by Benjamin A. Roach

Scheduling Timber Cutting for Sustained Yield of Wood Products and Wildlife

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FOREWORD

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ABSTRACT

Providing relatively uniform yields of hardwood timber for future generations will require adjustment of the presently unbalanced age-class distribution in the eastern hardwood forests. Because the home ranges of most species of wildlife are relatively restricted, maintaining stable wildlife populations throughout these forests will require adjusting and regulating timber age classes by much smaller units of land (several hundred to several thousand acres) than would be needed for sustained yield of timber alone. It is commonly believed that regulating timber production by such small units of land would be prohibitively expensive. But where the small unit has an age-class distribution approaching the average distribution for the forest as a whole, cost increases should be insignificant. The key to successful regulation of timber age classes for combined timber and wildlife production, with minimum impact on costs and timber yields, is the long-term planning of cutting schedules for small units of land.

MY MAJOR PURPOSE in this paper is to show the need for planning timber cutting a long way ahead — for either timber production or wildlife production, but especially for wildlife. A secondary purpose is to show how I think we might go about it.

GENERAL ASSUMPTIONS

My first assumption is that future generations will need all the timber that can be produced, but will always be willing to trade off some timber growth for other benefits — wildlife, water, recreation, and aesthetics.

Another basic assumption is that assuring full and dependable timber yields over long periods — sustained yield, in other words — will necessitate a regulated distribution of timber age or size classes, at least in the general forest zones on public lands and increasingly on industry lands.

A third major assumption is that even-aged management will be the system of management generally used to regulate large-scale timber production because:

- Single-tree selection cutting can be used only for tolerant species, and even for these it is much more difficult to regulate for sustained yield than is even-aged management.
- Single-tree selection cutting provides only one general set of habitat conditions over large areas and for long periods. It thus fails to provide the diversity of habitat required by many species of wildlife, and wildlife populations are correspondingly limited.
- Small-group selection cutting may provide acceptable habitat for many species of wildlife, and it may be used to reproduce most species of trees; but the extreme difficulty of controlling cutting rates under it will limit its usefulness to small tracts and other areas where regularity of timber yields is not required. In short, we can practice group-selection cutting, but we can't regulate it on large areas over long periods.

That leaves only some form of even-aged management for large-scale production of timber and wildlife. I am talking about the general forest zone, not special areas where other uses may take precedence over regulated timber production. Please note, also, that even-aged management doesn't mean simply clearcutting some area every time the mood may strike. Rather it means carefully shaping individual timber stands through a long period of development toward a planned yield of specific products on a definite schedule, then harvesting when the objective is fulfilled and conditions needed for regeneration are present. The planned shaping of the stand is the basic feature of even-aged management, not the fact that clearcutting may have been selected for the regeneration method.

I have also had to make some subsidiary assumptions related to wildlife management. One is that it will be as impossible to optimize habitat conditions for all species of wildlife on the same area as it is to grow all species of trees on the same area. Therefore, both timber management and wildlife management must be coordinated toward production and maintenance of certain types and groups of species whose habitat requirements are compatible on a given area.

Another assumption is that the size of cutting area (stand size) adopted for timber management must be coordinated as far as possible with the habitat requirements of the wildlife species to be favored.

And a final assumption is that many wildlife species require some diversity of habitat, by which I mean the appropriate variety of plant species and successional stages that the animal must have continually in order to live in the area. A corollary is that, for maximum sustainable wildlife populations, the diversity must be supplied within areas judged to be roughly equivalent to the bird's or mammal's home range. Timber management requires having all size classes of trees from seedlings to mature timber, each size class or structure adding its own peculiar contribution, or impact, to habitat.

Therefore, it is the responsibility of the timber manager to provide the necessary range of stand structures, or conversely to disperse the unsuitable structures for minimum impact, over the wildlife species' home range. Basically, this means that timber-cutting schedules must be more stringently controlled for wildlife benefit than would be necessary for sustained yield of timber alone, and that the control must be exercised on smaller units of land.

I propose to examine the implications that this last assumption holds for timber management to see if certain basic adjustments can reasonably be incorporated in a timber-production program, and if possible to get an idea of the magnitude of costs involved.

A MANAGEMENT EXAMPLE

Obviously I can't cover the whole field, and I don't know enough about wildlife management even to try. Therefore, I'm going to work with a specific example, featuring species with which I am at least a little bit familiar. I am going to try, on paper, to manage a hypothetical compartment on a large forest for combined production of oak timber and white-tailed deer. And since I like to hunt grouse too, I'll try to at least keep them in mind from time to time. Please remember that this is only an example. Different types or different species would require different solutions. I'm merely trying to illustrate a method.

My compartment is 1,000 acres of oak. This may be somewhat larger than the usual concept of a unit of deer range, but for a reason that will develop as I go along, I don't think it will make much difference in this case.

The timber-management objective on my compartment has been set for large sawtimber on a rotation of 100 years, with a 10-year cutting interval.

Choosing Average Stand Size

One of the first things I must do is decide on the average size of stand that I want on this compartment, and there are a number of considerations that bear on the decision. The trees don't care what size stand they grow in as long as the area is big enough for satisfactory regeneration and development. Any size from about ½ acre on up will be satisfactory to the trees.

For administering the timber-management program, a relatively few large stands make for convenience and easier control. Timber operators like large stands, too, because they don't have to move so often, and their administration and supervision can be more routine. In both cases, though, as long as a stand is large enough to provide an economic cut and satisfactory administrative control, it's doubtful that efficiency will improve much with larger stands.

To the silviculturist, large stands are a mixed blessing. On the one hand, large stands mean less work drawing stand boundaries and fewer stand examinations and prescriptions. On the other hand, the larger the stand, the more variation there is in such things as site quality, and the less accurate the prescription will be. In my opinion 20- to 30-acre stands seem about right for the types I'm familiar with, although there are many areas where smaller or larger stands would be satisfactory for silvicultural purposes.

As far as the deer are concerned, the main factor is probably the amount of browse and herbage produced when stands are regenerated. If stands are too small, a large deer population can wipe out tree reproduction when we try to regenerate. If stands are very large, much good browse and herbage is unutilized. But deer don't seem to be very good surveyors, and they are blessed with the means to get quickly from one place to another when the mood strikes. So I doubt that any size between 5 acres and 100 acres is going to make much difference to a deer if the width of the area is not too great and if the surrounding area provides the other requirements for a suitable habitat.

But a 100-acre stand seems pretty large for grouse. One authority recommends 5-acre stands in a 20-acre grouse range in aspen. The 5-acre stand seems a little small for both timber management and deer management, so I compromised on a 20-acre average stand size. This is what I will work for on my compartment. The administrator and the logger should be able to live with this stand size. The deer don't really care, and it should be at least several times better for grouse than 100-acre stands.

Because I want to keep my first attempt at combined timber-wildlife production as simple as possible, I am happy to discover that my sample compartment is all the same timber type and site class (mixed oak, site index 70). If I'm successful on my first attempt, I can work in the other complications later.

Adjusting Timber Age-Class Distribution

If I were concerned only about timber production I would not try to regulate timber age-class distribution on an area as small as 1,000 acres. I'd combine the compartment with many others and work toward a balanced distribution over perhaps 50,000 or 100,000 acres.

Management for deer entails a different dimension. From what I've seen and read, deer make much use of open, newly regenerated areas, of brushy sapling-filled areas, and of areas of mature timber in close combination with these. But deer seem to spend little time in dense stands of poletimber from which they get little food and apparently little enjoyment.

There's no way that we can grow timber from sapling size to large sawtimber without going through a long pole stage. Thus it seems to me the only way we can grow timber on an area without having the deer break their lease for long periods is to keep the pole stands interspersed with enough younger and older stands within the deer's normal range to satisfy the animal's requirements.

The best that I can arrange for the deer on my compartment, and still grow timber efficiently, is to balance the timber age-class distribution on it. This arrangement will provide the maximum continuous proportion of non-pole timber. Ideally, then, at any time 10 percent of the timber stands on the compartment should be 0 to 10 years of age, 10 percent should be 10 to 20 years of age, 10 percent should be 20 to 30 years of age, and so on.

COMPARTMENT 1 YEAR : 1974

80	80	70	70	70	70	70	60	60	60
60	60	60	60	60	60	60	60	60	60
60	60	60	60	60	50	50	50	50	50
50	50	50	50	50	50	50	50	50	50
40	40	40	40	40	40	40	40	10	10

Figure 1.—Age distribution of timber stands on sample compartment.

To get this distribution on my sample compartment I will have to regenerate 100 acres of timber on the compartment every 10 years. There's no other way.

One of the key factors that will determine the approach to regulated age-class distribution on my compartment is the distribution now present. And I discover that, unfortunately, the present age-class distribution is nasty; most of the compartment is in middle-aged stands:

Age class (years)	*Percent of area*	*Number of 20-acre stands*
80	4	2
70	10	5
60	36	18
50	30	15
40	16	8
10	4	2

And to make matters even worse, the age classes are not distributed at random but are concentrated in blocks (fig. 1).

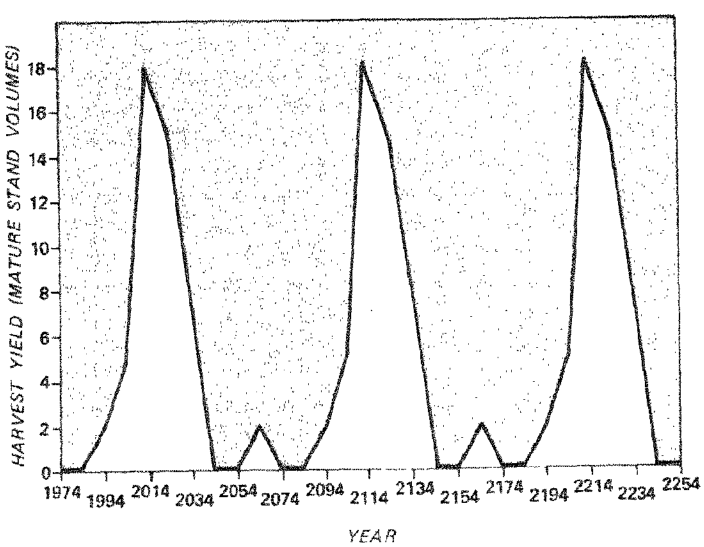
COMPARING YIELDS UNDER DIFFERENT CUTTING SCHEDULES

To compare different cutting schedules later, I need to establish the pattern of yield and the volumes that would be obtained if I didn't try to adjust age-class distribution but simply perpetuated this one, cutting individual stands as they reach maturity (fig. 2). The unit of volume that I used is the harvest yield of one mature 20-acre stand. In other words, when I cut one 100-year-old stand of 20 acres, I get one harvest yield unit.

Since the oldest stand on the sample compartment is 80 years old in 1974, under the system of simply cutting stands as they mature, no stands will be harvested for 20 years. In 1994 two mature stands will be harvested. In 2004 five more stands will mature and will be harvested, and so on. After 90 years, in the year 2064, the entire compartment will have been cut over and will have provided 50 full harvest yields.

Incidentally, this schedule of cutting is the only one that causes no reduction in total yields. Any cutting schedule that changes the present timber age-class distribution on this compartment will reduce total yields over the adjustment period. But it seems obvious that some adjustment is desirable because the yield from just cutting stands as they mature is very uneven. A short period of timber abundance — 2014 to 2034 — will be followed by a long period of timber scarcity — 2044 to

Figure 2.—Yields expected from maintaining present age-class distribution.

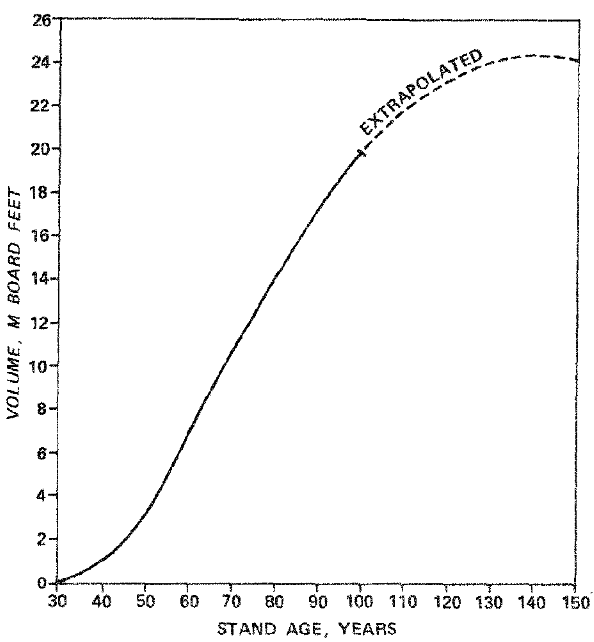


2104. There will be a feast-and-famine cycle, a short feast followed by a long famine. There will be not only a feast-and-famine cycle in timber from this area; there will also be a feast-and-famine cycle for deer as the bulk of the area leaves the brush stage and goes through a long pole-timber stage.

Many different cutting schedules could be devised to eliminate or reduce this feast-and-famine cycle. I will examine four alternative schedules that occurred to me and calculate the loss of yield that will result from each. Then I will add some simple constraints to improve or sustain deer habitat and see how much additional loss these would entail.

To compare wildlife and timber costs later, I need to determine the cost in physical yields that age-class regulation alone will entail on my sample compartment. I have calculated the expected yields for four alternative cutting schedules. For simplicity, and to make clear the basic principles involved, I am using only the final harvest yields to compare results of different cutting schedules. Thinnings can be used to help level out long-term yields,

Figure 3.—Board-foot (Scribner) yield for even-aged oak, site index 70 (adapted from Schnur).



and they provide a powerful tool for helping adjust figurative age-class distributions. But they also add complications that I don't have space to discuss.

My figures are based on Schnur's board-foot Scribner yield table for even-aged oak stands, site index 70 — up to 100 years *(Schnur 1937)*. I had to extrapolate from there to estimate yields for older stands (fig. 3). My extrapolation is guesswork, of course, but the curve looks reasonable; and as long as the same curve is used for all cutting schedules, relative differences should be legitimate.

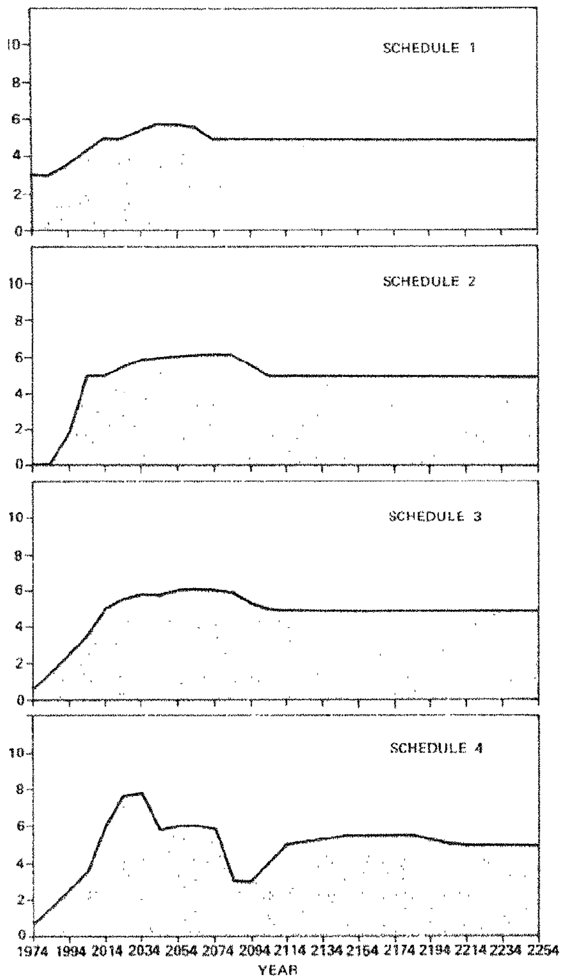
In the yield table I used, mean annual increment peaks between 100 and 110 years of stand age. Thus cutting stands younger than 100 years of age means a loss of production. And carrying stands beyond 110 years of age likewise entails a loss of production. The alternative cutting schedules that I examined all necessitate either cutting some stands early, or carrying some stands past maturity, or both, with corresponding decreases in total yield over the adjustment period. I will consider these losses of yield to be the costs of regulating age-class distribution.

Cutting Schedule No. 1

Once we decide that we need to break up this feast-and-famine cycle of timber yields and deer browse, one of the most obvious courses is to go all out for fully regulated yields as quickly as possible. With a 100-year rotation, a 10-year cutting interval, and 50 stands of 20 acres each in my compartment, I will need to regenerate 5 stands each cutting interval, the first cut taking place immediately. To avoid excessive loss of yield, I'll always cut the oldest stands first. I'll call this system Cutting Schedule No. 1.

Using this cutting schedule in my sample compartment requires cutting 6 stands 30 years before maturity, 9 stands 20 years early, 5 stands 10 years early, 5 stands 10 years late, 10 stands 20 years late, and 3 stands 30 years late. I will have achieved my desired distribution of age classes in only 90 years, and the pattern of yields has been greatly leveled out from the former pattern of feast and famine (fig. 4).

Figure 4.—Projected yields from cutting schedules.



However, Cutting Schedule No. 1 causes a reduction in yield over the 90-year period equivalent to the 100-year harvest from 3.36 stands (fig. 5). This amounts to 6.7 percent of the expected yield for the period. Three-fourths of this loss came from cutting stands before they were mature; the other one-fourth resulted from carrying stands beyond maturity.

Well, 6.7 percent of a rotation yield seems like a high price to pay for early regulation of yields, especially when the major impact hits us in the pocketbook within the next 30 years. And this sacrifice is only in physical quantities; it doesn't take into account the fact that the loss in value will actually be much greater. This is because present stumpage rates give a considerable bonus for large high-grade trees. When we cut stands early, the large high-grade trees are the very ones we're sacrificing. Since we can expect the stumpage differential between large and small timber to persist for the next few decades at least, cutting a stand early now means a much greater loss of value than cutting the stand the same length of time late. So the true loss from Cutting Schedule No. 1 will be relatively even greater than the 6.7 percent loss of physical yield would indicate.

We should expect considerable losses under this sort of schedule. Everyone knows that it's bad practice to cut immature timber.

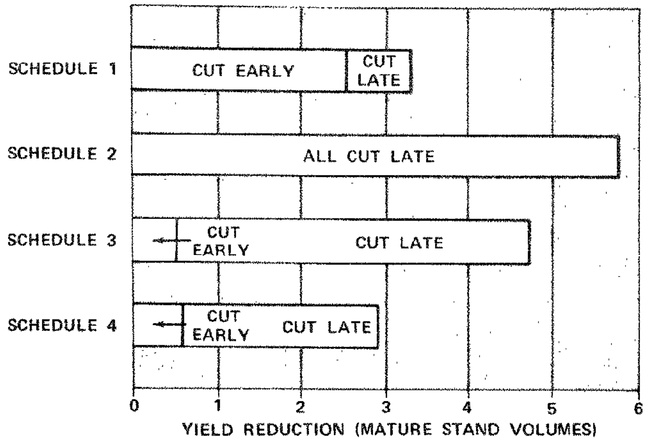
Cutting Schedule No. 2

The large short-term loss from cutting immature timber can be avoided simply by letting stands mature before harvesting them. Cutting Schedule No. 2 is designed to explore this approach. Under this schedule I will still shoot for full regulation, but I will delay starting it until enough stands reach maturity to carry the full cut. I will begin harvesting stands as soon as the first ones reach maturity; and as soon as enough stands reach 100 years of age, I will regenerate 5 stands per cutting interval thereafter. I'll always cut the oldest stands first.

Under Cutting Schedule No. 2, no stands are cut early, but many must be carried beyond maturity; 5 stands are cut 10 years late, 7 stands 20 years late, 10 stands 30 years late, 7 stands 40 years late, 8 stands 50 years late, and 1 stand must be carried until it is 160 years old. It takes 120 years, only 30 years longer than the first alternative, to reach a balanced distribution of age classes; and this schedule provides a bonus 80 to 120 years from now of about 20 percent more timber than would normally be expected (fig. 4).

However, this has been achieved only at a great sacrifice of immediate volume. I get no harvest yields for 20 years. And you may be surprised to learn that, in fact, total loss of yield under this schedule considerably ex-

Figure 5.—Projected loss of yield from cutting schedules.



ceeds the losses under the first alternative. Total loss is equivalent to the harvest volume from 5.8 mature stands, or about 9 percent of the expected yield over 120 years (fig. 5).

At first sight this seems astonishing. How is it possible that the good guys who are only trying to prevent the cutting of immature timber would actually be causing a greater loss of yield than the self-admitted timber beasts?

The reason is that, as stands pass maturity, they add less and less volume. In fact, as they get older and start to deteriorate — and as insects, rot, wind, ice, and drought take their toll — stands will sooner or later start to lose volume. By delaying cutting of an oak stand on my compartment for 60 years past maturity, I estimate that I stand to gain only about 20 percent over the normal harvest volume. In the meantime, I've lost 60 percent of the next rotation. The loss is not just the volume that a 60-year-old stand would contain; it is 60 percent of the final yield of that stand, which is much greater. If you don't believe me, consider what would happen if I carried a stand for 200 years. For a nominal increase in the yield of that one stand, I would have lost an entire rotation yield from another.

The obvious course now is to see if I can find a compromise between the two extremes, and I'll briefly describe two that occurred to me. There may be better ones, but these will do for me until someone comes along with something better.

Cutting Schedule No. 3

Cutting Schedule No. 3 is a one-rotation compromise; it simply splits the difference, so to speak, between the first two schedules. If you recall, under my first alternative I had 4 cuts before I was cutting any mature stands. In that period I had cut 20 stands. Under Cutting Schedule 3, I'll cut just half that many. I'll cut 1 stand in 1974, 2 in 1984, 3 in 1994, 4 in 2004, and thereafter 5 stands per period. As before, I'll cut the oldest stands first.

Under this schedule, it takes 130 years to reach full regulation; and during the last two-thirds of the adjustment period, the yield pattern is very similar to that of Cutting Schedule No. 2: between the years 2054 and 2094 there will be a 20-percent bonus of timber yields (fig. 4). The main difference from No. 2 is that we do get some immediate volumes. Compared to Cutting Schedule No. 1, however, short-term yields are considerably depressed.

The total yield loss under Cutting Schedule No. 3 exceeds the loss under my first alternative by 1.3 stands (fig. 5). However, over the adjustment period, the percentage loss is the same — 6.7 percent. Also, the large early loss associated with the first alternative is greatly reduced; only 11 percent of the total comes from cutting stands before maturity, compared to 75 percent for Schedule 1. The short-term impact is therefore very much less.

Compared to my second alternative, the loss from Cutting Schedule No. 3 is less by a full stand, and Schedule 3 does provide some immediate volume.

Cutting Schedule No. 4

My last alternative—Cutting Schedule No. 4 — starts off like No. 3. During the first 4 cutting intervals, only 10 stands are cut. Then as soon as enough stands reach maturity, I cut more stands than called for—5 more as a matter of fact. Cutting more stands than called for gives increased yields in the middle of the first rotation, which in turn causes decreased yields in the middle of the following rotation. In effect it means spreading the adjustment period over an extra rotation. Under this schedule it will be 230 years before the compartment is fully regulated (fig. 4).

Under Cutting Schedule 4, however, yield losses are the lowest of all — the equivalent of only 2.9 stands or 2.4 percent over the adjustment period (fig. 5). It does cause an up-and-down cycle in the yields that the others don't, and I can't predict how much this might pinch when the time comes. Compared to the other schedules, though, No. 4 holds the impact of both cutting early and cutting late to relatively low levels.

We might note that yields can be increased temporarily under any of these cutting schedules by adopting a shorter rotation. This cannot be done safely, though, unless the next generation stands are constantly thinned and perhaps fertilized from an early age, or unless product specifications and rotation objectives can be changed — for example to grow bulk fiber rather than board feet.

SOME POINTS OF SIGNIFICANCE

Now, here are a few significant points that have emerged from my study thus far.

One is that our hardwood forests are badly unbalanced in the distribution of age classes of timber. This is because of the heavy cutting of timber that took place in the eastern forests from about 1890 to about 1935. Unless we begin exercising more thought toward the regulation of stocking and timber age classes within these forests, we are very likely to saddle the next several generations with recurring cycles of timber feast and timber famine.

We could say that, since the next several generations are bound to be smarter than we are, let them do it. This ignores the fact that we are in a better position to begin this regulation than will occur again for probably another 3 or 4 generations. The bulk of our timber is of an age where it will furnish reasonable volumes per acre, but it is not yet so close to maturity that initiating regulation will result in holding mature timber for long periods. Now is the best time for the adjustment process to begin.

The second key point is that, if the age-class distribution is unbalanced, correcting the distribution will in most cases reduce total yields over the adjustment period. It makes sense to begin looking for the lowest cost alternative.

Third, contrary to popular belief, when age distribution is unbalanced, refusing to cut timber until stands reach maturity is the most costly of all adjustment procedures in terms of lost production.

Finally, at least for those wildlife species that require some diversification of forest structure as their habitat, attaining a balanced distribution of timber age classes on areas as nearly as possible the size of a unit of the species' home range is probably the most important thing timber management can do to help stabilize wildlife populations and habitat and lay the basis for future management. And I propose to show that timber management can afford to do this on small units — in the range of 500 to 5,000 acres — and that the cost of doing so should generally be charged to the cost of regulation per se, and not as a cost of wildlife management.

COSTS OF REGULATING AGE-CLASS DISTRIBUTION

The two basic costs of regulation are the loss of yield resulting from changing the age-class distribution and the out-of-pocket cost of administering the field work. I'll discuss the loss of yield first.

The age-class distribution on my sample compartment was chosen to approximate the typical distribution over a large forest. If the large forest has this distribution and if the whole forest is regulated for sustained yield under any of the cutting schedules I illustrated, the loss of yield over the forest will be the same, percentagewise, as I have shown for the compartment.

There is a major difference between the forest and my compartment, however; and that is the manner in which the age classes are distributed. Over the forest, the age classes are not arranged in contiguous blocks; they are more or less randomly distributed, due to the nature of the early cuttings. It's fairly common to find blocks of several hundred acres of one age or size class. But due to variations in site quality and early cutting history, it's rare to find blocks as large as 1,000 acres that don't display a good deal of variation in stand ages, stand sizes, and stand structure.

On any small unit that has an age — or size-class distribution approaching the average distribution over the forest, the loss of yield from adjusting the distribution will be the same, percentagewise, as for the forest as a whole. In fact, it seems logical to assume that the distribution on the small unit can differ some degree from the forest average without a significant change in the yield loss, but I admit that I don't know how to identify the degree. My point is, though, that where a distribution approaching the forest average occurs on a small unit, why not take advantage of it? There would seem to be a considerable benefit to wildlife in doing so, and doing so would have little or no impact on yields.

It is true that if a small unit contains only one or two age classes, then regulating distribution on the unit would entail greater yield losses than the average. This increased loss would properly be considered a charge against wildlife, but it should be possible in many cases to enlarge the unit somewhat to include a greater range of ages. Another possibility is to use different thinning schedules in some stands of the same age to vary size-class distributions and hence prospective maturity dates.

So I'm not plugging for uniform 1,000-acre regulatory units throughout a forest, with uniform 20-acre stands. I'm saying we should take advantage of the opportunities presented in our present mixed-up forests to deliberately regulate by small units. Some might be as small as a few hundred acres, others might be several thousand acres. The forester and the wildlife manager working together should be able to work out cutting schedules in such a way as to greatly improve opportunities for wildlife management without any significant impact on timber yields.

But how about the administrative costs? Won't the dollar cost of administering the field work be greater for many small units than for one large one? No, they shouldn't.

Present working circles, or working groups, or regulatory units, or sustained-yield units — whatever you want to call them — derive from the time when selection cutting was our gospel. Under selection cutting, *if* we are managing species that will reproduce and grow under the system, and *if* we have a chosen diameter distribution established homogeneously throughout the unit, and *if* we apply selection cutting in such a way as to continuously maintain that diameter distribution, *then and only then*, regulation is automatic and differences between periodic inventories will reveal the amount and sizes of timber that can be cut from the unit in a given period. In our applications of the system we assumed that it didn't make any difference what part of the unit the volume came from because we could balance it out next time, though no one ever explained how a fixed homogeneous diameter distribution could be maintained by a hit-or-miss system of cutting.

Nevertheless, when all those "ifs" were satisfied, and assuming that our assumption was correct, large regulatory units made sense. The larger the unit, the more flexibility it offered, and the lower the administrative costs. For example, sampling intensity for inventory could be lower on large units.

Unfortunately, with the exception of a few research areas, I know of no place in the country where all those "ifs" were satisfied at the same time. In the great majority of cases none of them were.

Conversely, if the species is not adaptable to selection cutting, and if the diameter distribution is constantly changed by cutting or growth, and especially if we're using even-aged management by stands, then the difference between successive inventories is worthless for regulation and nearly always grossly incorrect as a guide to the allowable cut. If it is adhered to, it merely ensures that any feast-and-famine cycles inherent in the present age-class distribution are continually perpetuated.

Well, if the old working-circle/periodic-inventory/cut-by-the-seat-of-the-pants method doesn't work, how can we regulate the cut? It's very simple. Basically, it's the same thing I did in calculating yields on my sample compartment. For any given regulatory unit we build the cut up, stand by stand. We know that in X years, stand A will be mature and will yield so much volume; we know that in X years, stand B will be due for a thinning that will provide so much more volume, and so on. We not only know how much volume will be available in any given year; *we know where that volume will be.* We can calculate how the volumes and the location of those volumes will change if we adjust age-class distribution. And we can explore alternative schemes for adjusting the distribution and compare the relative losses in reduced yield.

The groundwork for this is already laid, because we already use the individual stand as a basic control unit. We examine by stands; we make silvicultural prescriptions by stands; we mark timber by stands; we schedule and control cultural operations and logging operations by stands. It follows that, if we do everything by stands, it doesn't make any difference what sizes of regulatory units we have. The dollar cost of administering the regulation will be the same. The only possible difference I can see is whether it takes the computer longer to add up totals for 5,000 individual stands or by subtotals from 100 units of 50 stands each.

For the above reasons, then, if the age distribution on the regulatory unit is broad enough to make regulation feasible, the cost of adjusting age-class distribution on small units is a cost chargeable to timber management only, not to wildlife.

TIMBER COSTS INCURRED FOR WILDLIFE BENEFIT

Now let's see what kind of costs are chargeable to wildlife, and if possible get some idea of the amounts.

Constraints to Cutting

I want to re-examine Cutting Schedule No. 1. You will recall this was strict regulation, regenerating 5 stands per cutting interval, beginning immediately. After 90 years, the sample compartment will contain all age classes of timber from new regeneration areas to 90-year-old sawtimber. But these units are in 100-acre blocks. In effect I've made stands of 100 acres instead of 20 acres.

If the brushy areas were distributed throughout the compartment in 5 separate 20-acre patches, it would probably be a little more convenient for the deer. And the 100-acre patches are a long way from optimum for grouse habitat.

I don't know what the best compromise is, of course. I think the only thing to do is lock the forester and the wildlife biologist in a small soundproof room until they arrive at a mutually acceptable average stand size for any given regulatory unit. In the meantime I'll stick with my 20 acres. To help ensure good distribution of the 20-acre regeneration areas, I'm going to subdivide my sample compartment mechanically into 5 units, and each cutting interval I'll try to put one regeneration cut into each unit. This is my first wildlife constraint.

The extent to which this can be done successfully will depend greatly on the present distribution of age classes on the compartment. To keep yield losses as low as possible, I want to always cut the oldest stands first, and the location of the older stands within the compartment may be incompatible with spreading the cuts throughout. But I won't know until I try.

Also, to get as much diversity of habitat as possible, I'm going to enter another constraint. I will try to avoid putting a new regeneration area side by side or end by end with one cut 10 years ago. Diagonal is OK, but common boundaries aren't.

Planning Cutting Schedules

The best way that I have found to go about planning these more complicated schedules is to get a number of outline maps of the compartment, with the stand boundaries on them, from the Xerox machine. Then I enter the present stand ages on one of the maps, and pick out the stands for regeneration cutting during the first cut.

Next I take a second map and enter the stand ages as they will be 10 years after the first cut. And I select the stands that will be regenerated during the second cut. And so on.

I can't emphasize too strongly that *this planning process must be carried to completion* — to the end of the adjustment period. And if you'll take any assumed distribution of age classes by stands and try to make out a cutting schedule for it, you'll soon discover why. Everything would go smoothly for several cutting intervals. Then suddenly I'd find myself in a trap where either I had to cut an excessive number of stands early, or let some go for longer than necessary, or violate some wildlife constraints. Then I'd have to back up several cutting intervals and start over.

It is not very professional to put a forester several generations from now into a trap that proper planning and foresight on our part would have avoided. Therefore, I earnestly recommend that you get some compartment outline maps, set up some assumed age-class distribution and start investigating what can happen from incomplete or careless planning of cutting schedules. I think it will prove to be very instructive.

Actually, this process is what a mathematician might refer to as a spatial game. Such games are well adapted to computer solution, and I can foresee the day when this process will be handled by computers. But the average forester will probably not have ready access to a computer for several years yet, and he will be pleased to know that he can do a creditable job with paper and pencil and a couple hours of practice.

This is not to imply that, once adopted, the plans cannot be changed. They can be changed at any time. But each time a change is made, the new plan must again be carried through to the end of the new conversion period. Otherwise there will be no way to calculate the benefits and costs that the changes will entail.

Our inability to calculate the costs and benefits of alternative plans has been a major shortcoming of past planning procedures. A citizen's group may not like the cutting plans we are following and ask why we don't change the system and do thus and so instead.

The question has been difficult to answer satisfactorily because we have been unable to show the impact (or benefit) of the proposed change on production. We have been unable to say whether the change will reduce yields or not, or by how much. A procedure such as I have outlined will permit us to calculate the effect on yields of any changes in cutting policy.

Yield Reductions from Wildlife Constraints

At any rate, I went through this planning process on my sample compartment for each of 4 cutting schedules we went through earlier — but this time with the wildlife constraints that I had imposed. Then I recalculated the yields. Table 1 lists the yield losses with and without the wildlife constraints that I assumed.

The main point to be noted here is that the added cost of constraints that I set up for wildlife benefit is only about 1/4 to 1/3 as large as the cost of attaining age-class regulation per se. Of course, it would be possible to impose additional constraints that might greatly increase this cost. But I have a feeling that just the constraints I imposed here will go a long way toward helping to stabilize wildlife populations and helping to improve the dispositions of wildlife managers.

SOME LOOSE ENDS

One is the question: What if my compartment is not exactly contiguous with a unit of deer range? I don't think it will matter very much. By the end of the first cutting interval, the same procedure should have been initiated in all the surrounding compartments. By 30 or 40 years later, timber age classes should be showing pretty good dispersion on my sample compartment *and on surrounding compartments*. No matter where that deer estab-

Table 1.—Yield reduction on sample compartment from different cutting schedules with and without wildlife constraints

Schedule	Years to regulation	Yield loss	Yield loss	Loss due to wildlife
	Years	*Stands*	*Percent*	*Percent*
NO WILDLIFE CONSTRAINTS				
Schedule 1: Immediate regulation	90	3.36	6.7	—
Schedule 2: Delayed regulation	120	5.80	8.9	—
Schedule 3: Partially delayed	130	4.70	6.7	—
Schedule 4: Partially delayed, extra rotation	230	2.90	2.4	—
WITH WILDLIFE CONSTRAINTS				
Schedule 1: Immediate regulation	100	4.55	8.3	1.6
Schedule 2: Delayed regulation	130	8.23	11.8	2.9
Schedule 3: Partially delayed	130	5.98	8.5	1.8
Schedule 4: Partially delayed, extra rotation	230	3.86	3.2	0.8

lishes his home range, the area should display about the same pattern of timber age classes as the unit that I initially assumed as the home range.

Another question is, How to handle differences in timber type and site quality within a compartment? I don't have time to go through the procedure I used, but briefly it consists of making stand boundaries conform to site-class boundaries, selecting appropriate rotation lengths for each site class or type-class, deciding on the age-class distribution desired in each site class when it is completely regulated, and then developing cutting schedules for each class as though it were a separate small compartment.

By plotting the planned regeneration cuts for each site class simultaneously on the same compartment map, adjustments in cutting schedules can be made as necessary to disperse cuts throughout the whole compartment.

Another question is how to handle unique or spatially recurring situations now included in timber compartments but that are not amenable to redistribution as timber age classes are. I refer to such things as spring seeds for turkeys, patches of aspen in an oak or northern hardwood type, or deer yards in the northern latitudes.

If such things are more closely related to the geology than to the timber type — spring seeps, for example, I think they and any necessary buffer zones should be excluded from the timber-management compartment, or at least excluded from the area regulated for timber production just as a picnic area would be. If they are more closely associated with the timber, they can be set up as a separate type or site class, with more specific wildlife constraints assigned, and managed accordingly.

CONCLUSIONS

1. Providing relatively uniform yields of hardwood timber for future generations will require adjustment of timber age-class distributions for sustained yield. For most forest types I see no alternative.

2. Because of heavy timber cutting around the turn of the century, the bulk of our hardwood timber is now approaching maturity. Thus our generation is in a more favorable position to begin the adjustment than will

occur again for a whole hardwood timber rotation.

3. The regulation of timber age classes must be carried out deliberately but with careful foresight and timing. Pushing immediately for full regulation will cause a severe loss of timber values in the short-term future. Delaying initiation of regulation until present stands reach maturity will severely restrict short-term yields and cause large losses in total yield. Compromise alternatives are needed, based on relative costs involved.

4. Avoiding up-and-down cycles in wildlife populations necessitates continuously providing any diversity of habitat required by the wildlife species within the species' home range. Thus optimum yields of wildlife will require adjusting and regulating timber age classes by much smaller units of land than is needed for sustained yield of timber alone.

5. Regulatory methods and allowable cut determinations carried over from the practice of selection cutting are inapplicable and, with unbalanced age distributions, grossly inaccurate when grafted onto even-aged management. The proper method for even-aged management is the summation of individual stand volumes in conjunction with scrutiny of various possible cutting schedules. When this is done, the size of area regulated is unimportant from the standpoint of reduced timber yields — if the distribution of age classes on the small unit is not greatly different from the average distribution throughout the forest. If the small unit contains only one or two age classes, then regulation on the small unit can entail increased loss of yield in the initial rotation. In such circumstances the extra loss of yield is properly considered a charge against wildlife, or the regulatory unit should be enlarged to include a greater range of age classes.

The administrative cost of regulating age-class distribution should be about the same regardless of the size of the regulatory unit, if average stand size is not made too small for efficient operation.

6. Constraints for wildlife benefit such as deliberate dispersal of cuts will further increase cost of regulation, but this cost does not seem serious. Additional constraints may be more costly, but it is time for wildlife managers to present them for consideration in such a way that they can be quantified and scheduled. With my limited knowledge of wildlife needs, I can only guess at the type of constraints needed. I am saying to wildlife managers, the measures that I have outlined form a matrix within which I believe timber management can operate. What more do you need and how can we work it in?

I might note that we in timber management would appreciate it if you can arrange to monitor changes in wildlife populations as a result of changes in timber and habitat practices. Opinions are poor substitutes for hard data.

7. The key to successful regulation of timber age classes for combined timber and wildlife production with minimum impact on costs and total yields is the long-term planning of cutting schedules by small units of land. Such planning has been lacking in the past. Without such planning we have been unable to quantify and compare the benefits and costs of alternative approaches. We have expected the public simply to take the forester's word that he knew best, that he knew what he was doing, and that he had made adequate provision for forest uses other than timber production. And as you know, nowadays nobody takes anybody's word for anything.

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