

2012 Pine Commodity-Based Survey Guidelines



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On the cover: (left) white breasted nuthatch, *Sitta carolinensis*, a native species that consumes pine seeds. Photo by Michael Ostry (USDA Forest Service). (center) 150-yr old red pine, *Pinus resinosa*. Photo by Joseph O'Brien (USDA Forest Service). (right) Developing cones of red pine. Photo by Joseph O'Brien (USDA Forest Service). Images were acquired from Forestry Images (www.forestryimages.org).

Draft Log

July 2010:

- 1) Addition of CAPS-Approved Method for Survey and Key Diagnostics for all pests from the CAPS Approved Methods table (Appendix M in CAPS National Survey Guidelines).
- 2) Addition of "Keys to Symbols" for Survey and ID section.
- 3) Updated information including Table 1 and "Mistaken Identities" from Appendix M
- 4) Removed *Leptographium truncatum* (root disease). Jacobs et al. (2005) indicate that observations of *L. lundbergii* from the United States are actually *L. truncatum*. There are taxonomic issues, but the pathogen appears to be present based on recent molecular evidence.

February 2011:

- 1) Addition of *Cronartium flaccidum* (Scots pine blister rust) and *Mycosphaerella gibsonii* (needle blight of pine).

March 2012:

- 1) Removal of *Dendrolimus superans*. Due to recent taxonomic changes, this pest is under review. An attractant is not available at this time for *Dendrolimus superans*. *D. superans* should not be listed as a survey target for 2012.
- 2) Addition of *Dendrolimus punctatus* and *Panolis flammea*.
- 3) 2012 version posted to CAPS Resource and Collaboration website.

Revisions by Talitha Molet, USDA-APHIS-PPQ-CPHST

Chapter 1. Introduction

R.C. Venette

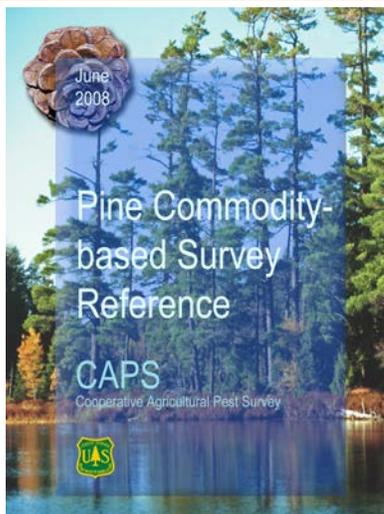


Figure 1 Cover of the survey reference for exotic pests that may harm pines. This reference includes data sheets for 24 threatening exotic pests of pine, including information on biology, survey, and identification.

This document is the second in a series of survey guidelines to help pest survey coordinators detect exotic pests that might become established in forests. The first document, *Oak Commodity-based Survey Guidelines*, addressed pathogens and insects that are not known to be established in the United States but might harm oaks (*Quercus* spp.) if they were to be introduced. The current document does the same thing, but now with an emphasis on pines (*Pinus* spp.). The recommendations follow a commodity-survey philosophy, recently adopted by the Cooperative Agriculture Pest Survey (CAPS). For trees, the philosophy is not intended to restrict surveys to areas where pines or oaks are grown commercially. Rather, the intent is to use survey techniques that can detect multiple species at the same time instead of a single pest. This survey approach provides a way to increase detection capacity for more than one pest without substantially increasing costs. Much of the cost for a survey comes from travel to field sites. By looking for more than one pest at each site, the value of each field visit increases considerably.

No survey method works equally well for all pests at all times. However, the Guidelines put pests into groups based on the part of the plant that may be affected. Sampling methods are described that will apply to multiple species within each group.

These *Survey Guidelines* deal with nine insects and two pathogens. None of these species are native to the United States, and none are known to occur here. A companion document, *Pine Commodity-based Survey Reference* (Fig. 1), provides more biological information about each of the eleven pests (Venette 2008), but some of that information is summarized here. *Pine Commodity-based Survey Reference* includes information for an additional nine insects and two pathogens that are threats to pine but do not rank as highly or are established in a small portion of the United States. Future versions of these *Guidelines* may address a modified list of targeted pests.

The list of targets does not include some significant, exotic pests of pine. The Guidelines do not address the Sirex woodwasp, *Sirex noctilio*. USDA APHIS has a specific program designed to detect and monitor this species. The *Survey Guidelines* for pines are not intended to replace or modify those detection protocols.

The primary goal of the Guidelines is to improve the likelihood of detecting one or more of the target pests. Ideally, pest populations would be found while they are still small and spatially confined. If these small populations can be found, eradication or containment becomes an appropriate management tool¹. The *Guidelines* do not

¹ Myers, J.H., Simberloff, D., Kuris, A.M., Carey, J.R., 2000. Eradication revisited: dealing with exotic species. *Trends in Ecology and Evolution* 15, 316-320.

describe the response to the detection (for example, how to identify the area that is currently infested or estimate the density of any given species).

A second goal of these *Guidelines* is to recommend an adequate number of samples that would allow a manager to state with confidence that any one of these pests is below a specified level. This level is more formally known as the incidence, the proportion of sample units with a target insect or pathogen. (See *Survey Design and Sampling Methods* for sampling terms.) Even though a survey cannot prove that a pest is absent, it does provide evidence that the pest is below a specified incidence.

The third goal of the *Guidelines* is to provide consistent recommendations so results provided by multiple agencies or states can be combined in a meaningful way. When multiple agencies conduct surveys in the same way, the combined results increase the overall confidence that a targeted pest is below a specified incidence regionally or nationally.

A final goal of the *Guidelines* is to increase awareness about a suite of species that may be unfamiliar to many pest survey coordinators. None of the targeted species occur in the United States. Pest survey coordinators may not appreciate the potential threat these species pose.

This document is modeled after the *Oak Commodity Survey Guidelines* that were developed in support of the CAPS program. Even if you are not a member of the CAPS program, we hope this particular document will help you develop a detection survey for exotic insects and diseases that may affect pines.

Portions of the recommendations may need clarification or adjustment as funding levels change, new threats are identified, or detection technologies improve. APHIS and the Forest Service welcome comments on these recommendations. Any feedback will help to ensure that future *Guidelines* will be clear and informative.

These *Guidelines* were intended for the contiguous United States. Pines are diverse and occur throughout the country (Fig. 2). Proposed workplans for the CAPS program should be directed through appropriate State Plant Health Directors and Regional APHIS offices.

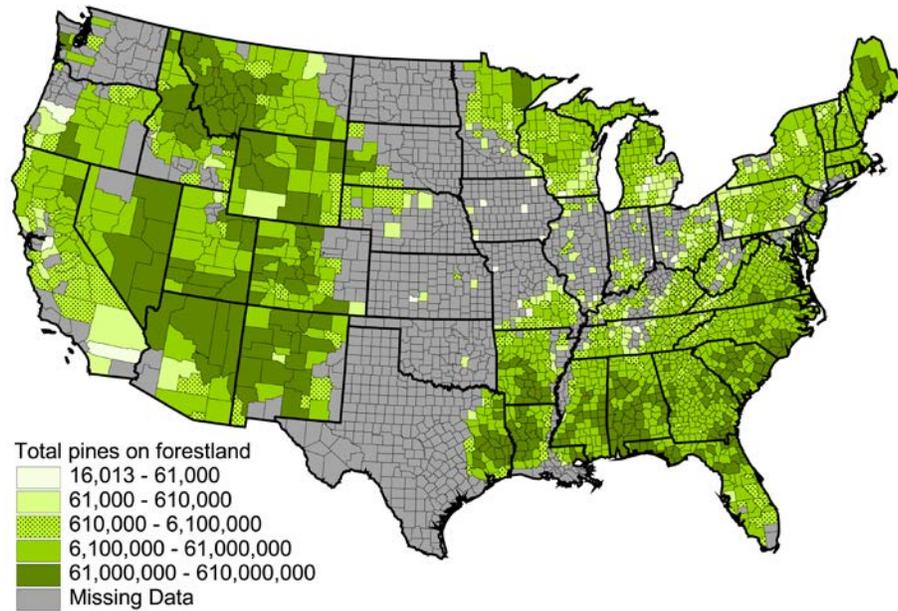


Figure 2. Number of pines per county on forestland.

Organization of Chapters: Chapter 1 introduces the Guidelines and presents the ten target pests for survey. Chapter 2 provides an overview of the survey design. Chapter 3 gives an overview of the plant parts likely to be affected by each of the target pests. Chapter 4 describes specific methods that would be appropriate to detect the target species in the field. Chapter 5 provides a technical summary of diagnostic features of each pest. The chapter is not a field guide. Rather, it provides short excerpts from key literature to support laboratory identification of field-collected material.

Appendix M1: The survey methodology presented in Appendix M1 in the 2011 CAPS National Survey Guidelines lists the most up-to-date, CAPS-approved methods for survey and identification/diagnostics of CAPS target pests from the Priority Pest List, consisting of pests from the 1) commodity- and taxonomic-based surveys and 2) AHP Prioritized Pest List. The information in this table supersedes any survey and identification/diagnostic information found in any other CAPS document (i.e., Commodity-based Survey References and Guidelines, EWB/BB National Survey Manual, etc.). All other CAPS documents will be revised to include the information contained in this table; however, this table should always be the authoritative source for the most up-to-date, CAPS-approved methods.

Chapter 2. Survey Design & Sampling Methods

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Background: Specific terminology is used to describe components of a sampling plan. The terms that are used in this document are defined in Table 1. This portion of the document is intended to describe the number of sample units (i.e., trees or traps) that would be needed to detect at least one of the ten species targeted in this survey with a specified level of confidence. Surveys that are designed to achieve a 95% or 99% probability of detecting a species would be ideal but can be labor intensive and costly. If resources only allow for a smaller sample size, the likelihood of detection will be considerably less. Additional statistical advice is provided on how to interpret the survey results, especially if none of the targeted pests is found. The statistical foundation of this survey is identical to *Oak Commodity-Based Survey Guidelines*.

Table 1. Definitions of statistical terminology used when developing sampling plans.

Term	Definition
Confidence	the probability of observing zero, one, two, or more sample units infested with a target species after inspecting a certain number of sample units. For detection surveys, statisticians are often interested in the probability of not finding any pests. When this value is subtracted from 1, it gives the probability of finding at least one infested sample unit (common default, 0.95 probability of finding at least one infested sample unit). Family confidence is the same idea, but refers to the probability of detecting at least one of several targeted species in the same survey.
Incidence	the proportion of the sample universe that is positive. In other words, it has the target species).
Negative	the absence of a pest in a sample unit.
Positive	the presence of the target species in a sample unit. Density of the target species does not matter. A tree found with one larva and another tree found with 1,000 larvae would each count as a separate single positive.
Sensitivity	the probability that a sampling method (e.g., visual inspection or pheromone-baited trap) will find a pest when it is present in a sample unit.
Sample size	the number of sample units that are examined during a survey
Sample unit	the “thing” that is likely to contain the species that you are looking for. A sample unit could be a pine tree or a defined unit of land with pines (for example, a wooded acre).
Sample universe	all of the sample units that have some chance of being selected for inspection. The sample universe could be all of the pines in your state or all of the forested land with pines.

This sampling plan rests on three critical assumptions about how samples will be collected. First, we assumed that the number of pine trees in an area is large (more than 2,000 trees). This assumption is clearly true when the area of interest is an entire state and the state has pine. This assumption might not be true if the area of interest is a single stand of trees. Second, we assume that the number of infested (positive) trees is small. For early detection surveys, this assumption is true by design. Third, we assumed that trees will be selected at random. Random sampling is not easily done. If samples are simply selected arbitrarily, those samples will often reflect subtle (or not so subtle) behaviors of a field scout. For example, younger, smaller trees may be preferentially surveyed over older, larger trees. Sites that are closer to roads or trails may be selected more often than sites that are more remote. These subtle differences in sampling frequency may

inadvertently skew the results of the survey. If any of the assumptions is incorrect, the sampling recommendations will not be valid.

To conduct a commodity survey, you will need to complete three major phases. Phase 1 involves planning for the survey. In this phase, you will need to determine how many samples to collect and where to collect samples. Phase 2 involves going to the field to do the survey. Phase 3 describes how to interpret the results of the survey, especially if none of the target pests is found.

Phase 1. Plan the survey. *How many trees do I need to inspect?* Table 2 describes the number of trees that should be examined (i.e., the sample size) to achieve a desired level of confidence of detecting one of the targeted species. To use the table, the likely incidence at the time of detection should be specified and the sensitivity of visual inspections should be estimated. Incidence describes the proportion of trees that are thought to be infested. Sensitivity refers to the likelihood that a sampling method (for example, visual inspection of a tree) will reveal a targeted pest when it is present in a sample unit (Table 2). Factors that influence the sensitivity of visual surveys include pest size, pest activity, pest behavior, and the part of the tree that is infested. Experience with surveys for Asian longhorned beetle suggests that the sensitivity of ground-based visual inspection of trees was as low as 30%¹, primarily because damage was high in the tree. We anticipate that ground-based, visual surveys for pine pests will have about the same sensitivity or less.

Consider a quick example. In West Virginia, there are approximately 201 million pine trees on forestland (Fig. 2). Imagine a resource manager who wanted to do a very thorough job of sampling. Without considering any statistics, the manager devoted enough resources to inspect 10,000 trees for the ten pests mentioned in these Guidelines, and this project was all the staff could accomplish in a season. In this example, we will assume that the 10,000 trees were selected completely at random and that the staff were very thorough. If any of the target pests would have been on a tree, there is a 95% chance it would have been found. At the end of the season, none of the target pests was observed.

Did the resource manager really need to inspect 10,000 trees? Perhaps yes, economic, environmental, or political considerations within the organization may have dictated such a large sample size. However, in many instances, substantially smaller sample sizes may be adequate. Survey programs may suffice if they are designed to detect at least one infested tree when the incidence of infestation is 10% or 1%. Without going into the math (details are provided in Appendix A), field personnel would only need to inspect 52 or 544 trees to be 95% confident of finding at least one infested tree when the incidence of infestation is 10% or 1%, respectively (Table 2). If we make the more realistic assumption that field crews only have about a 30% chance of observing one of the pests when it is present, the sample sizes would increase to 170 or 1,728 trees, respectively. Thus, a well designed survey can ensure that neither too little nor too great an effort is put into a survey.

¹ Smith, M.T. 2004. Tapping the senses to catch Asian longhorned beetles. *Agricultural Research* (Feb): 12-13.

Table 2. Sample size needed to detect at least one of the targeted pests based on the sensitivity of the sampling method, the desired incidence at the time of detection, and the desired confidence level. Confidence, incidence and sensitivity are expressed as proportions (e.g, an incidence of 0.1 = 10%). For example, to be 95% confident of detecting one of the ten targeted pests at an incidence of 10% when using a method that has a sensitivity of 20%, 257 samples must be collected.

Incidence	Sensitivity					
	0.1	0.2	0.3	0.5	0.6	0.95
<i>Group Confidence=0.99</i>						
0.001	68,021	34,009	22,671	13,601	11,334	7,157
0.002	34,009	17,003	11,334	6,799	5,665	3,577
0.003	22,671	11,334	7,555	4,532	3,776	2,383
0.004	17,003	8,500	5,665	3,398	2,831	1,787
0.005	13,601	6,799	4,532	2,718	2,264	1,429
0.006	11,334	5,665	3,776	2,264	1,886	1,190
0.007	9,714	4,855	3,236	1,940	1,616	1,020
0.008	8,500	4,248	2,831	1,697	1,414	892
0.009	7,555	3,776	2,516	1,508	1,256	792
0.01	6,799	3,398	2,264	1,357	1,130	713
0.02	3,398	1,697	1,130	677	563	355
0.03	2,264	1,130	752	450	374	235
0.04	1,697	847	563	337	280	176
0.05	1,357	677	450	269	223	140
0.06	1,130	563	374	223	186	116
0.07	968	482	321	191	159	99
0.08	847	422	280	167	138	86
0.09	752	374	249	148	123	76
0.1	677	337	223	133	110	68
<i>Group Confidence=0.95</i>						
0.001	51,927	25,962	17,307	10,383	8,652	5,464
0.002	25,962	12,980	8,652	5,190	4,325	2,731
0.003	17,307	8,652	5,767	3,459	2,882	1,819
0.004	12,980	6,489	4,325	2,594	2,161	1,364
0.005	10,383	5,190	3,459	2,075	1,728	1,091
0.006	8,652	4,325	2,882	1,728	1,440	908
0.007	7,416	3,707	2,470	1,481	1,234	778
0.008	6,489	3,243	2,161	1,296	1,079	681
0.009	5,767	2,882	1,921	1,151	959	605
0.01	5,190	2,594	1,728	1,036	863	544
0.02	2,594	1,296	863	517	430	271
0.03	1,728	863	574	344	286	180
0.04	1,296	647	430	257	214	134
0.05	1,036	517	344	205	170	107
0.06	863	430	286	170	142	88
0.07	739	368	245	146	121	75
0.08	647	322	214	127	106	66
0.09	574	286	190	113	94	58
0.1	517	257	170	101	84	52

Table 2 (cont.) Sample size needed to detect at least one of the targeted pests based on the sensitivity of the sampling method, the desired incidence at the time of detection, and the desired confidence level. Confidence, incidence and sensitivity are expressed as proportions.

Incidence	Sensitivity					
	0.1	0.2	0.3	0.5	0.6	0.95
<i>Group Confidence=0.9</i>						
0.001	44,996	22,497	14,997	8,997	7,497	4,734
0.002	22,497	11,247	7,497	4,498	3,748	2,366
0.003	14,997	7,497	4,998	2,998	2,498	1,577
0.004	11,247	5,623	3,748	2,248	1,873	1,182
0.005	8,997	4,498	2,998	1,798	1,498	945
0.006	7,497	3,748	2,498	1,498	1,248	787
0.007	6,426	3,212	2,141	1,283	1,069	674
0.008	5,623	2,810	1,873	1,123	935	590
0.009	4,998	2,498	1,664	998	831	524
0.01	4,498	2,248	1,498	898	748	471
0.02	2,248	1,123	748	448	373	235
0.03	1,498	748	498	298	248	156
0.04	1,123	560	373	223	185	116
0.05	898	448	298	178	148	92
0.06	748	373	248	148	123	77
0.07	641	319	212	126	105	65
0.08	560	279	185	110	91	57
0.09	498	248	164	98	81	50
0.1	448	223	148	88	73	45
<i>Group Confidence=0.7</i>						
0.001	34,010	17,004	11,336	6,801	5,667	3,579
0.002	17,004	8,501	5,667	3,399	2,833	1,788
0.003	11,336	5,667	3,777	2,266	1,888	1,192
0.004	8,501	4,250	2,833	1,699	1,415	893
0.005	6,801	3,399	2,266	1,359	1,132	714
0.006	5,667	2,833	1,888	1,132	943	595
0.007	4,857	2,428	1,618	970	808	510
0.008	4,250	2,124	1,415	849	707	446
0.009	3,777	1,888	1,258	754	628	396
0.01	3,399	1,699	1,132	679	565	356
0.02	1,699	849	565	338	282	177
0.03	1,132	565	376	225	187	118
0.04	849	423	282	168	140	88
0.05	679	338	225	134	112	70
0.06	565	282	187	112	93	58
0.07	484	241	160	95	79	49
0.08	423	211	140	83	69	43
0.09	376	187	124	74	61	38
0.1	338	168	112	66	55	34

Where in the state should I look? These Guidelines assume that samples are taken at random from the landscape. Future versions may take advantage of risk maps that describe where the target pests might first arrive, establish, and cause harm. For the moment, the guidelines do not use risk maps because spatially focused sampling has a

significant effect on the interpretation of results. If risk maps are not prepared consistently for the entire nation, it is uninformative to combine results from different states.

Surveys for the CAPS program will typically involve an entire state. In other cases, the survey might only involve trees within urban areas or trees within a particular stand. In order to achieve a random sample within the area of interest, the general location of all pines must be known before the survey is conducted. Any pine tree that has some chance (even if it is very small) of being selected for inspection is included in the sample universe. This chance should be the same for every tree in the sample universe. Pines that have absolutely no chance of being selected for inspection are excluded from the sample universe. A similar situation applies when traps are being used. In this case, the sample unit technically is not the trap itself. Rather, the sample unit is the area over which a trap is likely to draw a species of interest. So the sample universe becomes the area that has some definable chance of being included in the survey.

Selecting sites for survey often begins with a map (or series of maps) of the resource. Detailed procedures for selecting sites are provided in other guidelines (e.g., the Oak Survey Guidelines), and those details will not be repeated here. The process can get quite elaborate. The detailed technical procedures should not obscure the simple notion that the sites are to be picked at random. For planning purposes, we recommend identifying a few more potential sites than will be visited. Once personnel go to the field, some of the potential sample sites may prove to be inaccurate (not currently in pine) or inaccessible. To get good coverage of the sample universe, we recommend surveying 3-5 trees per site. So, if a plan calls for inspections of 170 trees, for example, field personnel will need to visit from 34-57 sites.

Phase 2. Conduct the survey. For this portion of the survey, consider the Guidelines more descriptive than prescriptive. We assume that you have some experience with pest surveys, and that you will use this experience when conducting the survey for pine. For example, we assume that you will know to bring appropriate safety equipment to the field. We also assume that you are familiar with the importance of carefully labeling any field specimens that might be brought to the laboratory for identification.

In general, when going to the field, attempt to get as close as possible to the field sites that were selected during the planning process. If sites were selected using a geographic information system, a handheld global positioning system (GPS) unit will simplify locating sample points in the field. Simply navigate to the latitude and longitude of a pre-selected site. If the site is hazardous, inaccessible, or does not currently have pines, either select another sample site or move to pines that are as close as possible to the intended sample site.

Once you have arrived at the sample site, select 3-5 trees for inspection. Inspected trees should be at least 50 m apart. A single trip per stand per year should be adequate for most pests. Visits should be scheduled when most pines in a stand have preferred feeding sites for most targeted pests (See Chapter 5). During the growing season, pines at the same site may vary in their susceptibility to pest attack because trees differ by species, age, and local growing conditions.

Chapters 3-5 provide more explicit detail of where to look and what to look for. Trees with obvious damage (e.g., discolored needles, needle drop, or pitch tubes) should be examined very carefully. In general, many insects in this survey may be found with visual inspection of needles, branches, or trunks. Root and soil sampling are needed to detect certain root pathogens. In these cases, a specified volume of soil is removed from roots

that are relatively near the soil surface. It is perfectly acceptable to use multiple sampling methods on a single tree to detect the diversity of arthropods and pathogens that are the focus of this survey. The amount of time required to inspect a single tree may be much greater than would normally be spent on visual surveys for a single pest. However, the extra effort is more than offset by the savings gained by focusing on multiple pests in a single system.

If traps will be used, field personnel must visit each stand at least twice and should consider repeating any visual inspections. Plant symptoms may become more evident as the season progresses. Multiple inspections are not required. Trapping involves the use of a device to capture insects, bacteria, or fungal spores from a specific area. For insects, the chances of successfully trapping an individual are substantially improved if the trap is baited with a chemical attractant, often a pheromone. Pheromone lures are available for several of the moths targeted in the survey. The use of pheromone traps will require at least two visits to the field: once to set up the trap and once to take it down. Lures must be replaced every 7 weeks, so intermediate visits may be needed as well. If trapping is to be used, we recommend placing at least one trap per survey site; however, it is preferable to use the same number of traps as the recommended total number of trees. Traps should be placed at least 50 m [ca. 160 ft] apart.

While it may be obvious to collect detailed information if a potential positive is found, it is equally important to record a tree or a trap site as negative if none of the targeted pests is found. It may not be possible to diagnose infection or confirm species identity in the field, so each field visit may simply provide an opportunity to collect specimens (insect, soil, or plant tissue) for additional processing in a laboratory.

Phase 3. Interpret the results. The design of the survey is important, especially if none of the target pests is found. It may be tempting to think that none of the pests occur in an area because of the survey results. Unfortunately, this interpretation is not entirely correct. Remember the phrase, "You can never prove a negative." Unless field personnel can look at every part of every tree and be 100% confident that a pest would be seen and recognized if it were present, there is always a chance that a pest could have been found if a few more trees were inspected or if trees were inspected a little more thoroughly.

Let's return to the example of the pine survey in West Virginia (first considered in Phase 1). To recap, the sample unit was a single tree, and the sample universe was 201 million trees (see Table 2 for definitions). The sample size was 10,000 trees. There were no positive sample units, just negatives. Without going into the math for the moment, the manager can be 95% confident that the incidence of infestation in the sample universe is no more than 0.000546 or 0.0546% of all West Virginia pines. This is a powerful survey, much better than most. Fortunately, this result applies to each of the ten target species, not just one. (A statistical adjustment was made to account for the number of pest species that are being surveyed.) Still, even with the intensive survey effort in this example, up to approximately 110,000 infested trees ($0.0546\% \times 201,000,000$) could be in the state and have gone undetected, even with scouts that are highly likely of finding the pests. Appendix B provides details for how to calculate the upper limit of the proportion of infested sample units when no target pest is found.

What if all the samples had been collected from Nicholas county, West Virginia? In this case, the state would have remarkable data for this one county, but it would be unable to say anything about the potential for any of the pests to be in the rest of the state. In this situation, the sample universe would be redefined. As a result, even though the same

percentage of trees might be infested (0.0546%), the result would only apply to the 1 million pines that are in the county. The result would indicate that as few as zero or as many as 546 infested pines occur in the county.

This portion of the West Virginia example illustrates the value of having good spatial coverage throughout a state. For efficiency, field personnel may want to examine all trees in just a few sites. Although this approach would take considerably less time, it again causes some problems with the interpretation of the results. When sampling is not done at random, the sample universe is redefined. Sometimes this re-defined sample universe makes sense (e.g., all the pines in Nicholas county), but sometimes the re-definition is more difficult (e.g., all pines within 100 meters of a county road).

Chapter 3. Summary of Survey Strategies

E.M. Albrecht

This chapter provides the CAPS-approved survey strategies for the eleven pests described in this document. Additional details are provided in Chapter 4. Tables 5-9 summarize plant symptoms associated with the targeted pests in the field. Table 5 provides an overview of the part of the plant that is likely to be affected by the targeted pests. Tables 6-9 describe specific symptoms that might be observed on the affected plant part. A dot (●) indicates a potential symptom caused by a particular species. None of the symptoms can be used on its own to confirm the presence of any pest. Chapter 4 provides additional guidance if you believe you have found a targeted pest.

Table 4. CAPS-approved survey methods for eleven exotic pests of pine

Scientific name	Common name	Survey method available		
		Visual survey	Trapping	Spore trapping
Arthropods-beetles				
<i>Dendroctonus micans</i>	Great spruce bark beetle			
<i>Hylobius abietis</i>	Large pine weevil			
<i>Monochamus saltuarius</i>	Sakhalin pine sawyer			
<i>Monochamus sutor</i>	Small white-marmorated longhorned beetle			
<i>Tomicus destruens</i>	Pine shoot beetle			
Arthropods-moths				
<i>Dendrolimus pini</i>	Pine-tree lappet			
<i>Dendrolimus punctatus</i>	Masson pine moth			
<i>Lymantria mathura</i>	Pink gypsy moth			
<i>Panolis flammea</i>	Pine beauty moth			
Pathogens-fungi				
<i>Cronartium flaccidum</i>	Scots pine blister rust			
<i>Mycosphaerella gibsonii</i>	Needle blight of pine			

Table 5. Plant parts affected by eleven exotic pests of pine

Scientific name	Common name	Plant part affected			Symptom table
		Needles	Branches/ stems	Roots	
Arthropods-beetles					
<i>Dendroctonus micans</i>	Great spruce bark beetle				6, 7, 8
<i>Hylobius abietis</i>	Large pine weevil				6, 8, 9
<i>Monochamus saltuarius</i>	Sakhalin pine sawyer				6, 7, 8
<i>Monochamus sutor</i>	Small white-marmorated longhorned beetle				6, 7, 8
<i>Tomicus destruens</i>	Pine shoot beetle				6, 7, 8
Arthropods-moths					
<i>Dendrolimus pini</i>	Pine-tree lappet				6, 7, 8
<i>Dendrolimus punctatus</i>	Masson pine moth				6, 7, 8
<i>Lymantria mathura</i>	Pink gypsy moth				6, 7, 8
<i>Panolis flammea</i>	Pine beauty moth				6, 7, 8
Pathogens-fungi					
<i>Cronartium flaccidum</i>	Scots pine blister rust				6, 7, 8
<i>Mycosphaerella gibsonii</i>	Needle blight of pine				6, 7, 8



Table 6. Symptoms on the whole tree

	Reduced resin production	Defoliation	Deformed growth	Presence of adults	Presence of eggs/egg masses	Presence of larvae	Presence of pupae	Resin exudation
Arthropods-beetles								
<i>Dendroctonus micans</i> (great spruce bark beetle)*				•	•	•	•	•
<i>Hylobius abietis</i> (large pine weevil)						•		
<i>Monochamus saltuarius</i> (Sakhalin pine sawyer)*	•			•	•	•	•	
<i>Monochamus sutor</i> (small white-marmorated longhorned beetle)*	•			•	•	•	•	
<i>Tomicus destruens</i> (pine shoot beetle)				•	•	•	•	•
Arthropods-moths								
<i>Dendrolimus pini</i> (pine-tree lappet)		•		•		•		
<i>Dendrolimus punctatus</i> (Masson pine moth)		•			•	•	•	
<i>Lymantria mathura</i> (pink gypsy moth)		•			•	•		
<i>Panolis flammea</i> (pine beauty moth)		•			•	•	•	
Pathogens- fungi								
<i>Cronartium flaccidum</i> (Scots pine blister rust)		•	•					•
<i>Mycosphaerella gibsonii</i> (needle blight of pine)*		•	•					



Table 7. Symptoms on needles

	Browning/necrosis of needles	Chlorosis	Feeding damage	Retention of needles
Arthropods-beetles				
<i>Dendroctonus micans</i> (great spruce bark beetle)*		•		
<i>Monochamus saltuarius</i> (Sakhalin pine sawyer)*		•		•
<i>Monochamus sutor</i> (small white-marmorated longhorned beetle)*		•		•
<i>Tomicus destruens</i> (pine shoot beetle)	•	•		
Arthropods-moths				
<i>Dendrolimus pini</i> (pine-tree lappet)			•	
<i>Dendrolimus punctatus</i> (Masson pine moth)		•	•	
<i>Lymantria mathura</i> (pink gypsy moth)			•	
<i>Panolis flammea</i> (pine beauty moth)			•	
Pathogens- fungi				
<i>Cronartium flaccidum</i> (Scots pine blister rust)	•	•		
<i>Mycosphaerella gibsonii</i> (needle blight of pine)*	•			



Table 8. Symptoms on branches/stems

	Boring dust	Branch death	Cankers	Entrance/exit holes	Feeding damage	Galleries	Gummosis	Oviposition scars	Peeling, discolored bark	Pitch tubes
Arthropods-beetles										
<i>Dendroctonus micans</i> (great spruce bark beetle)*				•		•	•		•	•
<i>Hylobius abietis</i> (large pine weevil)		•			•	•				
<i>Monochamus saltuarius</i> (Sakhalin pine sawyer)*				•		•		•		
<i>Monochamus sutor</i> (small white-marmorated longhorned beetle)*				•	•	•		•		
<i>Tomicus destruens</i> (pine shoot beetle)	•			•	•	•				•
Arthropods-moths										
<i>Dendrolimus pini</i> (pine-tree lappet)					•					
<i>Dendrolimus punctatus</i> (Masson pine moth)		•			•					
<i>Lymantria mathura</i> (pink gypsy moth)					•					
<i>Panolis flammea</i> (pine beauty moth)		•			•					
Pathogens- fungi										
<i>Cronartium flaccidum</i> (Scots pine blister rust)		•	•						•	
<i>Mycosphaerella gibsonii</i> (needle blight of pine)*		•								



Table 9. Symptoms on roots

	Feeding damage
Arthropods-beetles	
<i>Hylobius abietis</i> (large pine weevil)	•

* Pests that have visual surveys as the CAPS-approved method.

Chapter 4. Detailed Survey Tables

E.M. Albrecht and E.E. Davis

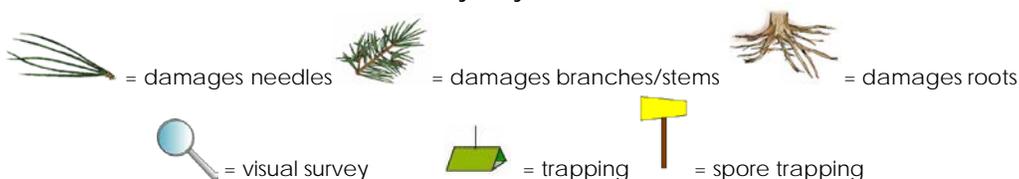
For each of the eleven pests included in this survey, this chapter provides additional detail about the period of activity, the plant part that would be affected, and the CAPS-approved survey method. Periods of activity are generally based on phenological patterns observed within the species' native range. Activity periods in the United States may differ. This chapter also includes a brief summary of what to do if a suspect is found. The guidance provided here is focused primarily on steps to collect a useful sample or specimen. Several additional steps are needed to confirm the identity of the organism. The *Pine Commodity-based Survey Reference* and Chapter 5 provide additional details on diagnostic methods.

If you believe you have found a targeted insect (moth): Take samples of the immature and adult insect. Be sure to include a sample of the host material on which it was found. Plant samples should be labeled and placed in a sealable plastic bag accompanying the insect samples. Labels should indicate date, geographic location, and identity of host plant. If a pheromone trap is used, it should be disassembled and wrapped in clear plastic wrap. Place adult specimens in a sealable plastic bag. Do not place more than one specimen in a container. Larvae should be preserved in ethyl alcohol. Label the sample and keep it in a cool, dry place until identification can be made. Care should be taken to preserve the specimen intact, as damaged, crushed, or moldy insects are difficult to identify. Species-level identification should be made by a qualified taxonomist. Submit the specimen for identification within 72 hours after collection.

If you believe you have found a targeted insect (beetle): Take samples of the immature and adult insect. Be sure to include a sample of the host material on which it was found. Note shape, size, and location of exit holes. Plant samples should be labeled and placed in a sealable plastic bag. Labels should indicate date, geographic location, and identity of host plant. Place insect specimens in a small, rigid plastic container which should be included in the plant sample bag. Label the sample and keep it in a cool, dry place until identification can be made. Care should be taken to preserve the specimen intact, as damaged, crushed, or moldy insects are difficult to identify. Species-level identification should be made by a qualified taxonomist. Submit the specimen for identification within 72 hours after collection.

If you believe you have found a targeted pathogen: Take samples of the suspected material (symptomatic needles, tissue etc.) Plant samples should be labeled and placed in a sealable plastic bag. Label the sample and keep it in a cool, dry place until identification can be made. Labels should indicate date, geographic location, and identity of host plant. Be sure to note whether the host plant is alive or dead. Submit the specimen for identification within 24 hours after collection.

Key to Symbols



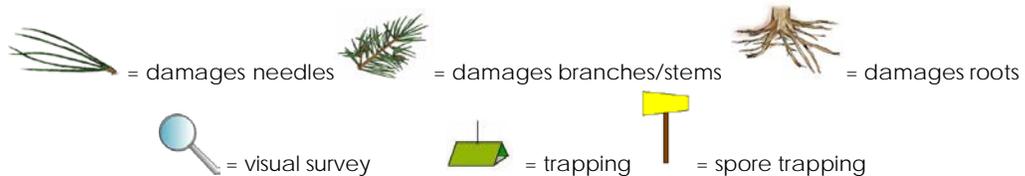
Beetles

Scientific Name	Common Name	Survey Method Available
<i>Dendroctonus micans</i>	Great spruce bark beetle	Time Frame: Adults emerge between May and August.
	Plant Part: needles branches/stems	
	CAPS-Approved Method: Visual Survey	
	Look on branches and stems for:	<ul style="list-style-type: none"> • Round exit holes • Peeling, blackened bark • Fan-shaped gallery in sapwood • Eggs, larvae, pupae, and adults in subcortical galleries • Attacks are consistently in the lower bole of a tree
	Other plant symptoms may include:	<ul style="list-style-type: none"> • Yellow, brown, or reddish-brown foliage or crowns • Purple-brown (when wet) or white and crusty (when dry) pitch tubes • Resinosis • Dieback of branches

Adult *Dendroctonus micans*.

[Image from Maja Jurc, <http://www.bugwood.org>]

Key to Symbols

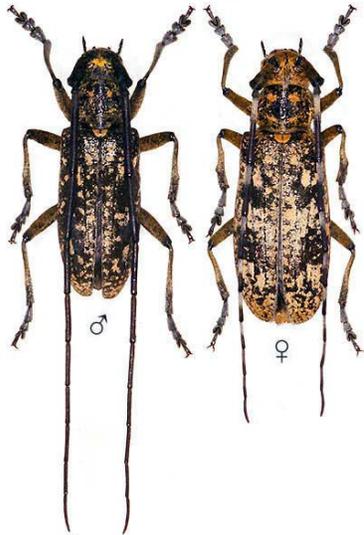


Scientific Name	Common Name	Survey Method Available
<i>Hylobius abietis</i>	Large pine weevil	Time Frame: Adult emergence can occur between late May and early June.
 <p>Adult <i>Hylobius abietis</i>. [Image from Gyorgy Csoka, http://www.bugwood.org]</p>	Plant Part: branches/ stems roots	
	CAPS-Approved Method: Trap and lure The trap is a multi-funnel trap. The lures are effective for 56 days (8 weeks).	
Any of the following Trap Product Names in the IPHIS Survey Supply Ordering System may be used for this target: <ul style="list-style-type: none"> Multi-funnel Trap, 12 Funnel, Wet Multi-funnel Trap, 8 Funnel, Wet 		
The Lure Product Names are "Alpha Pinene UHR Lure" and "Ethanol Lure"		
Beginning in 2012, the wet collection cup method will be the only method approved for use with multi-funnel (Lindgren) traps.		
The release rate of this lure is highly temperature-dependent. However, CAPS has listed a conservative length of effectiveness that will be effective for even the warmest climates in the CAPS community.		
<ul style="list-style-type: none"> IMPORTANT: Do not place lures for two or more target species in a trap unless otherwise recommended. Trap spacing: When trapping for exotic wood-boring and bark beetles, separate traps with different lure combinations by at least 30 meters (98 feet). 		

Key to Symbols

 = damages needles
  = damages branches/stems
  = damages roots

 = visual survey
  = trapping
  = spore trapping

Scientific Name	Common Name	Survey Method Available
<i>Monochamus saltuarius</i>	Sakhalin pine sawyer	Time Frame: Adults emerge in spring to early summer, depending on climate.
	Plant Part: needles branches/stems	
	CAPS-Approved Method: Visual Survey Look on branches and stems for: <ul style="list-style-type: none"> • Round emergence holes • Oviposition scars • S-shaped larval feeding galleries • U-shaped pupal chambers • Adults feeding on young shoots 	
Plant Symptoms (associated with pine wilt disease caused by <i>Bursaphelenchus xylophilus</i> and <i>B. mucronatus</i>): <ul style="list-style-type: none"> • Reduced resin production • Chlorosis • Wilting of needles 		

Adult male and female *Monochamus saltuarius*.

[Image from M. Hoskovec, <http://www.uochb.cas.cz/~natur/cerambyx/>]

Key to Symbols

 = damages needles
  = damages branches/stems
  = damages roots

 = visual survey
  = trapping
  = spore trapping

Scientific Name	Common Name	Survey Method Available
<i>Monochamus sutor</i>	Small white-marmorated longhorned beetle	<p>Time Frame: Adult flight occurs from mid June-September.</p> <hr/> <p>Plant Part: needles   branches/stems</p> <hr/> <p>CAPS-Approved Method: Visual Survey  Look on branches and stems for: <ul style="list-style-type: none"> • Round emergence holes • Oviposition scars • S-shaped larval feeding galleries • U-shaped pupal chambers • Adults feeding on young shoots </p> <p>Plant Symptoms (associated with pine wilt disease caused by <i>Bursaphelenchus mucronatus</i>): <ul style="list-style-type: none"> • Decreased resin production • Chlorosis • Wilting of needles </p>



Adult male and female *Monochamus sutor*.
 [Image from M. Hoskovec, <http://www.uochb.cas.cz/~natur/cerambyx/>]

Photo © M.Hoskovec

Key to Symbols

 = damages needles
  = damages branches/stems
  = damages roots
 = visual survey
  = trapping
  = spore trapping

Scientific Name	Common Name	Survey Method Available
<i>Tomicus destruens</i>	Pine shoot beetle	<p>Time Frame: Adult flight occurs in spring to mid summer and in fall to early winter at temperatures between 12-24°C [53.6-75.2°F]. Reproductive flight occurs in autumn.</p> <hr/> <p>Plant Part: needles branches/stems</p>  <hr/> <p>CAPS-Approved Method: Trap and lure The trap is a multifunnel trap. The lure is effective for 56 days (8 weeks).</p>  <p>Any of the following Trap Product Names in the IPHIS Survey Supply Ordering System may be used for this target: Multi-funnel Trap, 12 Funnel, Wet Multi-funnel Trap, 8 Funnel, Wet</p> <p>The Lure Product Names are "Alpha Pinene UHR Lure" and "Ethanol Lure."</p> <p>Beginning in 2012, the wet collection cup method will be the only method approved for use with multi-funnel (Lindgren) traps.</p> <p>There are two alpha pinene products available in the IPHIS Ordering Database: 1) Alpha Pinene Lure and 2) Alpha Pinene UHR Lure. The Alpha Pinene Lure is an un-gelled lure in a bottle dispenser that is used by the PPQ Program for <i>Tomicus piniperda</i> (pine shoot beetle). This lure should only be used for the program survey.</p> <p>The Alpha Pinene UHR Lure is a polysleeve, ultra-high release dispenser used for other EWB/BB targets. This lure should be used with the Ethanol Lure for the following four EWB/BB targets: <i>Hylurgops palliatus</i>, <i>Hylurgus ligniperda</i>, <i>Monochamus alternatus</i>, and <i>Tomicus destruens</i>.</p> <p>The release rates of these lures are highly temperature-dependent. However, CAPS has listed a conservative length of effectiveness that will be effective for even the warmest climates in the CAPS community.</p> <ul style="list-style-type: none"> • IMPORTANT: Placing lures for two or more target species in a trap should never be done unless otherwise recommended. • Trap spacing: When trapping for EWB/BB, separate traps with different lure combinations by at least 30 meters (98 feet).

No image available

Key to Symbols

 = damages needles
  = damages branches/stems
  = damages roots
 = visual survey
  = trapping
  = spore trapping

Moths

Scientific Name	Common Name	Survey Method Available
<i>Dendrolimus pini</i>	Pine-tree lappet	Time Frame: Adults appear in midsummer.
		Plant Part: needles  branches/stems 
		CAPS-Approved Method: Trap and lure The trap is a milk carton trap. The lure is effective for 28 days (4 weeks). 
The Lure Product Name is " <i>Dendrolimus pini</i> - <i>Dendrolimus sibiricus</i> Lure."		
A killing agent, a DDVP strip, is also required for these two target species.		
The lure is hung inside the top of the trap at the level of the entry ports. Preferably, the lure is placed inside the lure holders, which are typically distributed with the lures, and the lure holder is stapled to the trap. If the lure holder is not available, the lure can be stapled to a garden tie and hung inside the trap. The killing agent, the DDVP strip, is placed in the bottom of the trap.		
The wing trap was the recommended trap in 2011 for <i>Dendrolimus pini</i> . For 2012, the modified gypsy moth milk carton trap is the preferred trap. For 2012, a combined lure is to be used for both <i>D. pini</i> and <i>D. sibiricus</i> (<i>Dendrolimus pini</i> - <i>Dendrolimus sibiricus</i> lure). Therefore, using the milk carton trap (the preferred trap for <i>D. sibiricus</i> and also an effective trap for <i>Dendrolimus pini</i>) and the <i>Dendrolimus pini</i> - <i>Dendrolimus sibiricus</i> lure will allow for negative data reporting from one trap and lure combination for two targets.		
Trap modification instructions: Modify the standard gypsy moth milk carton by cutting a single large entry port (2.5 cm wide x 3 cm high) in each side by using a utility knife or similar tool to cut out the section of paperboard between the two existing entry ports. A plastic-funnel (see Lance, 2006, Fig. 3) is placed inside the trap (tube-down) so that the top edge of the funnel is at the level of the bottom of the entry ports. The lure is hung inside the top of the trap and a killing agent (DDVP strip) is placed in the bottom. Lures should be replaced at least monthly in cooler areas and perhaps as often as every 2-3 weeks in hotter climates (Lance, 2006).		
The Otis lab has a limited number of funnels available. Funnels will be shipped on a first come first serve basis and should be ordered through the IPHIS Survey Supply Ordering Database. Funnels can be reused for multiple years if cared for properly. Funnels should be removed from traps at the end of the season, washed in soap and water, rinsed, and stored dry.		

Adult *Dendrolimus pini*.
 [Image from Stanislaw Kinelnski, <http://www.bugwood.org>]

Key to Symbols

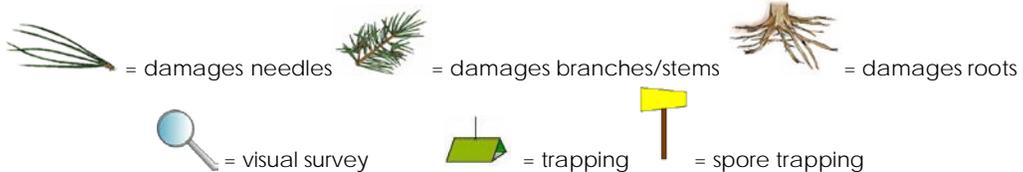
 = damages needles
  = damages branches/stems
  = damages roots
 = visual survey
 = trapping
 = spore trapping

Please keep the funnels and re-use in subsequent years or ship the funnels back to the Otis lab so that other states may use them.

- **IMPORTANT:** Placing lures for two or more target species in a trap should never be done unless otherwise recommended.
- **Trap spacing:** When trapping for more than one species of moth, separate traps for different moth species by at least 20 meters.
- **Notes:** The BHT (butylated hydroxytoluene) and Tinuvin found in the lure are stabilizers; anti-oxidant and light-stabilizers, respectively.

Lance, D. 2006. Guidelines for detection trapping of exotic Lymantriid and Lasiocampid moths. USDA-APHIS-PPQ. 11 pp.

Key to Symbols



Scientific Name	Common Name	Survey Method Available
<i>Dendrolimus punctatus</i>	Masson pine moth	<p>Time Frame: Depending on climate, this species can be found year round. In southern China, the first generation moth flight peaks in early to mid-August (Zhang et al., 2003).</p> <hr/> <p>Plant Part: needles branches/stems</p>  <hr/> <p>CAPS-Approved Method: Trap and lure The trap is a wing trap. The lure is effective for 21 days (3 weeks).</p>  <p>Any of the following Trap Product Names in the IPHIS Ordering Database may be used for this target: Wing Trap Kit, Paper Wing Trap Kit, Plastic</p> <p>The Lure Product Name is "<i>Dendrolimus punctatus</i> Lure."</p> <ul style="list-style-type: none"> • IMPORTANT: Do not place lures for two or more target species in a trap unless otherwise recommended. • Lure Placement: The lure type is a rubber septum. The lure should be placed inside a lure holder, which is usually included with the trap. The lure holder should be stapled to the underside of the top of the trap on a non-sticky area. • Trap Spacing: When trapping for more than one species of moth, separate traps for different moth species by at least 20 meters (65 feet). <p>Zhang, A.-B., Z.-J. Wang, S.-J. Tan, and D.-M. Li. 2003. Monitoring the masson pine moth, <i>Dendrolimus punctatus</i> (Walker) (Lepidoptera: Lasiocampidae) with synthetic sex pheromone-baited traps in Qianshan County, China. Japanese Society of Applied Entomology and Zoology 38(2): 177-186.</p>



Mature larva of *D. punctatus*.
[Image from William M. Ciesla, Forest Health Management International, Bugwood.org]

Key to Symbols

 = damages needles
  = damages branches/stems
  = damages roots

 = visual survey
  = trapping
  = spore trapping

Scientific Name	Common Name	Survey Method Available
<i>Lymantria mathura</i>	Pink gypsy moth	Time Frame: The first generation occurs between April and October.
 <p>Adult male <i>Lymantria mathura</i>. [Image from David Mohn, www.bugwood.org]</p>	Plant Part: needles branches/stems	
	CAPS-Approved Method: Trap and lure The trap is a wing trap. The lure is effective for 84 days (12 weeks).	
	Any of the following Trap Product Names in the IPHIS Survey Supply Ordering System may be used for this target: Wing Trap Kit, Paper Wing Trap Kit, Plastic The Lure Product Name is " <i>Lymantria mathura</i> Lure." The lure (a string dispenser) should be stapled to the inside of the upper half (lid) of the trap on the non-sticky area.	<ul style="list-style-type: none"> • IMPORTANT: Placing lures for two or more target species in a trap should never be done unless otherwise recommended. • Trap spacing: When trapping for more than one species of moth, separate traps for different moth species by at least 20 meters (65 feet).

Key to Symbols

 = damages needles
  = damages branches/stems
  = damages roots
 = visual survey
 = trapping
 = spore trapping

Scientific Name	Common Name	Survey Method Available
<i>Panolis flammea</i>		<p>Time Frame: In the United Kingdom, this moth flies from March to April and is found in coniferous forests and plantations (Kimber, 2011).</p> <hr/> <p>Plant Part: needles  branches/stems </p> <hr/> <p>CAPS-Approved Method: Trap and lure  The trap is a plastic bucket trap (also known as a "Unitrap" or universal moth trap). Refer to the Plastic Bucket Trap Protocol (Brambila et al., 2010) for detailed instructions on how to use the trap. The lure is effective for 6 weeks (4 weeks in very hot climates).</p> <p>The Lure Product Name is "<i>Panolis flammea</i> Lure."</p> <ul style="list-style-type: none"> • IMPORTANT: Do not place lures for two or more target species in a trap unless otherwise recommended. • Trap spacing: When trapping for more than one species of moth, separate traps for different moth species by at least 20 meters (65 feet). <p>Brambila, J., L. D. Jackson, and R. L. Meagher. 2010. Plastic Bucket Trap Protocol. USDA-APHIS-Cooperative Agricultural Pest Survey Program.</p> <p>Kimber, I. 2011. 2179 Pine Beauty <i>Panolis flammea</i>. UK Moths. Accessed on March 23, 2011 from: http://ukmoths.org.uk/show.php?bf=2179.</p>



Adult female *P. flammea*.
 [Image from Stanislaw Kinelski, www.bugwood.org]

Key to Symbols

 = damages needles
  = damages branches/stems
  = damages roots
 = visual survey
  = trapping
  = spore trapping

Fungi

Scientific Name	Common Name	Survey Method Available
<i>Cronartium flaccidum</i>	Scots pine blister moth	Time Frame: Aeciospores are usually observed in early summer in England (Greig, 1987). Uredinia and hair-like telia appear on the lower leaf surface of the alternate hosts in mid to late summer.



Aecia of *Cronartium flaccidum* on pine.

[Image from Ondrej Zincha, www.biolib.cz/en]

Plant Part:
needles
branches/stems



CAPS-Approved Method:

Visual and/or spore trapping

Visual survey, spore trapping, or a combination of these methods is the approved survey method. For visual survey, collect twigs, bark, or leaves from symptomatic plants with signs (fruiting bodies) of the pathogen. Spore traps, similar to those used for soybean rust monitoring, can be used to detect spores.



The first symptoms of disease are yellowish, necrotic spots on the pine needles. Chlorosis and necrosis of the infected sites, yellowing and premature defoliation of leaves/needles, branch death, bark discoloration, cankers (lesions) and deformed growth are also commonly observed symptoms of the disease (CABI, 2005). Resinosis (excessive resin exudation) can be seen in the lesions.

Cronartium flaccidum affects plants by growing within the vascular system and impeding nutrient and water uptake. Mycelia grow on young shoots. As the pathogen spreads within the host, it interferes with normal tree growth by killing the cambium and damaging vascular tissue. This damage results in the loss of conductive ability, premature leaf loss, and eventual death of the tree. The pathogen can girdle the part of the tree located above the canker (Mordue and Gibson, 1978).

The disease may occur on pines of all ages. The development of disease is usually rapid and lethal to seedlings and young trees (Martinsson and Nilsson, 1987). Infection, which takes place primarily via needles, leads to swelling of young shoots and to production of blister-like structures in the cortex, which split to reveal masses of orange aeciospores. The time from infection to visible aeciospores can take several years. In England, the aeciospores are usually observed in early summer (Greig, 1987). Spermogonia with spermatial fluid ('sweetish droplets') also occur on the infected bark. Uredinia and hair-like telia appear on the lower leaf surface of the alternate hosts in mid to late summer.

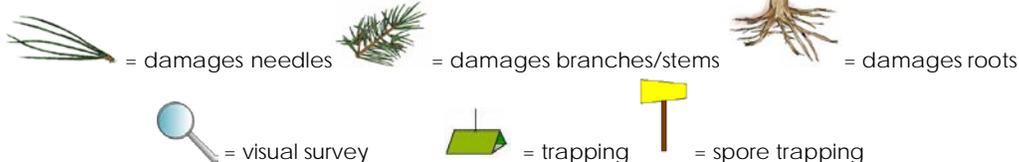
CABI. 2005. Forestry Compendium. Wallingford, UK: CAB International. <http://www.cabi.org/compendia/fc/>

Greig, J.W. 1987. History of *Peridermium* stem rust of Scots pine (*Pinus sylvestris* L.) in Thetford Forest, East Anglia. *Forestry* 60(2): 193-202.

Martinsson, O., and Nilsson, B. 1987. The impact of *Cronartium flaccidum* on the growth of *Pinus sylvestris*. *Scand. J. For. Res.* 2: 349-357.

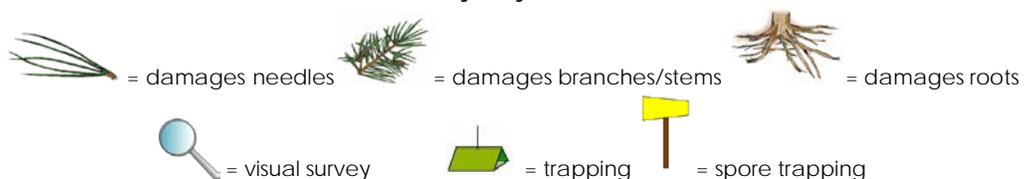
Mordue, J.E.M., and Gibson, I.A.S. 1978. *Cronartium flaccidum*. CMI Descriptions of Pathogenic Fungi and Bacteria. No. 680.

Key to Symbols



Scientific Name	Common Name	Survey Method Available
<i>Mycosphaerella gibsonii</i>	Needle blight of pine	Time Frame: Latent infections give rise to symptoms in the spring the following year.
 <p>Needle blight of two-year old <i>Pinus thunbergii</i> caused by <i>Mycosphaerella gibsonii</i> in Japan [Image from H. Hashimoto, www.bugwood.org]</p>	Plant Part: needles branches/stems 	CAPS-Approved Method: Visual  Visual survey. Conduct a visual survey for symptoms and collect symptomatic (blighted) needles.
	The pathogen causes brown-needle disease. The pathogen targets older leaves in young saplings (1-2 yrs. old), forming lesions on the needles. The infection starts as light yellow-green bands (5-10 mm long) around the needles and spreads from the lower crown to the tips of branches. The lesions fade to yellow then brown then to a gray-brown color. Needles DO NOT exhibit the reddish tint that is characteristic of other diseases.	Fruiting bodies of <i>M. gibsonii</i> form and look like dirty areas on the lesions. The stroma of the fungus erupts through stomata, and under humid conditions dark olive brush-like tufts of elongate conidia develop on the stomata.
This pathogen causes severe defoliation, leading to stunted growth, and sometimes plant death. Dead foliage usually remains on the tree for many months but can be shed during high wind or heavy rain (Ivory and Wingfield, 1986).		Ivory, M.H., and Wingfield, M.J. 1986. First report of <i>Mycosphaerella gibsonii</i> in South Africa. <i>Phytophylactica</i> 18: 51-53.

Key to Symbols



Chapter 5. Diagnostic Methods

E.M. Albrecht and E.E. Davis

Beetles

Scientific Name	Diagnostic Method Available
<i>Dendroctonus micans</i> 	CAPS-Approved Method: Morphological.
	Microscope Required?: YES. To be certain of the presence of <i>D. micans</i> , it is necessary to examine slide-mounted specimens under a microscope.
	Mistaken Identities: <ul style="list-style-type: none"> Of the 19 species of <i>Dendroctonus</i> worldwide, seventeen are indigenous to the United States (Wood 1982, Furniss 1996). The galleries of <i>D. micans</i> are similar to those of the North American species <i>D. rhizophagus</i>, <i>D. terebrans</i>, and <i>D. valens</i>. These beetles primarily infest <i>Pinus</i> spp., which is a minor host for <i>D. micans</i> (CAB 2006). <i>D. micans</i> may be confused with <i>D. punctatus</i>, with which it is "almost identical" (Wood 1982, Bevan and King 1983, Furniss and Johnson 1989, Furniss 1996). Furniss (1996) identified 9 characteristics to differentiate adults of each species. <i>D. micans</i> may also be confused with <i>D. murrayanae</i> and <i>D. rufipennis</i>. Adults may be positively identified by close examination of morphological characters by a well-trained taxonomist. <p>Bevan, D., and C. J. King. 1983. <i>Dendroctonus micans</i> Kug. - a new pest of spruce in U.K. Commonwealth Forestry Review 62: 41-51.</p> <p>CAB. 2006. Crop Protection Compendium. CAB International. Available online at: http://www.cabicompendium.org/cpc. Accessed 14 March 2007.</p> <p>Furniss, M. 1996. Taxonomic status of <i>Dendroctonus punctatus</i> and <i>D. micans</i> (Coleoptera: Scolytidae). Annals of the Entomological Society of America 89: 328-333.</p> <p>Furniss, M., and J. B. Johnson. 1989. Description of the gallery and larva of <i>Dendroctonus punctatus</i> LeConte (Coleoptera: Scolytidae). Canadian Entomologist 121: 757-762.</p> <p>Wood, S. L. 1982. The Bark and Ambrosia Beetles of North and Central America (Coleoptera: Scolytidae), a Taxonomic Monograph. Great Basin Naturalist Memoirs 6: 1359 pp.</p>
	Morphological Guides: <p>Brown, B. 2009. Screening aid to separate Scolytinae bark beetles for other similar appearing bark beetles. Available online at: http://caps.ceris.purdue.edu/webfm_send/536</p> <p>Furniss, M., and J. B. Johnson. 1989. Description of the gallery and larva of <i>Dendroctonus punctatus</i> LeConte (Coleoptera: Scolytidae). Canadian Entomologist 121: 757-762.</p> <p>Haack, R. 2001. EXFOR Database Pest Report: <i>Dendroctonus micans</i>. USDA Forest Service. Available online at: http://spfnic.fs.fed.us/exfor/data/pestreports.cfm?pestidval=35&langdisplay=english. Accessed 18 October 2006.</p> <p>Wood, S. L. 1982. The Bark and Ambrosia Beetles of North and Central America (Coleoptera: Scolytidae), a Taxonomic Monograph. Great Basin Naturalist Memoirs 6: 1359 pp.</p>
	<u>Adult</u> Description of the genus <i>Dendroctonus</i> Erichson 1836:

Key to Symbols



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“Frons without a median groove or impression below upper level of eyes; lateral elevations of frons and transverse elevated callus of pronotum never present in either sex; epistomal process usually narrower and less prominent, lateral margins raised or not ... Declivital interstriae smooth and shining, most punctures impressed, a few of them granulate in female; epistomal process rather narrow, distance between eyes three or more times its basal width; episternal area of prothorax punctate, granules minute or entirely absent ... Declivital striae weakly if at all impressed, 2 apically curved toward sutural striae; declivital interstriae 1 feebly elevated, 2 as wide or wider than 1 or 3 (except near apex); discal striae less than half as wide as interstriae; epistomal process usually transversely concave (except *micans*), rather broad, lateral margins moderately oblique (less than 55 degrees from horizontal) ... frons smooth and polished, with deep close punctures, but almost entirely without granules between punctures; striae punctures on declivity rather large, three or more times as large as those of interstriae ... epistomal process flat; body stouter, 2.3 times as long as wide; striae punctures more strongly impressed; northern Europe and Asia; 6.0-8.0 mm” (Wood 1982).

Egg

No unique features of *D. micans* eggs have been described. Eggs resemble other bark beetle eggs, which are white, oval, and slightly more than 1 mm long (Haack 2001).

Larva

“Spiracular tubercles present, sclerotized; sclerotized areas or plates present on dorsal surface of one or both abdominal segments 8 and 9 or 9 only ... a lightly sclerotized, inconspicuous dorsal plate usually present on segment 9 only” (Furniss and Johnson 1989).

Pupa

No unique features of *D. micans* pupae have been described. Pupae resemble other bark beetle pupae, which are white, mummy-like, and have some adult features (Haack 2001).

Key to Symbols



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Scientific Name	Diagnostic Method Available
<i>Hylobius abietis</i>	CAPS-Approved Method: Morphological.
	<p>Microscope Required?: YES. To be certain of the presence of <i>H. abietis</i> it is necessary to examine slide-mounted specimens under a microscope.</p>
	<p>Mistaken Identities:</p> <ul style="list-style-type: none"> • <i>Hylobius abietis</i> is a fairly large and very distinct pest. It will not likely be confused with any native weevils. • <i>H. abietis</i> could be confused with the congeneric species <i>H. congener</i> and <i>H. pales</i>, which “fill a similar niche” (Drooz 1985, Leather et al. 1999, Petersson and Orlander 2003, Rose et al. 2005). Both <i>H. congener</i> and <i>H. pales</i> exist in the US (Dixon and Foltz 1990, Nordlander et al. 2003b). <i>H. abietis</i> also closely resembles all <i>Pissodes</i> sp., particularly <i>P. castaneus</i> and <i>P. pini</i> (CAB 2006). Adults may be positively identified by close examination of morphological characters by a well-trained taxonomist. • Lekander (1978) provides a key to four species of <i>Hylobius</i>.
	<p>CAB. 2006. Crop Protection Compendium. CAB International. Available online at: http://www.cabicompendium.org/cpc. Accessed 18 October 2006.</p>
	<p>Dixon, W. N., and J. L. Foltz. 1990. Pine reproduction weevils, <i>Hylobius pales</i> (Herbst) & <i>Pachylobius picivorus</i> (Germar) (Coleoptera: Curculionidae). Florida Department of Agriculture and Consumer Services, Division of Plant Industry.</p>
	<p>Drooz, A. T. 1985. Insects of Eastern Forests. USDA Forest Service, Washington, D.C.</p>
	<p>Leather, S. R., K. R. Day, and A. N. Salisbury. 1999. The biology and ecology of the large pine weevil, <i>Hylobius abietis</i> (Coleoptera: Curculionidae): a problem of dispersal? Bulletin of Entomological Research 89: 3-16.</p>
	<p>Lekander, B. 1978. Larval characters of Scandinavian <i>Hylobius</i> species (Coleoptera: Curculionidae). Entomologica Scandinavica 9: 129-134.</p>
	<p>Nordlander, G., H. Bylund, G. Orlander, and K. Wallertz. 2003. Pine weevil population density and damage to coniferous seedlings in a regeneration area with and without shelterwood. Scandinavian Journal of Forest Research 18: 438-448.</p>
	<p>Petersson, M., and G. Orlander. 2003. Effectiveness of combinations of shelterwood, scarification, and feeding barriers to reduce pine weevil damage. Canadian Journal of Forest Research 33: 64-73.</p>
	<p>Rose, D., G. A. Matthews, and S. R. Leather. 2006. Sub-lethal responses of the large pine weevil, <i>Hylobius abietis</i>, to the pyrethroid insecticide lambda-cyhalothrin. Physiological Entomology 31: 316-327.</p>
	<p>Morphological Guides:</p>
	<p>Day, K. R., G. Nordlander, M. Kenis, and G. Halldorson. 2004. Biology and life cycles of bark weevils, pp. 331-349. In F. Lieutier, K. R. Day, A. Battisti, J. C. Gregoire and H. F. Evans [eds.], Bark and Wood Boring Insects in Living Trees in Europe, a Synthesis. Kluwer Academic Publishers, London.</p>
	<p>Lekander, B., H. H. Eidmann, B. Bejer, and E. Kangas. 1985. Time of oviposition and its influence on the development of <i>Hylobius abietis</i> (L) (Col, Curculionidae). Journal of Applied Entomology 100: 417-421.</p>
	<p>PaDIL. 2005. Large Pine Weevil (<i>Hylobius abietis</i>). Pest and Disease Image Library (PaDIL). Available online at: http://www.padil.gov.au/. Accessed 12 February 2007.</p>
	<p><u>Adult</u> “9-16 mm long, elytra are purple-brown in new adults, turning reddish brown to dark brown. Elytra have patches of long narrow yellow scales (ensiform)”</p>

Key to Symbols



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=culture

arranged in small groups in short irregular lines; surface is finely punctured. Pronotum has irregular patches of yellow ensiform scales, surface is punctured and wrinkled with a raised central line; shape is broader than long, strongly convex and constricted at the front. Head has 2 small patches of yellow scales, is extended to form a long cylindrical snout with mandibles at the tip. Antennae are elbowed and attached to the snout near the end. Legs have sharp claws with a strong tooth on the inner edge of each femur" (PaDIL 2005).

Larva

"Fully grown larvae may be 9.5-16 mm in length" (Day et al. 2004).

Larvae are typical of the genus *Hylobius*. Lekander (1978) provides a description.

Key to Symbols



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Scientific Name	Diagnostic Method Available
<i>Monochamus saltuarius</i> 	CAPS-Approved Method: Morphological. Adults can be identified by a cerambycid taxonomist.
	Microscope Required?: YES. To be certain of the presence of <i>M. saltuarius</i> it is necessary to examine morphological features under a microscope.
	Mistaken Identities: <ul style="list-style-type: none"> One hundred fifty species of <i>Monochamus</i> are known from the Holarctic region, with about 10 indigenous to North America. <i>M. saltuarius</i> resembles <i>M. carolinensis</i> and <i>M. titillator</i>, both of which are native North American species (reviewed in Ciesla 2001). The species also resembles <i>M. alternatus</i>, with which it shares a portion of their host range and distribution. Indeed, the larval characters of the two species are difficult to distinguish without the aid of an expert in cerambycid identification (reviewed in CAB 2005).
	Ciesla, W.M. 2001. EXFOR Database Pest Report: <i>Monochamus saltuarius</i> . USDA Forest Service. Available online at: http://spfnic.fs.fed.us/exfor/data/pestreports.cfm?pestidval=74&langdisplay=english . Accessed 19 October 2007.
	CAB. 2006. Crop Protection Compendium. CAB International. Available online at: http://www.cabicompendium.org/cpc . Accessed 1 June 2007.
	Morphological Guides:
	CAB. 2006. Crop Protection Compendium. CAB International. Available online at: http://www.cabicompendium.org/cpc . Accessed 1 June 2007.
	<u>Adult</u> "The body of the adult is predominantly black (11-20 mm), head with sparse yellowish-grey pubescence; pronotum and elytra in both sexes with numerous yellowish or whitish spots; legs and first antennal segments partly with grey spots; antennal segments 3 to 11 in male, uniformly black; in female basal halves of these segments with whitish-grey pubescence, antennae long ... Elytra parallel-sided (male) or from base slightly enlarged posteriorly (female), apically separately rounded. Abdominal sternite V short, apically emarginate, at posterior angles with long dense hairs forming a cluster on each side (female) or rounded, with uniform brownish bristles (males) ..." (CAB 2005).
	<u>Egg</u> "The eggs are white, almost parallel-sided or slightly tapering towards one pole, broadly rounded at the poles, 3.0-3.5 mm long and 0.8-1.2 mm wide ..." (CAB 2005).
	<u>Larva</u> "The larvae are cylindrical and elongate with an oval head and no legs. Pre-diapause larvae are milky-white, whereas diapausing larvae are yellowish-white, whitish-yellow or yellow ... The body of late-instar larvae is 20-28 mm long; the head width is 3.5-4.0 mm. Head flat, half retracted into the prothorax. Epistoma in anterior half reddish-rust, barely convex; in posterior half, bright, flat; at anterior margin laterally with three long bristles on each side of the longitudinal suture with a pair of staggered bristles (inner bristle slightly in front of lateral); near antennal socket with three bristles in transverse row, on disk with two bristles in transverse row. Labrum somewhat rusty, highly tapering towards the base; at anterior margin broadly rounded; in anterior half with long rusty bristles; in posterior half glabrous, medially with pair of long wide-set bristles. Mandibles black, elongate, gently sloping apically ..." (CAB 2005).
	<u>Pupa</u>

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"The pupae are milky-white and 14-20 mm long; the width of the abdomen is 4.5-4.8 mm. The pupae are characterized by a large number of spinules in the frontal region and long, large sclerotized spinule at the apex of the urogomphus. Head medially with deep longitudinal trough, lateral to it in front of antennae with numerous long setiform spinules forming broad, longitudinal field; at anterior margin near base of clypeus with six spinules forming transverse row interrupted medially, occiput glabrous, lustrous. Labrum elongate, apically broadly rounded; in anterior half along margins with long acicular spinules. Upper ocular lobe with two bristles. Antennae in second half bent ventrad, here spiralled, forming two incomplete (female) or two complete loops (male).

Abdomen moderately elongate, gradually tapering towards tip. Abdominal tergites in posterior half convex in anterior half transversely depressed, medially with longitudinal groove, lateral to it in posterior half with rusty acicular spinules directed backward and forming dense transverse band divided by median longitudinal groove. Two to three rows of spinules observed in each transverse band. Tergite VII is convex, lustrous, triangular, gently rounded apically, in posterior third with solitary minute, sometimes barely perceptible, setiform spinules. Tergite semi-circular, convex, lustrous, and without spinules. Urogomphus at the tip of abdomen is highly extended, terminating in long large, slightly anteriorly curved, sclerotized spinule. Ridges bordering the tip of the abdomen laterally (ventral view) with two to five minute setigerous spinules on the ventral side. Valvifers of female spherical, basally slightly wide-set, apically with small tubercle, bent towards each other ..." (CAB 2005).

Key to Symbols



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Scientific Name	Diagnostic Method Available
<i>Monochamus sutor</i> 	CAPS-Approved Method: Morphological. Adults can be identified by a cerambycid taxonomist.
	Microscope Required?: YES. To be certain of the presence of <i>M. sutor</i> it is necessary to examine morphological features under a microscope.
	Mistaken Identities: <ul style="list-style-type: none"> One hundred fifty species of <i>Monochamus</i> are known from the Holarctic region, with about 10 indigenous to North America. <i>M. sutor</i> resembles <i>M. scutellatus</i>, a native North American species (reviewed in Ciesla 2001). An expert in cerambycid identification is required to distinguish <i>M. sutor</i> from other <i>Monochamus</i> species (reviewed in CAB 2005).
	Ciesla, W.M. 2004. EXFOR Database Pest Report: <i>Monochamus sutor</i> . USDA Forest Service. Available online at: http://spfnc.fs.fed.us/exfor/data/pestreports.cfm?pestidval=159&langdisplay=english . Accessed 19 October 2006.
	CAB. 2005. Crop Protection Compendium. CAB International. Available online at: http://www.cabicompendium.org/cpc . Accessed 1 June 2007.
	Morphological Guides: <p>CAB. 2005. Crop Protection Compendium. CAB International. Available online at: http://www.cabicompendium.org/cpc. Accessed 1 June 2007.</p> <p>Ciesla, W.M. 2004. EXFOR Database Pest Report: <i>Monochamus sutor</i>. USDA Forest Service. Available online at: http://spfnc.fs.fed.us/exfor/data/pestreports.cfm?pestidval=159&langdisplay=english. Accessed 19 October 2006.</p>
	<p>Adult</p> <p>"The overall body length of the adult is 15-26 mm. The body is moderately elongate with head not broader than the pronotum. Head and pronotum have a deep median longitudinal groove with deep uneven punctuation and dense or sparse grey or brownish hairs. The antennae are 2.5 times the length of the body on males and less than 1.5 times the length of the body for females. The eyes are deeply faceted, broadly emarginated, with the upper ocular lobes close to each other. The distance between the ocular lobes is less than the interspace between the antennal bases. The scutellum is whitish-yellow and the prothorax has a pair of projections. The elytra have several irregular, faint, bronze or gold coloured markings. Females are slightly larger than males" (CAB 2005).</p>
	<p>"Adults superficially resemble the indigenous northern pine sawyer, <i>Monochamus scutellatus</i>. They are 15-24 mm long with a black body color with a metallic sheen. The scutellum is a whitish-yellow color and the prothorax has a pair of projections. The elytra have several irregular, faint, bronze or gold colored markings. The antennae are more than twice the body length on the males and about 1.5 times the body length on females. Females are slightly larger than males (Bistimmungensüben an Insekten 2002)" (Ciesla 2004).</p>
	<p>Egg</p> <p>"The eggs are white, matte, becoming brownish with time, elongate, slightly curved, rounded at poles, overall length 3.8 mm, width 0.8 mm" (CAB 2005).</p>
	<p>Larva</p> <p>"The larvae are white, opaque legless grubs, averaging 35-40 mm in length when mature. The head capsule is amber in colour, with well developed, black chewing mouthparts. Overall, the body length of mature larvae is 40-50 mm; the width of the head is 4.1-4.7 mm" (CAB 2005).</p>

Key to Symbols



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Pupa

"The pupae are moderately elongate, white, opaque and cylindrical. They are exarate, with antennae, legs and wings free from the body. The abdomen is elongate, gradually tapering to a posterior tip" (CAB 2005).

Key to Symbols



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Scientific Name	Diagnostic Method Available
<i>Tomicus destruens</i> 	<p>CAPS-Approved Method: Morphological. Examination by a taxonomist with expertise in the weevil subfamily Scolytinae is required for identification. To determine if the species is <i>Tomicus</i>, use Passoa and Cavey (1994) followed by Brodel (2005—rev2009). To determine species of <i>Tomicus</i> (<i>destruens</i>, <i>minor</i>, <i>piniperda</i>) use Brodel (2005—rev2009) with Brodel (2000). These references can be found in Appendix M of the current CAPS National Survey Guidelines.</p>
	<p>Microscope Required?: YES. To be certain of the presence of <i>T. destruens</i> it is necessary to examine morphological features under a microscope.</p>
	<p>Mistaken Identities:</p> <ul style="list-style-type: none"> • <i>Tomicus destruens</i> can be mistaken for other families and genera of small beetles with the naked eye. • <i>T. destruens</i> is morphologically similar to <i>T. piniperda</i> (Faccoli 2006) and the two species are difficult to distinguish in the field (Gallego and Galián 2001, Faccoli 2006). <i>T. piniperda</i> is native to Europe, Asia, and North Africa and was introduced into the US in 1992 (Kohlmayr et al. 2002, reviewed in CAB 2006), while <i>T. destruens</i> is currently confined to the circummediterranean region. <i>T. piniperda</i> is the only representative of its genus in North America (reviewed in CAB 2006). • <i>T. destruens</i> is also similar to <i>T. minor</i>. • Maternal and larval galleries are distinct enough to allow identification to genus (reviewed in Ciesla 2003). Larvae and callow (young) adults of <i>T. destruens</i> and <i>T. piniperda</i> are easy to differentiate (Lekander 1971, Faccoli 2006).
	<p>CAB. 2006. Crop Protection Compendium. CAB International. Available online at: http://www.cabicompendium.org/cpc. Accessed 18 October 2006.</p> <p>Ciesla, W. 2003. EXFOR Database Pest Report: <i>Tomicus destruens</i>. USDA Forest Service. Available online at: http://spfnic.fs.fed.us/exfor/data/pestreports.cfm?pestidval=9&langdisplay=english. Accessed 18 October 2006.</p> <p>Faccoli, M. 2006. Morphological separation of <i>Tomicus piniperda</i> and <i>T. destruens</i> (Coleoptera: Curculionidae: Scolytinae): new and old characters. European Journal of Entomology 103: 433-442.</p> <p>Gallego, D., and J. Galián. 2001. The internal transcribed spacers (ITS1 and ITS2) of the rDNA differentiates the bark beetle forest pests <i>Tomicus destruens</i> and <i>T. piniperda</i>. Insect Molecular Biology 10: 415-420.</p> <p>Kohlmayr, B., M. Riegler, R. Wegensteiner, and C. Stauffer. 2002. Morphological and genetic identification of the three pine pests of the genus <i>Tomicus</i> (Coleoptera, Scolytidae) in Europe. Agricultural and Forest Entomology 4: 151-157.</p> <p>Lekander, B. 1971. On <i>Blastophagus destruens</i> Woll. and a description of its larva (Col. Scolytidae). Entomologisk Tidskrift 92: 271-276.</p>
	<p>Morphological Guides:</p> <p>Brodel, C.F. 2005—rev 2009. <i>Tomicus</i> Bark Beetles: A Key for Separating Program Species <i>piniperda</i> from European Exotics <i>destruens</i> and <i>minor</i>.</p> <p>Brodel, C. F. 2000. Distinguishing <i>Tomicus minor</i> from <i>T. piniperda</i>.</p> <p>Brown, B. 2009. Screening aid to separate Scolytinae bark beetles for other similar appearing bark beetles. Available online at: http://caps.ceris.purdue.edu/webfm_send/536</p> <p>Ciesla, W. 2003. EXFOR Database Pest Report: <i>Tomicus destruens</i>. USDA Forest Service. Available online at: http://spfnic.fs.fed.us/exfor/data/pestreports.cfm?pestidval=9&langdisplay=english. Accessed 18 October 2006.</p> <p>Faccoli, M. 2006. Morphological separation of <i>Tomicus piniperda</i> and <i>T. destruens</i></p>

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(Coleoptera: Curculionidae: Scolytinae): new and old characters.
European Journal of Entomology 103: 433-442.

- Lekander, B. 1971.** On *Blastophagus destruens* Woll. and a description of its larva (Col. Scolytidae). Entomologisk Tidskrift 92: 271-276.
- Passoa, S., and J. Cavey. 1994.** Key to help screen *Tomicus piniperda* (L.) from other North American Scolytidae (Coleoptera). USDA, APHIS, PPQ. NA-TP-06-93. Available online at: <http://www.barkbeetles.org/exotic/tmcspnpe.html>
- Peverieri, G. S., and M. Faggi. 2005.** Determination of age in larvae of *Tomicus destruens* (Wollaston, 1865) (Coleoptera Scolytidae) based on head capsule width. Redia 88: 115-117.

Adult

"Mature colour of elytra reddish, antennal club of the same colour of the antennal funicle, third antennal segment with abundant vestiture of many setae, upper margin of the first antennal club segment with only short and regular setae, second interstriae of the declivity transversely wrinkled, with 2 or 3 rows of punctures, length/width of elytra <1.7, elytra/pronotum length <2.35, elytral length/pronotum width <1.9" (Faccoli 2006).

"Callow adults of both species [*T. destruens* and *T. piniperda*] have a similar homogeneous yellow colour, thus for young specimens other characters must be used for identification" (Faccoli 2006).

"The declivity ... [is] weakly, irregularly, transversely wrinkled, most easily seen on interstriae [sic] 2 where no setae occur, but in most *T. destruens* specimens the sculpture of the second declivital interstriae was more wrinkled than in *T. piniperda*" (Faccoli 2006).

"The ratio between length and width of the elytra was different between species, higher in *T. piniperda* (>1.7) than in *T. destruens* (<1.7). Also, the ratio between elytra and pronotum length was higher in *T. piniperda* (>2.35) than *T. destruens* (<2.35). Finally, the ratio between elytral length and pronotum width was higher in *T. piniperda* (>1.9) than *T. destruens* (<1.9)" (Faccoli 2006).

Egg

"The immature stages (eggs, larvae and pupae) lack sufficient characteristics for positive identification to species. Eggs are a pearly white color." (Ciesla 2003)

Larva

"Head capsule index 0.95. Frontal shield broad, triangulate with straight sides and distinct endocarinal line. Frontal setae five pairs of which pair 2 is the longest. Epistoma posteriorly limited by a continuous, slightly curved line which laterally bends backwards. Medially, on the anterior edge a large tubercle.

Antenna short and broad without differentiation. On the flat antennal field five setae of equal length, four of which are situated laterally of the antenna.

Clypeus with convex sides and gently concave anterior border. The medial of the clypeal setae about three times longer than the lateral ones.

Labrum with a rounded, flattened anterior border. The lateral pair of the antero-medial setae poorly developed, bristle-like, the medial one vigorous of equal breadth.

On the epipharynx the antero-lateral setae parallel to the anterior border of epipharynx. Medial epipharyngeal setae of equal size, in three pairs. Between the second and third pairs two groups of sensillae, each with three organs. Posterior sensillae lacking. Tormae short, broad, parallel or slightly convergent caudally.

Mentum with broadly attached arms and faintly indicated axis. Palpus with two distinct articles. On labium, the four setae of the same length and of equal

Key to Symbols



=microscope



=culture

breadth. Setae in the posterior pair on the ligula much closer to each other than the setae in the anterior pair. Submentum with spines along the lateral border. The three setae situated in a triangle with the medial one exterior to the others" (Lekander 1971).

Tomicus destruens has four larval instars. "The mean value of head capsule width was 0.48 mm for the Ist instar, 0.638 mm for the IInd instar, 0.845 mm for the IIIrd instar and 1.141 mm for the IVth instar" (Peverieri and Faggi 2005).

Pupa

"The pupae are white, mummy-like and have some adult features including wings that are folded behind the abdomen" (Ciesla 2003).

Key to Symbols



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Moths

Scientific Name	Diagnostic Method Available
Dendrolimus pini 	<p>CAPS-Approved Method: Morphological. This species may occur in mixed populations with similar species. <i>D. pini</i> is morphologically distinctive, but identification should be confirmed by a qualified taxonomist. For larvae, use Passoa (2007); for adults, use Passoa (2009). These references can be found in Appendix M of the current CAPS National Survey Guidelines.</p>
	<p>Microscope Required?: Yes. To be certain of the presence of <i>D. pini</i> it is necessary to examine morphological features under a microscope.</p>
	<p>Mistaken Identities:</p> <ul style="list-style-type: none"> <i>Dendrolimus pini</i> may be confused with the closely-related <i>D. superans</i> (EPO 2005). Neither species is present in the US (reviewed in Ciesla 2004). Adults may be positively identified by close examination of morphological characters by a well-trained taxonomist.
	<p>EPO. 2005. Data Sheets on Forest Pests: <i>Dendrolimus sibiricus</i>. European and Mediterranean Plant Protection Organization. Available online at: http://www.eppo.org/QUARANTINE/insects/Dendrolimus_sibiricus/DENSDSI_ds.pdf. Accessed 2 June 2005.</p>
	<p>Ciesla, W. M. 2004. EXFOR Database Pest Report: <i>Dendrolimus pini</i>. USDA Forest Service. Available online at: http://spfnic.fs.fed.us/exfor/data/pestreports.cfm?pestidval=158&langdisplay=english. Accessed 18 October 2006.</p>
	<p>Morphological Guides:</p> <p>Ciesla, W. M. 2004. EXFOR Database Pest Report: <i>Dendrolimus pini</i>. USDA Forest Service. Available online at: http://spfnic.fs.fed.us/exfor/data/pestreports.cfm?pestidval=158&langdisplay=english. Accessed 18 October 2006.</p>
	<p>Kolk, A., and Starzyk, J. R. 1996. Pine moth (<i>Dendrolimus pini</i> L.), pp. 705 pp., Atlas skodliwych owadów lesnych (The atlas of forest insect pests). Multico Warszawa, Warsaw.</p>
	<p>Passoa, S. 2007. Quarantine Significant Lepidoptera of Concern to the Southern United States. Presentation given at the Invasive Arthropod Workshop. Clemson University. May 7-9, 2007. Slide 44. Available from Appendix M of the most current CAPS National Survey Guidelines.</p>
	<p>Passoa, S. 2009. Screening Key for CAPS Target Lepidoptera in the Eastern and Midwestern United States (males). Lab Manual for the Lepidoptera Identification Workshop. University of Maryland. Available from Appendix M of the most current CAPS National Survey Guidelines.</p>
	<p>Watson, L., and M. J. Dallwitz. 2007. British insects: the families of Lepidoptera. Available online at: http://delta-intkey.com. Accessed 1 May 2007.</p>
	<p>Winokur, L. 1991. Phenology and development in <i>Dendrolimus pini</i> (L.) (Lepidoptera: Lasiocampidae): a preliminary study. Entomologist's Gazette 42: 243-250.</p>
	<p>Adult</p> <p>"Male reddish ochre, more of less gray; superior wings chestnut at the base and extending to the disc; before the middle is a sinuated striga with a lunular white spot upon it, and beyond the middle an oblique ochraceous fascia, the inner margin crenated with a brown line, the outer one very much sinuated and marked with strong brown spots; inferior wings pale castaneous. Female paler" (Watson and Dallwitz 2007).</p>
	<p>"The first pair of wings are with a small white spot and wide dark strip. Antennae of females are slightly saw-shaped, while those of males are double comb-shaped" (Kolk and Starzyk 1996).</p>

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"Adults are covered with thick scales on both the wings and body. Males have a wingspan of 50-70 mm and females a wingspan of 70-90 mm. The forewings are gray-brown to brown in color. They contain a reddish brown lateral band, edged on both sides with an irregular dark-brown to black stripe. The hind wings are red brown to gray brown in color. Body color is brown. Coloring of the males is typically darker than the females" (Ciesla 2004).

The sex of moths may be determined at eclosion (emergence from pupal cocoons) "from the form of the antennae which are more plume-like in males" (Winokur 1991).

Egg

"Eggs are about 2 mm long, blue green in color when first deposited, later turning to gray" (Ciesla 2004).

Larva

"Mature larvae range in size from 50-80 mm and are covered with soft gray or brownish hairs. Thoracic segments 2 and 3 have thick bands of hairs of alternating steel blue and black. The dorsal surface of each abdominal segment contains a black mark flanked by irregular white lines" (Ciesla 2004).

"A V-shaped spot [occurs] on the eight segment of the body" (Kolk and Starzyk 1996).

Pupa

"Pupae range from 30-35 mm in length, are brown to black in color with both ends rounded. They are enclosed in a yellow-brown spindle shaped cocoon, which also contains remnants of the steel blue thoracic hairs" (Ciesla 2004).

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Scientific Name	Diagnostic Method Available
<i>Dendrolimus punctatus</i>	<div data-bbox="386 279 440 352" style="display: inline-block; vertical-align: middle;">  </div> <p data-bbox="483 279 1372 352">CAPS-Approved Method: Morphological. Genitalia dissection is required to get to the genus level. Identification to species level requires confirmation by Lepidoptera specialist.</p> <hr/> <p data-bbox="483 384 776 407">Microscope Required?: Yes.</p> <hr/> <p data-bbox="483 438 683 462">Mistaken Identities:</p> <ul data-bbox="532 464 1372 541" style="list-style-type: none"> <li data-bbox="532 464 1372 541">• This species is similar to <i>Dendrolimus punctatus tabulaeformis</i> (CABI 2010) as well as other <i>Dendrolimus</i> species. There are no other <i>Dendrolimus</i> species present in the United States. <p data-bbox="483 569 1284 621">CABI. 2010. Crop Protection Compendium Wallingford, UK: CAB International. www.cabicompendium.org/cpc</p> <hr/> <p data-bbox="483 648 724 672">Morphological Guides:</p> <p data-bbox="483 674 1284 726">CABI. 2010. Crop Protection Compendium Wallingford, UK: CAB International. www.cabicompendium.org/cpc</p> <p data-bbox="483 728 1354 781">Ciesla, W. M. 2001. <i>Dendrolimus punctatus</i>. EXFOR Database Pest Reports. Accessed April 12, 2011 from: http://spfnic.fs.fed.us/exfor/index.cfm.</p> <p data-bbox="483 808 1354 886"><u>Adult</u> "The adult has a wingspan of ca 50-80 mm [1.97 to 3.15 in] with females being somewhat larger than the males. Color of wings is typically a medium, dull gray or brown. The front (mesothoracic) wings have two dark lines" (Ciesla 2001).</p> <p data-bbox="483 913 1325 963"><u>Egg</u> "Eggs are rose to light brown in color and deposited in rows on pine needles" (Ciesla 2001).</p> <p data-bbox="483 991 1354 1089"><u>Larva</u> "The mature larva is 55–70 mm long [2.17 to 2.76 in]. Abdominal and thoracic segments have alternating patterns of light gray and black bands. The black bands contain a series of orange markings. The larvae are covered with fine hairs (setae) that have urticating properties and can cause skin and eye irritation" (Ciesla 2001).</p> <p data-bbox="483 1117 1372 1402">"The larvae have two colour forms: brownish-red and black. The scale-like setae on the body may be white or golden-yellow. The head is brownish-yellow. The frontal and adfrontal areas are dark brown. The adfrontal border is not smooth. There are distinct poisonous setae on the dorsal surfaces of the meso- and metathorax. Each abdominal segment has subdorsal anterior scale-like setae with serrate tips. The scale-like setae on the eighth abdominal segment are most distinct. There are abundant white setae on the lateral sides of the body. There is a pair of longitudinal bands from the head to the last abdominal segment. A white spot exists on the posterior upper of the spiracles in segments from the mesothorax to the eighth abdominal segment. Below the longitudinal band, a short oblique spot extends to the ventral surface at the anterior of each segment" (CABI 2010).</p> <p data-bbox="483 1430 1372 1507"><u>Pupa</u> "The male pupae are 19-26 mm [0.74 to 1.02 in] long. The female pupae are 26-33 mm [1.02 to 1.30 in] long. The end of the anal hook varies from a closed circle to being slightly curved upwards" (CABI 2010).</p>

Key to Symbols



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Scientific Name	Diagnostic Method Available
Lymantria mathura 	CAPS-Approved Method: Morphological. Adults and late instar larvae are easily identified.
	Microscope Required?: YES. To be certain of the presence of <i>L. mathura</i> it is necessary to examine morphological features under a microscope.
	Mistaken Identities: <ul style="list-style-type: none"> <i>Lymantria mathura</i> is not likely to be confused with other lymantriids, particularly if a specimen is an adult or late instar larva (EPPO 2005). Eggs or neonates are incredibly difficult to distinguish, and molecular tools are being developed to aid with identification (Armstrong et al. 2003). <i>L. mathura</i> may be confused with <i>L. monacha</i> (not known to occur in the US) or <i>L. dispar</i>.
	Armstrong, K. F., P. McHugh, W. Chinn, and F. E.R. 2003. Tussock moth species arriving on imported used vehicles determined by DNA analysis. New Zealand Plant Protection 56: 16-20.
	EPPO. 2005. Data sheets on quarantine pests: <i>Lymantria mathura</i> . European and Mediterranean Plant Protection Organization. Available online at: http://www.eppo.org/QUARANTINE/insects/Lymantria_mathura/DSL/AMA.pdf . Accessed 29 September 2005.
	Morphological Guides:
	Moore, F. 1865. On the Lepidopterous insects of Bengal. Proceedings of the Scientific Meetings of the Zoological Society of London.
	Pogue, M. G., and P. W. Schaeffer. 2007. A Review of Selected <i>Lymantria</i> Species Potentially Invasive to North America. Forest Health Technology Enterprise Team, Technology Transfer, FHET-2006-07. Available online at: http://caps.ceris.purdue.edu/webfm_send/132
	Roonwal, M. L. 1979. Field-ecological studies on mass eruption, seasonal life-history, nocturnal feeding and activity rhythm, and protective behavior and coloration in the sal defoliator, <i>Lymantria mathura</i> (Lepidoptera: Lymantriidae), in sub-Himalayan forests. Records of the Zoological Survey of India 75: 209-236.
	<p>"<i>Lymantria mathura</i> Moore (Lepidoptera: Lymantriidae) is a moderate sized moth... There is marked sexual dimorphism in size and colour. The male is smaller (wing expanse male: 35-50 mm; female: 75-95 mm), with the forewings brown and hindwings yellow. In females the forewings are white with dark markings, and the hindwings pink..." (Roonwal 1979).</p>
	<p>Male: "Upperside-fore wing greyish white, markings brown, with pale-brown interspaces; with two or three black and yellow spots at the base; two transverse subbasal irregular lines, between which is a broad band; a round spot within the cell and a blackish curved streak at its end; three transverse discal lunulated bands, the first broad, the others narrow; a marginal row of spots: hind wing dull yellow, with a blackish discal spot, narrow submarginal maculated band, and a marginal row of small spots. Underside dull yellow, suffused with pale brown between the veins, with darker-brown discal and marginal spots. Thorax white, with yellow and black spots. Abdomen yellow, tuft white, with dorsal, lateral, and a row beneath of black spots. Head at the sides, palpi in front, and legs yellow; palpi above and at the sides, and spots on the legs, black. Antennae brown. Expanse 2¼ inches" (Moore 1865).</p>
	<p>Egg-masses and covering hairs: Egg masses are laid from ground-level up to about 18 m [60 ft.] of the trunk, but are most dense between the levels of 0.5 to 5 m [1½-16 ft]. They are flat, of an ovoid-elongate or other shape, with irregular edges, and vary in extent from about 0.5 x 1 cm to 6 x 15 cm. From a distance the egg masses are visible as characteristic white, fluffy patches against the</p>

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dark-coloured bark. Each egg-mass contains about 50 to 1,200 or more eggs which are laid 2 to 4 layers deep directly on the bark. An egg-mass is covered over with a nearly one-millimetre, white thick felt-like covering composed of long, white, silken hairs (... these hairs are shed by the female from the anal tuft ...). The hairs are about 800-1200 μ long and 3.1-6.2 μ in diameter; one end is knob-like, the other pointed; a few such hairs are also mixed with the eggs. Freshly laid eggs are rounded, have a flat base, the maximum and minimum diameters varying from 1.13-1.19 mm and 0.86-0.92 mm respectively" (Roonwal 1979).

Egg-mass after hatching: "After the majority of eggs have hatched, an egg mass presents a changed appearance. Firstly, the hair-covering which has hitherto (for several months in the case of the overwintering eggs) remained pure white, now becomes dull-coloured, a dirty cream, and, in a few cases, with irregular patches of pale buff. Secondly, the hair covering is pierced by numerous rounded holes of varying diameters (c. 0.5-3 mm) through which the newly hatched larvae have escaped. Beneath the thin, hole-pierced, hairy covering, there is a flat, hollow space containing the remnants of eggshells and a few remaining eggs which have not yet hatched" (Roonwal 1979).

Larvae: "Three main colour forms are found in mature caterpillars, the following proportions being noticed in 1,613 caterpillars examined: grey-white 66%, intermediate 11%, and blackish brown 23%. The details of colour are described below briefly.

Form I (Grey-white): Ground colour dirty white tinged with grey. Dorsal: Head white with numerous black or brown spots; frons with a longitudinal median black streak; rest of body grey-white, with numerous fine dots forming paired patches. A transverse yellow-brown streak present between pro- and mesothorax, and another in middle of metathorax; abdominal warts blackish; paired lateral papules on abdomen white, with tufts of long white and brown hairs. Long pencil-like plumes of hairs on head and on, end of abdomen black. Ventral: Brownish pink; legs and prolegs brown, the latter with a black patch externally.

Form II (Intermediate): Dorsal: Ground colour pale brown, with a median white patch on abdominal terga 4 and 5. Ventral: As in Form I.

Form III (Blackish brown): Dorsal: Ground-colour dark brown to almost black; numerous black spots visible in brown larvae but merged with ground-colour in darker ones; several small white dots present on abdominal terga 4 to the last, and large white patches on terga 4-6. Ventral: Ashy, suffused with a little pink in the median parts; rest as in Form I.

In the masses of caterpillars on tree trunks the various colour types are mixed on individual trees; this fact has a protective value by making detection by enemies difficult" (Roonwal 1979).

"The size ... characteristics of the six larval stages are given below briefly...

Stage I. Length 3 mm; head-width 0.5 mm. Generally black dorsally; meso- and metathorax and segment 5 of abdomen brown; legs black; prolegs pale brown with a black patch externally.

Stage II. Length 5 mm; head-width 0.7 mm. Generally black dorsally; meso- and metathorax greyish; last abdominal segment pale brown with blackish tinge; rest as in Stage I.

Stage III. Length 13 mm; head-width 1.5 mm. Head brown; body black

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above, paler below; thoracic terga with yellow-brown spots; legs black, prolegs brown with a black external patch.

Stage IV. Length 20 mm; head-width 2.5 mm. Head above either black (brown distally) or pale green with black dots; sides brown; body black with white warts; meso- and metathorax with brown stripes anteriorly; legs and prolegs as in Stage III.

Stage V. Length 30-40 mm; head-width 3.5 mm. Head above brown to grey, speckled with black; body black with many minute white spots; pro- and mesothorax with a transverse brown streak at the distal edge; ninth abdominal segment with a pair of prominent dorsal white spots; legs and prolegs reddish brown, the latter with a large black patch externally.

Stage VI. Length 60-85 mm; head-width 5-6 mm. With sexual dimorphism, females being longer (males: 60-65 mm, females: 70-85 mm). Colour pattern similar to Stage V, but in ground-pattern three types recognizable, viz., grey-white, blackish-brown and intermediate (vide infra). Older larvae well 'camouflaged' against tree trunks" (Roonwal 1979).

Pupa: "The pupa is of the 'obtect adecticus type,' and the appendages are firmly soldered to the body. It is buff to dark brown, about 20-36 mm long, and shows sexual dimorphism; the female pupa is paler, larger and heavier than the male, as follows:

Female: Buff to pale brown. Length (including hair tufts) 30-36 mm; maximum width 10-14 mm. Weight 0.88 gm (average of 18 pupae).

Male: Very dark chocolate brown, Length (including hair tufts) 15-25 mm; maximum width 6-8 mm. Weight 0.14 gm (average of 53 pupae)" (Roonwal 1979).

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Scientific Name	Diagnostic Method Available
Panolis flammea	 <p>CAPS-Approved Method: Morphological. A brief description of all life stages can be found in Carter (1984). Both South (1961) and USDA (1958) include a description of the adult and larvae. South (1961) also includes a colored plate of the adult male and female. Descriptions of this pest can also be found in Hampson (1905) and Novak (1976).</p> <p>Adults have hairy eyes (as do all Hadeninae) which can be seen even in sticky trap material. Forward any specimens with hairy eyes to your regional domestic identifier for identification.</p> <hr/> <p>Microscope Required?: YES.</p> <hr/> <p>Mistaken Identities:</p> <ul style="list-style-type: none"> The pupae of <i>P. flammea</i> are similar to both <i>Semiothisa liturata</i> and <i>Bupalus piniarius</i> and can be frequently found in the soil together in the United Kingdom (Bevan and Brown 1978). <p>Bevan, D. and R. M. Brown. 1978. Pine looper moth [abstract]. Forest Record 119: 13pp.</p> <hr/> <p>Morphological Guides:</p> <p>Carter, D. J. 1984. Pest Lepidoptera of Europe with special reference to the British Isles. Dr. W. Junk Publishers. Dordrecht, the Netherlands. 431 pp.</p> <p>Hampson, G. F. 1905. Catalogue of the Lepidoptera Phalaenae in the British Museum, Vol. 5. British Museum of Natural History, London. 634 pp.</p> <p>Novak, V. 1976. Atlas of Insects Harmful to Forest Trees. Volume 1. Elsevier Scientific Publishing Company. Amsterdam, The Netherlands. 125 pp.</p> <p>South, R. 1961. The Moths of the British Isles, Vol. 1. Frederick Warne & Co. Ltd., Great Britain. 427 pp.</p> <p>USDA. 1958. Insects not known to occur in the United States. Cooperative Economic Insect Report, Vol. 8. USDA-ARS-Plant Pest Research Service. p. 67-68.</p> <p><u>Adult</u> "This night moth has a wing span of 30 to 35 mm [1.18 to 1.38 in]. The basic colour of the thorax and wings changes from red-brown to gray-brown. The bristle-shaped antennae of the males are composed of segments which resemble saw-like points while the antennae of the females are simple. The front edge of the thorax is decorated with a pale coloured band and on both sides there are some light coloured patches. The abdomen is yellow-gray. The end of the male is angularly broad, whereas the end of the female is conical and has a blunt point. The forewings are decorated with almost round or kidney-shaped patches. The dark moth has markings consisting of dark, transverse and zigzagging bands. The hind wings are gray. The resting moths sit with their roof-like wings folded. In the pine bark they coalesce in colour with the surroundings (mimicry)" (Novak 1976).</p> <p><u>Egg</u> "The flattened, circular eggs are centripetally notched, and each has a small declivity in its middle. At first the eggs are whitish but later turn violet-brown. The size of an egg is 0.6 mm x 0.8 mm [0.02 x 0.03 in]" (Novak 1976).</p> <p><u>Larva</u> "The yellow-green larvae of the 1st instar are 2 to 3 mm [0.08 to 0.11 in] long and have a large conspicuous yellow head (mean width 0.4 mm [0.02 in]). The fully grown caterpillars are 37 to 40 mm [1.06 to 1.57 in] long, dark green with a brown head, and are about 3 mm [0.11 in] wide.</p> <p>A broad white band occurs in the middle of the dorsum. On both sides there are narrow white bands and on the underside there are wide orange bands" (Novak, 1976). "It is not until the fifth or final stage (instar) that the caterpillar develops the characteristic bright orange stripe on either side" (Heritage 1997).</p> <p><u>Pupa</u> "The free shiny brown pupa is 16 to 18 mm [0.63 to 0.71 in] long and ends with</p>

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two thin spines. On the dorsal side of the abdomen is a characteristic declivity”
(Novak 1976).

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Fungi

Scientific Name	Diagnostic Method Available
<i>Cronartium flaccidum</i>	 CAPS-Approved Method: Morphological. Characteristics of pycnia, aecia, aeciospores, uredinia, urediniospores, telia, and teliospores can be used to distinguish from other rust fungi (Mordue and Gibson, 1978).
	<p><i>C. flaccidum</i> can be cultured (axenically) by seeding aeciospores on modified Schenk and Hildebrandt's and Harvey and Grasham's media and incubating at 23-25°C (73-77°F) in the dark (Moricca and Ragazzi, 1994). Further study is possible <i>in vitro</i> on <i>Pinus</i> spp. callus tissue (Ragazzi et al., 1995).</p>
Microscope Required?: YES.	
Mistaken Identities:	
<p>At least eleven <i>Cronartium</i> species and six species of <i>Peridermium</i> occur in North America on pine (Chalkey, 2010). To a certain extent, these can be distinguished by the aeciospore and urediniospore morphology, as well as by symptomatology. While some cause stem cankers, other rusts produce galls or witches brooms in infected stems or branches. Others cause no symptoms at all (Chalkey, 2010). <i>C. flaccidum</i> belongs to a distinct group of <i>Cronartium</i> species distinguished by their aeciospores (in which an echinulate surface alternates with smooth areas) (Moricca and Ragazzi, 1996). <i>Cronartium comandrae</i>, a widespread North American pine stem rust that also infects two-needle species like <i>C. flaccidum</i>, produces unique tear-drop shaped aeciospores on pine (Chalkey, 2010)</p>	
<p>Symptoms can be confused with those of <i>C. ribicola</i>, the causal agent of white pine blister rust. <i>C. ribicola</i> does not infect <i>Pinus sylvestris</i>, whereas <i>C. flaccidum</i> does not infect five-needle pines or <i>Ribes</i> species (Kaitera and Nuorteva, 2006b). Kaitera and Nuorteva (2006a) conducted inoculation studies with <i>C. ribicola</i> on the main alternate hosts of <i>C. flaccidum</i>. The authors found that neither uredinia nor telia developed on the leaves of <i>Vincetoxicum hirundinaria</i>, <i>V. nigrum</i>, <i>Melampyrum sylvaticum</i>, <i>M. pretense</i>, <i>M. nemorosum</i>, <i>M. arvense</i>, <i>M. cristatum</i>, or <i>M. polonicum</i>.</p>	
<p>In Europe, other rust that can attack pines also have a heteroecious life cycle similar to <i>C. flaccidum</i>, but usually infect different alternate hosts. <i>Coleosporium tussilaginis</i>, the pine needle rust, shares a few telial hosts with blister rust, but produces its spermagonia and aecia on pine needles, not on the stems. Also, teliospores of this rust on species of <i>Melampyrum</i> are single to cylindrical, produced not in long columns but in waxy crusts. <i>Melampsora populnea</i> infects the shoots of two-needle pines, causing shoot bending and/or tip death. Its linear aecia lack a peridium and the aeciospores are significantly smaller than those of <i>C. flaccidum</i> (Chalkey, 2010).</p>	
<p>Chalkey, D. 2010. Systematic Mycology and Microbiology Laboratory, ARS, USDA. Invasive Fungi. Scots stem pine rust -<i>Cronartium flaccidum</i>. http://nt.ars-grin.gov/sbmlweb/fungi/index.cfm.</p>	
<p>Kaitera, J., and Nuorteva, H. 2006b. Susceptibility of <i>Ribes</i> spp. to pine stem rusts in Finland. For. Path. 225-246.</p>	
<p>Morica, S., and Ragazzi, A. 1996. Culture characteristics and variation of <i>Cronartium flaccidum</i> isolates. Can. J. Bot. 74(6): 924-933.</p>	
Morphological Guides:	
<p>Mordue, J.E.M., and Gibson, I.A.S. 1978. <i>Cronartium flaccidum</i>. CMI Descriptions of Pathogenic Fungi and Bacteria. No. 680.</p>	
<p>Morica, S., and Ragazzi, A. 1996. Culture characteristics and variation of <i>Cronartium flaccidum</i> isolates. Can. J. Bot. 74(6): 924-933.</p>	
<p>Morica, S., and Ragazzi, A. 1996. Culture characteristics and variation of <i>Cronartium flaccidum</i> isolates. Can. J. Bot. 74(6): 924-933.</p>	

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Ragazzi, A., Morrica, S., and Dellavalle Fedi, I. 1995. Growth of axenic cultures of *Cronartium flaccidum* on callus tissue of *Pinus nigra* var. *laricio* and *Pinus sylvestris*. Eur. J. For. Path. 25: 31-37.

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Scientific Name	Diagnostic Method Available
<i>Mycosphaerella gibsonii</i>	 CAPS-Approved Method: Morphological. The fungus may be cultured on V8 juice + pine needle decoction agar, in natural light at 25°C (day), 0-10°C (night) from symptomatic material (Suto, 1971). Higher night temperatures (15°C) cause abnormal conidial formation.
	 Pathogen may be identified morphologically by examination of the ascoma, asci, and ascospores (if sexual stage present) or conidia (if asexual stage present) (Evans, 1984; Ivory, 1987).
	Microscope Required?: YES.
	Mistaken Identities: <ul style="list-style-type: none"> • May be confused with <i>Dothistroma</i> blight (<i>Mycosphaerella pini</i>), but the pathogen may be distinguished by examination of the conidia. Symptoms may also be masked by or confused with <i>Sphaeropsis sapinea</i> (Ivory and Wingfield, 1986).
	Ivory, M.H., and Wingfield, M.J. 1986. First report of <i>Mycosphaerella gibsonii</i> in South Africa. <i>Phytophylactica</i> 18: 51-53.
	Morphological Guides: Suto, Y. 1971. Sporulation of <i>Cercospora gibsonii</i> on culture medium. <i>Journal of the Japanese Forestry Society</i> 33: 319-326. (English summary). Evans, H.C. 1984. The genus <i>Mycosphaerella</i> and its anamorphs <i>Cercoseptoria</i> , <i>Dothistroma</i> , and <i>Lecanosticta</i> on pines. <i>Mycological Papers</i> 153: 60-84. Ivory, M.H. 1987. Diseases and disorders of pines in the tropics. Overseas Research Publication No. 31. Overseas Development Administration. Oxford Forestry Institute, UK.

Key to Symbols



=microscope



=culture

Appendix A. Formulas for detection surveys

R.C. Venette

Because the sample universe (total number of oaks that might be inspected) is large relative to the number of trees that are likely to have the eleven pests, binomial statistics apply.

The common equation is: $P[X = x] = \binom{n}{x} p^x (1-p)^{n-x}$, where $P[X=x]$ is the probability of observing x successes (positives), n is the sample size, p is the likelihood of having a success after observing one sample unit, $(1-p)$ is the likelihood of not having a success after observing one sample unit. $\binom{n}{x} = \frac{n!}{x!(n-x)!}$ and $n! = n \cdot (n-1) \cdot (n-2) \cdot (n-3) \dots 1$.

The probability of having no success after inspecting n sample units is $P[X=0] = (1-p)^n$. So, the probability of having at least one success is $P[X>0] = 1 - (1-p)^n$

The probability of having a success on the first trial is related to the incidence (i) and the sensitivity of the sampling method. For a single trial, a positive is only possible if an infested unit is selected and the pest is properly identified. To state this mathematically, $p = i \cdot Se$. A negative can arise if we select an infested unit but fail to identify it or if we fail to select an infested unit. Mathematically, this can be written as $(1-p) = i \cdot (1-Se) + (1-i)$. We can substitute these values into the above equation, which gives

$P[X = x] = \binom{n}{x} (i \cdot Se)^x (i \cdot [1-Se] + [1-i])^{n-x}$. As before, we solve for the case where no

positives are observed, and this gives $P[X = 0] = (1 - [i \cdot Se])^n$. So the probability of having at least one success = $1 - P[X=0] = P[X > 0] = 1 - (1 - [i \cdot Se])^n$ and this is a very useful formula.

An interesting dilemma arises when selecting $P[X=0]$. Typically we would like this to be low, and we might want to set it at 0.05. Keep in mind that $P[X=0]$ is the situation where we conclude that the pest is not present, even though it is in reality. The "error" of 0.05 (call it α) applies to one pest. If we sample for multiple pests, our error goes up, and we are virtually assured of missing at least one pest just by chance alone. As a result, we need to modify our error rate so that the overall "family" error is no more than this initial value of α . To maintain an overall error rate of α we divide it by the number of species (g) that we are surveying for. As a result, for calculation purposes our confidence in detecting a single species becomes $P'[X>0] = (1 - [\alpha/g])$, we use $P'[X>0]$ to denote the probability for multiple species. Table A1 shows the adjustment of α for different numbers of species in a survey. Keep in mind that although we use the adjusted error or adjusted confidence in our calculations, we can only claim the family error rate or $(1-\alpha) \cdot 100\%$ family confidence.

We now have some very powerful formulas.

$n = \frac{\log(1 - P'[X > 0])}{\log(1 - i \cdot Se)}$ which is the exact formula behind Table 2.1

Table A1. Adjustments in error and confidence level based on the number of species in a survey to maintain the desired overall "family" error rate.

Desired "family" error	Number of species in survey	Adjusted error	Adjusted confidence
0.01	1	0.01	0.99
	2	0.005	0.995
	3	0.003333	0.996667
	4	0.0025	0.9975
	5	0.002	0.998
	9	0.001111	0.99889
	10	0.001	0.999
	20	0.0005	0.9995
0.05	1	0.05	0.95
	2	0.025	0.975
	3	0.016667	0.983333
	4	0.0125	0.9875
	5	0.01	0.99
	9	0.00556	0.9944
	10	0.005	0.995
	20	0.0025	0.9975

Appendix B. Formulas to calculate maximum incidence of infestation when no pests are found

R.C. Venette

Consider the case where a state has conducted a survey and found no pests. Can we conclude that the pests are absent? No, with continued search there is a chance that the pest might be found, but we can establish an upper limit to the incidence of infestation. In this case, we assume that the number of sample units inspected (n), the sensitivity of the sampling method (Se) and a desired probability of detection ($P[x>0]$) are known. (Keep in mind that $1 - P[x>0]$ is the probability of not detecting a species.)

We begin with the formula:

$$P[X = 0] = (1 - [i \cdot Se])^n$$

from Appendix A which gives the probability of not observing one of the species, $P[X=0]$, if we know i , Se and n . We can think of $P[X=0]$ as an error rate, with the error being the failure to detect the pest when it is present. For detection surveys, we would like this error to be low. For example, we might set $P[X=0] = 0.05$. However, as we include more taxa in the list of targeted species, we have a greater likelihood of concluding that at least one of the species is not present when they are. If we set $P[X=0] = \alpha$, we can adjust the probability of not observing any of the pests according to the formula $P[X=0] = \alpha / g$, where g is the number of species for which we are searching. This adjustment is known as a Bonferroni correction and is an approximation for a more accurate but more complex correction. The Bonferroni correction works well if n is large. With the correction, the “family” error is no more than α for the g pests we are looking for. If we substitute the corrected error into the equation from above, we obtain:

$$P[X = 0] \approx \frac{\alpha}{g} \approx (1 - [i \cdot Se])^n$$

After rearranging the equation to solve for i , the incidence of infestation, we obtain:

$$i \approx \frac{1 - \left(\frac{\alpha}{g}\right)^{1/n}}{Se},$$

where $P[X>0]$ is the probability of detecting at least one of the species targeted in these guidelines, n is the number of sample units inspected, and Se is the sensitivity of the sampling method. $P[X>0]$, i , and Se are expressed as proportions. In this case, i represents the upper limit of the $(1-\alpha) \cdot 100\%$ confidence limit on the incidence of infestation. The lower limit of this confidence interval is 0.

For example, assume a state conducted visual surveys for all eleven pests. Due to restricted budgets, survey crews were only able to look at a total of 100 trees, but these trees were randomly selected from forestland across the state. Assume that the visual survey had a sensitivity of 30%. We would now like to calculate the upper 95% confidence limit on the incidence of infestation. This level of confidence requires an initial α of 0.05. Putting this information into the equation above, we have:

$$i \approx \frac{1 - \left(\frac{0.05}{9}\right)^{1/100}}{0.3}.$$

Solving this equation, we find that $i = 0.169$. In other words, we can be 95% confident that the incidence of infestation is at or below 0.169 or 16.9%.