LESSON 8 Forest Pathology in the Context of Forest Management

LESSON OVERVIEW

Content

In this lesson we will extend some of the concepts that have been covered in this course by considering them in the context of silviculture and forest management. The relevance of forest tree diseases to various kinds of forestry issues will be emphasized. A large section of this lesson will be devoted to the assessment of disease losses.

The content of this lesson is discussed under the following topics:
- Disease losses and the purpose of management
- Estimation of disease-caused losses
- Stands vs. forests
- Concluding remarks

Objectives

At the conclusion of this lesson, you should be better able to relate what you have learned earlier in this course about trees and diseases to broader issues in forestry. You will also develop a greater appreciation for the complexity of assessing forestry losses due to diseases.

Reading

Study the material in the commentary that follows.

Lesson Study Instructions and Assignment

As you read the material, try to relate it to your knowledge of forest biology and management. Unless your understanding of diseases is well integrated with all the other things you know about forests, you will find it difficult to translate your knowledge into appropriate practice.

Answer the self-testing/review questions, then complete Assignment #3 (in Appendix A), which deals with the content of Lessons 5, 6, 7 and 8, and submit it to your tutor for marking. Check the course schedule for the deadline.

COMMENTARY

Disease Losses and the Purpose of Managment

Most of the diseases that you have studied in this course are native diseases that have always been part of natural forest ecosystems, and that sometimes play critical roles in such ecosystems. For instance, life on Earth as we know it would soon come to a halt without the recycling of carbon tied up in wood back to the atmosphere by decay fungi. Or, to take another example, the diversity of stand types resulting from the action of various root diseases may well be critical in maintaining essential habitat for various organisms that in turn play a major role in the stability of forest ecosystems.

Why then are diseases usually considered to be damaging? The answer, I think, is that "damage" has meaning only in the context of some human goal or purpose. If the purpose of management of a particular tract of forest is to produce wood, or to provide forage, or to provide water, or some combination of such purposes, then diseases will sometimes frustrate that purpose. Diseases don't destroy the forest, but they may lead to a type of forest that isn't very suitable for the particular purpose we have in mind.

Another, and important way in which diseases can be damaging, occurs when we alter the natural forest in order to achieve some purpose, usually by silvicultural means such as particular harvesting systems, planting, spacing, fertilization, use of species that wouldn't occur naturally, and so on. Such actions may upset the natural balances and result in disease development to levels that would not occur in natural forests. A good example would be rapid regeneration by the planting of conifers following harvesting, a practice which favours the survival and spread of several root diseases. Natural regeneration patterns with long regeneration periods and mixtures of species allow a large part of the root disease inoculum in stumps to die off before a new crop is infected. I'm not arguing that planting should be abolished, but I am saying that at times and in certain places, it can have detrimental effects.

Estimation of Disease-Caused Losses

Incidence, Severity and Intensity

A central and difficult issue is the measurement of damage. It is usually fairly easy to obtain a measure of the amount of disease. Two terms are commonly used in this regard: **incidence** is the frequency of occurrence of a disease, measured as the proportion or percentage of plants or plant parts infected; and **severity** is a measure of the amount of disease on these infected plants. Thus the incidence of white pine blister rust in a white pine plantation might be 70%, meaning that 70% of the trees are infected, and the severity could be 3.2 infections per tree, meaning that infected trees have, on average, 3.2 infections each. (Sometimes it is more appropriate to express severity as the average number of infections per tree for all trees rather than just the infected trees.) Obviously, in most situations, incidence and severity are related. As the proportion of infected plants increases, the number of infections per diseased individual also increases. That need not always be the case, however. If, for instance, part of a host population carries a major gene for resistance that imparts virtual immunity to a disease, then, once the susceptible plants have been infected, the incidence will not increase any further, but the severity may continue to increase. The product of incidence and severity (both as proportions), is sometimes called **disease intensity**, and is usually related most closely to the amount of damage incurred.

Spatial Distribution

The spatial distribution of infection may be important, especially if one is speaking of young stands. If, for instance, 20% of the trees at age 10 are infected by a lethal disease, but such trees are randomly distributed throughout the stand, then (assuming no further spread beyond that age) the disease can sometimes be regarded as a natural thinning agent, and the effect on volume production may be positive. For example, western gall rust often behaves in this fashion. Lethal stem infections occur mainly during the first fifteen to twenty years, and such infections are usually randomly distributed in lodgepole pine stands (and such stands are commonly rather dense). If, on the other hand, the infected trees are clumped, as is the case with root diseases, then close to 20% of the area is rendered non-productive, (and if the original stand had too high a stocking level, that stocking level is retained in the uninfected portions of the stand). In such a case, the loss in volume at maturity may be close to the incidence of the disease at an early age. Thus in addition to incidence and severity, one would also want to know about the spatial distribution of a disease.

Disease Intensity and Volume Losses

Another consideration relates to the relationship between disease intensity and volume loss (accepting for the moment that the main purpose of management for the stand under consideration is wood volume production). Take, for instance, the case of a foliage disease such as Douglas-fir needle cast caused by *Rhabdocline pseudotsugae.* Needles are infected immediately after they emerge from the bud, but remain green and symptomless for about 11 months. Then sections of the needle turn red-brown, the fungus reproduces on the needle, and infected needles are shed. What is the impact (the loss in volume increment) if 50% of the needles are infected each year? Clearly, there are several aspects to this question. Infection probably results in increased rates of metabolism in the infected (but symptomless) needles. That increase may or may not be offset by compensatory increases in photosynthesis in either diseased or healthy needles, or, perhaps, the presence of the pathogen may lead to decreased rates of photosynthesis. Furthermore, how serious is the loss of older needles? Certainly, the current year's needles are the most efficient at photosynthesis, but the degree is not known precisely. A disease incidence of 50% of needles infected does not necessarily result in a 50% reduction in increment. The losses might be considerably greater, or considerably less. Studies that have related disease intensity in forests to productivity, usually as current annual increment (CAI), are few, and many of them are based on questionable assumptions.

Closely related to the above is the issue of tolerance. We have seen that losses due to a foliage disease are probably the result of the overall net decrease in photosynthate production. The extent of that reduction depends on the interplay of many processes at the physiological level. All individuals in a population do not exhibit the same reduction in photosynthate in response to the same disease intensity. Tolerant individuals exhibit a smaller loss per unit of disease intensity than intolerant ones. Disease tolerance is a valuable, genetically-determined trait that can be selected for, parallel to disease resistance. In fact, variation in tolerance may be as important as variation in resistance.

There is a fourth aspect to the estimation of losses from measures of incidence and severity, and that is the time dimension. Losses occur because, *at the time of harvest,* the expected volume (and/or quality) isn't there. Losses in stand volume at an early age are of concern only if they result in a reduced final volume. Hence we need to know how a disease intensity that fluctuates over time will affect final volume. This introduces a further set of uncertainties that are best demonstrated by considering how one might measure losses.

The basic experimental approach to measure losses would be to compare the growth of diseased trees with that of healthy controls. Obviously, the controls should be exposed to the same environment as the diseased trees. One way to achieve this is to compare the volume (or increment) of healthy and diseased trees growing side by side in the same stand. Alternatively, one might set out to describe the relationship between disease severity and volume increment, because trees growing together in the same stand, and thus presumably exposed to the same environment, usually show variable amounts of disease, rather than being either healthy or diseased to a particular severity. The relationship between disease severity and volume production for a particular individual or clone is, of course, a measure of the tolerance of that clone. When one tries to determine that relationship for a population of trees, variation in tolerance will be a source of error that we must accept.

The central difficulty in an experiment of the sort described here is that trees in a stand are in competition with each other. Severely diseased trees will be poor competitors. Compared to healthy trees, their root systems won't have as much energy supply and their ability to absorb their share of nutrients and water will be reduced. That share will be available to the healthy trees. Furthermore, as time passes, diseased trees increasingly will occupy inferior crown positions. The result is that the healthy trees in the stand use a disproportionately large part of the available nutrients, water supply and light. The healthy trees grow faster than they would if all trees in the stand were healthy and competing on even terms for space, nutrients and water. The difference in volume (or increment) between healthy and diseased trees (or the slope of the relationship between disease severity and volume increment) is the result of both the direct effect of the disease and the effect of increment transfer from diseased to healthy trees. Another way of stating this is that the decrease in volume production per hectare (usually as CAI) is less than the average difference in increment between healthy and diseased trees multiplied by the number of diseased trees.

The effects of disease on competition are shown in Figure 8.1. The height of trees in (A) represents average tree volume on the site if all trees were healthy. In (B), some of the trees are diseased, others are healthy. (Remember, tree height represents average tree volume.) The healthy trees in (B) are larger than those in (A) because they experience less competition from their diseased neighbours than the healthy trees in (A) from their healthy neighbours. In (C) all trees are diseased. Here the effect of unequal competition is removed, and as you might expect, the diseased trees in (C) are larger than the diseased trees in (B). Figure 8.1 demonstrates that if we estimate the losses due to disease as the difference between healthy and diseased trees as shown in (B), then we will be overestimating the effect of disease considerably.

The above analysis serves to remind us that the parameter of interest is volume per hectare, rather than tree volume. The effect of disease should be estimated by comparing the productivity of healthy and diseased stands rather than comparing healthy and diseased trees within stands. That approach, however, raises another difficulty. The stands to be compared should be the same in all respects except for the presence of the disease. Two aspects are important: the stands should have the same history of establishment and pattern of stocking over time; and they should be on sites of the same productivity. The former is often difficult to achieve, and the latter difficult to measure.

Let us consider stand productivity first. One of the best measures of productivity is site index that is estimated from height-over-age curves. If the disease affects height growth, then the site index of diseased stands will be underestimated. In fact, we need to know the very thing we are trying to determine, namely the decrease in productivity caused by disease, before we can select appropriate stands to make that determination! An alternative method is to use ecological approaches to estimate site productivity. Such methods are less precise, and may also be confounded by the presence of a disease. For instance, if disease results in a less dense canopy, or in reduced water or nutrient uptake, understory vegetation in the diseased stand may be much richer than in healthy stands.

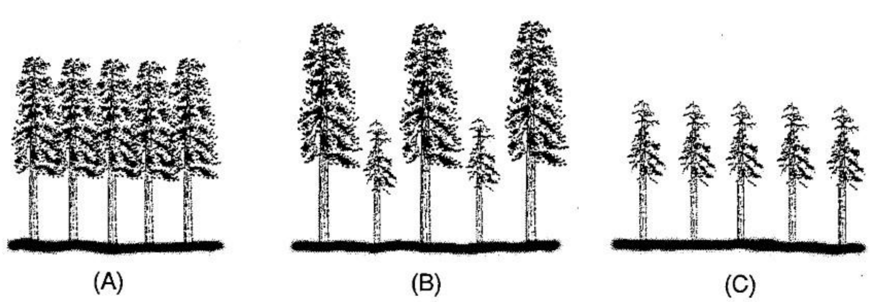

FIGURE 8.1
Simplified illustration of the relative size of trees in stands that are (A) all healthy, (B) mixed healthy and diseased, and (C) all diseased.

The requirement for a similar stand history also introduces uncertainties. Take, for instance, the case of lodgepole pine dwarf mistletoes. Infected stands have usually originated after a disturbance (e.g., cool fires, or a mountain pine beetle epidemic) that has removed most but not all trees in the previous stand, and that has left the forest floor largely undisturbed. Neighbouring healthy stands will be healthy because the same disturbance has been more severe (e.g., a hot fire) removing all trees and a large part of the forest floor. The effect of stand history on volume production is often hopelessly confounded with the effect of the disease.

In conclusion, estimation of losses caused by diseases is a very tricky process. The best approach would be to start with young, healthy stands that can be shown to be identical in site productivity and stand history, and to introduce the disease artificially into some of these. Usually a considerable amount of time must elapse before a valid assessment of the effect of disease can be made. Studies of this sort are very rare for forest diseases. In the meantime, you should be aware that most published figures on disease loss are based on questionable methods, and in fact are mostly best guesses rather than factually based estimates. Furthermore, such estimates are usually made by the very people whose status and jobs depend on diseases being serious. I'm afraid that this has on occasion resulted in rather generous estimates of losses.

Now that you have been properly forewarned, it is time to look at Table 8.1 (adapted from Woods and Van Sickle, 1994, B.C. Ministry of Forestry Publication BC-X-354) which lists estimates of annual losses to various insects and broad groups of diseases. Notice first that the single largest loss, amounting to about half of all pest-caused losses, is attributed to butt and heart rots. Most of this loss accrues in old declining stands, and little can be done about it other than appropriate scheduling of harvests. As such old stands are harvested, the loss associated with decay will decline. At the same time, however, losses to root diseases will increase unless strong remedial action is taken. Much of the decay listed under butt rots is in fact caused by root disease pathogens acting as butt-rots in these very old stands. Losses due to

TABLE 8.1
Annual mortality and growth loss from forest pests in British Columbia, 1988–1992.

Pest	Mortality	Growth Loss	Total	
			volume	percent
Mountain pine beetle	2,055	0	2,055	7.7
Other bark beetles	1,031	0	1,031	3.8
Conifer defoliators	1,671	969	2,640	9.8
Hardwood defoliators	0	162	162	0.6
Subtotal Insects:	4,757	1,131	5,888	21.9
Butt and heart rots	0	13,680	13,680	51.0
Dwarf mistletoes	0	1,797	1,797	6.7
Root rots	4,128	1,350	5,478	20.4
Subtotal Pathogens:	4,128	16,827	20,955	78.1
Total:	**8,885**	**17,958**	**26,843**	**100.0**

dwarf mistletoe could in theory be eliminated in one rotation. However, the large clearcuts required to do so are no longer acceptable, and various constraints on practice for good biological and social reasons mean that dwarf mistletoe losses will be with us for a long time.

STANDS VS. FORESTS

You are probably familiar with the expression, "You can't see the forest for the trees." A similar expression can sometimes apply to foresters: "You can't see the whole forest for the stands." Silviculture, including disease management, is typically focused on stands. In the case of forests managed primarily for wood harvest, the aim is to increase stand productivity to a maximum. However, we need to remember that the management unit is a *forest* consisting of *many stands,* and that the aim should be to optimize the wood flow of wood and other resources from the *forest.* Optimizing the productivity of an individual stand does not necessarily lead to that goal.

A common problem in many management units (e.g., a timber supply area, or TSA) is one of age-class distribution. In many TSAs there is an area of operable mature timber that will support the allowable cut for perhaps one or two decades, while the remainder of the area is occupied by young, well stocked, vigorous stands that won't reach maturity for another forty or more years. Older immature stands are often rare. This age-class gap presents a major management problem. In order to sustain communities one needs a steady supply of wood. Yet in many TSAs, that will be difficult to achieve. In such TSAs one can identify a period early in the next century during which it will be difficult to maintain the harvest at rates close to the long run sustainable yield. It is clear that in such management units a prime purpose of silviculture is to bring some of the younger immature stands to a harvestable size as quickly as possible. Juvenile spacing and fertilization are the common techniques.

If you now think back to the various ways in which we can deal with tree diseases, you will realize that almost always they involve something that must be done at the time of harvest and stand renewal. Take for instance the two most damaging groups of diseases, the dwarf mistletoes and the root rots. For dwarf mistletoe, the approach is eradication at harvest or a switch to resistant species. Little can be done to affect the course of the disease in immature, infected stands. Similarly, for the root rots, control is achieved at harvest by stump removal or a switch to resistant species. Again, treatment of immature stands is not economically feasible. Thus the opportunities to increase stand productivity through disease management do not usually come at a stage of stand development that will allow the manager to use them to solve the looming age-class problem.

Another example of the way in which the structure of the whole forest affects decisions about individual stands is provided by young, mistletoe-infected stands. Often it can be shown that the overall yield of a piece of land will be greater if infected stands are destroyed and replaced with healthy stands than if such stands are maintained until they reach a harvestable size. If the decision is based on the goal of maximizing *stand* productivity, the answer is clear — destroy the stand and start again. An implication of that decision, however, is a change in the pattern in which wood becomes available from the forest over time. That change can sometimes be very detrimental.

The conclusions from this section are clear. Decisions about individual stands can be made only in the context of the whole forest and the purpose of management of that forest. This approach, however, seems to be very difficult to apply. Very often, the people who are required to make decisions about stands do not know the status of the whole forest, resulting inevitably in poor decisions.

It has been argued throughout this course that forest pathology is a subset of silviculture; that techniques and approaches to limit the impact of diseases should be seen as silvicultural techniques, competing with other silvicultural opportunities for a limited budget. In this section that argument has been extended by examining the context in which all silvicultural decisions must be made. It is not until that context is understood and appreciated that the correct decisions for the treatment of forest tree diseases can be made.

Concluding Remarks

Now that you have nearly completed this first course in forest pathology, it is worthwhile to consider again the objectives that were set out at the beginning. The emphasis throughout has been to give you enough information to allow you to consider forest tree diseases in decisions concerning the forest. Throughout there has been a practical slant. There is a large body of scientific knowledge in plant pathology that has been skimmed over very lightly, and there is a great deal more to learn. Almost nothing has been said, for instance, about the use and mode of action of fungicides, mostly because the use of fungicides can seldom be justified in forests in the light of ecological, economic, and social considerations. Nothing has been said about the physiology of diseased tissues, and the large body of information about the delicate biochemical interactions of pathogens and hosts. The reason is that foresters must necessarily base their decisions on an understanding at the ecological level, and need not, and indeed cannot, know all the physiological and biochemical processes that give rise to ecological phenomena.

You will all be aware that the Forest Practices Code contains requirements and guidelines for disease management. Many of you may wonder why there have been no references to that code in this course. There are two main reasons. First, administrative devices such as codes and guidelines come and go over very short time intervals; they are also specific to particular administrative regions (in this case B.C. or certain Forest Regions within B.C.). Wherever you find employment you will have to become familiar with the local administrative procedures, and such procedures are constantly revised. So learning about a particular code at a particular time doesn't prepare you for a lifetime of work — at best, it prepares you for your first job.

The second and more important reason for omitting any reference to the Forest Practices Code is that, in the view of the course author, the Code is a step backwards in forest practice. The Code, with its regulations and guidelines, attempts to define acceptable practice. But it will inevitably fail to do so, because it cannot possibly take into account all the factors and considerations that must enter into a prescription for a specific situation. Each ecosystem and each stand is unique — there are no two stands anywhere in the world that are identical in all respects and that therefore can be adequately dealt with by a common set of prescriptions. In every particular situation there will be a number of critical factors which must be taken into account in a prescription, but the set of these will differ from site to site. Competent professionals with local experience are much better at identifying such factors than any general checklist could possibly do. So, simply meeting Code requirements (and no more) usually means a sub-optimal prescription. Most professionals will agree with this, and many try to go beyond the code, or try to ignore parts of the code that are irrelevant to the local situation. However, the administrative burden of the code, and particularly the extra work involved in obtaining relief from inappropriate provisions, greatly reduces the ability of professionals to do their work efficiently. For these reasons, reasons which would require a book to set out in full, I believe that the Forest Practices Code as it is currently formulated, is a step backwards that will result in a level of practice much lower than would be possible with current staffing and economic resources. Training of professionals should be directed at two goals, namely to achieve an understanding of (1) the function and response of ecosystems, and (2) the way society functions, so that the forester's special technical knowledge can be put to appropriate use. Most of this course is aimed at the first of these, in the expectation that better understanding will lead to better practice.

The first objective of the course was that you should be able to recognize and identify the common and damaging diseases of Pacific coast forests. Apart from the large number of decay fungi, about a dozen or so species of pathogens are responsible for most of the losses, and these have all been discussed and described in detail.

The second objective was that you should be able to interpret disease signs and symptoms of forest and shade trees around the world. You should now know enough about tree diseases that you can recognize the presence of a disease in trees or stands, and that you can make a pretty good guess about the type of disease you are dealing with, particularly in coniferous stands. The details will of course vary from place to place, and if you are going to work in places other than the Pacific Northwest, you will need further study to become familiar with the locally important diseases. That is even true within the Pacific Northwest; some diseases are of great importance in certain specific localities, but minor when considering the whole area, and not all such diseases have been covered. This course is only the start of a lifetime of learning about the forest.

The final objective was that you should know enough about the common diseases of the North American Pacific coast forests to deal with them effectively by appropriate silvicultural prescriptions. You will now recognize that this final objective has been the main guide in the selection of material studied.

Good luck!

SECTION ASSIGNMENT

SELF-TESTING/REVIEW QUESTIONS

Test your understanding of the material in this section by attempting to answer these questions. Do not proceed to the next lesson until you are satisfied with your proficiency in this section.

Do *not* send your answers to the tutor for marking. If you continue to have difficulty with a question after you review the relevant material, you may wish to discuss it with your tutor.

After you answer the questions in this part, proceed to Appendix A and complete Assignment #3 for submission to your tutor for marking.

1. For a particular forest type in your area, list three possible purposes of management, and describe and explain which of the common tree diseases in that area might be of concern for each of these, and which are neutral or beneficial.
2. What is meant by *disease incidence, severity, intensity,* and *tolerance*?
3. Why is the spatial distribution of a disease an important consideration in addition to disease incidence, severity and intensity?
4. What is the main confounding effect when tree disease losses are estimated from a comparison of the growth of infected and healthy trees growing together within a stand?
5. What is the main difficulty in experimental design when tree disease losses are estimated from a comparison between healthy and diseased stands?
6. Explain, giving local examples, why decisions about disease management in individual stands must be placed in the context of the purpose of management of the whole forest.