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THE ROLE OF INSECTS IN THE CONSUMER-DECOMPOSER INTERFACE OF DOUGLAS-FIR

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INTRODUCTION

During the 1972 field season, intensive investigations of the role of insect fauna, especially scolytid beetles, in the consumer-decomposer interface of Douglas-fir, Pseudotsuga menziesii var. menziesii (Mirb.) Franco were conducted. Scolytid beetles are important components of the interface for two reasons: (1) at least one species of beetle, Dendroctonus pseudotsugae Hopkins, has the ability to kill apparently healthy trees, and (2) all species possess the ability to condition the dead or dying host for invasion by decomposer organisms, either directly through the dispersal and transport of fungal spores or indirectly through the creation of entry ports for fungi in the outer bark and sapwood.

All of the 1972 studies were conducted in the city of Seattle watershed near Cedar Falls, Washington, in second-growth Douglas-fir stands. The investigations concentrated on the role of insects in down or recently felled material. This period in the consumer-decomposer continuum was selected because it provided a wealth of information for later decisions on the direction for future work, i.e., whether to concentrate effort on trees in the process of being killed, or on trees in the latter stages of decomposition. Preliminary results indicate that studies of dying trees may be most fruitful.

Briefly, the studies included the classification and role of the insect fauna of freshly felled Douglas-fir; host selection behavior of scolytid beetles; attack characteristics of the Douglas-fir beetle; and preliminary investigation of the tree-killing phase of insects, in particular, factors affecting the host selection of living trees by the Douglas-fir beetle. More detailed accounts of each study are included in the following section.

INSECTS ASSOCIATED WITH FRESHLY FALLEN DOUGLAS-FIR

In order to fully investigate the role of insects in the Douglas-fir consumer-decomposer interface, both the kinds and numbers of organisms associated with the host tree at any given time must be known. The time continuum includes everything from healthy standing trees, to freshly fallen trees, to trees in the late stages of decomposition. The freshly fallen tree, the intermediate stage between the live tree and the late stages of decomposition, is the logical choice for initial assessment of the role of insects in the consumer-decomposer interface.

In order to systematically assess the insect fauna associated with this stage, trees were serially felled from April through August in shaded and unshaded environments, and after colonization by the resident insect fauna, collections were made. The identities of the organisms in these collections are now being catalogued. They include many species reported for the first time as associated with Douglas-fir or, in some cases, any tree, and possibly a few previously unidentified species. The insect fauna may be broadly classified as phloem feeders (at least 18 species), heartwood and sapwood feeders (a minimum of 18 species), fungus feeders (22 species), and parasites and predators (46 or more species).

The complete species lists of insects associated with recently fallen Douglas-fir will be published in future internal reports and elsewhere. These will include a summary of all known biological information, compiled from field observations and published accounts, for each species. Clearly there are differing degrees of known facts for different species, thus it will not be possible to present a complete explanation on the roles of all species within the insect community of fallen Douglas-fir.

In addition to the discussion of each species, brief commentaries on many of the higher taxa give distinguishing characteristics of Douglas-fir inhabiting group; they emphasize species diversity or continuity, and they describe characteristics of species which relate to niche distribution as found in Douglas-fir. Included will be illustrations of most of the species taken from Douglas-fir; these illustrations will replace lengthy morphological descriptions which would require a highly technical vocabulary.

THE ANALYSIS OF THE ATTACK DISTRIBUTION OF AN ENDEMIC DOUGLAS-FIR BEETLE POPULATION

The Douglas-fir beetle, Dendroctonus pseudotsugae Hopkins, is an important element in the consumer-decomposer interface of Douglas-fir. It is one of a few forest insects with the ability to kill apparently healthy trees and thus serve as a control function. Although the beetle has tree-killing potential, it normally confines its attacks to down material.

Important factors in the host-conditioning ability of the beetle (e.g., for the entry of decomposer organisms) are the density and pattern of attack. Theoretically a large number of regularly spaced attacks may be most effective in host conditioning. In order to assess these important parameters, and secondarily to develop a sampling technique, the distribution and pattern of attacks were studied in 15 felled, naturally infested Douglas-fir. Additionally, the effects of certain selected factors on beetle density and attack response were investigated. A summary of the pertinent results follows.

1) The distribution of D. pseudotsugae attack did not vary significantly with tree height, but did vary significantly by stem circumferential position. The lowest attack density was on the upper bole, and the highest on one side, with intermediate densities on the opposite side and the bottom of the log.

2) A sampling technique for estimating the mean density of attack within the infested portion of trees was developed. The number of trees and the number of samples within each tree needed to estimate the mean density of attack with a standard error of ten percent of the mean were calculated. The optimal quadrat size for the within-tree samples was shown to be between 464 and 929 cm^2.

3) The attack spatial pattern was shown to be regular. Empirical arguments were advanced which indicated the uniform spacing of attacks was the result of a beetle-controlled spacing mechanism dependent on the production of the pheromone 3-methyl-2-cyclohexen-1-one (MCH-one).

4) Tests of selected treatments in the field showed that virgin females in bolts, screened in such a way that the closest another beetle could approach in any direction was 1.27 cm, were more successful in eliciting attack responses than any other treatment.

5) Field tests also showed that beetles preferred to attack trees with the rough bark textures as smooth bark trees were less heavily infested.

More detailed accounts of the methodology and results can be found in two internal reports by R. L. Hedden and R. I. Gara now in press.

HOST SELECTION BEHAVIOR OF THE DOUGLAS-FIR BEETLE

Dendroctonus pseudotsugae Hopk. through its complex host selection behavior is able to select Douglas-fir trees for colonization. During the dispersal phase of host selection the beetles disperse and locate host material in response to host volatiles. Soon after the location of host material the already feeding beetles begin to produce pheromones. These pheromones trigger the aggregation of large numbers of Douglas-fir beetles to the allocated host.

Recently, researchers have suspected differences within populations of Douglas-fir beetles. There may well be early emerging pioneer beetles that are capable of selecting the weakened host necessary for colonization. These beetles then produce pheromones that in combination with host volatiles may serve to guide the remaining population to the selected host. The late emerging adults, on the other hand, may possibly respond to the pheromone-host volatile complex.

During the early portion of the field season investigations were initiated to outline the mechanisms of D. pseudotsugae host selection. Hardware cloth (1.2 cm mesh), circular, barrier traps were used to deploy candidate test volatiles and trap the responding beetles. Of special interest were the beetle responses to Frontalin, an aggregation pheromone, and 3-methyl-2 cyclohexen -1-one, an antiattractant (pheromone), and combinations of monoterpenes with Frontalin. While studying the response of beetles to baited barrier traps we found that D. pseudotsugae preferred to land on shaded traps of a horizontal configuration.

Later, other studies were conducted on the host-selection mechanisms of early and late emerging adults. These field studies were conducted inside a cheese cloth cubical (6m by 6m by 4.5m in height). In this flight arena early and late emerging beetles were flown in the presence of host and insect volatiles. The early emergers oriented their flight toward host volatiles and ethyl alcohol. In contrast, the late emerging adults oriented their flight toward the pheromone, Frontalin, in combination with host volatiles.

Another study starting in June was designed to test the relationship of aged vs. fresh host material to in-flight scolytids. Accordingly, bolts of differing degrees of aging were placed inside olfactometers. Few D. pseudotsugae were caught, but interesting results were obtained concerning another scolytid, an ambrosia beetle, Gnathotrichus sp. During June, July, and early August, Gnathotrichus preferred the most aged bolt sections. However, from middle August through September Gnathotrichus landed in the greatest numbers on trapping devices containing the freshest material.

An in-depth study on the correlation of pressure of moisture stress (PMS) and the ability of D. pseudotsugae to colonize selected trees was conducted on two sites with differing soil types. One soil was shallow with a solid rock base 25 cm below the soil surface. The other site consisted of a sandy-loam soil with no rocky floor above 180 cm below the soil surface. PMS measurements were taken simultaneously at both sites on a total of 14 large-diameter Douglas-fir trees to characterize them according to their water stress. Three other trees were monitored at three-week intervals in the same areas for seasonal and diurnal variations.

During the moisture stress study the trees were baited with a chemical combination known to be attractive to D. pseudotsugae. The results of this study demonstrated that trees with large PMS measurements were attacked by the greatest numbers of beetles. In contrast, trees with low PMS readings were not attacked. Trees were felled after being infested and the attack densities and successes were recorded at regular intervals on the bole of the tree. In all cases the infested trees proved capable of overcoming the beetle attacks by filling the egg galleries with resin and destroying the beetle broods.

A manuscript covering this material is now in preparation. This material will be submitted in greater detail as an internal report.

HOST-SELECTION BEHAVIOR OF *SCOLYTIDAE*

Field studies during 1972 were performed to elucidate the host-selection behavior of bark beetle species associated with felled Douglas-fir.

Douglas-fir billets, approximately two feet long and ranging in diameter from six to eleven inches, were placed in latin square configurations at two locations in the Cedar River Watershed. Each latin square configuration consisted of the following treatments: 1) freshly cut Douglas-fir billets, 2) freshly cut Douglas-fir billets in the presence of 95% ethyl alcohol, 3) Douglas-fir billets previously soaked in water for at least 72 hours, and 4) Douglas-fir billets infected with a sympatric bark beetle, *Pseudohylesinus nebulosus* Lec. The various treatments within the latin squares were changed at three- to four-week intervals to prevent positional effects. All billets of one latin square were covered with a fine-mesh screen to prevent responding beetles from boring into the host material. The other latin square consisted of billets without screening so that responding beetles were free to attack the host material. To sample beetles flying toward the treatments, one square foot sections of hardware cloth (barrier traps) were positioned over each billet; in order to trap the insects, the barriers were coated with Stikem Special. Insects were collected from the traps on a weekly basis. The billets in the unscreened latin square were subsequently taken back to the College of Forest Resources. There, the billets were measured and the attacks of Douglas-fir beetle, *Dendroctonus pseudotsugae*, and *Gnathotrichus* spp. counted.

The above experimental design facilitated observation of two critical phases of bark beetle host-selection behavior. In the screened latin square test, bark beetle response to host billets represents primary host attraction as the beetles were not allowed to attack the billets. In contrast, in the unscreened latin square test, bark beetles responded to a combination of primary and secondary attraction (pheromones); which occurred in the unscreened billets shortly after successful beetle attacks.

The types of information derived from this study were:

1. The identification of bark beetles associated with felled Douglas-fir at Cedar River Watershed.

2. Seasonal flight patterns of scolytids as correlated with weather factors (temperature, relative humidity, precipitation).

3. Response preferences of bark beetle species to the four treatments in terms of primary and secondary attraction.

4. Attack preference of Douglas-fir beetle and *Gnathotrichus* spp. on the billets of the unscreened latin square.

Treatment preferences (barrier traps) - Table 1 summarizes the treatment preferences of the six most common scolytids at Cedar River Watershed.

Two other scolytids, a Dryocetes sp. and a Phloeosinus sp., were collected in numbers too small to include in this summary. Except for the two ambrosia beetles, Gnathotrichus spp. and Trypodendron lineatum Oliv., the numbers of bark beetles caught in the unscreened latin square were much larger than in the screened latin square. This was attributed to the presence of secondary attraction (pheromones) in the unscreened latin square. The numbers of ambrosia beetles caught did not differ significantly between the latin squares.

Except for the Douglas-fir beetle, D. pseudotsugae, the treatment preferences of scolytods was similar in the screened and unscreened latin squares. On June 3, soaked Douglas-fir billets in the unscreened latin square attracted the greater number of D. pseudotsugae. However, in the screened latin square, Douglas-fir billets baited with ethyl alcohol caught the greatest number of D. pseudotsugae.

Seasonal flight patterns (barrier traps) - Table 2 summarizes the duration and peaks of flight activity for the six most common scolytids encountered at Cedar River. The maximum numbers of all scolytid species except Pseudohylesinus nebulosus were caught during the period between late May and early June. P. nebulosus was the first scolytid to fly in the spring, and its peak flight period probably occurred before initiation of the study. Barrier trap collections indicated the existence of re-emergence flights for all scolytids obsereed, except Pseudohylesinus grandis.

Attack preferences on unscreened billets - The treatment most preferred by Gnathotrichus spp. was the ethyl alcohol baited billets; the next heaviest attack was on the soaked billets. The number of Gnathotrichus attacks on fresh billets and P. nebulosus--infected billets was comparatively small. The same order of beetle preference was reflected in the barrier trap collections in both the screened and unscreened latin square. In contrast, the density of D. pseudotsugae attacks did not directly correspond to the barrier trap catches in the unscreened latin square. In several cases the ethyl alcohol--baited billets were heavily attacked early in the flight season, but the corresponding barrier trap catches were the same for the other treatments which were less heavily attacked at that time. Throughout the flight season, the ethyl alcohol--baited billets and soaked billets were the most heavily attacked treatments.

TABLE 1. Treatment preference (barrier traps).

Species	Unscreened	Screened	Comments
Dendroctonus pseudotsugae (DFB)	1. 5/18, highest number on *P. nebulosus*-infested Douglas-fir 2. 6/3, soaked billets caught highest numbers Seasonal total in latin square - 109	1. 6/3, highest numbers on etoh-baited billets 40	
Gnathotrichus spp. Mainly *G. sulcatus* but possibly some *G. retusus*	1. Etoh-baited billets caught highest numbers all season 2. Soaked billets next most preferred treatment 694	← 1. Similar ← 2. Similar 700	Agrees with literature
Pseudohylesinus nebulosus	1. *P. nebulosus*-infested Douglas-fir billets highly preferred 284	← 1. Similar 101	Indicates presence of unidentified pheromone
Pseudohylesinus grandis	1. *P. nebulosus*-infested Douglas-fir slightly preferred over other treatments 206	← 1. Similar 60	Indicates the secondary attraction of *P. nebulosus* is fairly species specific
Hylastes nigrinus	1. Etoh-baited billets and soaked billets slightly preferred over other treatments 222	← 1. Similar 97	No literature available
Trypodendron lineatum	1. Etoh-baited Douglas-fir billets preferred 31	← 1. Similar 21	Agrees with literature

TABLE 2. Seasonal flight patterns (Barrier traps).

Species	Duration	Peak	Comments
Dendroctonus pseudotsugae (DFB)	1. Early May to late June 2. Re-emergence flight: late July to early August	6/3-First flight 7/28-Re-emergence flight	1. Re-emergence flight collections had very few DFB
Gnathotrichus spp.	1. Early May to late September	6/3-First flight 9/6-Second flight	1. Longest flight season 2. Greatest numbers caught
Pseudohylesinus nebulosus	1. Early Spring or late Winter to end of July	*5/18-First flight 6/22-Second flight	*1. The peak of flight season occurred before this experiment began probably
Pseudohylesinus grandis	1. Early May to early July	6/3-Only flight	1. Shortest scolytid flight season
Hylastes nigrinus	1. Early May to late July	6/3-First flight 7/4-Second flight	1. Fairly early flight season
Trypodendron lineatum	1. Early May to middle of July	*6/3-Only major flight	1. Early flight season *2. Again it is possible the peak flight occurred before this experiment began