EVALUATING TIMBER HARVESTING IMPACTS ON WILDLIFE HABITAT SUITABILITY USING FOREX

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Abstract: Precommercial, commercial, and final harvesting operations can impact wildlife habitat suitability by altering the vegetation composition on a given site. Harvesting operations remove trees and many times provide the necessary perturbation to trigger successional conditions different from those that existed prior to the harvest. Although these new successional changes can be beneficial to a wide array of wildlife species, they also can alter the site such that some wildlife species that were once abundant will no longer find the site suitable. In this paper, FOREX is used to demonstrate how managers, loggers, and planners can evaluate the impact of proposed harvest treatments on wildlife habitat suitability. FOREX is an integrated expert system that explicitly considers the potential growth and yield of a stand, wood products and their development over time, the logging technology needed for harvests scheduled, the economic and market factors involved, and the impacts on wildlife habitat. Initial results suggest that a series of light thinnings can provide positive cash flows to the landowner and meet the habitat needs for many species of birds, amphibians, reptiles, and mammals for a long period of time. The results also show that removing all the downed, dead woody material from the forest floor is detrimental to many species of wildlife, and that the final harvest has the most impact on wildlife habitat suitability.

INTRODUCTION

As managers of forests and woodlots in the hardwood region of the Eastern United States try to meet increasing world demand for wood products, they are faced with numerous challenges. This demand is not only for wood products but also for suitable habitat for wildlife, visual and aesthetic quality, clean water, recreation, and social values. A major challenge for owners of forested land is to meet both financial and personal objectives while achieving goals at the ecosystem or landscape level.

These same forests are under occasional stress from several agents such as the gypsy moth, beech bark disease, forest tent caterpillar, pear thrips, and elm spanworm (Twardus 1995). A major threat to the present day oak-hickory forests is the gypsy moth. Hickory (*Carya* spp.) has declined due to several wood-boring insects, whereas white pine (*Pinus strobus*), which is associated with many different hardwood species, is coming back. White ash (*Fraxinus americana*) and black ash (*Fraxinus nigra*) are also declining due to a disease, ash yellows, caused by a mycoplasma-like organism. Ash anthracnose, a foliage disease, is also contributing to severe dieback and poor crown density. Butternut (*Juglans cinerea*), a highly valued tree for wildlife mast production and lumber products, is threatened by a devastating disease known as butternut canker (Twardus 1995).

Some of these same forest species are also experiencing serious regeneration problems because of high deer populations in some areas (Stout and others 1995). The change in harvesting practices from clearcutting to partial harvest methods such as single-tree, group selection, and selection cuts have added to the regeneration challenges (Sander and Clark 1971, Dale and others 1995, Weigel and Parker 1995). These contemporary harvest methods, although more costly to apply and less efficient for timber production, are being used in response to increasing concerns of the public to save and protect the existing forests (LeDoux and others 1991, 1993, 1994). The commitment to timber production in combination with ecosystem or landscape-level goals further complicates the task of managing forested lands.

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Of particular interest to all is how specific management activities affect the suitability of wildlife habitat. This challenge is further complicated by a lack of decisionmaking tools for integrated analysis. Accordingly, we have developed an expert system called FOREX that allows for integrated decisionmaking in the management of hardwoods forest (LeDoux and others 1995, 1996). FOREX considers the potential growth and yield, products and development of a stand over time, economic and market factors, and impacts on wildlife habitat. This system can be applied to all forest types in the Northeast, and currently considers impacts on wildlife habitat for northern red oak and oak-hickory forest types. As wildlife data on other forest types and regions become available, they will be incorporated into the FOREX database. In this example, FOREX is applied to hypothetical harvesting situations that a landowner might consider to assess the management impacts on wildlife habitat suitability.

METHODS

Description of FOREX and MANAGE

FOREX and MANAGE were the models used in this analysis. FOREX is an integrated expert system that uses data from simulation runs from MANAGE (LeDoux 1986; LeDoux and others 1995, 1996). MANAGE, a computer program written in FORTRAN V, integrates harvesting technology, silvicultural treatments, market price, and economic concerns over the life of a stand. The simulation is a combination of discrete and stochastic subroutines. Individual subroutines model harvesting activities, silvicultural treatments, growth projections, market prices, and discounted present net worth (PNW) economic analysis. Specifically, the model allows the manager to evaluate how alternative harvesting technology, silvicultural treatments, market price, and economic combinations affect costs and benefits over the life of a stand. The model uses a detailed individual user-specified tree list and then projects stand growth based on some user-specified silvicultural treatment, harvests the desired volume or stems with the logging system specified, sells the wood, and conducts economic analysis for the respective treatment and entry. MANAGE was run for numerous stands in the northern red oak and oak-hickory forest type with alternative combinations of silvicultural treatment and logging technology. The results from these runs were stored in the FOREX database. Only results from runs that breakeven or better were stored in the database.

Using FOREX, the user can obtain information on PNW, optimal thinning entry timing, optimal stand rotation age, diameter at breast height (dbh), volume by grade and value of the trees harvested, and, based on the logging system used, average slope yarding distance, truck class, road class, log-bucking methods, and number of thinnings desired. FOREX also provides information on the effect of harvesting treatments on wildlife habitat suitability. The user can obtain information on the PNW, dbh, and volume required for a specific set of management objectives, and perform a sensitivity analysis that eliminates the need to sort through numerous simulations.

Harvesting Treatments

The harvest treatments evaluated include precommerical thinning, multiple commercial thinnings, and final harvest. The objective for each treatment considered is to grow quality wood products, and in all cases except the precommercial thinning, to breakeven or return a profit to the landowner. The impact on wildlife habitat suitability is evaluated by focusing on the number of wildlife species for which the site would be suitable. Although species composition based on densities may change with harvesting treatments, we specifically focus on the potential numbers of amphibians, birds, reptiles, and mammal species. In some cases, woody debris in the form of cull logs and tops is left on the site and contrasted with removing all cull logs and tops.

Site and Stand Conditions

In this example, the land holding is a 300-acre forest in the northern red oak cover type. The species mix includes red oak (*Quercus rubra*), red maple (*Acer rubrum*), hickories (*Carya spp.*), black oak (*Quercus velutina*), scarlet oak (*Quercus coccinea*), and chestnut oak (*Quercus prinus*). The average site index of the stand is about 80. The stand is 30 years old and contains 326 trees per acre that are more than 5 inches dbh. The average dbh is 6.15 inches. The land is assumed to be located on gentle to moderate slopes and requires ground-based systems for harvests. The site is covered with greater than 25% rock cover, has greater than 30% forest litter cover, has active seeps, loose soils and small caves, and has at least 50 ft^3 per acre of dead and down material on the forest floor. The land has about 20% shrub cover and at least 29% ground cover. The forest model plot chosen for this analysis is representative of the northern red oak forest type.[2] The landowner wants to evaluate the impact of alternative harvest treatments and wood utilization options on wildlife habitat suitability.

RESULTS

The landowner's property attributes and objectives were incorporated into FOREX, which sorts through the database for combinations of conditions that will meet the user's objectives. The program returns the results for the conditions that will meet all objectives. The results for each harvesting treatment evaluated in this analysis are shown in Table 1.

Table 1. FOREX results by treatment

Attribute	Precommercial thinning[1]	First commercial thinning[2]	Second commercial thinning[2]	Final harvest
Yarding distance (ft)	800	800	800	800
Buck type	1	1	1	1
Road class	3	3	3	3
Truck class	2	2	2	2
Age (years)	60	90	150	160
Trees (no.)	28	70	34	74
Dbh (inches)	9.93	12.32	17.97	18.98
Volume (ft^3)	375.60	1503.37	1739.67	4369.99
G1 (bd. ft.)[3]	0	693.79	3965.23	1437.03
G2 (bd. ft.)[4]	0	0	787.65	0
G3 (bd. ft.)[5]	23.34	536.06	448.34	673.93
G4 (ft^3)[6]	368.67	1156.97	714.92	1562.08
PNW ($)	-121.47	45.95	51.30	127.91
Cash flow ($)	-294.85	270.73	1780.68	5966.89

[1] 10% of trees/acre removed.
[2] 30% of trees/acre removed.
[3] G1 = grade 1 volume.
[4] G2 = grade 2 volume.
[5] G3 = grade 3 volume.
[6] G4 = pulpwood.

The precommercial thinning would remove about 10% of the existing trees/acre and would be scheduled for age 60. The average dbh of material removed is 9.93 inches and about 375.60 ft^3 of wood products are harvested per acre. The wood removed is all pulpwood since the trees are too small to make sawlogs. This treatment could be prohibitively expensive and would likely never be implemented.

[2]U.S. Department of Agriculture, Forest Service. One-acre forest model plot. Unpublished data on file at Morgantown, WV: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station.

First and second thinnings were considered for meeting the multiple thinnings objective. They were considered alone. Precommercial thinning was not included in this set. The first and second commercial thinnings would remove 1,503.37 ft^3/acre and 1,739.67 ft^3/acre, respectively. The first commercial thinning at age 90 would return about $270.73/acre and the second thinning would return $1,780.68/acre. These thinnings become more profitable than precommerical thinning because we are removing larger trees that result in sawtimber products. The second thinning has a larger proportion of higher grade sawlogs.

The final harvest removes 4,369.99 ft^3 of wood products/acre and results in a cash flow of about $5,966.89 at age 160. The majority of the wood products are higher grade sawlogs. The trees measure about 18.98 inches dbh. About 1,562.08 ft^3 of pulpwood/acre is harvested at final harvest. This series of commercial thinnings and final harvest keep a stand of trees on the site for a period of about 130 years.

Integrating Wildlife Habitat Suitability

Forest wildlife populations and their habitats are products of the land and how it is managed for wood fiber (DeGraaf and others 1991, 1992) or in unmanaged stands from events that occur naturally. DeGraaf and others (1992) developed species/habitat matrices that forest managers, planners, silviculturists, loggers, and wildlife biologists can use to increase potential numbers of bird, amphibian, reptiles, and mammal species in New England forest types. Information is provided in the matrices for species occurrence and utilization by forested habitat and forest type by life history activities and seasons. These species/habitat matrices, which are tied to the seral states present in the development of a given forest type, have been incorporated into the FOREX database. With the FOREX program, actual stand attributes such as dbh, volume/acre, number of trees per acre, and species mix are matched with DeGraaf's and others (1992) guidelines to identify which species would find the site suitable by harvesting treatment. FOREX then reports the species of wildlife that would find the site suitable. The results are presented for before and after harvest conditions. The user can then gauge the impact of harvest treatments on wildlife habitat suitability.

The wildlife habitat suitability results from FOREX were validated by comparing them to results from the HAM model (Harvey and Finley 1995). The HAM model uses stand-level data, DeGraaf and others (1992) guidelines, and other wildlife data to predict wildlife species that may use the stand for breeding and feeding for the northern red oak and the oak-hickory forest types. Two levels of analysis are available. The first uses a small matrix constructed using cluster analysis to select functional groups of species that depend on one or more common habitat features. The second analysis uses an expert system, GNOSIS (Meyers and Foster unpublished[3]), developed at the Pennsylvania State University. GNOSIS uses the stand-level data to search the matrix species by species rather than by functional groups producing a list of species. Results from FOREX and HAM were identical for the conditions evaluated.

The stand and site conditions remain essentially the same before and after the precommerical, first, and second thinnings with respect to site attributes used in the guidelines (DeGraaf and others 1992). The proposed light thinnings do not alter habitat suitability because the residual stand conditions remain much the same as the initial stand.

Tables 2, 3, and 4 list the potential species that would find the site suitable before and after precommercial, first, and second thinnings.

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[3]Meyers, W. and M. Foster. unpublished. GNOSIS: An expert system. Penn State Univ. Sch. of For. Res.

Table 2. Potential species for initial stand before and after precommercial thinning

Redback salamander (*Plethodon cinereus*)	Blue jay (*Cyanocitta cristata*)
Northern brown snake (*Storeia d. dekayi*)	Common raven (*Corvus corax*)
Northern redbelly snake (*Storeia o. occipitomaculata*)	Ruffed grouse (*Bonasa umbellus*)
Northern ringneck snake (*Diadophis punctatus edwardsi*)	Red-eyed vireo (*Vireo olivaceus*)
Northern black racer (*Coluber c. constrictor*)	Scarlet tanager (*Piranga olivacea*)
Black rat snake (*Elaphe o. obsoleta*)	Purple finch (*Carpodacus purpureus*)
Eastern milk snake (*Lampropeltis t. triangulum*)	Masked shrew (*Sorex cinereus*)
Northern copperhead (*Agkistrodon contortrix mokeson*)	Northern red bat (*Lasiurus borealis*)
Timber rattlesnake (*Crotalus horridus*)	Coyote (*Canis latrans*)
Sharp-shinned hawk (*Accipiter striatus*)	Black bear (*Ursus americanus*)
Northern goshawk (*Accipiter gentilis*)	Red fox (*Vulpes vulpes*)
Great horned owl (*Bubo virginianus*)	White-tailed deer (*Odocoileus virginianus*)
Eastern wood-pewee (*Contopus virens*)	

Table 3. Potential species for stand before and after first commercial thinning

Redback salamander (*Plethodon cinereus*)	Eastern phoebe (*Sayornis phoebe*)
Northern brown snake (*Storeia d. dekayi*)	Blue jay (*Cyanocitta cristata*)
Northern redbelly snake (*Storeia o. occipitomaculata*)	American crow (*Corvus brachyrhynchos*)
Northern ringneck snake (*Diadophis punctatus edwardsi*)	Common raven (*Corvus corax*)
Northern black racer (*Coluber c. constrictor*)	Ruffed grouse (*Bonasa umbellus*)
Black rat snake (*Elaphe o. obsoleta*)	Red-eyed vireo (*Vireo olivaceus*)
Eastern milk snake (*Lampropeltis t. triangulum*)	Blackburnian warbler (*Dendroica fusca*)
Northern copperhead (*Akistrodon contortrix mokeson*)	Scarlet tanager (*Piranga olivacea*)
Timber rattlesnake (*Crotalus horridus*)	Purple finch (*Carpodacus purpureus*)
Sharp-shinned hawk (*Accipiter striatus*)	Masked shrew (*Sorex cinereus*)
Northern goshawk (*Accipiter gentilis*)	Northern red bat (*Lasiurus borealis*)
Red-shouldered hawk (*Buteo lineatus*)	Coyote (*Canis latrans*)
Broad-winged hawk (*Buteo platypterus*)	Black bear (*Ursus americanus*)
Great horned owl (*Bubo virginianus*)	Red fox (*Vulpes vulpes*)
Eastern wood-pewee (*Contopus virens*)	White-tailed deer (*Odocoileus virginianus*)

Table 4. Potential species for stand before and after second commercial thinning

Redback salamander (*Plethodon cinereus*)	Black-capped chickadee (*Parus atricapillus*)
Northern brown snake (*Storeia d. dekayi*)	Tufted titmouse (*Parus bicolor*)
Northern redbelly snake (*Storeia o. occipitomaculata*)	White-breasted nuthatch (*Sitta carolinensis*)
Northern ringneck snake (*Diadophis punctatus edwardsi*)	Brown creeper (*Certhia americana*)
Northern black racer (*Coluber c. constrictor*)	Red-eyed vireo (*Vireo olivaceus*)
Black rat snake (*Elaphe o. obosoleta*)	Blackburnian warbler (*Dendroica fusca*)
Eastern milk snake (*Lampropeltis t. triangulum*)	Scarlet tanager (*Piranga olivacea*)
Northern copperhead (*Agkistrodon contortrix mokeson*)	Brown-headed cowbird (*Molothrus ater*)
Timber rattlesnake (*Crotalus horridus*)	Purple finch (*Carpodacus purpureus*)
Sharp-shinned hawk (*Accipiter striatus*)	Carolina chickadee (*Parus Carolinensis*)
Northern goshawk (*Accipiter gentilis*)	Virginia opossum (*Didelphis virginiana*)
Red-shouldered hawk (*Buteo lineatus*)	Masked shrew (*Sorex cinereus*)
Broad-winged hawk (*Buteo platypterus*)	Little brown bat (*Myotis lucifugus*)
Red-tailed hawk (*Buteo jamaicensis*)	Silver-haired bat (*Lasionycteris noctivagans*)
Great horned owl (*Bubeo virginianus*)	Big-brown bat (*Eptesicus fuscus*)
Red-bellied woodpecker (*Melanerpes carolinus*)	Northern red bat (*Lasiurus borealis*)
Yellow-bellied sapsucker (*Sphyrapicus varius*)	Gray squirrel (*Sciurus carolinensis*)
Hairy woodpecker (*Picoides villosus*)	Southern flying squirrel (*Glaucomys volans*)
Eastern wood-pewee (*Contopus virens*)	Northern flying squirrel (*Glaucomys sabrinus*)
Eastern phoebe (*Sayornis phoebe*)	Coyote (*Canis latrans*)
Blue jay (*Cyanocitta cristata*)	Black bear (*Ursus americanus*)
American crow (*Corvus brachyrhynchos*)	Red fox (*Vulpes vulpes*)
Common raven (*Corvus corax*)	White-tailed deer (*Odocoileus virginianus*)
Ruffed grouse (*Bonasa umbellus*)	

Table 5 lists the species that would find the site suitable in the stand prior to final harvest. Table 6 lists the species that would find the site suitable after final harvest if at least 50 ft^3 of down wood and logs/tops were left on the site. Table 7 lists the potential species that would find the site suitable after final harvest if all down wood and logs/tops were removed from the stand. The differences in potential species numbers at each seral state are due to changes in habitat structure (Smith 1962). The largest potential species abundance and diversity is in the 90- to 160-year-old stands. Figure 1 shows the number of amphibians, birds, reptiles, and mammals by stand age for before and after treatment conditions. The potential species before and after harvest conditions remain the same for precommercial and commercial thinnings because we are removing 10 to 30% of the stand, leaving conditions essentially the same as prior to harvest.

Table 5. Potential species for stand before final harvest.

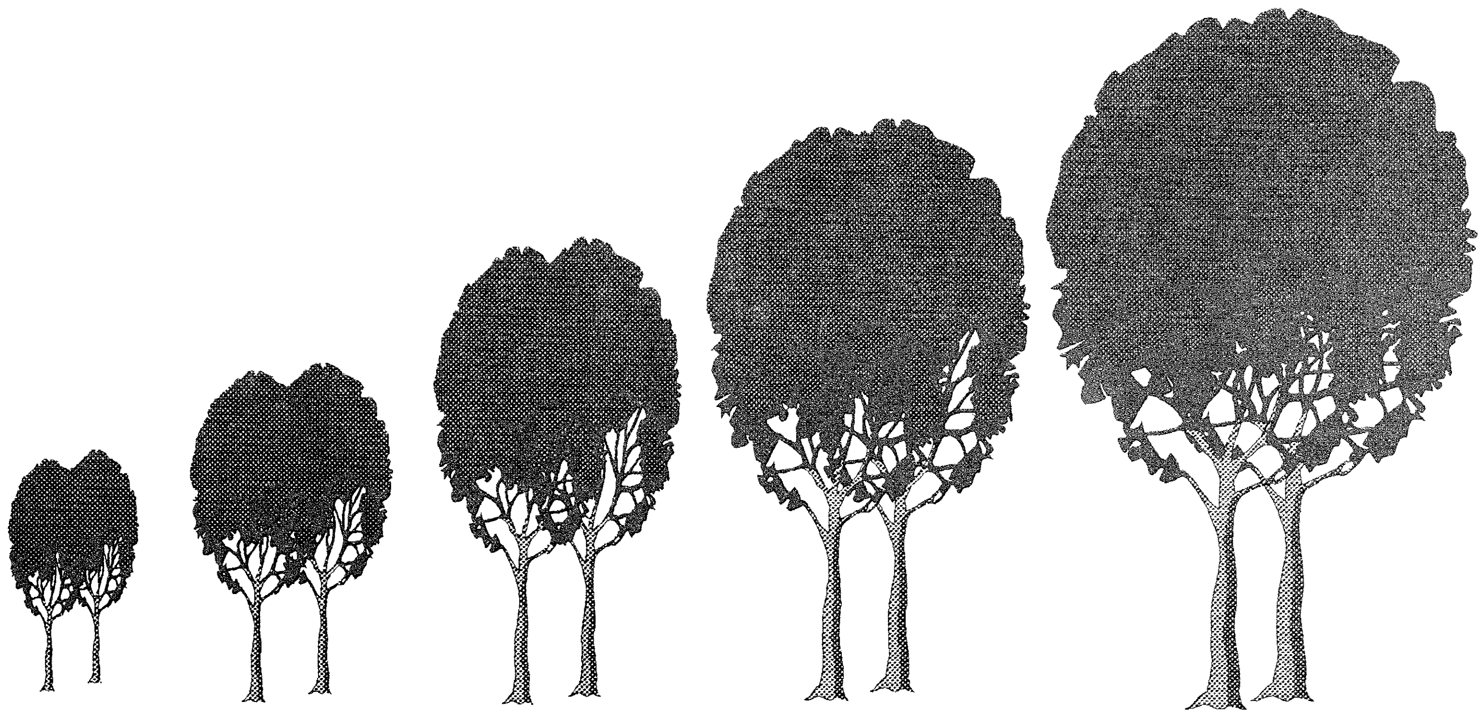
Redback salamander (*Plethodon cinereus*)
Northern brown snake (*Storeia d. dekayi*)
Northern redbelly snake (*Storeia o. occipitomaculata*)
Northern ringneck snake (*Diadophis punctatus edwardsi*)
Northern black racer (*Coluber c. constrictor*)
Black rat snake (*Elaphe o. obosoleta*)
Eastern milk snake (*Lampropeltis t. triangulum*)
Northern copperhead (*Agkistrodon contortrix mokeson*)
Timber rattlesnake (*Crotalus horridus*)
Sharp-shinned hawk (*Accipiter striatus*)
Northern goshawk (*Accipiter gentilis*)
Red-shouldered hawk (*Buteo lineatus*)
Broad-winged hawk (*Buteo platypterus*)
Red-tailed hawk (*Buteo jamaicensis*)
Great horned owl (*Bubeo virginianus*)
Red-bellied woodpecker (*Melanerpes carolinus*)
Yellow-bellied sapsucker (*Sphyrapicus varius*)
Hairy woodpecker (*Picoides villosus*)
Eastern wood-pewee (*Contopus virens*)
Eastern phoebe (*Sayornis phoebe*)
Blue jay (*Cyanocitta cristata*)
American crow (*Corvus brachyrhynchos*)
Common raven (*Corvus corax*)
Ruffed grouse (*Bonasa umbellus*)
Black-capped chickadee (*Parus atricapillus*)
Tufted titmouse (*Parus bicolor*)
White-breasted nuthatch (*Sitta carolinensis*)
Brown creeper (*Certhia americana*)
Red-eyed vireo (*Vireo olivaceus*)
Blackburnian warbler (*Dendroica fusca*)
Scarlet tanager (*Piranga olivacea*)
Brown-headed cowbird (*Molothrus ater*)
Purple finch (*Carpodacus purpureus*)
Carolina chickadee (*Parus carolinensis*)
Virginia opossum (*Didelphis virginiana*)
Masked shrew (*Sorex cinereus*)
Little brown bat (*Myotis lucifugus*)
Silver-haired bat (*Lasionycteris noctivagans*)
Big-brown bat (*Eptesicus fuscus*)
Northern red bat (*Lasiurus borealis*)
Gray squirrel (*Sciurus carolinensis*)
Southern flying squirrel (*Glaucomys volans*)
Northern flying squirrel (*Glaucomys sabrinus*)
Coyote (*Canis latrans*)
Black bear (*Ursus americanus*)
Red fox (*Vulpes vulpes*)
White-tailed deer (*Odocoileus virginianus*)

Table 6. Potential species for stand after final harvest with down logs and tops left on site

Northern brown snake (*Storeia d. dekayi*)
Northern ringneck snake (*Diadophis punctatus edwardsi*)
Northern black racer (*Coluber c. constrictor*)
Black rat snake (*Elaphe o. obosoleta*)
Eastern milk snake (*Lampropeltis t. triangulum*)
Timber rattlesnake (*Crotalus horridus*)
Cooper's hawk (*Accipiter cooperii*)
Golden eagle (*Aquila chrysaetos*)
Blue jay (*Cyanocitta cristata*)
American crow (*Corvus brachyrhynchos*)
Common raven (*Corvus corax*)
Ruffed grouse (*Bonasa umbellus*)
Wild turkey (*Meleagris gallopavo*)
Purple finch (*Carpodacus purpureus*)
Masked shrew (*Sorex cinereus*)
Coyote (*Canis latrans*)
Black bear (*Ursus americanus*)
Red fox (*Vulpes vulpes*)
White-tailed deer (*Odocoileus virginianus*)

Table 7. Potential species for stand after final harvest with down logs and tops removed

Northern ringneck snake (*Diadophis punctatus edwardsi*)
Timber rattlesnake (*Crotalus horridus*)
Cooper's hawk (*Accipiter cooperii*)
Golden eagle (*Aquila chrysaetos*)
Blue jay (*Cyanocitta cristata*)
American crow (*Corvus brachyrhynchos*)
Common raven (*Corvus corax*)
Ruffed grouse (*Bonasa umbellus*)
Wild turkey (*Meleagris gallopavo*)
Purple finch (*Carpodacus purpureus*)
Coyote (*Canis latrans*)
Red fox (*Vulpes vulpes*)
White-tailed deer (*Odocoileus virginianus*)



Age	30		60		90		150		160	
	Before	After	Before	After	Before	After	Before	After	Before	After
Amphibians	0	0	1	1	1	1	1	1	1	0
Birds	7	7	10	10	15	15	25	25	25	8
Mammals	3	3	6	6	6	6	13	13	13	5
Reptiles	6	6	8	8	8	8	8	8	8	6

Figure 1. Pottential numbers of amphibians, birds, mammals, and reptiles by stand age before and after treatment.

CONCLUSIONS

Results from FOREX consultation runs suggest that this integrated expert system can be used to evaluate the impact on habitat suitability for amphibians, birds, reptiles, and mammals for northern red oak and oak-hickory forest types. The system also will provide economic and harvesting results for chosen scenarios. The manager or landowner can then evaluate his/her decisions in an integrated manner.

Results for this demonstration suggest that precommercial and commercial thinning treatments that remove 10 to 30% of the stand do not alter the site enough to alter habitat suitability for species that found the site suitable prior to the harvest treatment. Results suggest that final harvest operations impact the habitat suitability the most. Final harvest operations remove a significant amount of vertical and horizontal structure that is found suitable by a large number of amphibians, birds, reptiles, and mammals. Results also suggest that removing all down and dead woody material from the site following any treatment is detrimental to wildlife habitat suitability. Results suggest that a few species of amphibians, birds, reptiles, and mammals find any seral state suitable for habitat and, thus, are not impacted by any harvesting treatment. The most important structural needs for most of the snakes are rocky cover, forest litter, and down and dead woody material on the forest floor.

Although we only considered precommercial, commercial, and final harvest treatments for the northern red oak forest cover type, results suggest that FOREX can be used to evaluate the impacts of alternative harvesting treatments on the suitability of wildlife habitat by making additional consultation runs. FOREX could also be linked to FIA inventory data to estimate and evaluate wildlife habitat suitability.

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