Damage Assessment of Bark Beetle Infestations on Benguet Pine (*Pinus kesiya* Royle ex Gordon) in Camp John Hay, Baguio City, Philippines

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**Abstract**

The damage of bark beetle infestation on pine trees, and contributing factors in Camp John Hay, Baguio City, Philippines was assessed to provide bases for management actions. Biophysical conditions and tree health within eight plots were evaluated and described. In each plot, three trees were chosen where bark beetles were collected and brought to the laboratory for identification. *Ips* and *Dendroctonus* spp. were identified to be of utmost concern in pine tree health maintenance. The girdling effect of these beetles as they form galleries coupled with pine wilt disease caused most deaths of pines. The stressed conditions of trees in this tourist destination increased vulnerabilities. Risk ratings and early signs of infestations of pines can be used to detect attacks for immediate sanitation cutting. Improved soil nutrition, and avoidance of physical damage and wounds can be undertaken to maintain tree health and reduce infestation.

**Keywords**

Bark beetle
*Ips* and *Dendroctonus* species
*Pinus kesiya*
tree health
damage assessment

**Introduction**

In the Philippines, the extensive pine forest of Camp John Hay (CJH) is an important tourist attraction. It is the most preserved pine forest of Baguio which is considered as the “lungs” of the city. Recently, this forest is threatened by localized infestation of bark beetles particularly in 2008 and 2013 (Banatao, personal communication, August 28, 2014). Potential losses in terms of timber, watershed, wilderness, recreation, and habitat values are at stake if conditions worsened. In 2013 alone, cutting permit for 136 pine trees was approved by the Department of Environment and Natural Resources (DENR). This was attributed by the head of CJH environment to beetle infestation coupled with disease infection (Dumlao, 2013). Hence, there is a need to assess the insect pest, relevant tree diseases and other factors that affect stand health and its vulnerabilities. This study documented the deaths of Benguet pine trees in CJH plots, the bark beetles that cause this and its prevalence and the risk of infestation in sampling plots. Other factors that might have contributed to the death of pine trees were also documented to provide basis for management actions.
Benguet pine (Pinus kesiya Royle ex Gordon), locally known as Saleng, is an indigenous tree species of the Southeast Asian countries including Philippines, Thailand, Burma and India. It is a medium size tree with a diameter at breast height reaching up to 140cm and a height of up to 40m (Highland Agriculture and Resources Research and Development Consortium [HARRDEC], 2003). Pines had a number of insect pests both in plantation and natural stands. There are two major groups of pine pests of great importance: the lepidopteran caterpillars like pine shoot and tip moths, and the bark beetles. In the Philippines, the documented pests of Benguet pine were Ips calligraphus (Germar), that killed pine trees in the 70's and 80's, pine shoot moths (Dioryctria rubella Hampson) and pine tip moths (Retinia cristata (Walsingham)) that had significantly damaged seedlings and saplings in the mid 80's (Lapiz, 1986b; PCARRD, 1995).

Bark beetles, especially Ips and Dendroctonus spp. (Curculionidae: Scolitidae) are described as the world's most devastating insects to attack pine and have caused extensive losses in the world's pine forests (Payne, 2006). These bark beetles are exotic to the Philippines and might have been brought by crate materials and other imported pine wood products that flow in Baguio City. The presence of Ips in Baguio has been observed as early as 1959 and infestation problems of I. calligraphus on pine trees has been reported in Benguet in 1970's, mid 1980's (Lapiz, 1986a) and early 2000 (Nair, 2007). It had already significantly damaged large plantations in other countries (Nair, 2007).

Ips calligraphus was documented in Luzon and thrives at elevation of 350-2300 masl (Lapiz, 1986a). The insect pest has short, yet variable life cycle with hot weather favoring its survival. The male insect is responsible for host selection, usually the stressed and weak trees and is responsible for creating the nuptial chamber, which later encourage the female to aggregate and form H or Y galleries (Lapiz, 1986b).

On the other hand, there is no formal documentation on the infestation made by Dendroctonus beetle in the Philippines, although it has been reported in China, which infested over 500,000 ha of pine forest, causing extensive tree mortality (Min et al., 2009). True to its name Dendroctonus, meaning “killer of trees”, extensive damage due to this insect pest had been reported in central, south and south-eastern US (Payne, 2006), Canada, Africa and Alaska (Beaver & Liu, 2010).

The southern pine beetle (SPB), Dendroctonus frontalis is considered the most destructive insect pest of pine in the southern and central America and parts of Mexico with an estimated damage cost of $900 million from 1960 through 1990 (Price et a1., 1992 as cited by Payne, 2006). It lives predominantly in the inner bark of pines and feed on phloem tissue where they construct winding S-shaped or serpentine galleries. Whereas, D. valens is a common beetle of Central America often associated SBP beetle, however, only little is known of the insect pest (Min Lu et al., 2009). D. frontalis is also sometimes confused with Ips spp. and D. terebrans or black turpentine beetle (Dixon, 1984; Olivier, 1986).

Unfortunately, once a bark beetle successfully colonized a tree, the tree cannot survive, regardless of control measures (Payne, 2006). The galleries created by both Ips and Dendroctonus can girdle a tree, causing its death. It can also carry blue-stain fungi that colonize xylem tissue and block water flow within the tree, causing tree mortality (Lapiz, 1986a; Thatcher & Conner, 1985; Payne, 2006). According to Dixon (1984) and Olivier (1986), widespread and severe pine tree mortality can occur during bark beetle epidemics.

**Materials and Methods**

**Study site**

The study was conducted in Camp John Hay, Baguio City which lies between 16.4147°N, 120.6114°E and 16.3845°N, 120.6048°E. It is located 251 km north of Manila and is composed of nine (9) barangays. CJH is a popular tourist destination in Baguio City. The climatic regime of the area falls under the Type I characterized by two distinct seasons – wet from May to October and dry during the rest of the year. The average temperature ranges from 17.3°C to 20.7°C with the coldest month in January and warmest in June. The average total rainfall from year 1952 to 2002 is 3878mm with an average monthly rainfall of 323.17mm (Calora et al., 2012).
Establishment and characterization of sampling plots and trees

Sampling plots were chosen based on recorded and recent occurrences of clustered tree deaths. Eight variable sized plots were established and mapped using GPS and ArcGIS. Mapping and spatial evaluation of patterns of dispersion was done using Google Earth. Each plot is at least 1000m² with at least 20 trees. Plots were irregularly shaped supposedly to capture the direction of spread of the bark beetles. A control plot was also established which consist of pines that are relatively healthy. The boundary of each plot is varied and was based on the location of the closest living tree to the cluster of dead trees (Figure 1).

All trees within each plot were surveyed. The diameter at breast height (DBH) and total height of each tree were determined using diameter tape and Haga altimeter, respectively. Health condition was assessed individually. Possible bark beetle infestation and disease infection indicators were recorded for each tree.

Figure 1. Sampling plots of the study within Camp John Hay, Baguio City Philippines

Trees were classified as dead, dying and healthy. Dead trees were characterized by advance stage of decay like loose bark on the tree trunk, defoliation or drooping dry leaves, and absence of resins or watery resins. Dying trees have evidence of bark beetle infestation and advance disease infection (Franklin et al., 1987). Signs of advance bark beetle infestation include presence of frass, bark beetles exit holes, brown and reddish crown color, and brooding stages of bark beetles and their galleries. In newly infested trees, white to yellowish pitch tube and patches of yellow-green and reddish crown color are the manifestations (Food and Agriculture Organization [FAO], 2009; Frank et al., 2016). Signs of disease infection include fruiting bodies on tree trunks, pronounced brown resins, wood decay and blue stained wood, and drooping dull green crown color (Eusebio, 1998). In this study, healthy pines are those having unsuccessful bark beetle entry or only have minor pests and diseases that likely will not cause tree deaths.
**Damage assessment**

Priority areas for treatment were assessed using a four-factor risk rating point system proposed by Swain and Remion (2012) with units converted from english to metric system. Factors used to assess risk include the: (1) presence of freshly attacked trees within the plot; (2) number of trees with developing brood’s ha*1; (3) average diameter size class of trees; and (4) stand density.

Possible contributing factors to pine susceptibility were characterized for each plot. The characteristic undergrowth and associated vegetation, drainage, slope, aspect and notable sources of disturbance for each plot were documented.

**Bark Beetle Collection and Identification**

Samples of bark beetles that could have caused deaths in trees were taken in each plot using purposive sampling and modified non-disruptive technique of insect collection as modified from McClelland et al. (1978) as cited by Hain (2012), and Gullan and Cranston (2014). Preference was made in trees with fresh attacks, with pitch tube or trees that are dying. Three pine trees with three bark samples each were chosen in each plot. Barks from tree trunks (10cm x 10cm) with evidence of insect entry and exit were removed by chisel and samples were taken in the laboratory to ascertain insect infestation and pathogenic infection. Samples of inner wood showing galleries brought by beetles were photodocumented. Adults, larvae, and eggs of bark beetles that were present in the infested bark of pine trees sampled were counted and recorded. Adult bark beetles were collected and brought to the BSU laboratory for identification.

Bark beetles were collected and identified using identification keys (Anonymous, 1989; Van Driesche et al., 2013; Armendariz-Toledo & Zuniga, 2017 and USDA Forest Service, 1989) and assistance of taxonomic expert Dr. Jessamyn Adorada from UPLB Pest Clinic who verified the collected bark beetles. The specimens were observed under the binocular dissecting microscope and were compared to pre-existing references on identification of the insects.

**Results and Discussion**

**Characterization of Pine Trees in Sampling Plots**

Around 420 trees in eight monitoring plots were evaluated for tree health in order to assess the cause of tree deaths in CJH. Except for plots 7 and 8, having low infestation/infection (<7%), most plots have pests incidence of 27% to 39% of the trees (Table 1). Majority of the dead and dying trees fall in the 21-60cm DBH class having a height of more than 10m (Figures 2 and 3). Based on a pairwise mean comparison using Tukeys HSD, tree deaths caused by these pests was most pronounced among trees of 41-60cm DBH, followed by 21-40cm DBH and it significantly differ with trees having a DBH of 20cm and below and DBH greater than 60cm (p ≤ 0.03).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plot 1</th>
<th>Plot 2</th>
<th>Plot 3</th>
<th>Plot 4</th>
<th>Plot 5</th>
<th>Plot 6</th>
<th>Plot 7</th>
<th>Plot 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of trees in the plot</td>
<td>26</td>
<td>87</td>
<td>55</td>
<td>48</td>
<td>55</td>
<td>65</td>
<td>42</td>
<td>20</td>
</tr>
<tr>
<td>No. of dead/dying trees</td>
<td>8</td>
<td>34</td>
<td>32</td>
<td>13</td>
<td>15</td>
<td>19</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Dead/ Infested tree (%)</td>
<td>31</td>
<td>39</td>
<td>58</td>
<td>27</td>
<td>27</td>
<td>29</td>
<td>7</td>
<td>0</td>
</tr>
</tbody>
</table>
### Table 2

**Location and characteristics of established plots and observed insect pests and diseases associated with Benguet pines**

<table>
<thead>
<tr>
<th>Plot Number</th>
<th>Plot Location</th>
<th>Plot Area (sq.m.)</th>
<th>Stand Density¹ (trees/hectare)</th>
<th>Site Condition</th>
<th>Dominance of bark beetle infestation in the plot</th>
<th>Other plot observations (Nagpala &amp; Balinsoy, Villanueva &amp; Pascua, 2014)</th>
<th>Associated Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Country State</td>
<td>1,225.05</td>
<td>210</td>
<td>steep slope, moist condition</td>
<td>wilt diseases and other pathogen more dominant than bark beetles</td>
<td>presence of <em>Ophiostoma</em> <em>Fusarium</em> and <em>Pestalotia</em>²</td>
<td>Dominant herb: <em>Ageratina riparia, A. adenophora</em></td>
</tr>
<tr>
<td>2</td>
<td>International Hotel Group</td>
<td>4,912.31</td>
<td>180</td>
<td>poor soil condition, soil compaction</td>
<td>bark beetles attack dominant</td>
<td>presence of parasitic nematode and <em>Pestalotia</em>²</td>
<td>Dominant grass: <em>Paspalum conjugatum, Cynodon, dactylon, Eleusine indica,</em> Stenothaphrum secundatum;</td>
</tr>
<tr>
<td>3</td>
<td>Golf course Panagbenga Park</td>
<td>2,110.95</td>
<td>260</td>
<td>poor soil condition; dense stocking</td>
<td>advance stage of bark beetle infestation; many pathogens</td>
<td>Abundant <em>Ophiostoma</em> and presence of <em>Pestalotia</em> and <em>Fusarium</em>²</td>
<td>Tree: African Tulip</td>
</tr>
<tr>
<td>4</td>
<td>Bontoc picnic area</td>
<td>1,564.46</td>
<td>310</td>
<td>dense stocking; frequented by tourists</td>
<td>bark beetles attack dominant</td>
<td>Presence of parasitic nematode and <em>Ophiostoma</em>²</td>
<td>Others: <em>Imperata cylindrica, Themeda triandra, Andropogon aciculatus, Chromolaena odorata, Lantana camara, , Portulaca oleracea,</em> Pseudelphantopus spicatus, <em>Elephantopus mollis, Tradescantia zebrina</em></td>
</tr>
<tr>
<td>5</td>
<td>Picnic Area</td>
<td>2,261.71</td>
<td>240</td>
<td>waterlogging evident; frequented by tourists</td>
<td>bark beetles attack more dominant</td>
<td>Presence of parasitic nematode, <em>Pestalotia</em> and <em>Fusarium</em>²</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Back of Manor Hotel</td>
<td>2,603.39</td>
<td>250</td>
<td>dense stocking; frequented by tourists</td>
<td>complex of bark beetles attack and diseases</td>
<td>Abundant parasitic nematode (<em>Tylenchus</em> sp³) and presence of <em>Pestalotia</em>²</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>AIM/Igorot Lodge</td>
<td>2,505.66</td>
<td>170</td>
<td>Pine wilt in pole sized pines; sanitation cutting started, poor soil condition with constant mowing</td>
<td>complex of bark beetles attack and pine wilt diseases</td>
<td>Abundant parasitic nematode population (<em>Aphelenchoides</em> sp³) and <em>Pestalotia</em> and presence of <em>Ophiostoma</em>º</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Tree top vicinity</td>
<td>1,050.80</td>
<td>200</td>
<td>slope moderate, young stand</td>
<td>minor insect pests like weevil</td>
<td>Gall causing nematode (minor)</td>
<td></td>
</tr>
</tbody>
</table>

Note: ¹Critical stand density: ≥297 trees/ha – high; 297-198 trees/ha-moderate; <198/ha – low (Remion, 2012)
²*Ophiostoma* cause blue stain fungi and is associated with pine wilt; *Fusarium* can also cause seedling/sapling pine wilt; *Pestalotia* associated with blight diseases;
³Nematodes of *Aphelenchoides* also associated with pine wilt (diagnostic feature: distinct grayish green leaves without falling from branches); *Tylenchus* sp associated with root knot disease
Dead trees were also more dominant in densely stocked trees, or greater than 198 trees per hectare (Table 2). Plot 4 (Panagbenga park) has one of the highest mortality; it was the oldest plot that received beetle attacks where some of the dead trees were debarked and had undergone decomposition. Decomposing trees were no longer included in the survey.

**Bark Beetles of Benguet Pine in CJH**

As observed, trees attacked by bark beetles were the more mature pines with DBH ≥ 21cm as supported by the study of Eusebio (1986b). Pine wilt in some trees were also observed to cause tree deaths in plots 4, 6 and 7. Pine wilt in CJH were likely due to *Ophiostoma* (Nagpala & Balinsoy, 2016), and *Aphelenchoides* nematodes (Villanueva & Pascua, 2016). Nematode-based wilt disease as observed in plot 7 did not show evidence of bark beetle infestation as they were observed in pole-size pines which are less preferred by bark beetles. Blight disease was also observed in plot 3.

The most noticeable cause of death among trees was caused by bark beetle attack which is present in all plots, except for the control. Each beetle deposit several eggs that eventually go to larval stage. Larvae cause the tunnelling effect on bark, known as gallery. The galleries formed by most of the bark beetles restrain food translocation. Also, bark beetles served as vector of wilt disease (Figure 4) which inhibit water transport (Min Lu et al., 2009; Chang et al., 2017).

The killing of the host tree or girdling progress
Damage Assessment of Bark Beetle Infestations...

Among the bark beetles collected, those attacked by *Dendroctonus* (no spine in abdominal tip) and *Ips* (with spine in abdominal tip) were the most serious. Apparently, there is a symbiotic relationship between the pines wilt disease and bark beetles in killing pine trees (Kirisits, 2007; Paine et al., 1997). It is either the bark beetles attacked the pine tree before the wilt disease forms or the wilt disease infects the tree first and weakened it, making it attractive to bark beetles, which is consistent with the review made by Guerard et al., (2000). Among the trees observed, both cases were true. *Ophiostoma* or blue stain fungi were seen in entry holes of bark beetles, indicating the beetles as the carrier. *Ophiostoma* impede water translocation, weakening the tree and making it more susceptible to beetle infestation (Chang et al., 2017; Nagpala & Balinsoy, 2016).

Several bark beetles (Figure 5) were collected from CJH, namely: *Ips grandicollis* with five pairs of spine at the abdominal tip; the six pairs of spine *I. calligraphus, D. terebrans, D. frontalis*, Ambrosia beetles (*Platypus sp.*) and a suspected pine bark beetle, *D. cf. valens*. All of these bark beetles were captured in plots 2 and 7 where fresh attacks were observed, but only *Platypus sp.* appear prominently in plots 1 to 7.

Payne (2006) noted that *D. frontalis* posed more risk to pine forest as they aggregate more, more difficult to treat even using pheromones and have longer life cycle and more generations per year. The clustered tree deaths that were observed in CJH is not the characteristic scattered pattern of attack of *Ips* and is more associated with the *Dendroctonus* bark beetle (Self et al., 2019). Payne (2006) stated that once pine trees were successfully attacked by bark beetles, nothing can be done to save it. A cluster of beetle infested trees subjected to insecticidal treatment were observed to last for three to five years only. Thus, instead of focusing on control measures, activities that will promote maintenance of tree health must be prioritized.

Two other species of *Ips* sp. and *D. cf. valens* were collected (Figure 5). Interestingly, these bark beetles differ slightly in morphology from previously collected samples, thus needs re-evaluation.
Figure 5. Bark beetles associated with Benguet pine trees: (a) five spine *I. grandicollis*, (b) six spined *I. calligraphus*, (c) Southern pine beetle or *D. frontalis*, (d) Platypus sp. 1, (e) black turpentine beetle *D. terebrans*, (f) Platypus sp. 2 and (g) *Dendroctonus* sp. (Adorada, personal communication, May 5, 2016). *Dendroctonus cf. valens* were mostly seen on the sapwood. Secondary bark beetles, *Platypus* sp. 1 and sp. 2, were observed browsing on growing fungus of dead wood, and are of least concern. *Monochamus* sp., a known vector of pine nematode causing wilt disease (Center for Agriculture and Bioscience International [CABI], 2007), was also observed in plot 2.

Presence of bark beetles can readily be assessed using signs of bark beetle attacks: presence of pitch tube, frass and exit holes, galleries and brooding stages of bark beetles in sampled bark, fading crown color, and blue stained wood of pine trees (FAO, 2009; Lee et al., 2011). All these signs are true to all bark beetles observed, except for pitch tube which is due to *Ips* and *Dendroctonus*. However, according to Self et al. (2019), *Dendroctonus* have more pronounced pitch tube since *Ips* only attack weak pines that are unable to produce resin pressure to produce sufficient pitch tube. Pitch tubes are popcorn-shaped sap plugs as a result of bark beetle entry (Frank et al., 2016). When tunnelling begins, a resin is released to plug the hole, serving as the tree’s first line of defense against the beetles. Pitch tube can also serve as evidence of the beetle’s aggregation, since it is more visible than exit holes especially at certain height. As observed in Benguet pine, it could be white, yellowish (Taylor, 2015; Wilson, 1977), pinkish or brown in color (DeMars & Roettgering, 1982) and can be indicative of tree health and how long the attack was made (Self et al., 2019). It can remain for few months before it is detached. In CJH, pitch tube were observed from the base up to 11m from the ground and may remain attached for about three months depending on weather condition.

Upon successful entry of one bark beetle, aggregation follows immediately. *Dendroctonus* beetles can mass attack in 3 to 5 days from successful entry (Payne, 2006). As observed, beetles aggregate in a span of one to two weeks in weak trees. Either the male of *Dendroctonus* spp. (Payne, 2006) or the female of *Ips* spp. (Lapiz, 1986b) bore first and release pheromones that attract potential mates. Mate clusters immediately depending on the susceptibility of the host. Underneath the bark, along chambers and galleries are eggs, larva in various stages, pupa and adult beetles. Bark beetle larva continually feed on the bark and form networks of galleries. These galleries can readily girdle the tree as they overlay each other, however, bark beetles usually avoid this by boring vertically. In this manner, more bark beetle generations can survive in each host tree. This observation is also consistent with the study made by Lee et al. (2011) on *Platypus* beetles. As this progress, needles of the tree usually turn from green to pale green or yellow then to red before it completely turned brown. The change in crown color is due to the girdling effect of beetles during gallery formations which limit food transport or it may be caused by wilt disease which
impedes water translocation to the crown causing shortage of food and water.

Both *Ips* and *Dendroctonus* have the ability to transmit blue stain fungi (Paine et al., 1997). Spores of blue stain fungi live on the exoskeleton grooves of the beetle and are introduced into the tree trunk during the attacks. The fungi grow within the tree and hinder the translocation of water from the roots to the leaves (Paine et al., 1997). This results to the change in crown color which was readily visible and can be used in reporting areas of possible bark beetle attacks after verification of the presence of *Ips* and *Dendroctonus* bark beetles.

Some pine trees were observed to contain as high as 235 bark beetle larva feeding on a 100cm² inside bark. Mature beetles usually bore holes from inside to escape the bark and transfer to other host trees, forming exit holes (FAO, 2009). Intervention on pest management must be done before exit holes are seen, to avoid further spread of insect pests. Once the tree is dead, it is mostly the secondary bark beetles like Ambrosia beetle (*Platypus* sp.) that is caught. As the tree dies, wood and bark decays, and becomes very loose that it can no longer be used. In other countries, treated wood coming from those attacked by bark beetles are still used (Sun et al., 2013).

All these signs and symptoms of bark beetle infestation like the changes in crown color, pitch tube, exit holes, frass, and presence of galleries and presence of bark beetles can be used for detection of the insect pest. But early detection is critical in the control of the bark beetle population. The change in crown color in some trees can be initially used for determining area of attack followed by inspection of the tree trunks for other signs. As pitch tube is observed, there is a chance to extend the life of the tree and improve the growing conditions of adjacent pines. Watering using fire hydrant can be done during summer, increasing spacing between trees, fertilizer application and limiting tourist visit in attacked areas can help.

Further, owing to very few literatures on effective treatment of pine bark beetle infestation and the uncertain and costly undertaking of pheromone treatment (FAO, 1982), there is a need to approach this problem holistically through the amendment of some DENR policies that favor immediate release of sanitation cutting permit which in this study took two years. The wood lifespan will be shortened by non-intervention considering that standing trees are more prone to forces of decay. Immediate sanitation cutting and wood treatment will help reduce the spread of insect pest and allow the use of treated wood for other productive purposes.

**Prevalence of Bark Beetles in CJH**

Clusters of bark beetle infested trees were observed in CJH. However, patterns of dispersion were difficult to trace since infestation had occurred few years ago. Clusters of dead/dying pines in CJH were distributed and some already traversed the areas in South Drive, Burnham Park, Teachers Camp, Imelda’s Park and some parts of Itogon. As mentioned by Lapiz (1986a), *Ips* can fly as far as 6km in search of a new host. The dense stocking of trees and their tourist frequented conditions likely facilitate their spread.

Plot 3 had the oldest infestation (3 years or more), with the most number of dead trees and where advance stage of decay in standing trees was observed such as loose barks and wood decay. This plot used to be the assembly point of the yearly Panagbenga celebration in Baguio city, prior to its infestation. Plot 2 had the newest bark beetle infestation where most trees still had green foliage and pitch tube as signs of bark infestations (Figure 6).

Once a tree is heavily infested, nothing could be done to save it and adult beetles emerge and infest other trees (Leatherman et al., 2011). Trees with a lot of exit holes can already be adult beetle-free because there is no more food on the dead tree. Since adult beetle could fly, the direction and rate of spread is very hard to predict. The nearest old and stressed tree is usually next to be attacked (Payne, 2006; FAO, 2009; Paine et al., 1997).

Bark beetles obtained from bark samples showed as high as 43 adults and 235 larvae per 100 sq. cm bark (Table 3). Most bark samples showed absence of eggs or remnants of bark beetles that already transfered to other trees. There is a high prevalence of beetle infestation in most plots. Plot 7 also had evidence of beetle infestation such as frass and exit holes but the sanitation cutting conducted before the survey reduced the available tree samples in this plot.
Factors affecting the pine trees’ health conditions at CJH

Plots near frequently visited sites, having close stocking of pine trees, with altered soil and vegetation condition, and poor drainage increased the vulnerability to bark beetle attacks (Table 3). Soil compaction due to trampling by visitors affects root health. Likewise, the alteration of understory to lawn type grass and its maintenance through constant grass cutting and removal of biomass result to poor soil nutrition. Grass cutting also damage saplings where they are wounded near the base, making them prone to disease infection. Thatcher et al. (1980) as cited by Payne (2006) noted that bark beetles usually attack stressed or damaged pines. Attacks are often restricted to senescent, stressed or damaged pines but epidemics occur. During epidemics, high beetle populations can overcome healthy vigorous trees by attacking in large numbers over a short period of time (Thatcher et al. 1980 as cited by Payne, 2006).

Tree age and health condition. More mature trees (>21 cm ≤60 cm in dbh) are preferred by bark beetles as host (p<0.03). Moore (2004) mentioned that the sap production in young trees was two to three times higher than older trees. It is also higher in healthier trees. Sap is one of the first line of defence of pines against bark beetles. Released sap or resins can plug bored holes of bark beetles and seals wounds. Resins also trap insect pests making some initial entry by bark beetles unsuccessful. However, some pines were observed to have nails, chops and spike markings. Tree health is compromised with bark damages caused by visitors and signages fastened on the trees.

Close spacing of pines. Highest mortality was observed in plots with closely spaced trees. Other than meeting tree branches, root grafting facilitates transfer of pests and diseases (Figure 7). Stiff competition for light and soil nutrition also aggravates the conditions in closely spaced trees (Rick, 2002). Bark beetles according to Schowalter (2012) are highly sensitive to close spacing as they become competitively stressed, thus wider spacing is recommended in order to better manage the bark beetle population.

Weather condition. Zamora and Lapiz (1987) and Rick (2002) mentioned that an increasing temperature favors bark beetle infestation while increasing rainfall is unfavourable for flight activity

Table 3

<table>
<thead>
<tr>
<th>Life Stages</th>
<th>Plot 1</th>
<th>Plot 2</th>
<th>Plot 3</th>
<th>Plot 4</th>
<th>Plot 5</th>
<th>Plot 6</th>
<th>Plot 7</th>
<th>Plot 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>11</td>
<td>2</td>
<td>43</td>
<td>2</td>
<td>1</td>
<td>11</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Larvae</td>
<td>20</td>
<td>13</td>
<td>235</td>
<td>-</td>
<td>-</td>
<td>40</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Egg</td>
<td>-</td>
<td>-</td>
<td>18</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: - indicates absence; + bark beetles presence were observed outside the bark, but were absent in inside bark.
and kills some bark beetles. *I. calligraphus* had existed in for quite some time at low population and the absence of rain and increase in temperature must have triggered its’ spread into pulse eruption as defined by Berryman (1987). It was noted during the El Niño in 2007-2008 when there was a drastic increase in death of pine trees due to bark beetles (National Oceanic and Atmospheric Administration [NOAA], 2007). Zamora and Lapiz (1987) observed that bark beetles, particularly *Ips* usually actively fly and bore its host during summer when temperature exceeds 18ºC. This could be related to stress brought by low water availability or a hotter climate that is more conducive to population growth of the bark beetle. Hence, the 0.4ºC increase in temperature in Benguet for the last 30 years (Calora et al., 2012), likely triggered the increase in bark beetle infestation.

**Risk Rating for Bark Beetles Control Priorities**

Using the guide to southern pine beetle spot growth and control priorities by Swain and Remion (2012), Table 4 shows that plots 3 to 6 needs to be sanitized the soonest possible. These are high priority areas for direct insect control, otherwise damage to adjoining area could be high. Timely sanitation cutting is needed for these plots. All other plots, except for the control (plot 8), and plot 7 which already underwent tree cutting are of moderate priority for sanitation.

<table>
<thead>
<tr>
<th>Plot number</th>
<th>Presence of fresh attacks</th>
<th>No. of trees with developing broods (ha⁻¹)</th>
<th>Average size class of Timber</th>
<th>Stand Density</th>
<th>Risk Rating Points</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>8 = 0</td>
<td>10</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
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<td>30</td>
<td>24 = 20</td>
<td>10</td>
<td>0</td>
<td>60</td>
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<tr>
<td>3</td>
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<td>99 = 40</td>
<td>10</td>
<td>10</td>
<td>90</td>
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</table>

*Note: Risk rating of >60 points are considered high priority areas, 40-60 as moderate; and <40 as low priority areas*
**Conclusions**

Most tree deaths in CJH were due to bark beetles that attacked pine trees and the complications it forms with wilt disease. The bark beetles that attacked pines in CJH were mostly those of *I. calligraphus*, *D. terebrans*, *I. grandicollis* and *D. frontalis*. These beetles girdle the trees as they form galleries. Both *Ips* and *Dendroctonus* spp. have the ability to transmit blue stain fungi which forms wilt disease and weakens the tree resistance against further bark beetle attacks. Once the tree is infested, control measures only delay the death of pine trees.

The infesting bark beetles preferred more mature trees which had less resins and are under stressful environment. Presence of bark beetles can readily be assessed using signs of bark beetle attacks such as pitch tube, frass and exit holes, galleries and bark beetles in barks and fading crown color. Patterns of dispersion in CJH were already difficult to trace since it had been in the area for several years and have spread to adjoining areas.

There is a high prevalence of beetle infestation in most plots with plots 1 to 6 having high risk rating and can likely spread to adjoining areas. The best way to address this is to improve the tree health conditions and develop positive stand management practices in areas surrounding the attacked trees.

**Recommendations**

Keeping the tree as healthy as possible is the best prevention measure against bark beetle infestation. In areas that are densely stocked, thinning of stands depending on growth stage can be practiced to ensure better nutrition. Regular watering in the morning using drip irrigation system or hydrants of fire trucks in frequented sites especially along the roads can greatly help improve the trees' conditions especially during summer. Avoiding the removal and burning of grasses and understory can also help in case fertilization is not being done in the park. There is also a need to maintain wide spacing or breaks and to undertake thinning in overstocked stands. If possible, monitoring of soil nutrients and pH must be regularly undertaken. In areas attacked by bark beetles, it is recommended to replant the area using seeds from resistant and healthy pines to improve stand performance.

Monitoring and timely sanitation cutting of the bark beetle infested stand and training activities for park guards to detect and address infestation is needed. Timely sanitation cutting to improve tree health can reduce the spread of insect pest. This prevents the escape of mature beetles that can infest other trees. Debarking of trees or wrapping the tree with clear plastic 6 mills thick can help kill the larvae of pest in inaccessible areas having low infestation priority. Woods coming from felled trees can still be used if cut in time, as long as it is kiln dried to ensure deaths of bark beetles, otherwise burning using blow torch may be done.

The Camp John Hay’s forest is one of Baguio City’s pride and it supports the tourism industry. Public awareness and concerted effort is needed to address the bark beetle infestation concern. Tourists and park maintenance crew must be cautioned to avoid tree vandalism and physical damage to the tree trunk. Pathways must be maintained in order to limit the spaces that are frequented by tourists. If this cannot be avoided, physical barriers or period of closures for certain portions of the park can be done. Such will not only prevent soil compaction and tree root damages, but also allow the area to recover.

**Acknowledgment**

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References


