest opening is an upland area of one-half to 10 acres with few trees or brush. Gravel pits and trails are considered types of forest openings. Forest openings are often established and maintained at log landing sites where timber has been removed. They are important because they generally contain forage grasses and legumes that are eaten by deer and other grazing animals. Small animals in openings provide prey for predatory birds and mammals. Openings are typically provided where deer management is a primary goal. There are 158 wildlife species in northern forests that use openings at some point in their lives. The Minnesota DNR has a goal that not less than five percent of the upland area of its forest management units shall be in permanent wildlife openings. These openings are often seeded with grass and legumes and are created at the site of log landings. Native species should be used when feasible. Dutch white clover is a well-used wildlife food in openings and trails but is not native.

Wildlife openings should be on south or southeast-facing slopes. They should have a 3:1 ratio of length to width. The width should be at least twice the height of the adjacent trees. Openings should be located along the edge of hardwood cut areas and be one to five acres in size. The optimum size is two to 10 acres, depending on the local situation. Seeding and maintenance of openings is essential. The area should be free of logging debris. Snake hibernating mounds or clumps of fruiting shrubs may be placed on the north edge of forest openings.

Bare ground and banks are used by 21 forest species including the belted kingfisher, snapping turtle, gray wolf, red fox, woodchuck, badger, common nighthawk, smooth green snake, killdeer, bank swallow, barn swallow, cliff swallow, and common flicker.

Cut banks at gravel pits should be preserved, and at least 50 percent of the pit floor should be bare ground. The DNR area forester or area wildlife manager should be consulted about forest opening management.

One innovative structure for use along the edge of forest openings is the "snake hibernating mound." It is essentially an underground brushpile and is designed to provide burrow sites for hibernating snakes. These mounds can be built along forest openings, road cuts, timber landings, or any land clearing which has resulted in the creation of slash and stumps. Mounds should be located on the north side of a clearing where they will receive sunlight.

Forest Edge

The edge between a cut and uncut forest or between forest and field can be good habitat for wildlife.

Forest edges should have irregular and not straight edges. This is the way natural edges occur. When cutting along edges, save special trees like den trees and tall snags. Trees, shrubs, and vines that bear nuts and fleshy fruits are valuable along woodland edges since sunlight stimulates heavy fruiting. Hickory, serviceberry, red-osier and gray dogwood, viburnum, blueberry, and grape should be preserved along forest edges.

Bird of Prey Nests and Heronries

Nesting sites of bald eagles, ospreys, hawks, and great blue heron colonies should receive special attention. These nesting sites should be reported to your local DNR area wildlife manager or regional DNR nongame specialist. They will give you advice on management of these sites.

Snags

You can allow snags to occur naturally on your woodlot or you may need to create them. Hardwood snags are preferred over conifers. However, pine and tamarack snags are long lasting and will provide good nesting and perching sites for ospreys if they are adjacent to lakes or beaver ponds.

In timber harvest areas, leave snags scattered throughout the cut area. More snags are desirable near water, oak clumps, brush piles and windrows.

In woodlots or cut areas, preserve approximately one to six hard snags per acre and as many soft snags as possible (Maser et al 1979).

In extreme circumstances where snags are lacking, you can create snags in a woodlot by girdling several diseased or deformed trees.

The best trees for creation of snags are diseased or deformed oak, sugar maple, basswood, ash and elm. Aspen is also good, if mature. Select trees that are over 12 inches in diameter, when possible. Girdling involves cutting a ring around the trunk through the bark and well into the sapwood so that the cambium layer between the bark and wood is completely severed.

A good strategy for wildlife management would be to maintain a variety of snags. On a 20-acre woodlot for example, wildlife managers recommend maintaining four to five snags over 18 inches in diameter, 30 to 40 snags over 14 inches in diameter, and 50 to 60 snags over five inches in diameter (Anonymous 1981, Kitts 1981, Maser et al 1979, Thomas 1979, and Thomas et al 1979).

When snags fall down, they should be left on the ground to provide food and cover sites for birds, small mammals, reptiles, and amphibians. Logs can also provide drumming sites for ruffed grouse.

In addition to the value of fallen logs in a forest setting, logs are also important in two other circumstances. Logs can be placed on the edges of wetlands so they are partially submerged. They will be used by turtles as basking sites and by other reptiles and amphibians. Logs or platforms comprised of several logs can also be anchored in a pond to create secure sunning and resting sites for both ducks and turtles.

Lowland Conifer and Bogs

The lowland conifer forest community is unique and important. It is characterized by mineral or peat soils, acid pH, and black spruce, tamarack, and northern white cedar. Rare orchids including the stemless lady slipper, dragon's mouth orchid, and calypso orchid are found in this forest type. Deer frequently use white cedar swamps as wintering areas.

This forest type is important to the gray wolf, great gray owl, pine marten, northern bog lemming, boreal owl, least chipmunk, wood frog, Connecticut warbler, northern parula warbler, yellow rumped warbler and yellow-bellied flycatcher.

Snags and old growth are important considerations to this forest type. Great gray owl nest platforms are also a management option.

Other Vegetative and Structural Habitat Components

Planting of nut and fruit-bearing trees and shrubs can enhance the value of a woodlot. Snags, logs, rock piles, brush piles, salt

licks, feeding stations, food plots, nest boxes, snake hibernating mounds, and small ponds can all be developed and maintained to enhance the value of the woodland for wildlife (Thomas 1979 and U.S.D.A. 1979).

In summary, landscaping woodlands for wildlife results in the creation or maintenance of woodlands that provide diverse habitats that benefit a broad range of wildlife while still providing opportunities for economic benefits.

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INTEGRATING HABITAT NEEDS OF MOOSE WITH TIMBER MANAGEMENT IN NORTHEASTERN MINNESOTA¹

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ABSTRACT.--Where softwood production is being emphasized, plantations are established, and competing hardwoods are suppressed with herbicides. These hardwoods, however, are critical forage for moose, an important wildlife resource of northeastern Minnesota. Moose favor young plantations for the high density of forage there. It was shown that spraying 2,4-D reduces browse availability for several years by about half, and that the recently more popular chemical, glyphosate, reduces browse by some three-quarters and for a longer span. Studies of growth in white spruce relative to varying levels of surrounding shrubs suggest that current Forest Service criteria for herbicide applications are more strict than necessary. In Minnesota emphasis is now shifting from mainly softwood production to more use of aspen; its regeneration requires no plantations or herbicides. It is suggested that a timber system optimally beneficial to moose should include mixed-species interspersions. Application of new techniques such as computerized mapping coupled with modelling will be tested for achieving better integrated resource management.

INTRODUCTION

Minnesota is the only state between the Rockies and New England where moose (*Alces alces*), the largest of the deer family, are common. Granted, there is a small but growing population in eastern North Dakota, a newly introduced nucleus in upper Michigan, and the famous herd at Isle Royale National Park, Mich., an island in Lake Superior. However, Minnesota has more than a token herd, and the majority of the state's 10,000-12,000 moose are in the northeast, mainly in and around the Superior National Forest.

As a natural resource having great esthetic and economic value, moose deserve special attention from forest-land managers. For example, in the

Boundary Waters Canoe Area (BWCA), one of Minnesota's most popular recreation areas, canoeists who chance to see a moose often recall this as the high-point of their wilderness trip. Presence of moose in northern Minnesota unquestionably contributes to tourism, hence to the economy. For hunters, the rare chance to take a Minnesota moose is highly prized.

Logging is common throughout the range of moose in northeastern Minnesota except in the BWCA, a designated wilderness area. Regional foresters have traditionally considered conifers, particularly red pine (*Pinus resinosa*), jack pine (*P. banksiana*), and white spruce (*Picea glauca*) to be the most valuable species, although quaking aspen (*Populus tremuloides*) and related species (*P. balsamifera* and *P. grandidentata*) are now increasingly in demand, hence gaining importance in Forest Service planning (USDA 1986).

Silvicultural practices in this region have generally centered on restocking. Typically, stands of 10-100 A are clear-cut, then prepared by rock-raking or some other technique for pulling up roots of hardwoods. Then they are planted with conifer seedlings. Even after site-preparation, subsequent control of competitors, or "release," is usually

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deemed necessary, and is practiced mainly with herbicides aimed at both herbaceous and deciduous-woody plants.

In the same areas, moose, while requiring interspersed patches of mature canopy for cover in both summer and winter, are strongly attracted to recently disturbed, upland sites such as clear-cuts. Here their preferred year-round forages-- most of the common hardwood tree and shrub species-- occur within their reach and in great abundance (Peek et al 1976, Allen et al 1988). Clear-cut patches of up to 200 A or more have great potential for supporting many moose for 10-25 yrs, after which canopy closure shades shrub-level browse production.

Site-preparation, even though severely impeding re-establishment of aspen and other fast-growing, early-successional trees, is not necessarily inimical to moose. Some suppression of vigorously sprouting species serves to keep new growth within reach (<9 ft) of moose for a longer span than otherwise. It also permits co-existence of a greater variety of deciduous species by suppressing the dominant competitors. Dietary variety is believed an important aspect of nutritional quality for moose (Miquelle and Jordan 1979). On the other hand, severe suppression of all hardwood browse in conifer plantations can greatly reduce foraging potential; and, when browse density drops below some minimum density relative to foraging efficiency, stands may become of no value at all to moose.

The purpose here is to describe our studies on how local timber practices have been affecting the quality of moose habitat. Our results can be viewed as ground work for a new synthesis of optimal coordination between producing timber and maintaining excellent habitat for wildlife such as moose, or any other species of concern. These efforts are also a direct response to the Forest Service mandate to emphasize integrated resource management.

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STUDY AREA AND ITS MOOSE

The majority of field work was done in the Tofte District of the Superior National Forest in Cook Co. of northeastern Minnesota. Soils and weather are typical of the boreal region on the Canadian

Shield (Maycock and Curtis 1960, Peek et al 1976). Vegetation is mixed conifer-hardwood, with dominant trees being white spruce, balsam fir (*Abies balsamea*), black spruce (*Picea mariana*), jack pine, paper birch (*Betula papyrifera*), quaking aspen, and, on elevated lands near Lake Superior, sugar maple (*Acer saccharum*). The most important broad-leaf, shrub/tree, browse-species for moose are aspen, paper birch, willows (*Salix* spp), beaked hazel (*Corylus cornuta*), juneberry (*Amelanchier* spp), pin cherry (*Prunus pensylvanica*), choke cherry (*P. virginiana*), mountain maple (*Acer spicatum*), red maple (*A. rubrum*), mountain ash (*Sorbus americana*), bush honeysuckle (*Diervilla lonicera*), green alder (*Alnus crispa*), and red-osier dogwood (*Cornus stolonifera*). The few common hardwood shrubs not taken include speckled alder (*A. rugosa*), thimbleberry (*Rubus parviflorus*), blueberry (*Vaccinium* spp), and most species associated with lowland bogs.

Densities of moose in the study region were roughly 1-1.5/mi² (Minn DNR). Summer forage comprises mainly leaves of the deciduous plants listed above plus a substantial but variable amount of aquatic forage, depending on sodium needs (Jordan 1987), and some herbs taken mainly in spring and fall. In winter, current twigs of most of the same woody species used in summer are taken, along with some conifers-- balsam fir, white pine (*Pinus strobus*), and northern white cedar (*Thuja occidentalis*) (Peek et al 1976).

MOOSE-TIMBER STUDIES

We present a summary of field studies, carried out from 1983 to 1987 primarily in the Tofte District of the Superior N.F. Technical details and complete data are in theses and publication or manuscripts in preparation, while some data are not yet analyzed. We add some interpretations and recommendations, and finish with a brief description of the next steps in developing techniques for coordination of wildlife-habitat needs with timber production.

A major study objective was to estimate amounts of forage lost from plantations due to herbicide applications. Of particular interest was a comparison of effects of 2,4-D vs. glyphosate. Also we studied the suspected impacts of hardwood shrubs on young spruce in order to evaluate the criteria in use on the Forest for prescribing release treatments. And, with the recent shift to aspen management, we began evaluating browse resources in "natural-regeneration" stands.

Browse Production in Plantations and the Effects of Herbicides

Weil (1987) analyzed spruce plantations 3 to 7 years after site preparation and found that, where release treatments had not been applied, available current browse for moose averaged 89 lb/A, while sites treated with 2,4-D averaged only 56 lb/A (Table 1). Weil also found for the same plantations that estimated biomass removed by moose

averaged 27 lb/A where herbicides had not been applied, compared to 18 lb/A in the treated sites.

Table 1.--Biomass and consumption by moose of current-year twigs and leaves of deciduous, moose-browse species in 3-7 year-old spruce plantations, comparing stands sprayed with 2,4-D vs. those not sprayed.

Treatment	lb(dry)/A	
	No Herbicide	Herbicide
No. of stands	10	11
Biomass	88 (± 7.1) ^a	56 (± 8.0) ^b
Removed by moose ¹	27 (± 3.3)	18 (± 2.7) ^b

¹Reconstructed by difference.

^aStandard error

^b $p < 0.05$

Kennedy (1986) and Kennedy and Jordan (1985) compared the impact of two herbicides, 2,4-D-- used commonly in the 1970s, and glyphosate ("Round-up")--the more preferred chemical of the early 1980s, on hardwood browse in plantations. They found that available browse in stands treated with glyphosate was roughly one-half that in 2,4-D treatments, and the latter was roughly one-half that in untreated stands (Table 2). Weather during treatment can strongly influence the effectiveness of herbicides.

Table 2.--Biomass of current-growth, deciduous, available moose-browse (leaves and twigs), comparing among two herbicides and a control on plantations treated in three different years. Each entry represents an average of biomass from plots within 3-5 stands, all measured in late-summer 1985 (Kennedy 1986).

Treatment	lb(dry)/A		
	Glyphosate	2,4-D	Untreated
Year Sprayed			
1981	52 (39) ^a	97 (36)	-
1982	96 (81)	81 (30)	-
1983	21 (28)	101 (9)	201 (72)

^aStandard deviation

Note that differences among 1982-treated stands suggest there were no impacts; because summer 1982 was dry, target species were already dormant hence, not very vulnerable when sprayed.

At the time of this study there were no examples in our area of glyphosate treatments that were more than 5 yrs old; hence we were unable to evaluate its longer-term effects. However, it appears that this herbicide, when applied as intended, kills entire root systems. In contrast, 2,4-D kills back only the tops in most browse species, allowing for reasonable regrowth within 3-5 yrs. In the latter case, spruce should grow above the slowly recovering deciduous plants, so that the needs of both moose and timber are met. Glyphosate, in contrast, may eliminate abundant browse for the remaining years over which the plantation would provide space and light for shrub growth. On the other hand, because glyphosate is probably the least health-threatening of herbicides to humans and other vertebrates, its use is recommended for hand application around individual conifer saplings where specific need is indicated.

Effects of Hardwood Browse on Young White Spruce

The issue of when to release plantations for preventing suppression of young white spruce, the most commonly planted species in our study area, was analyzed. From the standpoint of moose habitat, the question is rephrased: how long can hardwoods be left unsprayed before spruce growth is measurably suppressed? Posner (1984) and Posner et al (ms) sampled growth performance in 5-16 year-old spruce, using extent of shrubs surrounding individual saplings as the independent variable. It was found that, for all sapling ages examined, better growth was associated with some surrounding shrubs than with none. In the younger saplings, growth suppression was not positively correlated with increasingly heavy shrub densities, but it was related negatively as shrub density approached none (Table 3). Saplings over 9 yrs appeared more sensitive to heavy-shrub presence.

The overall conclusion was that Forest Service guidelines on timing of release were more cautious than needed. Were guidelines relaxed to better reflect the observed interaction between spruce and surrounding shrubs, chemical treatments could be delayed longer or omitted. This would save browse for moose and other wildlife, and it would save costs in softwood regeneration.

It should be noted that, where production of spruce is the objective, moose themselves can aid silviculture. Moose do not touch spruce, but they readily take most of its broadleaf competitors and even some coniferous ones, e.g. balsam fir. The greater the moose density, the more they will suppress broad-leaved perennials. At Isle Royale, where moose densities are as high as reported from anywhere, there are extensive areas in which all upland hardwoods are so suppressed by moose that they seldom exceed 6 ft (Krefting 1974, P. Jordan unpubl). Such extreme pressure is excellent if spruce or other nonpalatable species, e.g. jack

Table 3.--Current annual height increment and total height in 7-9-yr-old white spruce according to levels of surrounding shrubs (Posner 1984).

Shrub ¹ Level	Current-Yr Height Increment (in)	Total Height (in)
None	11 b	61 b
Low	12	75 a
Medium	14 a	83 c
Heavy	14	79 c

¹Shrubs included all hardwood bush and tree species. "Level" was a combined measure of densities, heights, and over-topping positions of stems within a circle around the sapling.

a, b, c: entries in the same column with different letters are significantly different, $p < 0.05$.

pine, are the only trees of commercial interest. It would not work, however, where balsam fir, white pine, birch or aspen is the expected timber crop. In any event, for moose to increase to high densities, quality and quantity of available browse must be abundant.

Browse Production and Natural Regeneration

The recent forest-industry shift to extensive use of aspen is leading to more stands in the Superior N.F. being managed for natural regeneration. Our studies were correspondingly shifted to measure browse characteristics under natural-regeneration management. Although these data have not yet been analyzed, some general observations can be offered. While great losses of forage from effective herbicide applications are totally contrary to moose management, too much browse production is not necessarily ideal either. Where aspen is resprouting vigorously and the stand is very large or local moose density is low, the sprouts tend to out-reach moose in 10 yrs or less. Then the site's value to moose rapidly declines, because much of the annual growth is unavailable, and the aspen is crowding out other favored species which moose seek to diversify their diets.

DISCUSSION AND CONCLUSIONS

For public forest lands in northeastern Minnesota, interactions between timber economics and recreational expectations create a demand for an integrated, multiple-use approach to management over the landscape. Commercial potential from forest products here is modest compared to the intensive timbering regions of the U. S. At the same time, the Superior National Forest and adjacent public lands offer an immense recreational potential for vacationers from throughout the upper

Midwest. Therefore, realistic integrated resource management must reflect the fact that wildlife and scenic considerations rate comparably with, if not higher than, forest products. Such recognition is indeed reflected in the recent 10-year plan of the Superior National Forest (USDA 1986).

Interpretations and Recommendations

Timber extraction and intensive silviculture need not conflict with maintaining good habitat for moose. This applies to many other important types of wildlife as well: bears and ruffed grouse, as pointed out by Rogers and Gullion respectively in these proceedings; plus deer, hares, and beaver. Important predators, such as the federally listed timber wolf in Minnesota, are in turn favored by high densities of forest herbivores associated with early succession vegetation. The question then is how does management optimize for all these public and commercial concerns on the same land at the same time.

Our studies suggest there are positive and negative aspects for moose in each timber-regeneration practice in use today. Clear-cutting in this region is widely viewed as favorable to wildlife, since it mimics fire and windthrow to which many common species are well adapted. Current Forest Service guidelines for clear-cutting provide for an ample interspersed cover patches and snags to serve a wide variety of wildlife. Site preparation prior to planting, because it reduces vigorous sprouting by a single species, can favor moose by keeping browse available longer and in greater diversity. However, sometimes site-preparation leads to scraping off patches of shallow top soil; this reduction of basic productivity is deleterious to all interests.

Heavy use of herbicides to control competition, particularly chemicals that kill entire root systems, causes major loss of browse potential associated with clear-cutting. On the other hand, natural-regeneration management can lead to rapid escape of post-disturbance emergents, leaving moose too few years to benefit from the forage. Obviously, optimization of moose and timber calls for some intermediate strategy, such as a mixing of commercial-tree species within stands.

Northeastern Minnesota can expect the demand for both softwoods and hardwoods to continue indefinitely; thus timber planning must provide for future supplies of both. Traditionally, managers and forest operators prefer uniform stands with one species per stand. However, if some stands were comprised of intermixed patches of conifers and emerging hardwoods, better habitat would be provided for moose in terms of cover and forage over a longer span of years. Herein lies a major challenge-- to design a mixed-species silviculture that is economically reasonable, from regeneration to harvest, and is a better solution to moose needs than possible with any combination of monoculture stands. We believe this is a reasonable goal

There is a strong need to bring recent computer-based technologies within reach of forest-land managers. These include techniques for evaluating condition and future potential of wildlife habitats, for inventorying timber resources, for projecting vegetative growth over many decades, and for reaching management decisions from inputs of economic, ecological, environmental, and recreational constraints. All such activities, furthermore, must be designed in parallel with wholly compatible information bases, so that criteria for one resource, e.g., wildlife, can be directly translated into realistic prescriptions for another resource, e.g., timber. Good progress has already been made within the Forest Service, but greatly expanding opportunities for computer applications lie ahead.

Technological applications can be developed today with an efficiency not possible just a few years ago. New methods include coupling computerized mapping (geographic information systems = GIS) with computer models of forest succession or of responses by wildlife populations to environmental events. For example, a habitat-suitability index model for moose of the Lake Superior region has just been completed (Allen et al 1988) and will soon be tested on the Superior N. F. Land-based, resource data-bases in turn can be coupled with decision-making models that incorporate all economic and environmental constraints for the purpose of examining various management options. It is along these lines that our research and development efforts with the U. S. Forest Service will next be directed.

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ABSTRACT.--Land managers need methods to assess, measure and predict the affects on wild-life of vegetation change resulting from silvicultural prescriptions. A data base was developed to relate vertebrates on the Chippewa National Forest to their habitats and special requirements, providing a simple method of comparing alternative land use proposals in terms of species richness and selected groups of species.

INTRODUCTION AND OBJECTIVES

Seldom do forest managers apply pure silvicultural prescriptions to land managed for a variety of uses. More often than not, the best and most appropriate silvicultural practice is modified to accommodate resources other than timber. This modification, often for a wildlife habitat need, may diminish the production of timber or increase management costs. The National Forest Management Act and other laws and regulations clearly mandate the USDA Forest Service to integrate wildlife habitat needs into the planning process, and further directs managers and planners to assess the affects of land management proposals on plant and animal diversity. Therefore, it becomes imperative that effects and trade-offs are understood and measurable, so that rational and informed interdisciplinary decisions can be made.

This paper has two objectives:

1. To display the relative value of forested communities in northcentral Minnesota in terms of vertebrate species richness, and for species having special status, and
2. To describe, in terms of animals and their habitat relationships, an analytical technique to display the effects of modifying silvicultural prescriptions to meet wildlife habitat objectives.

¹A paper presented at the Society of American Foresters Annual Convention held at Minneapolis, MN, October 18-21, 1987.

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SILVICULTURAL VS INTERDISCIPLINARY PRESCRIPTIONS

Silvicultural practices are designed to grow trees as quickly and efficiently as possible, with the ultimate objective of producing a high quality forest product. A wildlife habitat objective for the same land unit may require somewhat different type composition, age class distribution or stand features and may conflict with the best silviculture. While this wildlife objective may relate to a single species or group of species, ecologically-based management requires objectives and associated analytical methods related to communities and the elusive objective of "diversity" (Siderits 1975).

Composition objectives are guides designed to integrate forest type composition and age class distribution among resources over large landscapes. In the parlance of National Forest planning in the Eastern Region, this is part of the Desired Future Condition (DFC), setting the stage for "proactive" decision-making as opposed to the traditional and less desirable "reactive" mode. Composition objectives provide the framework on which to hang all other decisions relating to vegetation management over long time periods. It is an essential element in the conceptual framework of Integrated Resource Management (IRM) (USDA Forest Service, 1985).

The DFC concept is refined further by incorporating the preservation, enhancement or creation of specific stand features to integrate wildlife habitat objectives with silvicultural objectives. Some examples are:

- Deferral of harvest for old growth
- Retention of snags
- Retention of mast trees
- Retention of selected trees or tree groups for diversity
- Modification of stand size or configuration

How, then, can we rationalize and estimate the effects of altering silvicultural prescriptions for wildlife benefits? This has always presented a problem for land managers due to a lack of organized empirical information on habitat needs for all but a few game species. With the NFMA as a catalyst, the concept of Wildlife Habitat Relationships (WHR) evolved within the Forest Service in recent years to provide the tools and information needed to deal with the problem (Nelson and Salwasser 1982). We developed a system on the Chippewa National Forest called "Wildlife Habitat Associations" (WHA), which is a computerized data base designed specifically for the wildlife species and community types on the Forest, although it has been adopted and utilized throughout the Lake States and beyond. Land use proposals are weighed and alternatives compared in terms of entire wildlife communities (species richness), or for selected species or groups of species (such as threatened, endangered, sensitive, or game/fur). It is very user-friendly, and has proven to be a powerful tool (Mathisen 1982, 1983, 1985).

THE DATA BASE

In 1981, we assembled a group of 11 biologists and naturalists with local knowledge of wildlife and their habitat associations on the Chippewa. This group gathered a library of reference material and, together with their combined experience and knowledge, compiled information on the vertebrate species occurring on the Forest.

We used 8 interrelated components correlating 311 vertebrate species with habitat, season of use and status. Using the classification of Niemi and Pfannmuller (1979), 24 communities or animal habitats were used to accommodate the vertebrates on the Chippewa, reflecting vegetation, successional stage (age) and structure. Fourteen of these were forested communities.

Using the method of Thomas (1979), each species was categorized according to the communities commonly utilized for feeding and/or breeding. Because most species were oriented to more than one community, an attempt was made to assign one of them as the "critical community." It was impossible to assign a critical community to the more ubiquitous species.

Eight categories were used to relate special habitat requirements to each species: man-made structures, edge, decaying log, snags, riparian areas, mast and banks or bare ground.

Special status was based on four categories: game/fur, threatened/endangered, sensitive and management indicator species.

For this paper, I have compiled data base elements for the forested communities only; aquatic, wetland and other non-forested habitats are rarely altered with silvicultural decisions. Presentation further simplified by combining breeding and non-breeding use of the habitats.

The forested communities in the data base represent an assemblage of forest types with similar wildlife associations. They are:

Deciduous upland	Oaks, aspen, birch, northern hardwoods
Coniferous upland	Red, white and jack pine, spruce-fir
Coniferous lowland	Cedar, black spruce, tamarack
Deciduous lowland	Ash, elm

Each species was also classified according to their association with four age groups within each community:

Shrub/Sapling	Regenerating stands
Young	<10 years old
Mature	>10 and <70 years old, depending on forest type
Old growth	>70 and <120 years old, depending on forest type
	Beyond normal rotation age

Both type and age must be considered to assess importance and to evaluate alternatives, as demonstrated by DeGraff and Chadwick (1987).

Recently, a direct linkage was made between the WHA data base and the Eastern Region's Vegetation Management Information System (VMIS), expanding the analytical potential and usefulness of both data base systems.

IMPORTANCE VALUATIONS OF COMMUNITIES

What are the relative values of the four communities in terms of vertebrate species richness and in terms of species having special status? Species richness is a simple, although incomplete, measure of diversity, further defined in this context as "alpha" or within-stand diversity (Whittaker 1972). Table 1 shows the orientation of all the vertebrates on the Forest to the four communities, without consideration of community age or size. This is an expression of species richness.

TABLE 1.--Orientation of Wildlife to Generalized Communities in Terms of Species Richness.

Forest	Deciduous Upland		Coniferous Upland		Coniferous Lowland		Deciduous Lowland	
	No.	%	No.	%	No.	%	No.	%
Birds								
233	86	36.6	66	28.3	52	22.3	51	21.9
Mammals								
57	41	71.9	36	63.1	28	49.1	25	43.8
Herps								
21	12	57.1	9	42.8	2	9.5	8	38.1
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311	139	44.7	111	35.7	82	26.4	84	27.0

Clearly, species richness is highest in the deciduous upland types, with 139 species having this orientation (44.7 percent of all the species on the Forest). The coniferous uplands rank second in species richness, and the lowland types are at the low end of the diversity scale.

To the forest manager making a decision on what forest type to emphasize, this indicates that, in terms of within-stand diversity, the deciduous types are preferred. If the best silvicultural decision for a particular stand was to convert it from deciduous to conifer, the potential affect would be a 20 percent decrease in species diversity (20 birds, 6 mammals, and 3 reptiles and/or amphibians). This would be taken into consideration at the interdisciplinary level of decision-making.

This affect can be further supported by summarizing, in Table 2, the critical community element in the data base.

TABLE 2.--Critical Community Associations of Wildlife (number of species).

	Deciduous Upland	Coniferous Upland	Coniferous Lowland	Deciduous Lowland
Birds	34	23	5	2
Mammals	7	3	2	1
Herps	0	0	0	0
	--	--	--	--
Total	41	26	7	3

The deciduous uplands are critical habitats for 41 species, compared to 26 in the conifer types, and very few in lowland forested types. Relative to other forested communities on the Chippewa, this further supports the value of deciduous uplands.

The relationship of special status species to the four communities is shown in Table 3. In this table the threatened, endangered, and sensitive (T/E/S) species are combined, and game and fur (G/F) species are combined.

TABLE 3.--Relation of Special Status Species to Communities (number of species).

Forest	Deciduous Upland		Coniferous Upland		Coniferous Lowland		Deciduous Lowland	
	No.	%	No.	%	No.	%	No.	%
T/E/S								
20	6	30.0	10	50.0	10	50.0	4	20.0
G/F								
53	24	45.3	13	24.5	9	17.0	14	26.4
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73	30	41.1	23	31.5	19	26.0	18	24.6

Table 3 shows the relative value of the four communities when the management objective is to favor either or both of the T/E/S and G/F species. G/F species clearly favor deciduous uplands, where 24 of 53 species occur. T/E/S species are associated more with coniferous upland and lowland communities. Considering the special status species as a group, the deciduous uplands support more species than any other.

The forest manager, therefore, can objectively evaluate the effects of silvicultural alternatives concerning forest type emphasis in terms of wildlife species that, because of their status, merit special management considerations.

By computing a "wildlife habitat capability" score for each community considered, and totaling the four evaluation criteria (Table 4), this analysis can be carried one step further, providing the manager with data on the relative value or ranking of all four communities based on the sum of species richness value, values for critical community and special status species.

TABLE 4.--Wildlife Habitat Capability (WHC) of Four Communities.

Community	Species Richness	Critical Community	T/E/S	G/F	Total WHC
Deciduous Upland	139	41	6	24	210
Coniferous Upland	111	26	10	13	160
Coniferous Lowland	82	7	10	9	108
Deciduous Lowland	84	3	4	14	105

The fact that the deciduous upland community has the greatest capability does not mean that wildlife is best served by having only this community available. Each supports a unique assemblage of animals and, without the presence of conifer components, some species would be at very low population levels or non-existent. This leads to another level of analytical procedure.

An aggregation of communities is an expression of another aspect of diversity, called beta diversity or between-stand diversity, and considers species distribution in a wider context. This analysis is done at the interdisciplinary level for application to large landscapes such as compartments, opportunity areas or management areas. It becomes more complex, but the data base and the concept of WHC is utilized to assess land areas by relating WHC to the amounts of each community present. The end result here is an index value called the Habitat Capability Index (HCI). This value can be used to assess wildlife implications among alternative strategies for the DFC during the initial stages of planning.

Age, or successional stage, is another aspect of habitat valuation reflecting the structural characteristics of a community. The age relationship is much more dynamic than community type. A regenerating stand today may be a young stand within 10 years, and may have old growth features within 80 years. As age progresses, associated wildlife changes dramatically. Site index and rotation age, therefore, become important considerations for assessing value and predicting the future. The data base contains information on the orientation of wildlife to four age classes (Table 5).

TABLE 5.--Average Number of Species in Each of Four Age Classes.

Age Class	Species		
	All	G/F	T/E/S
Shrub/Sapling	130	20	6
Young	65	10	3
Mature	84	13	6
Old Growth	80	11	6

The relative value of community age in terms of species richness is highest in regenerating stands, and lowest in young stands. As the stand matures and becomes more vegetatively complex, species richness increases, falling off slightly when the old growth condition is reached. Game/fur species have a particularly strong orientation to the shrub/sapling stage, with about equal representation among the other three. Threatened, endangered and sensitive species show no particular affinity to age class.

To the land manager concerned with diversity as a management goal, this means that cutting is good, and reducing rotation age will generally be favorable. A timber sale in a mature stand will have the immediate effect of increasing within-stand diversity from an average of 84 to 130 potential species; about a 54 percent increase. As with forest type distribution, a patch-work of age classes contributes to between-stand diversity and becomes an important element in describing the DFC. In practice, both community type and age are considered simultaneously, and the HCI is computed on this basis.

The data base can thus be used as a simple model to predict effects of alternative prescriptions over time in terms of the HCI.

SPECIAL HABITAT REQUIREMENTS

In addition to communities and age classes, there are special requirements that must exist before habitat is suitable for some species. Snags for pileated woodpeckers are mandatory, while riparian habitat for raccoons is important, but not essential. We considered seven special requirements for the data base. Five of

these are important when making silvicultural prescriptions: snags, edges, downed logs, mast, and riparian areas

We are in the process of adding new information to the data base reflecting minimum habitat size for birds to evaluate the effect of forest fragmentation on avian species (Robbins 1979, Anderson and Robbins 1981). When this is done, we will be able to quantify and compare management schemes favoring edge-associated species with those favoring large, contiguous areas of forest cover.

These elements provide another level of detail to evaluate in relation to the species in the four communities. Table 6 shows the number of species in each community having one or more of these special requirements.

TABLE 6.--Special Requirements of Vertebrates Associated With Forested Communities (number of species).

	Total Species	Snags No.	Edge %	Logs No.	Riparian %	Mast No.
Deciduous Upland	139	49	35	73	53	51
Coniferous Upland	111	36	32	53	48	45
Coniferous Lowland	82	23	28	37	45	27
Deciduous Lowland	84	27	32	38	45	30

Snags

Wildlife species requiring dead or dying trees are present in all communities, ranging from 49 species in deciduous uplands to 23 in lowland conifers. Therefore, it becomes imperative, from the species diversity standpoint, to ensure that this stand feature is present in all communities and reflected in prescriptions. Silvicultural practices that discriminate against dead or dying trees, such as salvage cuts and fuelwood removal, must be carefully considered. The number of snags required to accommodate snag dependent wildlife were computed for each community (Thomas 1979) and incorporated as a standard in the Forest Plan.

Edge

Species having an orientation to edges or ecotones range from 73 in deciduous uplands to 37 in the lowland conifer types. Although some ecotones are natural due to soil or moisture gradients, others can be induced through management. Edge habitats can be enhanced by prescribing relatively small, well-dispersed stands. High levels of between-stand (beta) diversity will generally produce high levels of

edge habitat. Preserving within-stand features, such as conifer inclusions in deciduous stands and vice versa, will enhance edge habitats as well as within-stand diversity. Configuration of cutting unit boundaries is also related to edge. The more complex configurations will produce the greatest amount of edge. Conversely, some species (primarily birds) associated with the forest interior may be negatively effected as edge increases and stands become smaller.

Downed Logs

Most mature and old growth stands contain an abundance of stumps and downed logs from natural mortality and storm damage, unless silvicultural practices such as salvage cuts and slash removal have removed them.

While all communities support a substantial number of species requiring downed logs, species associated with coniferous uplands are particularly dependent on downed logs, with over 40 percent of all the species in this community having this requirement. Silvicultural prescriptions involving salvage operations, fuelwood gathering, prescribed burning and slash removal should be carefully considered to ensure this element of habitat is not depleted.

Riparian Associations

Where water and upland come together, a riparian habitat is featured. This is an important wildlife association, ranging from 51 species in deciduous uplands to 31 in lowland conifers. Many of the species associated with the old growth condition are also associated with riparian areas (40 in deciduous upland, 31 in coniferous upland, 30 in deciduous lowland, and 21 in coniferous lowland). High priority is given to extending rotation ages for old growth management in stands classified as riparian. Snag-users and downed-log users are disproportionately associated with riparian areas, and these stand features should be emphasized in these areas.

Mast

Mast produced by trees and shrubs is utilized as a food source by wildlife in all communities, ranging from 17 species associated with upland conifers to 7 in lowland deciduous types. While mast is provided by a number of trees and shrubs (e.g., oak, pine, and hazel), acorns are essential to important game species such as deer, black bear, and waterfowl. Silvicultural decisions should provide for retaining oak components as within-stand features in all communities, but especially in coniferous upland and deciduous upland types.

CONCLUSION

While the Wildlife Habitat Association data base does not answer all the questions on timber/wildlife relationships, it does provide an objective and organized way of dealing with wildlife habitat values and the consequences of

silvicultural and other land use proposals. The WHA data base is directly linked to our Vegetation Management Inventory System (VMIS) through the animal habitat component where WHC values are automatically generated and displayed on a stand-specific basis. Foresters and wildlife managers can now discuss, with less ambiguity than ever before, the relative merits of alternative management strategies. The final decision, as always, rests with the overall goals and objectives by which the land management system is driven.

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KIRTLAND'S WARBLER BREEDING BIOLOGY AND HABITAT MANAGEMENT¹

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ABSTRACT.--The Kirtland's warbler (*Dendroica kirtlandii*) is an early succession, area-sensitive species seldom found in stands smaller than 30 to 40 ha. This warbler occupies dense jack pine (*Pinus banksiana*) stands where trees are from 6 to 23 years old and from 1.7 to 5.0 m high growing on poor, sandy soils. Typically, it has been found in areas regenerated naturally by serotinous cones resulting from wildfires. In the past 2 decades, however, Kirtland's warblers have been found in naturally regenerated, unburned jack pine and in densely stocked pine plantations. Stands are managed on a 50-year rotation and clustered into discrete management areas. Extensive dispersal to find suitable habitat reduces breeding opportunities. Currently, about 15 percent of the males abandon territories, and about 15 percent of the resident males do not find mates. Clustering stands into management units and staggering the schedule of stand regeneration should minimize biogeographic dispersal problems. Because Kirtland's warblers colonize patches of taller, dense jack pine before they occupy habitat with shorter or less dense trees, the period of Kirtland's warbler occupancy in a management area can be extended by several methods such as varying tree spacing in a plantation. Researchers and managers have developed a variety of harvest options, site preparation methods, and pine regeneration alternatives for providing suitable Kirtland's warbler habitat. Several options do not require the use of prescribed fire. These management alternatives must not only provide suitable tree stocking and spacing for the Kirtland's warbler but also accommodate their spatial and temporal needs such as the size, chronology, and age diversity of stands.

The Kirtland's warbler (*Dendroica kirtlandii*) is an Endangered Species that is only known to breed in young, jack pine (*Pinus banksiana*) habitat in northern Lower Michigan. This warbler migrates to the Bahamas where it winters in low, broadleaf scrub habitat. The known breeding population is censused annually and has averaged 205 males from 1971 through 1987. The breeding population has been remarkably stable, ranging between 200 and 216 males for 12 of the past 17 years. The Kirtland's warbler occupies dense, jack pine stands where trees are from 5 to 23 years old and from 1.7 to 5.0 m tall. Typically, this habitat has been regenerated naturally by serotinous seeding resulting from wildfires in jack pine on sandy, porous soil. In the past 2 decades, however, Kirtland's warblers have been found in naturally regenerated unburned jack pine and in densely stocked pine plantations.

I will review and describe four general areas of Kirtland's warbler biology and management: (1) the habitat requirements of the Kirtland's warbler, (2) the demography of the Kirtland's warbler and the evidence for population regulation by habitat limitation, (3) a hypothesis of how geography of suitable habitat affects stand colonization success and duration of habitat occupancy, and (4) the management strategies and recommendations needed to meet Kirtland's warbler requirements for optimal spatial and temporal distribution of high quality habitat.

KIRTLAND'S WARBLER HABITAT REQUIREMENTS

The most obvious difference between occupied and unoccupied suitably aged jack pine habitat is the dense tree stocking of the stands used by Kirtland's warblers. Areas with less than 20 percent canopy cover rarely are used for breeding. Optimal habitat typically has more than 7,500 stems per hectare and between 35 and 65 percent canopy cover. Tree canopy cover is more useful for evaluating habitat quality than stocking frequency or stem density because it combines tree stocking, spacing, and height factors. In any stand, the stocking should have from 20 to 25 percent tree cover to have a good chance of occupancy. Plantations can be adequately stocked for Kirtland's warbler

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breeding with only a minimum of 2,800 stems per hectare because planted trees are less clumped than those in naturally regenerated areas. Red pine (*Pinus resinosa*) plantations have had breeding Kirtland's warbler in places where they are planted closely enough to satisfy Kirtland's warbler stocking requirements. Unburned jack pine clearcuts that are stocked from nonserotinous natural seeding have less than 20 percent of the tree density of areas regenerated by wildfire and are almost never stocked enough to be suitable breeding habitat. However, if unburned stands have more than about 2,000 stems per hectare, Kirtland's warbler may breed there at low densities and for a short duration. Jack pine habitat that has low productivity for Kirtland's warbler is characterized by tree foliage volume that is less than that found in areas considered to be suitable habitat. Suitable or optimal habitat is also marginal when it passes through the young stage where trees are short and foliage volume is low. The two classes of marginal habitat have low Kirtland's warbler productivity because of low male density, low pairing success, low site tenacity, and late breeding initiation.

Tree Foliage Volume

At least six trends identify tree foliage volume as the major factor of Kirtland's warbler habitat suitability. (1) Areas with dense regeneration are occupied first and those lacking minimal tree stocking are never used. (2) Stands of intermediate tree density are older than dense stands when first used (Buech 1980) and usually support fewer birds. (3) Territory sizes tend to be larger in the more open areas of a stand (Mayfield 1960, Smith 1979). (4) The average density of male Kirtland's warblers is higher in well-stocked plantations or wildfire areas (Probst MS). (5) Kirtland's warblers arrive later in the season in breeding areas with minimal foliage volume (marginal habitat) than in more suitable habitat, and abandon marginal habitat with greater frequency. (6) Pairing success of males in young or poorly stocked habitat is from one-half to two-thirds that in more suitable habitat (Probst and Hayes 1987). Because tree foliage volume is so important to Kirtland's warbler habitat suitability, the occupied habitat can be described by a range of tree heights and tree covers. The composition and height of ground cover become limiting outside the bounds of poor sites selected for Kirtland's warbler management.

I have hypothesized that the well-defined habitat requirements of this species can be explained by its foraging ecology. The upper and lower limits of stand age (tree height), tree density, and ground covers can be related to their foraging heights, sites, and modes. The canopy cover threshold for initial occupancy may be related to minimal foliage volume necessary for Kirtland's warbler foraging requirements. The decline of habitat could be related to a lack of live, lower branches (Probst MS) for fledgling cover and for foraging

space for the female (unpublished data).

Stand-Age Population Trends

Populations in burns generally build for 3 to 5 years after first occupancy, level off for 5 to 7 years, and decline rapidly within 3 to 5 years (fig. 1). In general, stands are not colonized by Kirtland's warblers until the average tree height reaches from 1.4 to 2.3 m (Probst MS). Breeding areas support highest male densities during the middle period of Kirtland's warbler occupancy (Probst 1986), at which time stands range from 2.4 to 3.9 m tall. Populations begin to decrease when tree heights reach 3.5 m or more and no live foliage is present below about 1.0 m. During the middle period of occupancy when Kirtland's warbler densities are highest, tree cover is between 27 and 60 percent, a condition found in fire-regenerated stands that typically have stem densities in excess of 5,000 per ha (Probst MS). Because trees are evenly distributed in plantations, optimal tree canopy cover can be produced with a tree density as low as 3,000 stems per ha.

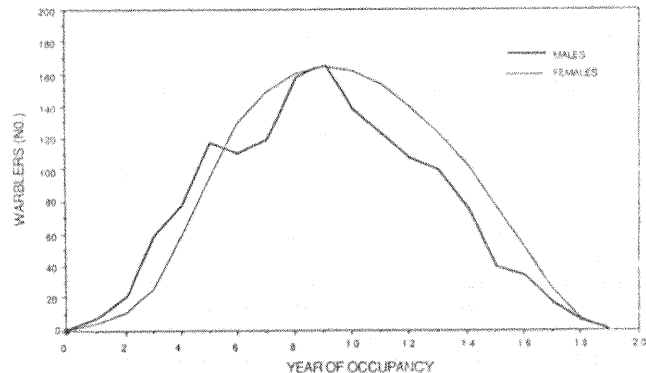


Figure 1.--Stand age population trends of male and female Kirtland's warblers. The male data were averaged from four wildfire areas in Michigan centered about the median year of occupancy. The female curve was inferred from data on pairing success in young versus older habitat (see text).

Ground Cover

Previous explanations of Kirtland's warbler habitat suitability have centered about the bird's nesting biology (Mayfield 1960, Walkinshaw 1983). The Kirtland's Warbler Recovery Team (appointed under authority of the Endangered Species Act of 1973) has emphasized the importance of fire to provide appropriate ground cover for nests, which are always on the ground. However, recent data show that on the very poor quality sites that characterize Kirtland's warbler habitat, ground cover does not appear to be limiting to Kirtland's warblers habitat selection. Both occupied and unoccupied stands almost always have a low, light cover of shrubs and grass-sedge interspersed with moss, lichen, and bare ground. Although initial post-fire ground cover species composition differs between burned and unburned stands, these differences decrease as stands mature (Abrams and Dickman 1982). This trend toward convergent succession of ground cover vegetation

when the stand is from 3 to 5 years of age has been confirmed in longer-term comparisons within sites that have varied fire and shade histories (unpublished data). Thus, I propose that ground cover vegetation on these poor-quality jack pine sites is not significantly altered by fire because most plant species present are fire adapted and regenerate quickly from underground roots or runners. The primary factors that influence ground cover species composition, instead of fire history, are site quality and recent shade history.

Broadleaf Coppice

Because the Kirtland's warbler has been found frequently in nearly pure jack pine stands, it has been thought that sprout growth from Northern pin oak (Quercus ellipsoidalis), big tooth aspen (Populus grandidentata), black cherry (Prunus serotina), and choke cherry (P. virginiana) would make the habitat unsuitable. However, it is likely that Kirtland's warblers are adapted to moderate amounts of oak, and they have been found at maximum densities in breeding areas with as much as 20 percent oak (Smith 1979). Broadleaf coppice is actively used for foraging, so it should not be detrimental if jack pine stocking is adequate. Broadleaf sprout-growth is beneficial in marginally stocked jack pine stands because it provides supplemental foliage volume for Kirtland's warbler foraging.

POPULATION REGULATION

Cowbirds

It is possible to conduct a comprehensive census of singing male Kirtland's warblers during the breeding season because of their distinct habitat requirements and restricted breeding range. Such censuses were done in 1951, 1961, 1971, and every year thereafter.

The population of singing males decreased from 502 to 201 between 1961 (Mayfield 1962) and 1971 (Mayfield 1972). The major reason for this population decrease appeared to have been nest parasitism by the brown-headed cowbird (Molothrus ater) (Ryel 1981). However, the population has stabilized since cowbird control beginning in 1971 cut parasitism rates from more than 66 percent of the nests (Walkinshaw and Faust 1974) to less than 3 percent (Kelly and DeCapita 1982). Productivity increased from less than 1 to 3.1 fledglings per pair (Walkinshaw 1983).

Fledgling survival rate may be as high as 75 percent per year (Probst 1986), so high winter mortality (Ryel 1981) is an unlikely explanation for the failure of the population to increase since 1971. The factors that may now be limiting population growth are habitat maturation and fragmentation, incomplete pairing success, fledgling mortality, and yearling dispersal to less suitable habitat or places outside the known breeding range.

Habitat

Strong evidence exists that the availability of suitable breeding habitat has been the principal factor limiting Kirtland's warbler population since cowbird control was begun. Because habitat is only suitable for a 10- to 16-year period, habitat maturation forces young birds to find new breeding areas. Thus, populations can be maintained or increased only if new breeding colonies are established to replace existing areas. Suitable breeding habitat available to the Kirtland's warbler has decreased since 1961 (Ryel 1981, Probst 1986). The amount of jack pine habitat in the 8 to 20 year stand-age range has not decreased much since 1951, but indirect evidence exists that the amount of suitable habitat (adequately stocked with jack pine) has declined significantly during the past 35 years. The density of male Kirtland's warblers in all suitably aged habitat fell from 3.0 males per 40 ha in 1961 to 1.0 males per 40 ha in 1984 (Probst MS). However, warbler densities in occupied habitat were similar in 1951 and the period from 1981 to 1985, even though the entire population has declined about 40 percent since 1951. This implies that the Kirtland's warbler population might have been filling most of the suitable habitat in recent years, with some overflow into less suitable or marginal habitat.

The population stability since 1971 could be related to population regulation by a fairly constant area of habitat. The minor population fluctuations that have been observed during the past 17 years have been related to a synchronous increase or decrease at maturing colonies (Probst 1986) and higher or lower proportions of Kirtland's warblers in suitable versus marginal habitat (Probst and Hayes 1987). The recent concentration of Kirtland's warblers into a small portion of the available suitably aged habitat is further evidence of population affected by the amount of suitable habitat. In the period from 1977 to 1983, three-fourths of the male population (between 155 and 180 males) was located in five or six major breeding areas (Ryel 1981, Probst 1986) whose combined total area represented only about one-third of the entire occupied habitat. This population concentration suggests that highly suitable habitat was limited to five large burns and one management area. Finally, the within-season movement pattern of Kirtland's warblers suggests that many birds are not breeding but are searching for better quality habitat (see below).

BIOGEOGRAPHY AND HABITAT UTILIZATION

Habitat area may affect colonization success, arrival dates, territorial establishment, and fledging dates. A scarcity of quality habitat may result in more territory being abandoned because birds may have to search for better nesting territories in order to secure a permanent pairing. In 1982 and 1983 about 15 percent of the resident males did not find mates (Probst and Hayes 1987). Any

dispersal to find more suitable habitat may reduce breeding opportunities. Delays in the initiation of breeding may cause birds to miss food resource peaks or sacrifice opportunities for renesting or second nesting. In 1987, about 22 percent of the male Kirtland's warblers abandoned territories established before 21 June. They could not have raised broods by that date. However, the colonization and dispersal patterns differ between marginal and suitable habitat. A higher proportion of males abandon territories in marginal habitat than in suitable habitat (1987 data in Fig. 2). In 1986, 93 percent of the territories in suitable habitat were occupied by 5 June, but only 52 percent of the less suitable Kirtland's warbler locations were occupied by that date. By 5 June, 84 percent of the adult males were established, in contrast to 73 percent of the subadult males. Higher proportions of subadult males were in marginal habitat (44 percent) than in more suitable habitat (23 percent) in 1986. Only 8 percent of the males vacated territories by the end of June in suitable habitat, but 19 percent of the males abandoned territories in marginal habitat. These trends indicate that young birds have difficulty establishing territories in crowded, more suitable habitat, and may delay breeding because of their late arrival. Current research results suggest that stand colonization is affected by stand size and distance from occupied breeding areas, as would be expected from within-season dispersal.

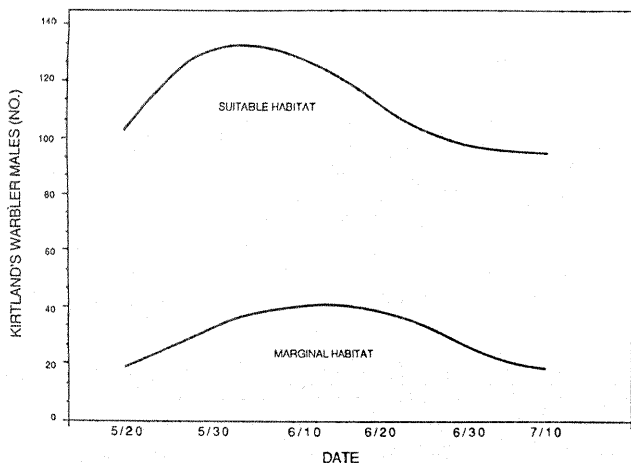


Figure 2.--Number of territories occupied by male Kirtland's warblers in marginal and suitable habitat during the 1987 breeding season. Trends were extrapolated to the entire known population (N=167 males) from a sample of males in suitable (N=58) and marginal (N=41) habitat.

In summary, habitat utilization by the Kirtland's warbler apparently is affected by both habitat quality and biogeography. Kirtland's warblers present a unique opportunity to study population regulation by habitat limitation because of their small breeding range, their concentration into 16-30 stands, and the facility of censusing their entire known population every year.

HABITAT MANAGEMENT

Kirtland's warbler land managers must supply

a sufficient area of suitable habitat in the right locations to maintain a viable breeding population. Within management units, stand prescriptions should strive to maximize the number of breeding pairs for the entire period of occupancy. The highest possible production of fledglings from a stand will be achieved by maximizing the duration of occupancy without compromising the average annual breeding density. In most circumstances, this objective can be achieved by increasing the probability of early stand colonization and by extending the period a stand is suitable for new colonists. However, an anticipated habitat shortage may be alleviated by managing only for early occupancy (near-term shortage) or late occupancy (long-term shortage).

Large-scale Considerations

The area set aside for Kirtland's warbler management totals 51,700 ha in 16 areas owned by the State of Michigan (30,000 ha) and 7 areas owned by the USDA Forest Service (21,700 ha in the Huron-Manistee National Forest). This land is being managed on a 50-year Kirtland's warbler management and commercial timber rotation. The Recovery Plan calls for regenerating about 1,030 ha per year so that about 10 times that area is always suitably aged for Kirtland's warblers. If this habitat objective is maintained, an overall density of 3.8 males per 40 ha would achieve a viable population of 1,000 males. The average density in all occupied Kirtland's warbler habitat has been less than two males per 40 ha from 1981 to 1985 (Probst MS). If this density continues, the population would be about one-half the target figure. However, the future managed habitat could allow a higher average density of males. If 75 percent of the Kirtland's warbler habitat (10,340 ha) were occupied at five males per 40 ha, the objectives of the Kirtland's Warbler Recovery Plan developed for this Endangered Species could be attained. More than 6,100 ha of wildfire and plantation habitat should be available in 1993 to provide carrying capacity for 300 to 750 male Kirtland's warblers.

Clustering stands into 23 State and Federal management units with staggered scheduling of stand regeneration should minimize most biogeographic dispersal problems. Each management area will have to be large enough to support a population that is sufficient to maintain a colony during the 8 to 12 years a stand is suitably aged for Kirtland's warblers. For example, at a density of 3 males per 40 ha (data in Mayfield 1962), from 240 to 335 ha of habitat would be required to support about 20 males. When jack pine is managed on a 50-year commercial rotation, five such stands totalling from 1,200 to 1,600 ha would be needed for each management area. The majority of the 23 Kirtland's Warbler Management Areas (KWMA's) are more than 2,000 ha in size, so the minimum area should be present in most of them. The minimum habitat specified above assumes occasional recolonization from other management areas and regular colonization of young stands from

adjacent occupied habitat.

The Kirtland's warbler is an early succession, area-sensitive species that is rarely found in stands smaller than 32 ha. The reasons for this minimum habitat size requirement are unclear, however, it appears that larger habitat patches support Kirtland's warblers for a longer time. This fact is probably related to both higher populations of Kirtland's warblers and the diversity of habitat patches generally present in larger areas. The current practice of managing contiguous blocks of more than 80 ha of similarly aged habitat should accommodate the habitat area requirement of the Kirtland's warbler.

Most adult migrant bird species (including Kirtland's warblers) return to the same breeding area each year (Berger and Radabaugh 1968, Greenwood and Harvey 1982, Walkinshaw 1983). Juvenile and yearling birds may stay on their natal grounds or disperse from there in late summer or the following spring. If few young birds randomly find habitat during migration, discovery of new habitat probably will be affected by distance from established breeding areas (see above). Thus, Kirtland's warbler habitat management should be directed primarily toward the current breeding range. Expanding the range should be attempted only near the periphery of the current range. Because establishing breeding populations is so difficult, it is imperative to keep each occupied KWMA close to its rotation schedule.

Landscape Design of Management Areas

Kirtland's warblers colonize taller and denser jack pine patches before they occupy habitat with shorter or less dense trees. It is possible to extend the period of Kirtland's warbler occupancy in a management area by several methods such as varying the timing of stand regeneration or the tree spacing in a plantation.

Current management guidelines prescribe maintaining 20 percent of each KWMA in each 10-year age class. Normally, cutting blocks are scheduled for harvest regularly throughout each 10-year period, but regeneration is not always on schedule. To ensure several years overlap in stand utilization by Kirtland's warblers, I emphasize that date of origin between cutting blocks should differ by about 5 years. This temporal overlap should make it unnecessary to maintain local populations by long-distance recolonization.

Site quality variability within a stand or unit can increase the period of occupancy by Kirtland's warblers because it creates a pattern of patches with varied foliage volume. Managers should be aware of the importance of this variety when scheduling planting or prescribing tree densities. For example, tree densities should be more uniform in areas with site variety because differences in height growth alone may provide the necessary variety in

foliage volume without requiring tree stocking differences.

Although the Kirtland's warbler is an early-succession, area-sensitive species, little evidence has been found to relate Kirtland's warbler densities or productivity to stand shape and configuration. However, I hypothesize that at least two Kirtland's warbler nest predators -- red squirrel (*Tamiasciurus hudsonicus*) and blue jay (*Cyanocitta cristata*) -- may be less common in stands with trees shorter than about 4 m. It seems reasonable to assume that predation rates might be higher near edges of stands bordered by more mature trees. Thus, it would be prudent to avoid long, narrow stands to minimize such edges. A majority of stands managed for Kirtland's warbler in the recent past tend toward minimal edge.

Improving Habitat Quality

Most recommendations for improving Kirtland's warbler habitat center about increasing natural regeneration and optimizing tree spacing in plantations. Kirtland's warblers do not commonly colonize a stand until tree canopy cover exceeds 20 percent. Maximum male populations were recorded in stands with 40 to 60 percent canopy cover. Jack pine areas with 20 to 60 percent canopy cover have more than 6,250 stems per hectare in naturally regenerated stands and at least 2,700 stems per ha in plantations. However, plantations should have about 5,000 stems per hectare to attract colonists at the earliest possible stand age. This prescribed tree density is best achieved with a 1.3- by 2-m spacing pattern. A rectangular spacing pattern has more variety in the timing of thicket formation among the trees than a square pattern and should provide a longer period of Kirtland's warbler occupancy. Experimentation with opening sizes is needed. I suspect that openings should be smaller and more numerous than in past plantations where they averaged about 25 percent of the stand area.

Duration of Stand Occupancy. Recommendations for maintaining KWMA populations (above) stressed a variety of large habitat patches in both the temporal and spatial scales. The same strategy can be employed to extend the stand utilization period by Kirtland's warblers. The following seven alternatives are suggested to extend the length of stand occupancy:

- 1) Plantations with a variety of tree densities should attract Kirtland's warbler colonists both early and late in stand life. Experimentation with alternative tree densities is recommended. Because the Michigan Department of Natural Resources is currently using variable spacing of 1.3 by 1.3 m combined with 1.3 by 2.6 m, I recommend that the USDA Forest Service use 1.3 by 2 m and 1.7 by 2.3 m.

- 2) In stands with more than 1,250 stems per hectare of tree stocking, it may be feasible to plant dense 0.8- to 1.3-ha patches on 20 percent of a stand, and avoid the expense of full

(large-scale) planting.

3) It may be possible to regenerate dense 0.4- to 1.3-ha patches by leaving small clumps of standing mature jack pine during prescribed burns. (The Michigan Department of Natural Resources has had some success burning strip cuts in jack pine.)

4) In unburned areas lacking appreciable advance regeneration, a shelterwood cut followed by supplemental planting could provide high-quality habitat, but this would be more expensive than other options.

5) Plant from 20 to 30 percent of some stands with red pine at the same spacing as in item #1 above.

6) Large residual patches (greater than 15-m wide) of mature trees within wildfire areas may have advance regeneration that can be released by removing the overstory from 6 to 8 years after a burn. These patches could extend stand occupancy. Such areas have been used for nesting at Muskrat Lake Burn in Oscoda County, Michigan.

7) Very poorly stocked areas in burns greater than 8 ha could be fill-in planted about 5 or 6 years after the fire at 1.7 by 2-m spacing. Because the Mack Lake Burn has so much well-stocked habitat, additional planting should be delayed there until 1988 to 1992.

Kirtland's warblers require a dense layer of foliage from 0-1 m up to 1.7-4 m in height. If tree ages in a stand are too diverse, few thickets will be at the proper heights. Thus, fill-in planting should be scheduled before the existing trees are from 1- to 1.2-m tall. In some places the interplanted pines were established too late to affect habitat quality. This is especially true in cases where red pine was used as fill-in stock (see below).

Tree Species Other Than Jack Pine. Red pine is suitable for Kirtland's warbler plantations but not for fill-in planting. Red pine appears to have been beneficial to Kirtland's warblers in three stands because it extended their occupancy period by keeping live, lower foliage longer than jack pine. However, red pine can grow too slowly in the first 10 years on these poor sites and this can complicate scheduling considerations. Furthermore, red pine is more sensitive to microsite differences, and its growth is less predictable than jack pine. The slow, unpredictable early growth of red pine makes it unsuitable for fill-in planting. I recommend that managers experiment with planting red pine at densities prescribed for Kirtland's warbler on appropriate sites adjacent to KWMA's now managed for red pine.

The presence of northern pin oak (Quercus ellipsoidalis), choke cherry (Prunus virginiana), or black cherry (P. serotina) may not be disadvantageous to Kirtland's warblers when dense jack pine thickets also are present. Broadleaf coppice is actively used for Kirtland's warbler

foraging. In places where jack pine regeneration is marginal, oak sprout-growth should not be sprayed because it may help provide the minimum foliage volume required for Kirtland's warbler foraging. Kirtland's warblers have been found at high densities in stands (Damon Burn) with up to 20 percent oak (Smith 1979).

Snags and Residual Trees. Snags and residual trees that escape wildfire or harvest can be valuable song perches for Kirtland's warblers and are clearly beneficial where cowbirds are controlled. When cowbirds are not controlled, nest parasitism is higher near snags (Anderson and Storer 1976). Residual oak and pine trees are used for both singing and foraging. We have no data on the maximum volume of overstory tolerated by Kirtland's warblers, but the trees or stringers must be widely spaced or habitat will not be utilized. Overstory removals in Kirtland's warbler habitat are difficult to evaluate because habitat maturation always accompanies the removals. Scattered pine or oak residuals may be important in attracting the first males to a breeding area because some individual male Kirtland's warblers spend a majority of their time foraging in isolated trees, stringers, or the edges of mature forests. However, the scattered trees should probably not exceed 5 percent of the canopy.

Slash. Slash and logging debris are used extensively for Kirtland's warbler foraging. At present, we do not know how much logs and slash add to habitat quality and how much this use of debris as a foraging substrate is strictly facultative. However, almost all foraging in openings or in dense ground cover is on logs, stumps, or slash, so managers should use caution when prescribing whole-tree harvesting on unburned stands. Removing most logging debris from unburned Kirtland's warbler stands will preclude a direct, incisive comparison of the suitability of unburned and prescribed-burned plantations. Therefore, I recommend that each Kirtland's warbler unit have at least one of its unburned cutting blocks harvested by conventional cutting.

Ground Cover Composition. Kirtland's warbler appear to accept most ground cover communities associated with dense jack pine stands on very poor sites. (The rejection by Kirtland's warblers of unburned stands with Carex sedges as a dominant ground cover is probably related to the open tree cover of stands with dominant Carex). If the ground cover requirements of the Kirtland's warbler are no more specific than a low, light cover of shrubs, grasses, and sedges, it should be possible to generate suitable habitat without fire (Table 1). If future patterns of habitat occupancy indicate a more specific ground cover requirement, steps can be taken to maintain or increase the xeric shrubs and/or retard ground cover succession on the better sites. Mechanical disturbance such as plowing or disking breaks up sod and low shrubs such as blueberry (Vaccinium sp.). This treatment is probably more effective than fire for altering ground cover composition. If

optimal tree densities are achieved in unburned stands, shade should be sufficient to help favor shrubs over grass and sedge.

Table 1.--Prioritizing stands for prescribed burning.

Higher Priority Stands	Lower Priority Stands
1. Many residual jack pines	Significant advance regeneration
2. Abundant slash	Less slash, smaller residual trees
3. Better sites (>50 \$1)	Poorer sites (<50 \$1)
4. Dense broadleaf undergrowth	Low to moderate hardwood competition
5. No other site preparation anticipated	Good potential for "V-plow" planting or other heavy scarification
6. No fire history during last rotation	Recent history of fire

Natural Regeneration vs. Plantation

Much of the past focus on Kirtland's warbler habitat regeneration has revolved around the need for fire. The future focus should be on the need for natural regeneration on burned or unburned sites (Table 2). Natural regeneration will improve the quality of habitat even in the best stocked plantations. Where natural regeneration is excellent, planting costs can be reduced substantially. For suggestions on improving natural regeneration, see "Duration of Stand Occupancy" under "Improving Habitat Quality".

Seed tree burns have been unsuccessful at regenerating jack pine in Kirtland's warbler habitat. Unacceptable delays have occurred in planting warbler habitat because so few days are suitable for burning in a season. Prescribed fire has the potential to dramatically cut the costs of planting habitat, but safety concerns will have to be addressed. Fire's role in providing ground cover vegetation is complex, and prescribed fire could be used to create changes in vegetation. However, I believe the effects of fire on ground cover are short-term and can be duplicated more effectively with a variety of mechanical means.

Table 2.--Jack pine management options.

Harvest Option	Site Preparation	Regeneration ^{a/}
Strip-cuts	Prescribe burn Plow	Assess stocking Plant as needed between strips
Shelterwood	Burn and scarify Scarify Plow	Assess stocking, plant as needed Direct seeding Assess stocking Plant as needed
Seed tree	Burn and scarify Roller - chop, plow	Direct seeding, assess stocking, plant as needed Full planting
Conventional clearcut	Roller - chop, plow	Full planting
Whole tree harvesting	Disc/narrow/plow	Full planting

^{a/}Kirtland's warbler management requires denser stocking than timber management.

The preferred method for regenerating jack pine has been seed tree harvest followed by prescribed burning (Table 2). However, this prescription has not provided adequate natural regeneration, and almost all areas have been stocked by machine planting. Shelterwoods have been mostly unsatisfactory for full regeneration, and windthrows are a serious problem with this option. Future stand regeneration should be modified to achieve more natural tree regeneration. If successful, costs will be lowered, and habitat quality will be raised. Natural tree stocking can be increased by leaving more standing volume before prescribed burns (leave strips or >3.7-m² BA) or by using shelterwood where natural regeneration is insufficient.

The recommendations outlined in this paper were made after many years of research and management of Kirtland's warbler habitat. They can be used to improve habitat quality and breeding success. However, successful implementation of these management alternatives will require further experimentation and careful attention to scheduling of stand regeneration. Such an effort will only be possible with the continued cooperation of several government agencies, researchers, and the Kirtland's Warbler Recovery Team.

Many of the ideas presented in this paper were developed with foresters, wildlife managers, and members of the Kirtland's Warbler Recovery Team. I especially wish to thank G. W. Irvine, William Jarvis, David Sorenson, Jerome Weinrich, and the staff on the Huron-Manistee National Forest for their ideas about jack pine management for the benefit of Kirtland's warbler. Michael DeCapita, Cameron Kepler, Mark Nelson, Thomas Nicholls, Ronald Refsnider, Gustav Swanson, and Jerome Weinrich made helpful corrections to the manuscript.

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ABSTRACT.--Wild, radio-collared black bears (*Ursus americanus*) that became habituated to close (0-12 ft) observation by researchers showed activity patterns and habitat use patterns similar to those of radio-collared bears monitored from airplanes. The habituated bears were active mainly by day, sleeping from 1-3 hours after sunset until dawn with periodic naps through the day. Food, shade, security, and water were important habitat components. In early spring, the grass understory of forested wetlands provided the majority of food although these wetlands comprised <1% of the study area. Wetlands were also used for cooling. Dense thickets of balsam fir (*Abies balsamea*) saplings were preferred for shade. White pines (*Pinus strobus*) >20 in dbh located <200 yds from forested wetland feeding areas provided the majority of refuge trees for mothers with cubs in early spring although these trees comprised <1% of all trees >10 in dbh. Late spring diets included newly sprouting upland forbs, expanding aspen (*Populus tremuloides*) leaves, and ants. In summer, berries, nuts, ants, and forbs were major foods. Forest edges, mature forests, marshes and moist areas all contained major foods. The most important fall food is acorns. Management recommendations are included for each season.

INTRODUCTION

The original range of the black bear (*Ursus americanus*) coincided with forested regions throughout North America (Pelton 1982). That

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range has been reduced through forest removal or fragmentation and continues to be reduced by an expanding human population. However, extensive range remains, especially in northern or mountainous regions unsuitable for commercial agriculture. Many of these areas are managed for timber production, recreation, and wildlife, but more detailed information on bear habitat requirements is needed. A study was conducted to obtain habitat information that managers can integrate into resource management plans and use in opportunity area planning and implementation.

METHODS

Three methods were used to learn habitat needs of black bears in northeastern Minnesota. First, 83 radio-collared black bears were monitored to determine home range size and how the availability of certain forest types affects survival, growth, and reproduction (Rogers 1987a). Secondly, more

than 1,200 fecal scats were examined to determine differences in diet between years when bears thrived and years when their growth and reproduction were poor. Habitats that produced the foods identified in the scats were then studied to determine what forestry practices led to those habitats being productive (Arimond 1979). Thirdly, current studies involve observing four wild, free-ranging, radio-collared black bears that are habituated to observers.

The habituated bears, who allowed observers to record data from within 4 yards for 24 hours at a time, showed movement and activity patterns similar to those of bears radio-tracked remotely. Although aware of the observers, the habituated bears paid little attention to them. The bears foraged and napped by day and slept at night as has been reported for other bears (Rogers 1987a). Mothers tended and nursed their cubs, and the cubs showed normal growth.

Data recorded from habituated bears included: habitat type, amount eaten of each food in each habitat, number of minutes spent on each activity in each habitat, and reactions to insects, weather, other bears, and other animals. Each of the three methods (radio-tracking, scat analysis, direct observation) provided unique but complementary information. Continuing study will involve further observation of habituated bears.

STUDY AREA

The studies were conducted in the Superior National Forest in northeastern Minnesota. The study area is approximately one-fourth lowland and three-fourths upland, with upland mixed coniferous-deciduous forest communities predominating (Peek et al. 1976). Vegetation is typical of the northern Great

Lakes region, containing components of both the boreal forest and the temperate deciduous forest (Maycock and Curtis 1960). Common upland trees are aspen (Populus tremuloides, P. grandidentata), paper birch (Betula papyrifera), red pine (Pinus resinosa), white pine (P. strobus), jack pine (P. banksiana), white spruce (Picea glauca), and balsam fir (Abies balsamea). Common lowland trees are black spruce (P. mariana), balsam fir, tamarack (Larix laricina), white cedar (Thuja occidentalis), black ash (Fraxinus nigra), and paper birch. Soils are noncalcareous sands and gravels and are often shallow, especially northward where rock outcrops are common on the Laurentian Shield (Minnesota Soil Atlas 1981). Glacial deposits tend to be deeper and more loamy southward toward Lake Superior and beyond (Wright and Watts 1969, Ojakangas and Matsch (1982).

BEAR MOVEMENTS

Radio-tracking revealed that black bears in northeastern Minnesota use larger areas than bears elsewhere (Rogers 1987b), probably due to the low fertility of the area (Rogers 1987a). Adult females maintained territories averaging 2.5 miles in diameter, and males concentrated their activities in ranges averaging 7.5 miles in diameter. These ranges are not unusually large, but 40% of the females (N=105) and 69% of the males (N=32) ranged 4-125 miles outside those areas in late summer and fall before returning to their usual areas for denning (Rogers 1987a). Most (70%) of the long movements (N=66) were to areas of deeper, more loamy soil and greater fruit and nut production than in the main study area.

SPRING HABITAT USE

Bears emerged from their dens when the weather turned warm enough in late March or April, but most remained lethargic until late April or early May when aspen catkins and green vegetation became available (Rogers 1987a). Swamp grasses, especially bluejoint reedgrass (Calamagrostis canadensis) and fowl mannagrass (Glyceria striata) were major foods in early spring. These species were found in the understories of tamarack swamps, alder (Alnus rugosa) swamps, and especially back ash swamps. In the spring of 1987, unusually low water levels increased bear access to swamp grass. The bears concentrated their feeding in ash swamps even though that cover type constituted <1% of the study area.

As upland forbs emerged, bears in the study area added large-leaved aster (Aster macrophyllus), false lily-of-the-valley (Mainantheum canadensis), smooth bedstraw (Galium triflorum), interrupted fern (Osmunda claytonia), and peavine (Lathyrus spp.) to their diets but ceased eating all but peavine when the leaves reached full size. As wild calla (Calla palustris) and jewelweed (Impatiens capensis) began to emerge, bears added these wetland and lowland plants to their diets and continued to eat them through summer. In other northern forests, jack-in-the-pulpit (Arisaema triphyllum) corms and young skunk cabbage (Symplocarpus foetidus) leaves are important spring foods (Elowe 1984, W. Breckenridge, pers. commun.), further indicating the importance of forested wetlands and lowlands to black bears. Most of the feeding on upland forbs by habituated bears was in the vicinity of ash swamps that they continued to use through May.

The presence of large pines appeared to be a major determinant of habitat selection in spring, especially by mothers with cubs. Nearly all the feeding by a mother with cubs was within 200 yards of white pines >20 inches dbh, which she used as refuges for her resting cubs. Elowe (1984, 1987) found that mothers with cubs in Massachusetts centered their

spring activities around large white pines and hemlocks in the vicinities of forested wetlands. Both white pines and hemlocks have rough, strong bark suitable for climbing by cubs. Cubs have been observed falling from aspen trees, spruce trees, and young red pines because their claws slipped on the smooth or flaky bark (Rogers and Wilker, unpubl. data). At least one death from a fall has been reported (Elowe 1987). Where large white pines and forested wetlands were near lightly traveled roads, the bears fed heavily on roadside dandelion (Taraxaum officinale), red clover (Trifolium pratense), and peavine in mid-May.

During May, ants surfaced and became part of the diet. By late May, ant pupae become abundant in the colonies while most upland forbs reached full size and were rejected. Ants, primarily carpenter ants (Camponotus spp.) in logs and stumps in open areas, then became the primary food until fruit ripened in early July. Most of the logs were from balsam fir trees that had been killed by spruce budworms (Choristoneura fumiferana) 1-2 decades earlier (Hardy et al. 1986). Logs in forest openings tended to hold the most ants.

SUMMER HABITAT USE

Fruit and hazelnuts (Corylus cornuta) were preferred summer foods and the major determinants of weight gain, reproductive rate, and cub survival for northeastern Minnesota bears (Rogers 1976, 1987a). Young females typically did not produce their first litters until after a year of abundant fruit and nuts; some females failed to reproduce until 8 years of age (average 6.3 years) (Rogers 1987a).

Under ideal food conditions, reproduction begins at 3-4 years of age (Alt 1980, Kordek and Lindzey 1980). Cub survival (N=11 years, 181 cubs) ranged from 59% to 88%, depending upon fruit and nut production in the year of conception and the first year of post-partum life (Rogers 1987a).

Important fruits in northeastern Minnesota were wild sarsaparilla berries (Aralia nudicaulis), cherries (Prunus virginianus, P. pensylvanicus), blueberries (Vaccinium angustifolium, V. myrtilloides), serviceberries (Amelanchier spp.), dogwood berries (Cornus rugosa, C. stolonifera), raspberries (Rubus strigosus), and mountain-ash berries (Sorbus spp.). In other northern forests, feral apples (Pyrus malus), buffalo berries (Shepherdia canadensis), black cherries (Prunus serotina), and blackberries (Rubus spp.) are also important summer foods (Elowe 1984, Bertagnoli 1986).

Few black bear foods (e.g., wild sarsaparilla berries and hazelnuts) are shade tolerant species. Black cherry and oak are forest canopy species but require openings for regeneration. Most fruit producing species

require much sunlight for maximum production. In northeastern Minnesota, blueberry, raspberry, and cherry (P. virginianus, P. pensylvanicus) production varied inversely with tree density during a 4-year study of 29 unburned sites (Table 1) (Arimond 1979).

Table 1. Combined production of blueberries, cherries, and raspberries in stands of different tree density in northeastern Minnesota, 1974-1977 (from Arimond 1979).

Trees/acre	No.	Average fruit production	
		Stands lbs/acre	Range(lbs/acre
Few or none	8	80	11-194
192-311	9	12	0-101
418-480	6	5	0-32
511-848	6	<1	0-3

The only burned site studied was more productive than any of the unburned sites; blueberry production averaged 318 lbs/acre during 1974-1977 (Arimond 1979). Two sites treated with 2,4-D produced only raspberries for the 3-4 years of study after treatment (Arimond 1979).

Forest openings such as burns, clearcuts, select cut areas, edges of rock outcrops, old homesteads, marsh edges, insect damaged areas, untraveled roadsides, power line rights-of-way, and old growth forests with numerous windfall openings are favored feeding areas in summers with good berry crops because these areas have the right amount of sunlight to stimulate berry production. Plants with no tree cover in southeastern Manitoba were found to experience greater frost damage and a less favorable water economy than plants under partial shade, with consequent lower productivity (Hoefs and Shay 1981). This may partly explain why feeding in large openings is concentrated near the edges where understory vegetation may be protected from thermal extremes. Black bears may also avoid the centers of large openings because of the absence of shade and escape cover (Jonkel and Cowan 1971). Black bears are easily heat-stressed in full sunlight (Rogers, unpublished data). McCollum (1973) found a dramatic decline in use of clearcuts beyond 200 yards of forest cover. Hugie (1982) reported little use beyond 135 yards of forest cover.

In a black cherry stand in Michigan, >90% of the fecal droppings of bears were within 10 feet of scattered, large (>10 inch dbh) hemlock trees (Rogers, unpubl. data). Elowe (pers. commun.) observed similar use of large hemlocks in New England. This suggests that refuge trees influence habitat use even within forest habitat in summer.

Although upland openings are favored feeding sites in summers with good berry crops (or mature upland stands when wild sarsaparilla berries are abundant), bears seek other habitats in years when berry crops fail. In 1987, when berries were scarce, a habituated female obtained much of her food in July and early August from alder and tamarack swamps where she ate wild calla and jewelweed. Other feeding sites were along seldom traveled forest roadsides, where she ate clover (*Trifolium* spp.) and wild lettuce (*Lactuca* spp.), and in mature upland spruce stands, where she ate bunchberries (*Cornus canadensis*). In early August, hazelnuts ripened and became her primary food from mid-August until they disappeared. During this period, she foraged far outside her territory, finding a productive hazel stand 22 miles away. She fed mainly in a 5 acre area there for 22 days, eating 2,605 hazelnuts in 24 hours on 27-28 August. The hazelnuts disappeared from that stand during the next week, and the bear started home. She arrived home on 7 September after pausing 2 days enroute in a round-leaved dogwood stand.

FALL HABITAT USE

Probably the greatest habitat deficiency in northeastern Minnesota and other forests north of Lake Superior is the paucity of nutritious fall foods. Hazelnuts, ants, and most species of berries become scarce in September. Bears then must turn to vegetation such as clover and peavine (or, in some years, to hornets) and begin losing weight. Acorn producing oak stands (primarily northern red oak, *Quercus rubra*) are uncommon, constituting <0.05% of the region. Bears that find the few oak stands show superior growth and reproduction because acorns allow them to extend their annual growth period into fall. Black bears can learn the locations of mature oak stands and pass this information on to their offspring (Garshelis and Pelton 1981, Rogers 1987a). A bear clan with a tradition of traveling 22 miles to an oak stand each fall showed the greatest weight gains and the highest reproductive rate observed in northeastern Minnesota among bears that ate only natural food (Rogers 1987a). A young female in this clan was the only study female to reproduce by 4 years of age without having access to garbage (Rogers 1987a).

South and east of Lake Superior, more fall foods are available due to a greater variety and prevalence of oak species, the presence of beech (*Fagus grandifolia*), and a more common occurrence of feral apples. However, even in those areas, northern red oak is the primary producer of fall mast.

Black bears in the northern Great Lakes Region commonly spend 4-7 months a year in dens. They enter dens between September and December, depending upon regional norms of food availability, and leave them between late March and early May, depending upon spring thaws and the presence of cubs (Rogers 1987a). Cubs are born in January every other year if nutrition is adequate or less often if the mothers are unable to gain sufficient weight in summer and fall (Rogers 1987a).

Preferred maternal dens are tree cavities (Jonkel and Cowan 1971, Johnson et al. 1978, Lentz 1980, Lentz et al. 1980, Rogers 1987a). These provide good thermal protection and reduce vulnerability to predation, human disturbance, harassment by dogs, and flooding by rain or meltwater. Cubs depend upon their mothers for warmth and will die if dens are flooded or mothers are disturbed and forced to leave the cubs for long (Smith 1946, Johnson and Pelton 1980, Alt 1984). However, tree dens are less critical in northern habitats than they are farther south where winter thaws and disturbance are more likely. In northeastern Minnesota, where most forests are second growth with few trees large enough to have suitable cavities, bears used burrows, rock crevices, brush piles, rock-raked windrows, and surface nests (Rogers 1987a). Winter thaws there were not sufficient to flood dens, and few people other than loggers used the forest in winter. One family of bears was killed and eaten by wolves (*Canis lupus*), but this was the only predation to occur during overwinter observations of 206 occupied dens (Rogers and Mech 1981). Overwinter survival was >99%. Denning habitat did not appear to be a critical habitat feature in that area.

BLACK BEAR HABITAT MANAGEMENT

Probably the most important consideration for maintaining black bear habitat is maintaining large enough blocks of diverse forested land with few enough permanent human residents that black bears can reproduce faster than they are killed. More than 90% of the mortality among black bears (N=35) that reached the age of independence (1.5 years) in northeastern Minnesota was from human-related causes, primarily bullets (Rogers 1987a). Hunting deaths are not considered a long-term threat because those deaths can be regulated through game regulations, but the killing of nuisance bears by permanent human residents is unregulated, and the presence of permanent residents can reduce population viability. The lower the land fertility or the higher the permanent human population, the more land will be required to maintain a viable population of bears (Rogers and Allen 1987). Another factor in bear survival is human attitudes. Black bears in Wisconsin and Pennsylvania coexist with higher human populations than in northeastern Minnesota due to lower

poaching/nuisance losses. Thus, education may ameliorate problems of high human density (Rogers and Allen 1987).

Although bear density strongly depends upon human tolerance, reproductive success of adult females and survival of cubs through 1.5 years of age depend primarily upon food supply. Consequently, silvicultural prescriptions should be oriented toward increasing production and diversity of food species, especially fruit and nut producing species. One of the most effective actions a forest manager can take to maintain bear habitat is to maintain mature stands of oak where these are scarce. Within the Superior National Forest, oak cutting is now banned except for regeneration cuts (E. Lindquist, pers. commun. 1987). Outside the Forest, some of the scarce, mature, red oak stands have been cut for firewood, significantly reducing habitat quality for black bears and other species.

Once a red oak stand is lost, it is difficult to reestablish without specific management toward that goal (R. Jacobs, pers. commun.). Time to full maturity is long. Northern red oak begins to fruit when approximately 25 years old but does not produce abundant acorns until 50 years of age (Fowells 1965). Some acorns then are produced each year with good crops every 2 to 5 years for 100 years or longer (Fowells 1965, Elias 1980). Production may maximize at 20-22 inches dbh and decline with decreasing size, according to a study in the southern portion of the species' range (Downs and McQuilkin 1944). A 10 inch dbh tree may produce 0.4 lbs of acorns/year, a 14 inch dbh tree may produce 15.8 lbs/yr (Shaw 1970). A fully stocked mature stand would be expected to include 70-90 square feet/acre basal area of mature trees, 15 square feet/acre of pole-sized trees, and 5 square feet/acre of smaller trees.

Maintaining mature stands of other locally scarce, food producing trees such as mountain-ash (*Sorbus* spp.), black cherry, feral apples, wild plum (*Prunus* spp.), and beech is also beneficial. Most other fruit or mast producing species of northern forests are shrubs or forbs and tend to be more common. Many of these understory species are shade intolerant, and their fruit production can be enhanced by thinning the overstory, as has been shown in Washington (Lindzey and Meslow 1977), Montana (Jonkel and Cowan 1971), Michigan (Manville 1983) and Minnesota (Arimond 1979) (Table 1). However, thinning of commercial stands can severely damage established shrub species; therefore, an effort should be made to minimize damage to ground species. Prescribed burning (Arimond 1979, Gruell 1980) and curtailing of grazing can also improve productivity of fruit and mast producing species. Containerized plantings or seeding in favorable sites may increase distribution (Irwin and Hammond 1985). The value of forest

openings to bears and other omnivores can be further enhanced by plantings of legumes (*Trifolium* spp., *Vicia* spp., *Lathyrus* spp.) (Jonkel and Cowan 1971:21).

Clearcuts may be beneficial or detrimental depending upon their size, configuration, and herbicide treatment. Benefits of clearcuts decrease with increasing size because of the reluctance of bears to move far from forest cover (Young 1980). Islands or peninsulas of forest cover in clearcuts can increase use of surrounding open areas (Lindzey and Meslow 1977), especially by mothers with cubs due to their greater reluctance to leave forest cover (Herrero 1979). Broadcast application of herbicide can kill all the major fruit and mast producing species of the northeastern United States. Reestablishing those species requires 4-10 years or more (Arimond 1979, Rogers, unpubl. data). However, hand application of herbicide allows survival of berry producing species and enhances fruit production under the opened canopy (McComb and Hurst 1987). Logs from herbicided trees can become suitable for ant colonies within 10 years (Rogers and Wilker, unpubl. data). Several researchers found that bears avoided clearcuts for approximately 10 years after timber harvest but favored them after that interval (Jonkel and Cowan 1971, Lindzey and Meslow 1977, Kellyhouse 1980). Whether this initial period of avoidance was due to lack of shade and escape cover, reduced food supply as a result of herbicide treatment, or other factors is unknown.

Forested or shrub wetlands with understories of bluejoint reedgrass, fowl mannagrass, or wild calla are important spring and summer feeding areas but are commonly distributed in such small patches (<2 acres) that they often are not delineated on survey maps and are consequently clearcut along with surrounding stands. Where such wetlands constitute less than 45 acres per square mile (7% of the area [Elowe 1984]), uncut buffer zones of 200 yard radius would help maintain the wetlands and the surrounding high use uplands for black bears, wood ducks (*Aix sponsa*), white-tailed deer (*Odocoileus virginianus*), muskrats (*Ondatra zibethicus*), and other herbivores (Martin et al. 1951, Elowe 1984, Rogers and Allen 1987). Minimizing disturbances of wetlands in spring when they receive greatest use will further benefit these species.

Habitat selection by mothers with cubs, and perhaps by other bears, partially depends upon the presence of white pines or hemlocks >12 inches dbh, especially in spring. The presence of at least one of these trees per 10 acres (65/square mile) in and around feeding areas would enhance habitat quality for black bears. This spacing is based on the assumption that bears will feed up to 200 yards from each tree (Rogers and Wilker, unpubl. data; Elowe 1987). However, additional refuge trees may be

beneficial, especially around forested wetlands used in spring when cubs are small. In observed feeding areas with several refuge trees per acre, nearly all refuge trees were used, even in late summer feeding areas.

In summary, silvicultural prescriptions should be oriented toward increasing production and diversity of food species. Black bears depend upon a diversity of foods, particularly in northern areas where fruit and mast crops frequently fail due to extreme weather. A diversity of foods, including a diversity of fruit and nut species, increases the likelihood of an adequate food supply due to differences in the times of flowering and fruiting of the different species. Of utmost importance in the maintenance of bear habitat is maintaining adequate space. The wide-ranging habits of black bears and their attraction to people's food make this species one of the first to be extirpated when forests are reduced or fragmented by the expanding human population. State and National Forests tend to be less fertile than the forests that covered much of the black bear's original range. The amount of land in those forests is sufficient, with proper management, to insure viable populations of black bears for the foreseeable future.

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ABSTRACT.--Logging practices of the late 1800's and early 1900's profoundly damaged fish habitat in rivers of northern Michigan. Huge inputs of sand and removal of large woody debris were the primary causes of habitat degradation. Detrimental effects persist to the present day and will not diminish soon unless habitat restoration is actively pursued. Habitat restoration goals on the Hiawatha National Forest are: eliminate major point sources of sand input; remove sand accumulations from river channels; manage riparian vegetation to provide required amounts of large woody debris; and install organic structure and rock spawning habitat where other methods will not provide an adequate fishery in the short-term. Specific techniques are summarized.

INTRODUCTION

Fisheries inventory has shown that unstable sand substrate, severe bank erosion and meager amounts of large woody debris are typical of many rivers on the Hiawatha National Forest (HNF) in Michigan's Upper Peninsula. Salmonid populations in these rivers are low despite favorable water temperature and chemistry. Similar conditions occur on the Huron-Manistee National Forests in the Lower Peninsula of Michigan.

The perception that these conditions are "natural" is common among river users. This stems from the fact that most efforts to find documentation of the pre-logging condition of North American rivers have occurred within the past 10 years. Consequently, public perception of acceptable resource condition is largely based on what people have experienced in their own lifetime. They assume that northern Michigan rivers always were full of sand and always had numerous eroding banks. For the same reason, scarcity of large

woody debris in rivers is considered to be a normal condition. It follows that attempts to increase fish populations by adding woody structure and stabilizing eroding banks have been viewed as enhancement of a natural situation.

Evidence from several sources indicates that rivers on the HNF were not always in the present condition. Fisheries workers found extensive deposits of gravel and cobblestone buried under 2-4 feet of sand. A sawlog bearing the stamp of a timber company that operated in the 1890's was found under 5 feet of sand in a riverbed. These discoveries led to study of old logging photos, historical accounts of pre-logging conditions and early logging practices, as well as recent research dealing with the impacts of historical logging on fish habitat. Together these sources led to the conclusion that HNF rivers were severely damaged by early logging practices and that habitat degradation persists to the present day.

Presented herein is evidence to support this conclusion. Much of the evidence is circumstantial and there is some extrapolation of data from other parts of the country to rivers of the HNF. Further study may show that some of the inferences made are wrong. Nonetheless, there appears to be ample evidence that many fisheries activities, traditionally called habitat "enhancement", are actually habitat restoration.

¹A paper presented at the Society of American Foresters National Convention held at Minneapolis, Minnesota on October 20, 1987.

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PRE-LOGGING CONDITIONS

Descriptions in journals of early surveyors, loggers, and fishermen reveal that large accumulations of fallen trees was a dominant characteristic of northern Michigan rivers prior to logging activity (Williams, 1880; Buttars, 1918; Northrup, 1958). Large pines and dense stands of cedar grew on the banks of most rivers. In some places, rivers were so completely covered with huge rafts of woody debris, on which vegetation had taken root, that no water could be seen (Leach, 1903). The slow decomposition rate of submerged pine and cedar contributed to the longevity and size of these debris jams.

In contrast to the frequent references to woody debris in rivers, early accounts made no reference to bank erosion. While not conclusive, this suggests that severe bank erosion was unusual in northern Michigan prior to the mid-1800's.

Rivers throughout northern Michigan supported large populations of resident and migratory fish. The grayling was the dominant resident gamefish in northern Lower Michigan while brook trout and grayling occurred in Upper Michigan (Mershon, 1923). The prolific grayling attracted the attention of wealthy, eastern anglers as early as the 1860's (Norris, 1883). Daily catches of 50-100 grayling, averaging 0.3 pounds, were not unusual for the skillful angler (Northrup, 1958). Spawning runs of walleye, lake sturgeon, whitefish and lake trout from the Great Lakes ascended the lower reaches of many Michigan rivers (Lawrie and Rahrer, 1972; Smith, 1972; Wells and McLain, 1972; Bertrand et al., 1976). These runs were an important source of sustenance for early European settlers and native Americans. The name of the Sturgeon River on the HNF reflects the past occurrence of lake sturgeon in that system. Sturgeon bones were found at a prehistory archaeological site on the river and the name of the village at the river mouth ("Nahma") means sturgeon in the local native-American language (John Franzen, Forest Archaeologist, personal communication). Names of other HNF rivers such as the Whitefish and Fishdam may reflect the early abundance of lake-run fish in these systems. In general, northern Michigan rivers offered diverse, productive fisheries prior to about 1880.

LOGGING PRACTICES

Initiation of most logging activities in northern Michigan occurred between 1850 and 1880

(Karamanski, 1984). The huge white pines and cedar offered what appeared to be an unlimited supply of building materials for midwestern towns and industries. By 1900, approximately 25 billion board feet of pine had been cut from the forests of Upper Michigan (Maybee, 1960). All of the trees were cut by hand, removed from the forests by horses pulling "big wheels" and transported to market by steam power or river drive.

After establishing a sawmill near the rivermouth, the difficult task of clearing the river began so that logs could be floated downstream (Leach, 1903). Fallen trees, debris jams and obstructions of any kind were removed. Failure to remove obstructions resulted in log jams that were expensive and dangerous to break up (Brown, 1936; Karamanski, 1984). Logs were rolled down riverbanks and into the water. High, steep banks that allowed logs to roll directly into rivers were favored "rollways".

When the timber supply had been exhausted along the larger rivers, loggers moved up the tributaries. On streams too small to readily float logs, a system of splash dams was constructed to provide ponds for holding logs. When the pond was full of logs the dam was opened ("splashed"), flushing its contents to the next pond downstream and so on until a larger river was encountered (Sedell et al., 1982). Most wooden components of splash dams have rotted away but the presence of earthen dikes on streams as small as 10 feet wide, indicates that few HNF streams escaped the effects of logging (Karamanski, 1984).

LOGGING EFFECTS

Fish habitat was not a concern at the time when rivers were being prepared for log transportation (Sedell et al., 1982). Angling for sport was almost exclusively a pursuit of a few adventurous, wealthy individuals who could afford to move to virgin waters when logging and other abuses depleted fish stocks closer to population centers (Northrup, 1958). The conservation ethic, later championed by Gifford Pinchot and Teddy Roosevelt, did not yet influence natural resources management decisions.

This situation resulted in poor documentation of the effects of logging on fish habitat. Logging era photos are as helpful as the few written accounts in revealing effects of logging on the aquatic resource in northern Michigan.

Removal of large woody debris (LWD) to facilitate log drives was the first major abuse to fish habitat. In a review paper, Sedell et al. (1984) summarize a considerable amount of recent research documenting the importance of LWD for creating and maintaining productive fish habitat. Current scouring around LWD creates pools and maintains spawning gravel free of sediment. Large woody debris provides hiding and feeding areas for fish and is important as an attachment site for invertebrates that fish feed on. On high-gradient bedrock streams, LWD traps gravel that would be swept away otherwise. Large woody debris provides critical overwintering habitat for juvenile salmonids. Removal of LWD causes instability in channel morphology that adversely impacts fish populations. It is readily apparent that removal of LWD by early loggers would have resulted in significant fishery losses even if no other abuses had occurred. Harvest of riparian timber eliminated the future source of woody debris for many decades. Even where the original timber species have regenerated, few have matured sufficiently to replenish the supply of LWD that was removed.

Another effect of logging activities was increased sediment input to rivers. Repeated scouring by thousands of logs, pushed along by high flows from splash dam releases, stripped vegetation from the sand banks. The combined practices of rolling logs down steep banks and log driving resulted in substantial channel widening (Brown, 1936). Historical photos of Bill's Creek, a tributary to the Whitefish River on the HNF, show that the channel was over twice as wide about 1900 as it is today.

Other photos of river drives on the HNF indicate that severe bank erosion was the rule rather than the exception where rivers abutted steep sand banks. Comparison of present riverbank conditions with those shown in historical photos suggest that these rivers are slowly returning to an equilibrium state where bank erosion is much less common. Today, there are many banks in various stages of healing. Many of the remaining sites of severe bank erosion on the Huron-Manistee National Forest were once used as log rollways (Ron Dunlop, Forest Fisheries Biologist, personal communication). On the HNF erosion is most severe where logging impacted the most infertile sand soils.

Fires that followed logging compounded the erosion problem immensely. For every 3 trees cut in northern Michigan 5 burned (Wendell Hoover,

Michigan DNR Park Interpreter, personal communication). Old photos show stumps with roots completely exposed because the upper, organic layers of the soil had burned away. Loss of soil nutrients and moisture holding capacity are responsible for the persistence of sparsely vegetated stump meadows across northern Michigan today.

Research has shown that increased streamflows resulting from present day timber harvest operations are not adequate to immediately transport all of the increased sediment load that is generated. Streamflow volumes typically increase 10-80 percent but sediment loads often increase 1000 percent or more (Cordone and Kelley; 1961; Reinhart et al., 1963; Fredriksen, 1970; Verry, 1986). Therefore, it seems likely that the net effect of over 50 years of logging and fires was a substantial accumulation of sand in river channels.

Alexander and Hansen (1983) found that important components of fish habitat including pools, undercut banks and gravel deposits, are lost as a result of moderate increases in sand bedload. Water surface elevation increases in the stream channel and in the riparian water table. High water table discourages regeneration of many native timber species but favors dense growths of speckled alder. This explains the presence of old pine and cedar stumps in many alder stands.

Alder is inferior to native timber species for providing LWD because stem diameter rarely exceeds 4 inches. Alder is also undesirable because it tends to slump into streams producing frequent, mid-channel accumulations of small debris that is easily moved by high flows. The result is wide, shallow streams that lack well-developed pools.

Evidence that sand generated by pre-1900 logging and fires could still affect northern Michigan rivers is provided by a study that documented the rate of sand movement through a stream. In the study done by Alexander and Hansen (1983) sand was continuously added to a northern Michigan trout stream for 5 years. The bedload created was no higher than occurs naturally in several area rivers. It took 21 months for sand to move one mile through the study area. Sand accumulations persisted in the stream channel for 4 years after all inputs were ended. There had been little recovery of deep

pool habitat by the end of the 4 year post-treatment period. Chronic sand inputs from eroding banks and roads contribute to the persistence of sand in rivers.

Even slightly elevated sand bedloads substantially reduce trout populations. A 17 parts per million (ppm) increase in sand bedload results in a 10 pounds per acre decline in trout populations (Alexander and Hansen, 1983). Many HNF rivers have sand bedloads of 30-80 ppm indicating considerable potential for improvement through sand control.

Splash dams damaged fisheries by blocking spawning migrations of resident and lake-run fish (Bertrand et al., 1976; Sedell et al., 1982). Release of log-laden water from dams in the spring resulted in sedimentation and scouring of the spawning habitat of grayling which became extinct in the early 1900's (Peterson, 1958). The combination of dams, increased sediment loads and sawdust in rivers contributed to the loss of river-running stocks of whitefish and lake trout as well (Bertrand et al., 1976; Smith, 1972). Michigan Department of Natural Resources records show no recovery of whitefish and lake trout runs and runs of walleye and lake sturgeon are meager or non-existent across most of their former range.

RIVER RESTORATION PROGRAM

Based on the evidence that rivers have not recovered from effects of early logging, the HNF developed a river restoration program having four primary goals: 1) eliminate point sources of sediment input to rivers; 2) reduce sand accumulations in river channels; 3) manage riparian timber stands to provide a sustained yield of LWD; and 4) install woody structure and gravel suitable for fish spawning where other methods will not provide an adequate fishery in the short-term. These goals are reviewed individually.

Eroding banks and roads are significant point sources of sediment entering HNF rivers. Forest hydrologists determined that eroding sand banks on the Indian River in Schoolcraft County contributed approximately 0.1 cubic yards of sand per lineal foot of bank annually (unpublished data). Stabilization of 2000 lineal feet of bank on this river since 1979 has eliminated the equivalent of about 20 truckloads of sand from this river each year. The stabilization process consists of placing 12-24-inch rock along the toe of the bank,

sloping the upper bank to an angle at which it will remain stable, then applying topsoil, seed and mulch. Sod from the surrounding area is mixed with the topsoil to speed establishment of native forbes and shrubs.

Runoff from the surface of gravel and sand roads contributes to sediment loads where approaches to rivers are long and steep. Typical grading practices create a berm along each side of the road. This traps most of the sediment-laden runoff on the road surface until it reaches the low point of the road which is usually directly over the river. This problem is being addressed by removing the berm and constructing lateral ditches that direct runoff into vegetated areas away from the river. Options such as paving approaches to rivers and use of longer culverts to minimize direct entry of graded road materials into rivers are now routinely considered when planning road construction and reconstruction jobs.

Treating point sources of sand does not quickly eliminate sand accumulations from rivers. Sediment basins, excavated in river channels, are a quick, effective means of removing sand accumulations. Low current velocity in the basin allows transported sand to settle out of suspension. As a result, sand accumulated in the channel downstream from the basin flushes out, exposing gravel and woody debris. A series of basins spaced along a river system eliminates accumulated sand much more quickly than would natural processes.

The typical basin is 200 feet long, 20 feet wide and 6 feet deep but size varies considerably depending on size of stream and amount of sand input expected. Basin dimensions are based on guidelines developed by Hansen (1973). Most basins fill and have to be cleaned out once every 2-4 years. Usually, spoil is spread immediately adjacent to the basin as specified by the Michigan Department of Natural Resources and the Forest Landscape Architect. Spoil sites are selected to minimize impacts on wetlands and floodplains. In visually sensitive areas, topsoil is spread over sandy spoil prior to seeding to speed revegetation. Establishment of clover and other plant species attractive to wildlife creates dual benefits from these projects. Benefits to salmonid habitat and populations in Lower Michigan have been well-documented by Hansen et al. (1982) and Alexander and Hansen (1982). Preliminary

monitoring results indicate that a similar response is occurring on the HNF (unpublished data).

Efforts to manage riparian timber on the HNF are directed toward converting alder to long-lived timber species and developing standards and guidelines that will assure adequate recruitment of LWD to rivers. Conversion to native cedar and spruce is accomplished by removing alder from strips averaging 25 feet wide along one or both banks. Removal is done by hand-cutting at ground level followed by hand-spraying of an appropriate herbicide to stump sprouts in June of the year after cutting. Cedar and spruce nursery stock is scatter-planted through the resulting meadows except where small openings are desired to enhance wildlife habitat. Alder removal alone substantially improves trout populations on some small streams (Hunt, 1979). However, other habitat manipulations must be done in addition to alder removal to gain a favorable population response elsewhere. Alder removal is a first step towards a long-term vegetative goal.

Guidelines for management of riparian timber stands on the HNF call for management that will recruit and maintain in the river at least one 12-inch diameter tree per 100 lineal feet of channel. This guideline is considered to be very preliminary as it is based on personal observations and some western research (Rainville et al., 1985). The traditional practice of leaving buffer strips along HNF streams has encouraged recovery of riparian stands.

Immediate demand for improved fisheries is met by a wide variety of habitat structures. Woody structure is provided by log bank covers, deflectors, half-logs, K-dams, tree drops and other devices which have been thoroughly described in numerous publications (White and Brynildson, 1967; Seehorn, 1985; Hunt, in press). In contrast, construction of spawning habitat in eastern streams has not been well-documented. The HNF has installed over 3400 square yards of spawning habitat for resident and anadromous salmonids. Some of these structures accommodate spawning lake sturgeon and walleye as well. Populations of juvenile salmonids have increased as much as 30-fold following installation of spawning gravel (unpublished data, Fishdam River).

Spawning areas are made by armoring each bank with cobblestone which prevents bank erosion, then installing a gravel layer 8-24 inches thick on the streambed. Low rock sills

spaced 3-5 channel widths apart along the structure produce hydraulic conditions that encourage spawning activity. Placement of woody structure on the spawning area results in heavier use. Most spawning areas are constructed immediately downstream from a sediment basin.

CONCLUSION

The effects of early logging in northern Michigan will persist for many more decades unless managers actively pursue habitat restoration. Faced with growing demand for fish and wildlife outputs, National Forests can not afford to have aquatic systems operating at less than full capability. Cooperation with State and private organizations and interdisciplinary project development will be the keys to restoring rivers of sand.

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Abstract.--Located along the fisheries rich rim of the Gulf of Alaska, the Tongass and Chugach National Forests annually produce fishery resources that are vital to international trade for local and regional economies of the State. In 1985, estimates of the State-wide commercial salmon harvest exceeded 138 million fish, making it the largest recorded catch in State history. The habitats on National Forests contribute significantly to this commercial harvest and also to the recreational and subsistence harvest as well. To maintain this production, important freshwater habitats must be protected. The Aquatic Habitat Management Handbook was developed to provide the management direction to protect fish habitat. The handbook is an interdisciplinary, inter-agency document based upon fish habitat management concerns and the possibility of potential impacts. It incorporates the latest research findings pertinent to Alaska into specific management prescriptions. Additionally, a process for streamside management area width determinations is presented, along with a discussion of the goals and objectives of a recently initiated study on the interactions of fish and forest management in second-growth forests.

INTRODUCTION

Fishing and timber have been southeastern Alaska's most important industries for several decades. Since the 1950's when timber harvest increased dramatically to supply wood for a newly established pulp industry, the potential effects of timber harvest on Alaska's fisheries have become an ever-increasing concern.

In 1985, the State-wide commercial salmon harvest exceeded 138 million fish, making it the single largest recorded catch in State history. Additionally, for the last 7 consecutive years, the salmon harvest has exceeded 100 million fish.

The habitats of the Tongass and Chugach National Forests contribute significantly to this commercial harvest and also to the recreational and subsistence harvest as well.

Because the best timber in a watershed is often found in valley bottoms in close proximity to streams, timber harvest and associated activities can reduce the productivity of fisheries habitat if they are not carefully planned and conducted. To maintain this productivity, these important freshwater habitats must be protected. This is not an easy task since the potential effects of timber management activities, including road building, on the habitats of salmonids vary from site to site, seasonally, and with the type of forest practice implemented. The spatial and temporal differences may be partially explained by climatic regimes, physiographic differences, and life cycles of the respective species.

For the last decade, the major controversy surrounding forestry/fishery interactions in the West has been the development of standards for the management of streamside vegetation. The central

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question is what quantity of merchantable timber must be left adjacent to fish streams to protect existing fish habitat quality and provide for suitable future habitat. Standards are highly variable and have ranged from 300 foot mandatory buffer strips to little or no vegetation along streams. The most logical of these is to leave a "proper mix" of deciduous and coniferous vegetation in sufficient quantities to protect fish habitat.

In this paper, I will highlight the Aquatic Habitat Management Unit (AHMU) concept in Alaska and its implications to fish and timber management and discuss the newly initiated second-growth vegetation management study on fish and their habitat.

When managing Aquatic Habitat Management Units, three aspects loom prominent: (1) AHMU width requirements; (2) specific prescription development for AHMU's; and (3) second-growth management along streams. A discussion of each of these will follow.

AHMU WIDTH DETERMINATIONS

The streamside "riparian" vegetation of southeast Alaska typically blends almost imperceptively into the upland forest zone. This seemingly subtle contrast is quite different from the riparian areas of the drier regions in the western United States. In those dry regions, water is frequently in limited supply and where it occurs in abundance, an obvious change occurs. In southeast Alaska, water is generally abundant in both terrestrial and riparian ecosystems. In the terrestrial ecosystem, excessive amounts of rainfall is a dominant factor affecting the type and productivity of plant communities. In the streamside "riparian" ecosystem, like those in the drier regions of the United States, water is somewhat more abundant than in the surrounding upland sites, with the exception of muskegs. How does one then classify this area?

In Alaska, the following criteria are used to guide the integration of soils, and channel type classification systems into the delineation of an Aquatic Habitat Management Unit.

Channel types (Marion et al. 1987) are used as the basis for grouping all the stream channels in a watershed into two broad groups: Incised and uncontained stream channels. Distinctly different geomorphic and hydrologic processes occur within these two groups. Incised stream channels are contained by the adjacent landform and have little effect on the adjacent landform. Mass transfer is predominantly in one direction: from landform to the channel. Mass transfer processes are mass erosion, leaf fall, and blowdown. The terrestrial ecosystem does directly influence the stream.

Uncontained (alluvial) channels are areas

where a two-way interaction occurs between the adjacent landform and the channel. Mass transfer occurs through bank erosion, channel migration and overflow, leaf fall, and blowdown. Uncontained channel areas are important nutrient sources and processing zones, and generally contain a richer diversity of organisms than the incised channels. Flooding is a fundamental process in uncontained stream channels. Within these stream channels, the riparian area may be very broad and the adjacent terrestrial ecosystem may not directly influence the stream.

Uncontained stream riparian areas occur predominately within floodplain, alluvial fan, and dissected footslope landforms. These areas occur mostly along lower valley areas. These riparian areas are extremely dynamic as can be seen by the type of soils and plant communities occurring within these areas.

In uncontained channels, the outer boundary for the AHMU coincides with the outer boundary of associated landform. In some cases in southeast Alaska, these boundary distances have been as wide as 600 feet. In contrast, incised riparian areas occur predominately along the upper valley and mountain slope positions. These riparian areas, as the name implies, have stream flows which are well contained within the channel cross-sectional area. Channel banks are steep and generally composed of large material, either consolidated bedrock or well packed boulders, rubble, and cobbles. The riparian vegetation along these streams is often a narrow strip. The width of the riparian areas along these channels are determined by the identification of the adjacent unstable terrestrial soils that may directly influence the stream. These generally disjointed units are connected into a manageable AHMU by prescribing a 100 foot-wide riparian area as defined in the National Forest Management Act and Forest Service policy. This classification provides the land manager with an inventory description and map of riparian areas.

AQUATIC HABITAT MANAGEMENT PRESCRIPTIONS

Once the unit is defined, prescriptions for management are needed. Management schemes to maintain structurally and functionally diverse streamside management areas have been difficult to develop because of conflicting resource demands and the shortage of information on effects of silvicultural treatments on the biological and physical dynamics of streams. Thus in the past, management has generally relied on the vacuous use of prescriptions (i.e. mandatory buffer strips) that result in inefficiencies and inequalities as they do not provide for the necessary flexibility to balance the management between timber and fish. The Aquatic Habitat Management Handbook (1986) further refines the management. First it defines three classes of habitat. Classes are determined according to the importance of the

habitat to fish. These classes are defined as:

1. Class I AHMU. Streams with anadromous fish habitat or adfluvial resident sport fisheries. Also included is the habitat upstream from migration barriers known to be reasonable enhancement opportunities. Stream gradient is generally less than 6%.

2. Class II AHMU. Streams with resident fish populations and 6-15% gradient (can also include streams from 0-6% gradient where no anadromous fish occur). These populations have limited sport fisheries value. They generally occur upstream of migration barriers or steep gradient streams and other habitat features that preclude anadromous fish use.

3. Class III AHMU. Streams with no fish present but have potential water quality influence on downstream fish habitat. Stream gradient is usually in excess of 15% but may contain lower gradients.

The handbook provides guidance in facilitating fish habitat management through prescriptions while addressing multiple-use objectives. While it ensures a consistent approach throughout the National Forests in Alaska, it allows latitude for site specific prescriptions in response to habitat differences.

Salmonid habitat is complex but can be partially described using measurable physical elements. Maintenance of fish production relies on key habitat parameters such as proper water temperature, large woody debris and substrate composition. A precise blend of these key parameters creates good fish habitat.

When these key habitat parameters are compared to the potential impacts from land management activities, seven general fish habitat management concerns can be identified. These include: (1) streambank and streambed stability; (2) increased and/or depressed stream temperature; (3) fish passage through culverts; (4) special road construction techniques; (5) maintenance of existing water quality; (6) large woody debris; and (7) stream productivity. These concerns are the link between the AHMU concept and the specific fish habitat management objectives and prescriptions. These concerns are listed in Table 1 and are related to AHMU class applicability.

The management guidance provided in the handbook is organized within three levels. Class I AHMU'S require a range of timber harvest options from no cutting to complete harvest of commercial volumes of timber along streams. They contain the most restrictive timber harvesting prescription.

While class II and III objectives are respectively less restrictive. Specific prescriptions to meet these objectives were developed by an interdisciplinary team (TDT) using

the best available data specific to southeast Alaska. In a recently completed 5-year plan, it was estimated that 80% of the timber within 100 feet of the stream in class I, 40% in class II, and 10% in class III streams should be maintained to meet the objectives for maintenance of fish habitat.

A detailed discussion of one of the seven concerns, large woody debris (LWD), will provide an example of the knowledge and level of detail provided by the handbook. In addition to the section in the handbook on LWD, the Alaska Region of the Forest Service has additionally published an interagency brochure entitled: "Fish in the Forest - Large woody debris in streams, a new management approach to fish habitat" by Gibbons et al. 1986.

Table 1.--Frequency that fish habitat management concerns will result in prescriptions affecting land management activities.

Management Concern	FMU Classes		
	Class I	Class II	Class III
1. Maintenance of stream-bank and stream channel stability	1	1	1
2. Maintenance and/or enhancement of optimum stream temperature	1	1	2
3. Fish passage through stream crossing structures	1	2	3
4. Maintenance of water quality within established State standards	1	1	1
5. Maintenance of existing and providing future sources of large woody debris (LWD)	1	2	3
6. Maintenance or improvement of primary and secondary biological productivity within or adjacent to streams (including Second-Growth management).	1	3	3
7. Timing of bridge and culvert construction	2	3	3
1 - Always 2 - Occasionally 3 - Never			

All western Regions (1, 5, 6, and 10) of the USDA Forest Service have some specific standards for leaving large trees in streamside areas for fish habitat considerations. Forests in Oregon and Washington (Region 6) specify 9 to 25 trees greater than 16 inches dbh per acre for many anadromous fish streams. Forest guidelines in Region 6 often specify that 60 to 90% of the AHMU should be in mature or old-growth timber (Sedell et al., In press).

The AHMU Handbook in Alaska has a set of standards and guidelines based upon a sample from a large number of natural sites. The mean number of stems greater than 12 inches dbh per 100 feet of stream is between 13 and 24 for undisturbed habitat conditions. The guidelines require minimum tree sizes for specific stream widths: 1 to 20-foot wide stream require at least 12-inch dbh trees; 21 to 50-foot width requires 20-inch dbh trees; greater than 50-foot width requires 30-inch dbh trees and preferably with root wads attached. The minimum tree length for all channel widths is equal to 1.5 times the channel width.

Smolt yield increases are also predicted if woody debris is added to aquatic systems (fig. 1).

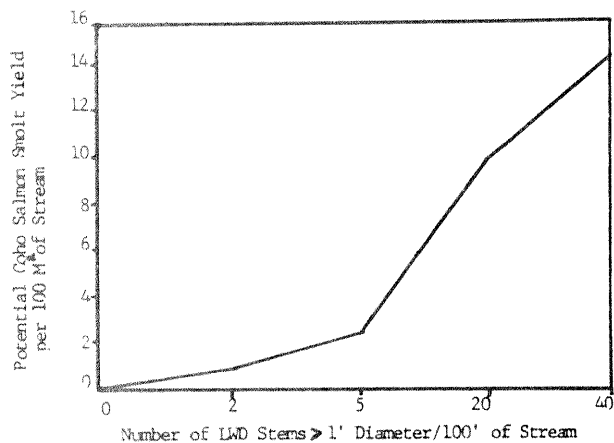


Figure 1.--Predicted coho salmon (*Oncorhynchus kisutch*) smolt yield as related to woody debris in streams of southeast Alaska.

These are preliminary data for Alaska and can not yet be reasonably extrapolated to other geographic areas. However, it does illustrate how such debris loading is related to potential coho salmon smolt yield. In that over 85% of the anadromous fish bearing streams in Pacific Northwest and probably elsewhere, have been cleaned of large woody debris, have no large conifers left in the streamside areas or have been scoured by debris torrents, knowledge of such

relationships is useful for future planning and rehabilitation (Sedell et al., In Press).

SECOND-GROWTH STUDY

The interactions of fish and forest management in second-growth vegetation in Alaska are not completely understood and with the increasing portions of the Forests being converted to second-growth status, more knowledge is needed. The premise for a study initiated in 1987 is that fish habitats in second-growth forests are qualitatively different from habitats in old-growth, and must be managed to ensure that fish production can be maintained at least at pre-disturbance levels. The anticipated life of the project is 5 years.

Timber harvest in the riparian zone imposes both long- and short-term changes in stream channel. The former best management practice of harvesting to the streams edge and subsequently removing woody debris from stream channels, for example, has resulted in a large number of stream channels in second-growth condition that lack the structure provided by large, stable woody debris and the necessary light production for good autotrophic stream production. Fish production in these streams has been lowered and is not expected to recover until the surrounding forest can provide new inputs of debris and light.

Resource managers can influence the type and quality of aquatic habitat in second-growth forests by manipulating carefully selected features. To accomplish habitat rehabilitation or improvement objectives in a biologically meaningful and efficient manner requires knowledge of the basic factors that determine the suitability of freshwater habitat for juvenile salmonids: food, living space, cover, and water quality.

The objectives of the study are:

1. Develop and document information on the production capability of aquatic habitats in second-growth forests.
2. Identify factors and processes influencing the production of juvenile anadromous salmonids in streams of second-growth forests.
3. Initiate experimental manipulations of stream channels, riparian vegetation, and fish populations to enhance growth and survival of juvenile anadromous salmonids.
4. Recommend alternative management programs, when necessary, for streams located in second-growth forests.

The management applications and long-term goals of the study will be to: (1) document information on the productive capacity of anadromous fish habitat in second-growth forests;

(2) identify factors that limit the production of anadromous fish; (3) predict the effects of silvicultural practices in second-growth forests on aquatic habitats; and (4) develop methods and procedures to maintain high levels of fish production in second-growth forest streams.

DISCUSSION

Today in southeast Alaska, resource managers are confronted with the responsibilities of making many significant decisions relating to the future use of Alaska's renewable natural resources. In the past 10 years, increased public attention has focused on critical environmental issues affecting the use of many natural resources, including timber and fish. Timber and fish are the two of the three most important resources with the greatest present economic value in southeast Alaska, and since, in many instances, each watershed produces both resources, it is inevitable that conflicts will arise when resource decisions are made in favor of one resource over the other. These potential conflicts which can arise from unaltered maintenance of streamside vegetation, improper culvert construction and other management actions will continue to occur as demands increase for a variety of goods and services produced from a static or declining land base. It is not a question of fish or timber since both resources are highly used, but rather integration of management and effective use of existing guidelines. As Martin (1976) points out, timber harvesting/fisheries issues are not simple to answer, but can only be resolved through proper application of existing knowledge, and for the most part, by the application of existing laws, regulations, and management guidelines. Recent legislative activities, special interest group pressures, judicial rulings, standards and prescriptions promulgated by private conservation groups, state and federal land management agencies provide ample evidence that the resolution of the timber/fisheries conflicts is one of our current pressing problems.

It is clear that one of the major problems concerning timber and fisheries management involves the management itself: namely, the effective application of existing guidelines. Many past management guidelines have been developed for southeast Alaska as a result of studies on the effects of timber harvesting on fish, water and soil throughout the Pacific Northwest. The new tiered prescriptions described are based upon recent research in southeast Alaska and provide the impetus and direction toward providing greater protection. The second-growth management study is aimed at providing answers pertinent to stream habitat manipulations related to past management priorities. The Aquatic Habitat Management concept, provides a viable system, which can be used to both manage timber and fisheries production in Alaska.

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Abstract: Riparian zones and stream channels can be deliberately modified directly or indirectly to increase fish populations that support sport fisheries. This paper focuses on field-tested techniques that have been used to successfully restore damaged riparian zones and stream channels or enhance naturally low fish carrying capacities of undamaged streams.

Twenty-two case history evaluations are reviewed (primarily representative of low and moderate gradient trout streams in Wisconsin) that documented quantitative improvements in salmonid populations and angling recreation as a result of management efforts to modify riparian zone vegetation and/or stream channel morphometry.

Twelve ecological principles of restoring or enhancing fish carrying capacity of streams are also reviewed.

INTRODUCTION

Pristine, unaltered riparian zones along streams of third order or higher classification are the rare exception rather than the norm within the borders of the 48 contiguous states. Direct or indirect consequences of agricultural, silvicultural or urbanization activities have deleteriously impacted both the greenbelt terrestrial zones and stream channels of nearly all such habitats (CEQ 1978).

It is not my intent in this brief review to characterize the diverse impacts of such ubiquitous degradation or to attempt a synthesis of the growing multiplicity of governmental and private agency policies and programs aimed at restoring the biotic integrity of riparian and instream habitats. Certainly much money and effort have been expended since the turn of the century to reverse degradation of riparian areas (Brouha 1987), and professional conferences, such as this one, should help to focus even greater effort on restoration activities. Much challenging work remains to be done: (1) to resolve conflicts over best societal use of riparian zones and the streams they border, (2) to prioritize sites most in need of remedial action, (3) to increase financial support to carry out rehabilitation efforts, and (4) to see to it that state-of-the-science management techniques are implemented once decisions have been made to proceed with restoration or enhancement programs.

¹ A paper presented at the Convention of the Society of American Foresters held in Minneapolis, MN, 18-21 October 1987 as part of Working Group C5 - Wildlife and Ecology.

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This paper focuses on one category of such state-of-the-science management procedures - techniques used to restore and enhance fish habitat. These techniques have received their greatest innovation, application and evaluation within programs aimed at improving instream and near-stream environmental conditions to benefit various species of salmonids (trout and salmon) during periods of stream-residency.

Considerable success has been achieved during the past three decades to attain this objective via a variety of techniques applicable to a variety of environmental conditions. I will describe some of these useful techniques and cite case history examples of successful applications.

Although the techniques and examples to be mentioned are all drawn from the narrow field of management focused on salmonid habitats, many of these techniques should be transferrable to riparian zones and streams that support other game fish species too.

Greatest application of salmonid habitat improvement projects, and successful outcomes, have centered in and along upper midwest streams of low to moderate gradient (0.5 to 1.5%) and where annual streamflow is largely dependent on groundwater input rather than surface runoff. As Platts and Rinne (1985), Hall and Baker (1982), Parkinson and Slaney (1975) and other investigators have cautioned, some of these midwestern-developed techniques are not automatically transferrable to streams and riparian zones in more arid regions or where stream gradients are more steep. I wholeheartedly agree with such precautionary advice to be aware of the limitations within which each habitat improvement technique is applicable, but I also stress the urgent need to more vigorously apply successful field-tested techniques to the many thousands of miles of degraded riparian corridors and stream channels where transferrable technology is "on the shelf" and ready for use.

RESULTS AND DISCUSSION

Examples of 22 biologically successful salmonid habitat improvement projects are summarized in Table 1 in roughly descending order from the most simple techniques to the more complex. Sixteen of the case history sites are located in Wisconsin, plus one each from British Columbia, Colorado, Minnesota, Montana, Pennsylvania and South Dakota. Techniques varied from such simple procedures as streambank fencing (Sheep Creek, CO) to prevent streambank and riparian zone damage by cattle, placement of large boulders in a stream channel to provide midstream cover for young salmon (Keogh River, B.C.), or adding half-logs to

provide cover for adult trout (W. Br. White River, WI) to much more intensive modification of stream channel morphometry via installation of bank covers and current deflectors (Big Roche-a-Cri Creek, WI and Lawrence Creek, WI).

Trout carrying capacity of some streams in Wisconsin was also enhanced by modifying the kind of terrestrial vegetation along the streambanks - cutting down dense stands of brush and trees so that a strong turf of natural grasses could become established. Reduction in shade canopy also allowed more sunlight energy to enter such streams and stimulate greater abundance of rooted aquatic plants (Lunch Creek and Spring Creek).

On other small heavily shaded streams, cut brush was put to beneficial use by tying it in bundles that were anchored along the shallow sides of stream channels and along the inside banks. Such "brush bundles" provided short-term cover for small trout and acted as sediment traps and current deflectors that helped to gradually create narrow and deepen stream channels (Beaver Brook and Radley Creek).

Some of the rehabilitation projects involved use of several techniques to achieve synergistic benefits: Blockhouse Creek, PA; Dogtown Creek, WI; Rapid Creek, SD; Split Rock Creek, MN.

Regardless of the choice of procedures employed to restore and enhance salmonid habitat, projects that have proven to be successful are consistently due to adherence to several biological principles. There are at least 12 such "principles" that I recommend for consideration when devising an administrative policy/philosophy base for a program of salmonid habitat management and as on-site guidelines to keep in mind when implementation plans are developed and implemented.

SOME GUIDING PRINCIPLES FOR SALMONID HABITAT MANAGEMENT¹

1. Learn from nature. What biotic and abiotic factors make locally good streams good? Try to restore the health of degraded streams based on local observations of healthy streams.

¹ Most of these principles have been reworded in part or borrowed intact from papers authored by White and Brynildson (1967) and White (1978). See Literature Cited for completed references.

Table 1. Summary results of 22 successful salmonid habitat improvement evaluations.

Improvement Technique	Principal Investigator	Application Site	Postimprovement Biological Changes
streambank fencing	R. Stuber (1985)	Sheep Creek, CO	Biomass of trout (mainly brown trout) was 96% greater in 1983 and 127% greater in 1984 in fenced study zones than in unfenced zones.
	D. Gunderson (1968)	Rock Creek, MT	Average number of brown trout over 6 inches was 27% greater and average biomass was 44% greater in ungrazed reach than in adjacent grazed reach.
boulder groupings	B. Ward and P. Slaney (1980)	Keogh River, BC	200% increase in coho salmon smolts (to 4800/mile).
streambank riprap	R. Kerr (1985) ¹	Willow Creek, WI	Average number of brown trout over 6 inches increased by 35% and average number over 10 inches increased by 86%.
half-logs	R. Hunt (1978)	W. Br. White River, WI	Average number of brown trout over 10 inches in April increased by 553% and average biomass increased by 187%.
	B. Apelgren and S. Stewart (1984) ¹	Kinnickinnic River, WI	In 5 study zones the average number of brown trout over 6 inches increased by 41%, the average number over 10 inches increased by 34% and average biomass increased by 51%.
streambank debris brushing	R. Hunt (1979)	Spring Creek, WI	Average number of brook trout over 6 inches in October increased by 53% and average biomass increased by 54%. Growth ratio of ages 0-II also improved.
	R. Hunt (1985)	Lunch Creek, WI	Average number of brown trout over 6 inches in September increased by 51% and average number over 10 inches increased by 82%.
streambank debris brushing and half-logs	R. Cornelius (1984) ¹	Clam River, WI	Average midsummer abundance of brook trout and brown trout over 6 inches increased by 65% and 525% respectively.
streambanks debris brushing, brush bundles and half-logs	R. Hunt (1986)	Radley Creek, WI	Average number of brown trout over 10 inches increased by 41% in one study zone and by 42% in another study zone. Average biomass increased in the two zones by 35% and 50%.
bank covers and current deflectors	R. Hunt (1976)	Lawrence Creek, WI	Average number of brook trout over 8 inches increased by 192% and average biomass increased by 130%. Angler hours increased by 196% and harvest increased by 191%.
	R. White (1972) and WDNR (1975) ¹	Big Roche-a-Cri Creek, WI	Average biomass of brook trout increased initially by 159% and long-term by 859%. Angler harvest increased initially by 96%. (No long-term measurement made of angler harvest.)
	T. Thuemler (1978) ¹	MacIntire Creek, WI	Average number of brook trout and brown trout over 6 inches in midsummer increased by 84% and 431% respectively. Average biomass of brook trout increased by 40% and that of brown trout increased by 490%.
"skyhook" bank cover and current deflectors	A. Hauber (1978) ¹	Plover River, WI	Average number of brook trout and brown trout over 8 inches in midsummer increased by 128% and 200% respectively. Average number of brown trout over 14 inches increased by 253% (to 67/mile).
	A. Hauber (1985) ¹	Prairie River, WI	Average number of brook trout and brown trout over 6 inches in midsummer decreased by 40% and increased by 426% respectively. Average biomass of brook trout decreased by 41% but average biomass of brown trout increased by 578%.
	A. Hauber (1985) ¹	Hunting River, WI	Number of brook trout and brown trout over 6 inches in June increased by 26% and 91% respectively. Biomass of brook trout and brown trout increased by 20% and 88% respectively.
sandbag bank cover and current deflectors	S. Ironside (1984) ¹	Neenah Creek, WI	Average number of brown trout over 6 inches in midsummer increased by 151% in Sta. 1 and by 756% in Sta. 2. The average number over 10 inches increased by 75% in Sta. 1 and by 124% in Sta. 2.
bank covers, current deflectors riprap	R. Glover (1986)	Rapid Creek, SD	During the 3rd-5th post development years average abundance of brown trout increased by 357% while average abundance of Mt. suckers decreased by 89% and average number of white suckers decreased by 70%.
	S. Johannes (1985) ¹	Dogtown Creek, WI	Average number of brook trout over 6 inches in September increased by 105% and average biomass increased by 65%.
jack-dams, tip deflectors	D. Spotts (1986)	Blockhouse Creek, PA	Average biomass of brown trout in late summer during the 3rd and 4th post development years was 752% greater than predevelopment biomass.
streambank debris brushing, brush bundles, bank cover and riprap	S. Johannes (1985) ¹	Beaver Brook, WI	Average number of brook trout and brown trout over 6 inches in July increased by 65% and 125% respectively.
current deflectors, bank covers and log/rock dams	J. Hale (1969)	Split Rock Creek, MN	Average number of brook trout in September increased by 356% and average biomass increased by 68%. Average biomass of white suckers decreased by 81%. Angler hours increased by 203% and harvest increased by 362%.

¹ Personal communication memoranda from principal investigators to R.L. Hunt (see In Press Literature Citation).

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2. Focus on identifying "limiting factors" at work in each candidate stream for renovation. Try to eliminate or ameliorate those factors that depress salmonid carrying capacity.
 3. Maintain or enhance baseflow whenever possible (natural flow of a stream when it is not being augmented by surface runoff). Riparian zone and entire watershed management activities should be considered to achieve greater and more stable baseflow.
 4. Consider species-specific and age-specific requirements of the salmonids present, including both environmental suitability and social interactions with other fish species and/or age groups.
 5. Follow a logical sequence of habitat improvement steps. These steps should usually include:
Examination of Site
Diagnosis of needs
Prescription of remedies
Planning and organization of work to be done
On-site treatment/development
Evaluation of results
Maintenance of development
 6. Disguise artificiality of man-made structures or modifications of channel shape. Restore esthetic conditions as quickly as is practical.
 7. Tailor management activities to the individual stream. Do not use techniques just because they have "worked" elsewhere, unless personalities of the streams are similar.
 8. Preserve, restore and accentuate the two most common natural characteristics of streams - the meandered channel profile and the riffle/pool sequence.
 9. Work with, not against, the inherent capacity of streams and watersheds to repair their biotic health.
 10. Encourage the right kinds of streambank vegetation to become dominant, depending on the character of the stream and riparian zone.
 11. Make the streamflow work beneficially. Bring the main threads of flow close to hiding/resting/security cover for trout.
 12. Integrate habitat management in the stream channel with other terrestrial management activities along the stream's riparian zone and the larger watershed (see also No. 3 above).
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David B. Rockland²

Abstract.--This paper addresses the economic benefit concepts that are relevant to comparing the relative values of timber and fishery resources. Each concept requires consideration in decisions affecting resource management of conflicting resource users. The concepts of economic value and economic impact are differentiated. Within the category of economic value, user values and non-user values are explained. Several of the methods by which economic benefits are quantified are presented. Standard value concepts for timber production and sport fisheries are compared with emphasis on how a manager should make tradeoffs between the two resource user groups. Means by which to make "apples to apples" comparisons are provided.

INTRODUCTION

The purpose of this presentation is to discuss the key economic concepts pertaining to sport fishing and their relevance to management decisions. Two years ago I had the pleasure of taking a unique job -- an economic advocate for sport fishing. During this period, I have seen how important economics currently is, and how important it can be, to the management of natural resources. Managers are asking economic questions in their decision-making process.

However, sport fishing economics is a term that some people have difficulty with. The terms sport fishing and economics are felt not to go together. Sport fishing is just fun, or frivolous and has no economic value or worth. The major point of this presentation is that sport fishing and fishery resources are of tremendous economic significance. Those economic benefits must be considered in the management of forestry resources.

WHY ECONOMICS?

The forest manager is faced with two confounding problems:

- 1) He/she has a budget to invest in the resources he/she manages. How does he/she invest that budget to create the greatest returns for the public for whom he/she is a steward of the resource?
- 2) Certain timber harvest strategies may impact fish and wildlife resources. How does the manager decide if the benefits associated with the timber harvest outweigh the costs imposed on the fish and wildlife resources?

Economics can provide the manager with a basis by which to address these questions. Any student in an economics course hears the same thing the first day of class: "What is economics?" The general answer is that economics is the study of the allocation of scarce resources amongst competing unlimited wants. Managers can use economics as a tool to help them make a decision concerning the resources they manage.

There are two general economic questions relevant to the managers: allocation of natural resources and allocation of financial resources, or investment. The resources the managers can use economic information for managing are fish and timber and money.

¹ The Society of American Foresters' 1987 Annual Convention in Minneapolis, Minnesota on October 19, 1987.

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The allocation of natural resources is a prevalent issue in decisions regarding which user group can use a resource. For example, if timber harvesting ruins fish habitat, the manager needs to decide who gets to use the resource, the timber harvestors or users of the fishery resource such as sport and commercial fishermen. Do the benefits from fishing exceed the foregone benefits in timber harvesting if the forest products industry were restricted or vice versa?

The allocation of financial resources is a question of how to spend one's budget. For example, should I stock this stream or plant and cultivate trees? Should water quality tests and stream enhancement be the focus of my staff's efforts or managing and enhancing timber products? The manager's decision need not always be an either/or, but may focus on enhancing all uses of natural resources simultaneously.

The economic benefits associated with fishery resources are probably unfamiliar to this audience of foresters. Therefore, the following discussion describes the economic benefits of fishery resources. Most of the discussion focuses on sport fishing, but the concepts are clearly relevant to other resource uses.

ECONOMIC BENEFITS: DEFINITIONS

There are two basic benefits that result from the fishery resource -- economic impact and economic value. An economic impact is the answer to the question: "What is the economic activity generated by the use of the resource?" Economic value is the answer to the question: "How much value do people place on the resource?" While these two benefits are distinct, they are not entirely inseparable. Neither benefit type has greater merit as an economic concept than the other. Rather, they answer two distinct questions.

Each question is important for different reasons. Local and state government officials often base decisions on the economic impact in their region which translates into jobs, income, and tax receipts. In contrast, economic value is the value people place on the fishery resource. This concept is certainly important to those people who value the sport fishing experience.

Values

Values attributable to the fishery resource occur to both users and non-users of the resource. User values take three forms: consumptive use, non-consumptive use, and indirect use. Consumptive use values accrue to commercial and sport fishermen and consumers of the fishery resource. "Catch-and-release" fishing is considered a consumptive use because the actual activity the user undertakes is most similar to "catch-and-keep" fishing. The fact that sport fishermen go fishing in preference of another activity and consequently spend money, time, and effort doing so, indicates they value the opportunity to go sport fishing and value the fish stock.

Just as fishermen place a value on fish and fishing, so do non-consumptive users such as photographers, snorkelers, aquarium visitors, and others who receive value from directly viewing but not consuming the resource. While non-consumptive user values may have greater application to wildlife (i.e. birdwatching), it is also clearly relevant to fisheries. The popularity of non-consumptive snorkeling and scuba-diving attests to the validity of the concept of non-consumptive use value as does the prevalence of people who watch salmon on their annual spawning run. A willingness to pay before foregoing the activity is an indication of a value of the fishery resource to non-consumptive users as are the expenditures, time, and effort made to undertake the activity.

An indirect use is when people do not come into contact with the resource, but still derive personal satisfaction from it. Indirect use for a fishery resource includes reading about fish, viewing pictures of fish, watching television specials about fish, and related activities. Examples of indirect use are people who enjoy paintings of a trout rising to fly or a commercial fishermen setting his nets. People spend money (e.g. books, magazines, television) to use the resource directly which in itself is an expression of value. There may be additional monies that an indirect user would be willing to pay before having to forego the opportunity for indirect use.

Non-users of the resource also may place a value on the fish. These values are also referred to as intrinsic values and result from sentiments about the resource that are not current-use related. Non-use values are categorized as option and existence values. Option value reflects uncertainty about future resource use and represents the value the individual places on the availability of resource use in the future. In other words, individuals will value the option of having the resource available in the future in the event they want to use it.

The value of the option of future use is termed "ordinary option value." Quasi-option value is where new information is expected in the future and therefore a value exists for postponing a decision about use until that information exists. For example, if there might someday be research in the future might produce a product from a species of wild trout that cures leukemia, there is a quasi-option value of holding off the irreversible loss of that strain of trout until more research is undertaken.

Some people may value a fishery resource even if they know they will never use it themselves. These values are called existence values. Existence values generally are motivated by altruism or the unselfish concern for other people or the fishery resource.

One type of existence value is bequest value which captures the desire to endow the resource to future generations. This is the value placed on knowing one's kids will be able to go fishing or eat salmon. If you are willing to have some of your tax dollars go toward stocking programs, where the fish would only be available for your children, then you have a bequest value associated with that stocking program. Other existence values may be motivated by altruism toward the fishery resource itself in the same way people place a value on knowing that whales and bald eagles exist in the wild and are not extinct.

Impacts

The purchases made in the course of consumptive, non-consumptive, or indirect use may impact the local, state, and/or national economies. These impacts are expressed in terms of jobs, sales, or wages and salaries. Total economic impact is based on expenditures made by consumptive, non-consumptive, and indirect users. The fact that total economic impact exceeds the expenditures results from the premise that sales in one industry not only impact that industry but the industries that supply goods and services to the initially affected industry.

Three levels of economic impact are discernable for sport fishing:

- o Direct Impact: The initial purchases by the recreational fishermen.
- o Indirect Impact: The purchases of inputs by the directly impacted business to produce the goods and services demanded by recreational fishermen. The initial round of indirect purchases has further indirect impacts as the suppliers to the direct businesses make purchases to meet that demand.

- o Induced Impact: The purchases of goods and services resulting from the wages paid by the directly and indirectly affected businesses. Induced impacts have additional indirect and induced impacts as well.

An example of the direct, indirect, and individual impacts would be where the direct impact was the purchase of a fishing rod by an angler. The indirect impacts would include the purchase of graphite, paint, and guides to make the rod. Further, indirect impacts might include the purchase of pigments by the paint supplier and aluminum by the guide supplier. The induced impact would include the purchases by households with wages made by employees of the tackle, graphite, paint, guides, pigment, and aluminum manufacturers.

Economic impact is a very important concept to fisheries managers. Economic impact measures the activity in the region's economy associated with the use of the resource which is very important to the economic vitality of the region. However, economic impact cannot be considered a "true" benefit of the fishery resource because economic impact results from the costs users incur to use the resource. A problem with considering these costs as benefits is that the greater the cost, the greater the benefits. A "true" economic benefit is the value of a good or service less all the costs of creating that product. Therefore, economic impact is not a "true" economic benefit because it results from the costs of creating the product (i.e. a fishing trip). However, economic impact is the measure of the benefit that industry and wage earners receive from the use of the fishery resource. Fishery management decisions should be considered in terms of industry impact as well as user and non-user values because industry impact translates into jobs, income, and sales.

A key point in understanding value and impacts is that they are not all additive. One does not add the direct, indirect, and induced impacts to the various types of user and non-user values to derive total benefits. Rather, the sum of the direct, indirect, and induced impacts is the total economic activity associated with the fishery and responds to the questions: "How is the economy affected?" or "How many jobs are affected?" Consumptive user value is how much the resource consumers (i.e. sport fishermen, commercial fishermen, fish consumers) value the opportunity to use the resource. The other values reflect amounts non-users value the resource either in terms of an option to someday use it, for their offspring to use it, or for other reasons.

ECONOMIC BENEFITS OF FORESTRY

Forestry produces economic benefits that follow the same general concepts as fisheries. Forests produce values to users such as timber production. Timber has value to both consumers of the resource, such as a homeowner whose house is made of wood, and producers of wood products who use trees as an input to their production.

Forests also produce values to non-consumptive users. For example, people value walks in the woods that do not involve consumption of the resource. Indirect users value the opportunity to view forests such as in magazines and on television.

Non-users of the forest also place a value on it. People may value the option to someday walk in the forest or have a home built of wood. Furthermore, society places a value on the existence of a forest even though they may never touch, see, or otherwise experience the forest or its products.

Timber production also creates economic impacts. These are the economic benefits with which this audience is most likely to be familiar. Jobs are created in a range of industry including harvesting, wood product manufacturing, wholesale and retail. These economic impacts may also be expressed as sales, tax revenues, wages and salaries, or output.

WHAT ORDER OF MAGNITUDE ARE THE ECONOMIC BENEFITS OF SPORT FISHING?

The sport fishing industry is comprised of businesses that supply goods and services to sport fishermen. It includes hotels, motels, restaurants, tackle manufacturers, boat manufacturers, magazine publishers, and gasoline distributorships. The U.S. industry was worth about \$28.2 billion at retail in 1985. In other words, on the order of \$28.2 billion was spent by sport fishermen for sport fishing in the form of direct impact. If the indirect and induced impacts are added, the total economic impact on the national economy of sport fishing is between \$50 billion and \$75 billion. Expressing those same numbers in terms of employment, on the order of 800,000 jobs exist in the United States as a result of sport fishing.

It should appear phenomenal how much economic activity occurs due to sport fishing. However, it is the number two form of recreation among adult Americans. More adults went fishing than played basketball, football, or tennis, or went bicycling. It is the top activity among adult men, fifth among women.

The value placed on sport fishing by sport fishermen is also of tremendous magnitude. For freshwater fishing, the total value in excess of expenditures has been estimated to be between \$23.8 billion and \$54.1 billion, with an average of \$38.9 billion. In other words, in addition to the amount freshwater fishermen spent to go fishing in 1985, they valued the opportunity to do so by an additional \$38.9 billion. Of this amount, approximately 28 percent was attributed to trout fishing, 60 percent was attributed to bass fishing, and the remaining 12 percent was attributed to rough fishing.

Since we are in the State of Minnesota, summary economic statistics of the economic impact of sport fishing for the State may be of interest. Those are:

- 1) The total retail sales associated with sport fishing in Minnesota in 1980 was \$468,845,000 according to the U.S. Bureau of the Census. In 1985, the estimated retail sales were \$681,875,195. The 1985 total can be disaggregated by type of merchandise as follows:
 - o Food and Lodging -- \$141.8 million;
 - o Transportation -- \$108.4 million;
 - o Licenses -- \$24.7 million;
 - o Boating and Fishing Equipment -- \$323.5 million; and
 - o Other -- \$83.5 million.
- 2) These retail expenditures have further economic effects on the State of Minnesota, estimated to be \$1,287,266,000 in total output and \$303,484,000 in total wages and salaries.
- 3) The total employment associated with sport fishing in Minnesota is approximately 15,700 person-years. This corresponds to roughly 18,000 to 20,000 people who are employed as a result of sport fishing.

APPLES TO APPLES COMPARISONS

As demands on natural resources and public funds increase, managers increasingly have to choose between competing interests. In those circumstances, managers can use commensurate economic estimates to make tradeoffs between mutually exclusive resource uses or investment of public revenues. As seen here by the magnitude of the economic benefits associated with sport fishing, managers need to be cognizant of the possible effects of their decisions on the sport fishing industry and the values placed on fishery resources.

The temptation often exists to choose an economic benefit measure such as economic impact (jobs) in the state and then see whether timber production or sport fishing has the bigger number. For example, suppose sport fishing creates 100 jobs, and timber production 10, the temptation is to argue that because sport fishing creates ten times more jobs than timber, timber production should be eliminated to avoid possible negative impacts on fish habitat and fish resources.

By allocating the resource away from timber production, 10 jobs are lost in timber, and the total jobs (fishery plus timber) from the resource declines from 110 to 100. For the allocation to sport fishing to make economic sense, there must be a gain in total jobs to an amount greater than 110; there must be an increase in employment in the sport fishing industry that exceeds the 10 lost jobs in the timber industry.

In sum, simply comparing the magnitude of relative total economic benefits does not provide a good case for allocation. Rather, the total benefits from the entire resource are determined and the question is then asked, "Is there some way to redistribute the fish resource such that the total pie of benefits from the resource grows?" There are, however, cases where it is not possible to determine tradeoffs between both user groups and relative comparisons between user groups are the best that can be done.

When making comparisons or tradeoffs between forestry and sport fisheries, the following comparisons are relevant:

- a) Retail value of timber products vs. retail expenditures by sport fishermen.
- b) Total economic impact of timber production and distribution vs. total economic impact of expenditures by sport fishermen.

- c) Profit earned by businesses in timber production and distribution vs. profits earned in the businesses distributing and producing goods and services purchased by sport fishermen to go fishing.
- d) The values consumers place on the opportunity to purchase timber products to the value people place on the opportunity to sport fish.

These are certainly not all the "apples to apples" comparisons that can be made. However, they do provide the guideline that likes must be compared to likes. Furthermore, tradeoffs and comparisons can be made between sport fishing, and fisheries values in general, and those associated with timber production.

CONCLUSION

Economics offers a system of measures to allow managers to make allocation decisions between alternative uses of natural and financial resources. Using economics, the manager can gauge, in part, if he/she is getting the greatest "bang for the buck" in terms of investment of money or allocation of natural resources.

Fishery resources have tremendous value. A major source of these values is sport fishing which employs 800,000 people nationally and has a user value of approximately \$40 billion for freshwater fishing alone. Where fishery resources are potentially degraded by forest management and harvest practices, managers must make tradeoffs between these two activities. Failure to take account of all the relevant economic measures can be disastrous, resulting in unemployment and losses of important values to our society and future generations.

FINDING OUT AND TELLING

Our job at the North Central Forest Experiment Station is discovering and creating new knowledge and technology in the field of natural resources and conveying this information to the people who can use it--in short, "finding out and telling." As a new generation of forests emerges in our region, managers are confronted with two unique challenges: (1) Dealing with the great diversity in composition, quality, and ownership of the forests, and (2) Reconciling the conflicting demands of the people who use them. Helping the forest manager to meet these challenges while protecting the environment is what research at North Central is all about.



U.S. Department of Agriculture, Forest Service.

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