

It's my pleasure to introduce Dr. Ralph Nyland. Dr. Nyland is the Distinguished Service Professor in silviculture and forest management at State University of New York, College of Environmental Science and Forestry in Syracuse, New York. Dr. Nyland has a bachelor's in forestry from Syracuse University and a Ph.D. in silviculture and forest management from Michigan State University. And he has published numerous technical articles and a recent book entitled *Silviculture, Concepts and Applications*.

Any time there's a discussion of forestry in the eastern US, it seems like the question comes up, what can we do about high-graded hardwood stands in the eastern US? It's a complex and persistent problem. And Dr. Nyland has spent a considerable part of his career working on this issue. And we look forward to hearing his innovative approaches to this issue. So with that, I'd like to turn it over to Dr. Nyland.

Thank you, Tom. Let's start with some basic definitions. And my thought here is that if we have a common understanding of what the words are and what the techniques mean, then when we talk about the effects of rehabilitation it may be more meaningful. So the definitions will deal with forest management and their use.

And the place to start then is with forestry itself. I'd like you to focus on three words here, science, art, common sense. Well, common sense is two words.

But forestry really draws upon a body of theory that helps us to appreciate what happens in forests and how our efforts change those dynamics. But we have to use judgment to pull together different possible techniques to come up with the right one that satisfies our owner's interest. And that takes a lot of common sense to figure out how to do it efficiently and effectively. Above all, we want to sustain those values. So forestry must, must take a long term perspective on life.

As a subset of forestry, we have the discipline of forest management. And you notice art and science comes back here again. When we moved to forest management, we're trying to take a bundle of objectives that a landowner might have and figure out how we can satisfy those objectives while still maintaining productivity over the long term. And productivity means more than just timber growth. It means productivity for habitat, visual qualities, water yields, and all of those kinds of things, again to

sustain those values over long periods of time.

And the silviculture, the discipline I work with, is a part of forestry that works at controlling the establishment, the growth, composition, and quality of forests. Now by controlling, I don't mean subdue, but rather that through the methods of silviculture, we try to influence the way stands grow and develop so that they are sustained through time and provide the benefits over the long term.

Beginning back in the late '80s and well in through the '90s, forestry began to focus on a new idea or a new-to-us idea called ecosystem management. Some people today think of it as sustainable forestry. But notice the effect here is creating, maintaining, and re-establishing desirable ecosystem conditions. So the whole focus here is back on the ecosystem. And we'll use stand-level treatments to bring that about.

So when you hear comments about operating landscape scales, we have to do that one stand at a time. When we even think about operating at the forest level, we must do that one stand at a time. And that is the role of silviculture.

Now as an aftermath of doing these things, sustaining these desirable systems, we will inevitably derive values. And part of the values will be commodities or uses, but the main focus is creating, maintaining, and establishing those desirable conditions.

OK. So silviculture focuses on the stands and the methods we use to manage individual stands. And the stand, by definition, is that part of a forest that we treat by some management activity, including a timber sale. It's the area we operate as a single entry. And it is also the unit of record keeping for the forest.

Silviculture really has only two purposes. And this is a very key point, that silviculture either regenerates a mature age class when it reaches some degree of maturity by definition of a landowner, or it tends intermediate age classes to nurture their growth and development towards some desired end. And this applies both to stands that have a single age class in them and to multiple age classes.

So where does timber harvesting fit in? Well, we use timber harvesting and tree cutting really as a means to accomplish these silvicultural purposes. So if we are tending, if we're properly regenerating, there will be excess trees to remove. And those trees we can put into the marketplace to generate revenues, to help pay the costs of management and ownership.

So let's consider silviculture. I like to envision silviculture as a big tool bag of techniques and methods and approaches that we can use to sustain the values of interest. And those values would involve ways to regenerate and the way we tend stands to serve those landowner interests. We can't practice silviculture without first understanding what the landowner wants long term. And then we can figure out how to go about doing that.

Recently I've been involved with a group from Quebec and Maine forest services, the province of Quebec, the Canadian Forest Service. We've been trying to think about the alternatives of silviculture and how they might break down into different kinds of broad pathways. And one of them we define as restoring, returning things to an original state.

Catherine Larouche in this discussion raised the idea that if you bought an old house and wanted to redo it so it was just like back in the 1700s, you would take out the plumbing. You'd take out the heating system. You remove the electric lights. You'd do all those things and you would restore it to that original state so you could experience things as they originally occurred. That would be restoration.

Most of what we do in silviculture we call refining, trying to improve on and sustain existing conditions, improving to move stands towards a more perfect condition relative to the objectives of the owner and that are ecologically sustainable through time. And the third part of it would be rehabilitating, that through some past use, some past activity or disturbance functionality essentially has been lost from a stand, at least relative to the interests of an owner. And so rehabilitation treatments try to re-establish that lost functionality.

Today we want to focus on rehabilitation and think about why we do it, what it would involve, and how we could go about implementing it. Through those discussions in Quebec, we struggled with a definition. And you see on the screen one that we ended up with, at least for the present. So we want to use ecologically acceptable methods. And we want to re-establish whatever desirable conditions fit with the interests of the landowner after some kind of an uncontrolled disturbance. Again, the interest of the landowner defines what we will do, the direction we'll take, and what we try to accomplish.

We believe that there are several natural and people-caused disturbances that would set the stage for a rehabilitation treatment of some kind. So the effects of ice and snow loading and windstorms would be one. This has been a major concern for us in the northern area, due to that 1998 ice storm that literally

damaged thousands and thousands of acres from New York up through the Saint Lawrence Valley and into parts of New England.

Fire, not a big natural disaster effect here in the moist, humid northeast, but certainly in eastern North America there are places where fires cause a lot of disturbance. Insects and diseases. Defoliating insects, such as the effect you see here of the forest tent caterpillar, those things bring change that proves unsatisfactory to landowners.

And cutting practices. Cutting practices go on forever. They never end. They always seem to come back. And they cause disturbance.

So if you think about diameter-limit cutting, that's a very common disturbance. Diameter-limit cutting simply means taking the big trees out and leaving the little trees behind. And we put it into a broad group of practices called selective cutting. Not selection cutting, but selective cutting. It is an undisturbed or an uncontrolled disturbance.

So let's use exploitive cutting to explore stand rehabilitation and what it might involve. Primarily we'll focus on the effects of diameter-limit cutting and how that has really disturbed the functionality, the composition, and the structure of forest stands. [COUGH] Excuse my cough. I've had a cold here.

Well, let's ask how much diameter-limit cutting we find out there compared to silviculture and what does it leave behind compared to silviculture. Back in the '90s, the New York Society of American Foresters wanted to find out what actually was happening across New York State based on a concern that disruptive cutting was becoming more widespread. So it decided to sample randomly chosen stands and look at the five characteristics of the residual, the residual stocking, measured in basal area per acre; the variation in that residual stock, and particularly compared to what had been present based upon a pre-cut estimate; whether the cutting left behind desirable species; did it change the average diameter by reducing it or increasing it; and what happened to the sawtimber potential. We weren't just focusing on one of these elements, but put them together into a combination effect on the stand. And for that, we rated each of these elements as either good, mediocre, or bad based upon some decision criteria that had been developed in advance.

Don't try to study this. The important thing I want you to see here is that there were six elements here that were evaluated. And in each of these, there were a fixed set of criteria that people used to make a

decision. And from that, we assigned points to each of these categories and ended up by averaging them to rate each stand on a scale of 1 to 3. And we had it broken down by 1/10 increments.

Here's the findings. Of the 63 stands that were randomly chosen and sampled, only about 2 out of 4, less than that, 38%, were considered good. These are stands that we would consider having be treated by silviculture or something similar to it, where production and other values could be sustained through time.

There's a high potential here to sustain those values. There's a lot of opportunities for long term production in these stands. The integrity for many other non-timber values seems to be assured. And there's opportunities to manipulate for other values into the future.

This may be the most frightening statistic, that half of what we found were of questionable condition. They were not silviculture. But yet they were not ravaged. I call these stands mediocre and put them into a class of what I call silviculture purgatory.

There's some hope out here. We might be able to rehabilitate these with creative thinking and good technique. But we've lost some of the values.

And the last group, only 1 in 7 about, were really poor. These are essentially lost stands. They're ravaged. They're degraded and dismal.

There's very little chance for the future. It's hard to imagine what one would do without making major investments to completely recoup the whole nature of what's in the forest there. The ravaged stands commonly were the subject of at least two diameter-limit cuts that took out the good stuff, left the bad stuff, and left patchy, un-uniformly distributed growing stock.

Well, that was a survey in New York. But there have been more recent surveys here in New York again, in Pennsylvania, Kentucky, and West Virginia. Here's one by Pell, questioned the potential for long-term sustainability of the stands that they found. Mary Ann Fajvan in West Virginia, all but a few of the 90 she surveyed were not sustainable. McGill in West Virginia, diameter-limit cutting was the most severe practice they found out there.

Munsell and Germain here in New York, found stands were mediocre and not sustainable. Schuler and McGill in the Appalachian region, that diameter-limit cutting had depleted quality sawtimber resources.

Stringer in Kentucky, 72% of stands were degraded by exploitive cutting. And most recently, Munsell and the group here in New York said that diameter-limit and premature cutting was pervasive across New York State.

And that makes me raise the question, is this really forestry? Or is it simply the process of finding, putting a value on, and efficiently extracting saleable product from forested lands? If so, that is not forestry.

My metric called it the green lie. That it looks like a forest. It smells like a forest. It sounds like a forest. But it's just a pretense for the real thing, and quite a pretense for the values that we could sustain from forests through appropriate silviculture. To me it's like closing the door after the sheep got out, where the value of the stand, the production potential, the potential to control habitat conditions, and visual qualities and water yields and all of that has really been just lost, at least for long, long periods of time.

We need to start by admitting that we really don't have effective tools for evaluating what the ecological impact has been from these kinds of exploitive harvests. It changes the forest. And we can speculate what it might do. But to measure this is difficult, so I will not try to assess the effects in the ecologic sense.

Rather I'd like to look at how the cutting may change stand conditions and ask if the residual conditions dictate or limit the treatment options for the future. To do this effectively, we need to remind ourselves what are the differences between even, uneven, and two-age stands, and to see if the age arrangement within a stand makes any difference in the way we approach it for the future.

So let's define those things. Even-aged means that the community has only small differences in ages between the trees that are present. And there's a convention in forestry that the spread of ages would not exceed 20% of the rotation length. So rotation, that's the planned number of years from when the stand is formed after a disturbance or a regeneration method until the final cutting, which is the regeneration method, when the stand reaches a specified degree of maturity. So if a stand were 100 years old at maturity, the spread of ages would not be more than 20 years within that stand.

These even-aged stands have a clear pattern of development. We start out with a lot of small trees. And as they mature through time, we have bigger trees. But natural mortality reduces the numbers present. And eventually, they become bigger with even fewer trees and reach a point of maturity where

we want to regenerate or replace that stand one more time.

And if we had a forest comprised of even-aged stands, they might be at different stages of development. But these conditions would occur in each one. So an even-aged forest has a collection of even-aged stands, each of them at different stages of development.

So in even-aged, then, all trees are generated at the same time or close to that. All develop the maturity together. All come of age together. And at some point, we must remove the entire community as the regeneration method to establish a new even-aged stand in its replacement.

The general silviculture here is that during the young stages of development, we tend these stands. Remember, regeneration and tending are two silvicultural practices. And our goal here is to reduce crowding and to focus the growth potential on the trees that have the characteristics best suited to the landowner's interest.

And we do that by thinning. Thinning favors the best trees of upper canopy positions. The key here is not only does this provide you with the best values at the end of the rotation, but it also gives you the trees with the best characteristics to use as seed sources for the next rotation. Remember, in forestry we use the phenotype, the outward appearance of the tree, as an index to its genetic potential. So if during tending we're nurturing the growth and development of phenotypically excellent trees, we get to the end of the rotation, we have them. We expect that will be a good seed source for the future.

Tending. Thinning influences the growth and development by focusing the growth potential on the trees that interest the landowner.

And then when the stand reaches that stage of development that we call mature by whatever criteria, then it's time to regenerate them. And one of the techniques we use is called shelterwood method, as an example, where we keep those trees of ideal phenotypic characteristics at uniform spacing. We use them as seed source. We use them to help mitigate the change of environmental conditions near the ground. And when the new cohort has become established, we remove those seed trees and have a new even-aged stand in its place.

Here you see an example of a shelterwood stand after the seed cutting, the widely spaced residuals, and the new cohort that has developed beneath them. That's even-aged.

Now, uneven-aged, the community has trees of markedly different ages, a wide spread of ages. And the convention here says that the spread of ages would exceed 25% of the life span for that age class. We don't have rotations with uneven-aged. We have lifespans of trees. So if I intended to grow an age class to 100 years, then the spread of ages within this uneven-aged stand would exceed 25 years. That's the convention.

So each stand has trees of different ages. And they commonly have different sizes. The young trees are small in diameter and short in height. The middle-aged trees are medium-sized and medium diameters, et cetera. But they all go together in the same stand so that we have this mixture of age classes even across the space of a stand.

And remember, only one age class reaches maturity at a time. So our silviculture will remove that mature age class and concurrently tend the intermediate age classes. So with even-aged stands, you would have this mixture throughout the whole stand. And with forests comprised of uneven-aged stands, you would have this uneven-aged mixture across the whole forest.

So the parts of each stand would regenerate at different times. Young, medium, old-aged trees present, each comes of age at a different time. So the silviculture here is to remove the oldest age class as the regeneration method, to tend the intermediate age classes. And we'll do this periodically, controlling, influencing growth and development, ensuring new age classes each time we enter the forest.

Using a sample of selection systems-- this is the uneven-aged regeneration method that opens space, in this case single tree spaces, to create environmental conditions conducive to regeneration of new trees. And when you couple it with tending of the immature age classes, you end up with a stand where these different age classes are intermingled. And you have a sustainable system at the stand level.

The third class of stands generally are two-aged, where the stand has, as it says, two distinct age classes. By convention the ages are separated by more than 20% of the lifespan for any one of them. So a typical two-aged stand would have some older, bigger trees, usually have wide spacing, and with a younger cohort beneath them. And through time, we would remove the old trees when they reach a stage of maturity, leaving behind the intermediate-aged trees. And we would then regenerate a new cohort beneath them and start this whole process over. The entry time may be perhaps 50-year cycles here.

And a regeneration cutting would look like this, with the widely spread residual trees and the new cohort forming beneath them. That's what the practice looks like, going from the condition on the left to the condition in the middle, which is only one age class left, regenerating a new age class and starting all over again. Two distinct ages present, great differences in the age between the two cohorts, each one comes of age at a different time.

Now let me tell you that in the study we did here in New York State, we did not find two-aged stands. They are not common. This is something that's been of interest in fairly recent times. But we just don't have them up here.

OK. There are some basic ideas to start from, to build a platform that we can begin thinking about rehabilitation and the effects of cutting. So I'm going to pause here and let Tom see what questions we should address before going on. Tom?

If you've got some questions for Dr. Nyland, you can type them into the notes box that's on the right side of your screen. While we're waiting to see if some questions appear, Dr. Nyland, what are some of the challenges to determining whether a particular stand is even-aged or uneven-aged? What are some of the indicators that we look for to make that type of call.

That's a good question in the sense that it's pivotal to making a silviculture decision. In even-age communities that have a shade-tolerant component, or have trees of different growth rates, you will often find trees of different diameters. In the ones where there's a shade-tolerant component, though, the trees will still be relatively tall for their diameter, but with small diameters. And the live crown ratios commonly will be, oh, as small as 10% or 15% in the smaller trees, while the bigger trees may have a 25%, 30% live crown ratio.

So a characteristic of an even-aged stand is that you have generally a foliar layer, a crown layer, that's well elevated above the surface. There is usually very little green foliage beneath that main canopy layer. And the small trees are tall for their diameter and have a very small live crown ratio.

In uneven-aged stands, the small trees are shorter, distinctly shorter. And the live crown ratios will be 40% to 60% in a managed stand. The medium-sized trees will be medium-height, again with a 40% to 60% live crown ratio, so that if you look at an uneven-aged stand, you will see a distinct green wall. The visibility will be short. If you look at an even-aged stand, you can often see through it for miles. To

complicate it here are stratified species mixtures, where the slower growing species will be a shorter height, but because it's over-topped, still will then have a short live crown ratio.

The bark characteristics of an even-aged stand at mid-rotation ages, the small trees will look like old bark. In uneven-aged stands, the small trees will have young-looking bark. Does that help?

That helps. If you're good with tree ID, can you get a pretty good indication by the species that are present, or not necessarily?

No, because-- well, to some degree you can, in the sense that uneven-aged stands usually are dominated by the more shade-tolerant species. The even-aged stands, at least in the more northern half of the region, would have a mixture of even- and uneven-aged. So if you do find a high proportion of shade-intolerant trees, there's a good chance that it's probably even-aged, except if it's been managed at low densities. Then we can regenerate mid-tolerant species in uneven-aged stands and grow them up into the main canopy layers.

We've got a couple of questions. The first one is from Rajan. I hope I said that name right. Can you please define once again selection cutting and selective cutting.

OK. Good. That's key too as we move ahead. Selection cutting is the silvicultural method for dealing with uneven-aged stands. And it involves then removing the oldest mature age class as the regeneration method and tending the immature age classes so that you nurture their growth and development of the best trees. So it is sustainable silviculture at the stand level.

Selective cutting, by definition of the Society of America Foresters, means creaming, culling, high-grading, choice species removed without regard for sustained yield. So it's really an exploitive harvest. And diameter-limit cutting fits into the category of selective cutting, because all you do is take out big trees and you don't do anything more. Hopefully that speaks to the question.

Another question from Zachary. What species are you managing for most in these uneven-aged stands?

In all silviculture, you really manage for the ones that are best suited to the site. In our northern hardwoods, the principal species would be sugar maple. So you probably would be managing for the species that are best fitting the landowner objectives, as long as they've got a reasonable degree of

shade tolerance. And if it was timber, you would look for the ones that have the highest timber value. If you have other objectives in mind, then you would look for the species that would serve those long-term objectives. But generally, it will be the species that is best suited to the site you're working on.

That's our last question. I think, Dr. Nyland, you could continue now.

OK. Let's go on then and return to the New York SAF timber harvesting evaluation and see what some characteristics showed up among the cutover stands. First off, we did not find that the cutting had just left four species. It had removed from the even-aged stands the more shade-intolerant component. In our case, it would be species like white ash and black cherry. But sugar maple is part of those stands as well. And sugar maple for us is a very desirable species.

You can see here the degree of shade tolerance, starting with the most shade-tolerant for us. This is in the northern hardwoods. American beech is the most shade-tolerant, followed by sugar maple. We would put red maple and yellow birch in the intermediate group. White ash is intolerant. And the very shade-tolerants would be black cherry and aspen. So the diameter-limit cutting essentially would have removed the bottom three species, and probably the yellow birch as well, leaving behind things like red maple or sugar maple or American beech.

Now, in the uneven-aged stands, those mostly have shade-tolerant species. And for us, that was sugar maple. So the diameter-limit cutting would have taken away the bigger sugar maple and left the smaller sugar maple. And remember, the characteristic here, in uneven-aged stands, those smaller sugar maple are younger sugar maple.

For the other characteristics, let's use a series of charts that'll have this general configuration. The vertical axis will show some kind of change, from bottom to top increase in the magnitude of the change. And then across the bottom, the stands are aligned by virtue of their stand rating score. So the very well-managed stands would be on the left, with a rating of 1 for example. And the ravaged stands would be on the right, a rating of 3. And then there will be some kind of a line which would show the direction of the change.

Now in all of these cases, we measured the stumps and reconstructed what appeared to be the characteristics of the pre-cut stand. And because of that, we could then compare what we believe was in the pre-cut stand to what we found in the residual stand and come up with an estimate of change.

And so here in average stand diameter, foresters call this quadratic stand diameter, or QSD. So the QSD either increases or decreases. Most silviculture treatments will increase the quadratic stand diameter or reduce it only slightly. As an example, if you're doing selection system and take the oldest age class out of an uneven-aged stand, inevitably you reduce the quadratic stand diameter slightly, but only by a small amount.

So here's our findings. Again, remember the good stands are on the left and the ravaged stands are on the right. And you see that the degree of ravaging or harshness of cutting increased the amount of change. It in all cases went from well managed stands to poorly managed stands, quadratic stand diameter dropped.

Even-aged stands, it would look something like this. Removing the biggest trees left these small ones behind. These are all the same age now, but they're small. Here's an example of diameter-limit cutting in an even-aged stand, taking out the bigger sugar maple, leaving whatever rest behind.

In uneven-aged stands where we have several age classes, diameter-limit cutting removes the older age classes, not just one, but the older age classes, anything that's as large as the threshold diameter. But the ones it leaves behind will be younger age classes that should have some good genetic potential in them.

This is an uneven-aged stand. That's the effect of a second-- a second-- diameter-limit cut in this stand, reducing the quadratic stand diameter.

We can look at the change, the potential for change in future growth and production. And here we particularly want to separate out what likely will occur in even-aged stands versus uneven-aged stands. So let's start with the even-aged stand subjected to diameter-limit cutting.

In even-aged stands, we separate the trees into four crown classes and use that as an index for a lot of our management decisions. The dominant trees are the biggest ones. Their crowns extend above the main canopy layer. They receive sunlight from the top and the sides. These are the trees that have grown best in the past, so the fastest-growing ones, the ones with best promise for the future. There is evidence that these are genetically the best for the particular site where they're growing.

Codominants are also good trees. Far more of these than dominants. Dominants are relatively few. But the codominants make up the main canopy layer.

They're good trees. They have good form and growth. They have good promise for the future. And they're genetically good, acceptable trees.

The third class we call intermediates. These are poor. Their crowns extend up into the base of the main canopy layer. They usually grow between cracks of light among the upper canopy trees.

They grow poorly. They've grown poorly in the past. They'll grow poorly in the future. These are genetically undesirable.

And the overtopped trees are just plain wretched. They're hanging on. They don't grow well at all. The live crown ratio could be 5% on these. They're very weak. They're woeful.

What's the implication? We've looked at the growth of trees in different crown positions following thinning in even-aged northern hardwood stands. And I'm focusing here on sugar maple.

So in the 15-year period after thinning, the dominant trees added about three inches, and the codominants nearly two inches. That's a good growth response after release. The intermediate trees grew only an inch and a third and the overtopped trees $2/3$ of an inch. That's a rather poor response after thinning.

So the general pattern that comes out of growth studies is that the dominants grow best. The codominants grow quite well. The intermediates grow poorly. And the overtopped trees don't grow well at all. They're terrible.

Here's the most recent data we have. And this again is following even-aged northern hardwoods, sugar maple, following thinning. And you notice that all of these lines, they're lower on the left-hand side and they're higher on the right-hand side. And then we displayed on it the years. This is the time period on the left and left to right.

So each line represents a tree of different diameter. And you see that the small trees grow less than the big trees for any period of time. If you leave the small trees, the growth potential is just poor. If you remove the big trees, then you've left behind those trees with poor growth potential. And that's what diameter-limit cutting does to our forests.

Now, contrast this with uneven-aged stands, where you have different trees of different ages and

they're different sizes. You note here that all of these trees have a relatively large live crown ratio, the proportion of total height and live foliage, and that as you go from big to small, you see a change in diameter but also in height.

Our work with growth of sugar maple in uneven-aged stands shows a distinctly different pattern from what we found with even-aged ones. These two curves here representing individual levels of stocking. The vertical axis is the growth of the tree, the annual growth. And the horizontal axis is the tree diameter. And these show that the small trees in even-aged stands have a high growth potential.

And notice that a 4-inch tree in 15 years will add about 2 inches. An 8- and 12-inch tree about 2 inches. And the 16- and 20-inch just under 2 inches. So they've got reasonable growth potential throughout. And this in stands cut to 75 square feet of basal area.

But the small trees will grow better. The two curves on the left show that if you reduce the stocking in the stand-- 75 square feet is the green line. 65 square feet is the black line. If you reduce the stocking in a stand, then you increase residual stand tree diameter growth.

So the difference is important. In even-aged stands, you can cut the big trees. You can remove the trees with the best growth potential. That's not necessarily the case in uneven-aged stands.

And while diameter-limit cutting is not desirable in uneven-aged stands, the key factor for long-term production of timber, anyway, is to control residual stocking and the spatial distribution of residual trees.

Now what about the change in tree quality? We didn't use a very high standard here. We looked at whether a tree could produce one eight-foot sawtimber and what is their number that is out there. The one eight-foot sawtimber, eight-foot sawlog is a minimum for a salable factory-grade sawlog, something that would be considered gradable and would bring value to a landowner reselling.

Here's that same diagram. Again, stands with the highest score are on the left, that is the best conditions. The trees with the poorest condition are on the right. And you notice as we go from the well-managed stands to the poor-managed stands, the proportion of total growing stock and good trees diminishes.

Here's the sawtimber growing stock. It's the same pattern. As we go from the good to the poor, we find fewer and fewer and fewer good trees.

An example of diameter-limit cutting in even-aged stands. And you see the rather poor quality stuff [INAUDIBLE]. Trees of subordinate canopy positions in even-aged stands just do not have good quality. And if you take the others away, you're leaving trees of poor quality.

Here's the same thing in uneven-aged stands. You see they've left trees of poor quality.

Now what about the uniformity of residual stocking? And I call that patchiness. And then we want to know how that might limit future stand treatments.

Same kind of diagram here. And notice that if we go from the well-managed to the poorly-managed stands, the degree of patchiness increases. The trees are less regularly, less uniformly distributed. With a few exceptions, there are some where there have been major improvements in uniformity. But in most cases, there's some degree of patchiness that's entered into a stand even with silviculture, because if you're regenerating something, you have to create these voids to make space for the new cohorts.

So here's an example of an even-aged stand prior to diameter-limit cutting. And afterwards you notice the patchiness that you end up with, as seen here, these big openings intermixed between areas of very tight spacing, intermixed with some individual trees.

In even-aged stands, they start out like this. Now, remember the sizes are associated with ages. You end up with patchiness if you do diameter-limit cutting, as you see here. And again, this cluster is various with dense trees and places where there's no trees.

The fifth criteria was interference. We didn't actually measure this, but I'm folding in here some things we've learned by other studies. Interference prevents the regeneration of successful species, whether you do it by natural or artificial regeneration. And the general rule of thumb we use up here in the Northeast, if interfering plants cover one third or more of the stand area, you have a high risk of regeneration failure.

Let me highlight four species that are our most common points of interference. And that is ascended or New York fern. American beech saplings in the understory. Those will appear before cutting and you can see them. Striped maple and pin cherry often appear after cutting.

Just look at this beech understory. The rule says if we find this on 1/3 or more of the stand area, we need to remove it as a site preparation technique before we do anything else. All those small trees are

beech in a stand that was heavily cut over in the past.

We've learned through our cutting trials, our demonstrations, that if you remove the beech understory, as you see on the left, we can promote desirable regeneration beneath the residual trees. Just taking out that dense beech understory makes a major change in the quality of light in the understory. And in the presence of the seed source, at least the sugar maple seed will germinate and we get advanced regeneration form. So this would be the first step, getting rid of the interference, getting advanced regeneration started, and then proceeding with management.

Ferns and grasses are a major issue, particularly in heavily cutover stands. Remember that in ecosystems, if you create a void, it gets filled with something. And if you don't have desirable trees to replace them, that is, you don't have a desirable seed source, something else will fill that void.

So following especially a second diameter-limit cutting, we often find the stands with a dense understory of herbaceous plants of one kind or another. Site preparation must remove that before you proceed with anything else. And we found that the only effective way to do the site preparation in these cases was with mist-borne herbicides.

So there's these five factors that showed up in our evaluations, at least that will influence what we do to plan for rehabilitation. One is the reduction in average stand diameter, the degree of it. The other is the potential for future growth, whether the trees left behind have a growth potential or not, the change in residual tree quality, and if it's there, the patchiness and the likelihood of interference, either it's present or will likely spread throughout the stand.

And note this. The good stands differ appreciably from the mediocre stands. It may differ appreciably from the poor stands. So rehabilitation really applies to mediocre and poor stands. In regular silviculture, it works with the good stands.

I judge that among the different things we've seen in cutover stands, that patchiness complicates prescription-making. It results from not only having an irregular distribution of residual trees, but also having an irregular stocking of ones that are usable, at least for timber production purposes. So we're faced with low stocking. And we're faced with irregular stocking. And we're faced with irregular stocking of good trees.

But these are all confounded by the high degree of variability that we find from one cutover stand to

another. And you can see that in these diagrams, that the spread of points around the trend lines can be quite broad, so that there's no ubiquitous treatment we can prescribe. This will require a detailed inventory before you start a prescription. It will mean assessing the nature of the growing stock and then coming up with a strategy for each stand.

In some cases, a single treatment might work, particularly if we can go to a low-density stocking, as you see in the upper right, the center, or the lower right. In other cases, we may have such poor growing stock that we can remove the whole stand, clearcut it, and start again.

I think with most cutover stands, though, you have this patchiness, which means that there is no one single treatment that might work there, unless you can remove all of the trees. And there is often some growing stock left behind that you could use to enhance the future or that will maintain some kind of a non-market value that's important to a landowner.

So many of us talking about these things have come to realize that these cutover stands will require a prescription that integrates multiple treatments within the same stand. Here you see an example from Mark Kenefic's work in Maine where there's some crop tree release. There's a tending of some residual conifers. And there's planting of spruce in the open spaces.

Remember the cutover stands have only a few good trees and often wide spacing. And that's what requires the heavy cutting to get rid of those dregs, leave the growing stock in a good condition, and trigger a new cohort to grow into the future.

So perhaps what we end up doing, based on the inventory we get, is to partially cut some parts of the stand to establish a new age class and grow the residual trees into the future, or at least the good ones. That would trigger a two-age arrangement, so we would get a new cohort started underneath those residual trees. They would grow up and we'd tend it as two-age into the future, parts of the stand.

Other parts of the stand have nothing worth talking about for the future. And so we would clear them all off, clearcut patches, and use natural regeneration to replace the old. Now this is a good option if you have advanced regeneration of desirable species. In many of the forest community types we have in eastern North America, and in the west as well, the key to reducing the risk of failure in clearcutting is to have well-developed advanced regeneration well distributed across the site. And if you have that, clearcutting will succeed.

You want to have advanced regeneration like I'm showing here on the screen. This is sugar maple beneath an even-aged sugar maple stand. It needs to be abundant and well-distributed. And if you have that and you take the over wood off and [INAUDIBLE], you'll get something like this.

In other parts of the stand, natural regeneration has already formed beneath the poor quality residual trees. And we could do an overstory, a released cutting in this case, taking away those older junk trees, releasing the understory for growth and development.

There will be some places with patches of good trees that just didn't have anything merchantable in that. And we went and applied traditional tending there to reduce the stocking to the best trees with uniformly distributed spacing to appropriate residual density.

But commonly it will be low-density, because there are often relatively few good trees even in these fairly dense patches. This is a stand, for example, that's been reduced to 45% relative density.

In uneven-aged stands, it will mean cutting to low residual density, like the example you see here, cut to about 55 or 60 square feet to the acre, and in the process trying to balance the age classes, trying to maintain this intermixing of age classes in proper proportions. At those low densities, we will generally find a cohort will develop beneath the openings, given no interference, given no herbivory. And then we can move into the future with a more traditional uneven-aged silviculture.

Parts of the stand, maybe important parts of the stand, just had no redeeming social value. And so we would just have to take all of the junk trees off there. We don't have advanced regeneration.

In many of those cases we have interference. We have to clean out the interference. And the only option we'll have then is to plant them. And probably with a conifer species, because of the difficulty of planting [INAUDIBLE]. And it will transform these wretched old areas with degraded hardwoods into essentially a plantation.

Jean-Martin Lussier up in Canada, working with the Canadian Forest Service, he and Daniel Pin, and some others, have been looking at how they might apply these kinds of treatments at a commercial scale using mechanized harvesting. And as they evaluate stands left behind by diameter-limit cutting, they find too that there's often these multiple treatments required.

Here's an example. In parts of the stand, they may have an option of a low density thinning, where the

AGS means Acceptable Growing Stock. You won't need any regeneration here. In other places, they will completely remove whatever is in the overstory, because it's unacceptable growing stock. And they might release acceptable advanced regeneration. That's the key. They will have acceptable regeneration here.

Where they don't have it, they'll try a shelterwood-like practice in the small area to establish that missing advanced regeneration. And in parts of the stands that are uneven-aged, they may use selection system cutting. What you put into these options depends upon your pre-cut evaluation and the alternatives that you can identify from that.

So they would use an approach much like this. They establish these trails for the feller buncher. And the orange and green circles represent trees of different sizes.

They would go through and on the first line at the left, they would apply treatment number one and then one. They set this up so the operator has a set of decision criteria and makes the decision based upon what that operator can reach with the arm of the feller buncher as they're parked. So we start off, look at the circle, apply treatment within reach of the feller buncher arm, then move up to the next place, make a decision, apply that treatment. And so they're going up the trail, stopping each time, making a judgment, and applying a treatment, and then go back on another trail.

And you see that when they finish here, they will be ending up with something that is diverse in its residual conditions. In some places, it's been partially cut. In some places, it will be even-aged patches. In some places, it will be uneven-aged. It will be what I want to call an any-aged condition of mixed quality, but improved, because of the treatment that they've given it.

So they've gone from this condition, which has this mixture of poor, good, and bad, to this condition, which involves this multi-treatment approach. You see right of center, there's a little patch cut. In other places, there's partial cuts.

But what other alternative do we have given the patchiness, given the lack of good growing stock, given the way the stand has been treated in the past, that we cannot expect to end up with uniform conditions throughout, but rather as a rehabilitation treatment, beginning to upgrade the stand in a way that we can move into the future with a more promising outlook? It's going to require a well-planned silviculture based on a valid inventory. And we'll apply our techniques in new and creative ways.

It will mean reviving the vitality of forests through these methods. It will re-establish appropriate biological diversity. It will reduce the spread of invasive plants. It will reverse the ecologic chaos.

It will reclaim the capacity for wood volume production, in a sense gaining control. Not subduing, but gaining influence over the way forest stands grow and develop into the future, based on a multi-treatment strategy for cutover stands. And that's what's new. That's what's new.

So the real need to overcome the bothersome past, to consider a new multi-treatment approach, and to rehabilitate the chaos in a controlled and deliberate manner, a multi-treatment of silviculture from the bag of many tricks. That's what we see for the future. So Tom, I guess I'd be glad to entertain comments and questions. Were there some?

Yes. And I have to apologize. I can't stay very much longer, about another seven or eight minutes. But one of the questions from Jake Meyer would have to refer back to a specific graph, so I'm going to have to pass on that. But Jake had a second question. Complete removal if quality is bad, question. Should we not leave some unacceptable growing stock for structure in the stand for wildlife consideration?

Recall that back at the start I argued that rehabilitation must address the objectives of ownership. And if structure is important, then yes, leave some structure. In some cases you may have no other option for seed source. And then you would leave some of those trees even though they're not desirable in the phenotypic sense.

So respond to the objectives of ownership. That's the first thing you have to ascertain in making any silviculture prescription. And then gear up your treatments to be sure that you've satisfied those.

We do have some time for some more questions if others want to type them into the box. Ralph, given the importance of a good stand evaluation and the multi-treatment strategy that you've described, I wouldn't want to eliminate anybody from working on their own stand, but how important is it to get a professional involved, a trained forester?

I've always felt that that's important. Allegedly people who come out of our forestry programs understand something about ecosystems. And they understand about trees and how they grow. And they understand how we can change patterns of growth and development.

But I must say that not all foresters are equal. And so the key is to find not just a forester, but someone

who has the experience and who has a demonstrated ability to practice silviculture in a fairly sophisticated way. And that will be the challenge of landowners, to find those people who in fact can do this job.

Would you say that the challenges and the impacts of diameter-limit cutting, for example, are greater with an even-aged stand? And also the 49% of stands that were in a mixed condition, how much of that do you think was even-aged?

Let me deal with the second part first. We've done some crude estimates and believe probably that due to the natural forestation of former agriculture sites, probably in the order of 75% of the forest area in New York State is even-aged, particularly outside the forest preserves of the Adirondack Mountains. So we probably were sampling mostly even-aged stands, although there were uneven-aged ones in there.

By far these cuttings are most devastating in even-aged stands, for the reasons I tried to articulate. The small trees in even-aged stands are runts. Once a runt, always a runt.

My colleague says this. If I were to cut the big trees out of an even-aged stand, it would be like going to a horse race, shooting the winners, and putting the losers out to stud. I think that sort of sums it up. When you cut the big trees out of these even-aged stands, you're destroying the future. In uneven-aged stands, there are small trees that are younger that should have reasonable genetic potential for growth and development. So by far this is most devastating in even-aged stands.

Brett has a question. What types of stands do deer leave alone?

Deer leave stands alone if there's no undergrowth in them. Deer certainly are a problem. And we've found through the experience, particularly in the north part on our Huntington Wildlife Forest, that the only way to effectively deal with deer is by hunting and to hunt the antler-less deer.

And there's evidence that if you start a hunting program and carry it on for a few years, you can reduce the density of the herd at a place to a level where the deer density is more in balance with the capacity of forest to produce food. And at that point, you will have reduced problems in regenerating forest trees. This can be done in areas as little as 250, 300 acres, probably. But the only way to deal with the deer is to hunt them and to hunt the antler-less deer. You must reduce the females in the population.

Nora has a good question. In an uneven-aged stand, is there an advantage to culling the overtopped

non-performers along the way?

The basic idea of tending in the uneven-aged stands, you've taken out the mature ones. And in each of the immature age classes, you are keeping the best and cutting the others to a residual number. So if you are periodically entering an uneven-aged stand and each time you're favoring the best of the cohort, you end up with great trees at the end by the time they reach maturity.

So in a sense, when you take out the poor of a cohort, you're favoring the best in that cohort. And you're also enhancing the growth conditions for ones in the younger cohorts. I'm not sure if that speaks to Nora's question.

Yeah, I think so. I think that it did address it. And the answer would be yes, that you'd be culling the overtopped non-performers along the way.

But in a prescription that reduces that stand to a balanced condition. So you want to practice selection system is we know how to do it, not just cut bad trees from a stand.

True.

You're looking for the residual density and the diameter distribution, with the diameter distribution being a surrogate for the age class distribution. And your goal is to work toward having equivalent amount of growing space in each age class.

I think we've just about reached the end. Oh, I do see a good question from Toby Alexander. When working in high-graded stands, do you have approaches to determine site index productivity for the stand when all you have left in the stand is what the suppressed or intermediate stems were there prior to high-grading? With these inferior shorter trees left behind, the stand may seem less worthy of investment for rehab and overlooked. Do you rely on soil maps, site indicator plants, regeneration, remaining species, height of residuals? How do you assess the productivity of the stand when it's been treated like this?

There really is no effective way that I've seen to evaluate productivity in our high-latitude hardwood forests simply because every tree in there has been affected by some snow damage or wind breakage. And the cardinal rule of site index is that you must use trees of upper canopy positions, never impeded in their growth by disturbance or something. So site index by definition does not apply to uneven-aged

stands, because the younger cohorts have grown in the shade of others. And in even-aged stands where the tops have broken off, you can't find a [INAUDIBLE].

So the test we made of site index in northern hardwoods, you come up with an average of 65 plus or minus 10. And that's the whole range of site classes people have defined. We just need to find a better way. The folks in parts of New England and in eastern Canada and other places rely on soils maps to get the general ideas. But we really do not have an effective way to judge site quality using a site index. That's about all I can say.

Well, Dr. Nyland, I sure appreciate your presentation. I'm going to call it good for today. And it will be available for replay from this same site. Is there anything that you wanted to add, Holli or Eddie?

I would just say thanks, everybody, for attending. And Tom, what would've been a small teleconference turned into an event for about 160 people. And we welcome their participation and welcome them back for another webinar of their choice. So come back and visit us again. And we appreciate it.