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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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KEYWORDS

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

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.

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 16.4147ºN, 120.6114ºE and 16.3845ºN, 120.6048ºE. 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 17.3ºC to 20.7ºC 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.

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.

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

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.

The knockdown method using chemical was also done to collect the beetles that caused tree deaths. Three pine trees with early signs of infestation received yellow-labelled insecticidal treatments and served as main source of bark beetles for identification. This minimized the collection of secondary bark beetle pests which is more dominant in dying and dead pine trees. Fine mesh nets were used to wrap the tree trunk having fresh pitch tube. An improvised catchment at the base of the trunk for collection of the insect pest was prepared prior to the application of insecticide that allowed collection of primary bark beetle pests.

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 ($\leq$7%), most plots have pests incidence of 27% to 39% of the trees (Table 1). Majority of the dead and dying trees fall in the 21-60cm DBH class having a height of more than 10m (Figures 2 and 3). Based on a pairwise mean comparison using Tukeys HSD, tree deaths caused by these pests was most pronounced among trees of 41-60cm DBH, followed by 21-40cm DBH and it significantly differ with trees having a DBH of 20cm and below and DBH greater than 60cm ($p \leq 0.03$).

Table 1

Number of dead trees in each monitoring plot

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

Table 2

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

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

Note: [1]Critical 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;
[3]Nematodes of Aphelenchoides also associated to pine wilt (diagnostic feature: distinct grayish green leaves without falling from branches); *Tylenchus* sp associated with root knot disease

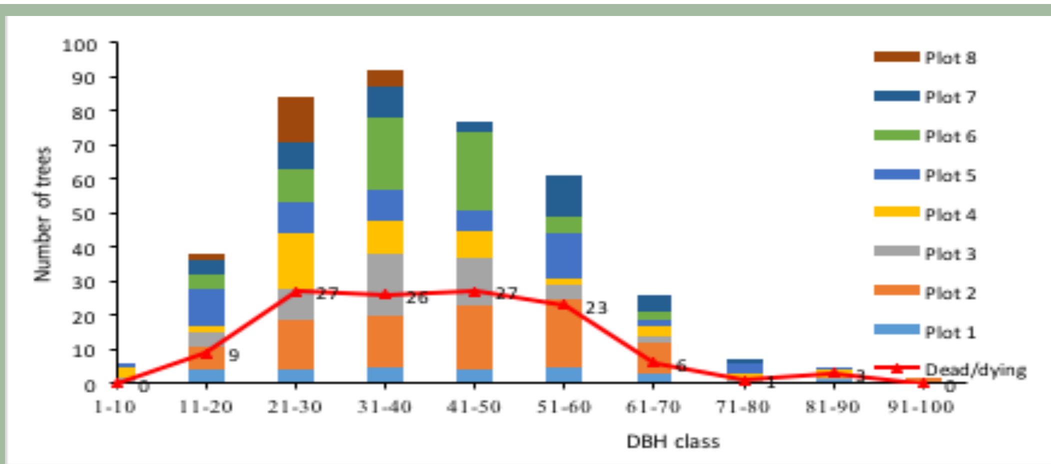

Figure 2. DBH distribution of all trees sampled and dead/dying trees

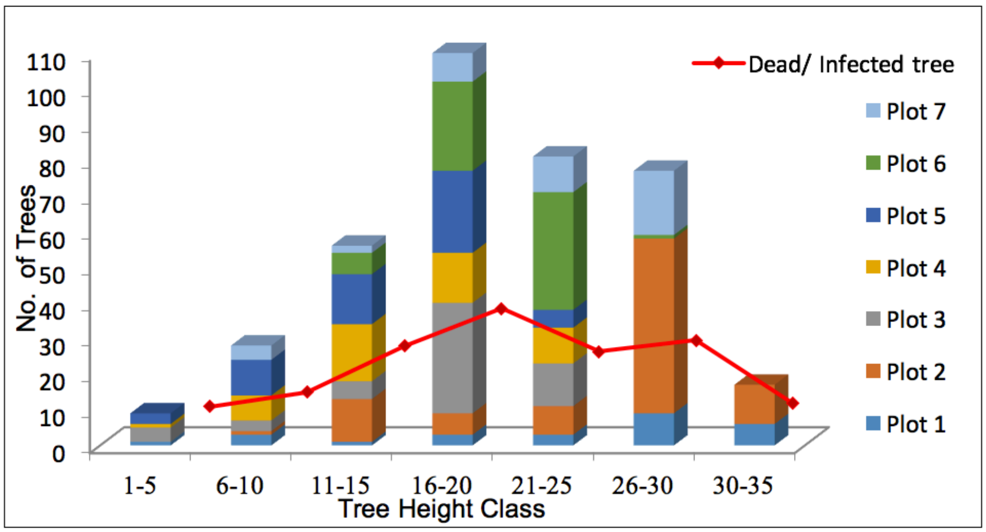

Figure 3. Height distribution of all trees sampled and dead/dying trees

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

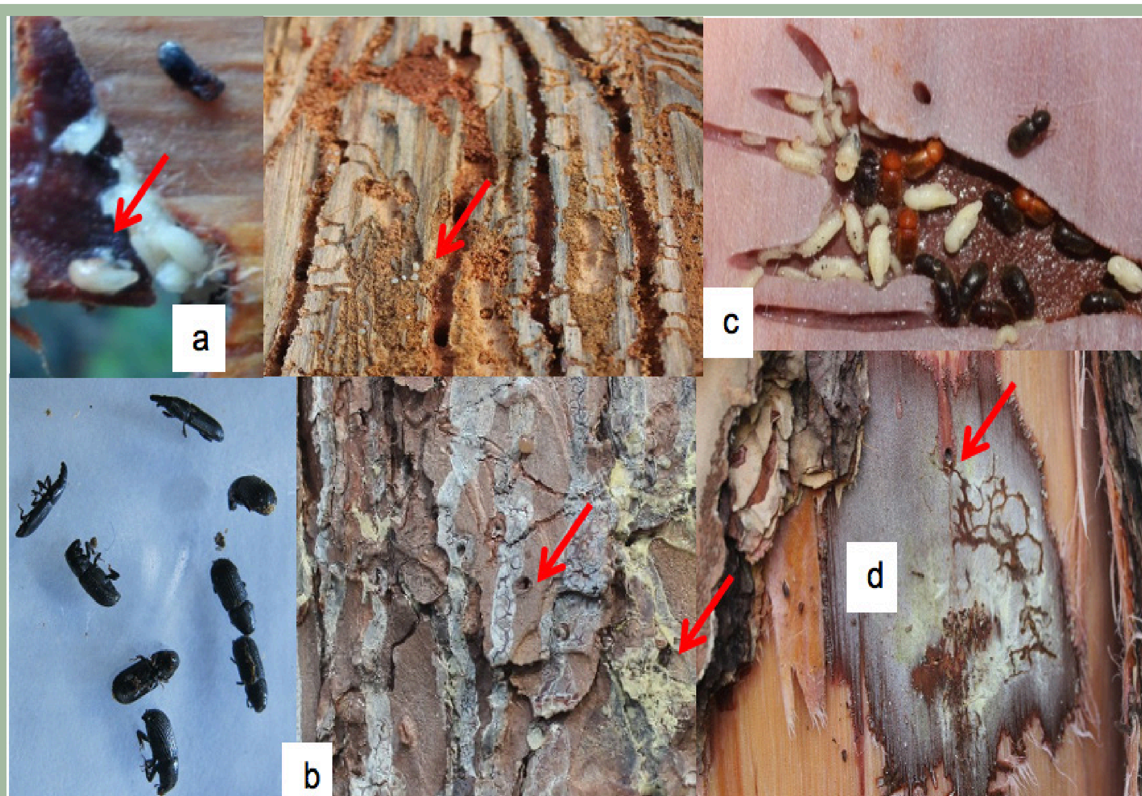

Figure 4. Evidence of inhibition of translocation process: (a) *Ips* and the galleries it formed, (b) *Dendroctonus terebrans* and their exit holes, (c) (*Dendroctonus sp.* of various stages and its galleries and (d) fungal disease brought by bark beetle entry

start once interlocking galleries are formed. 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

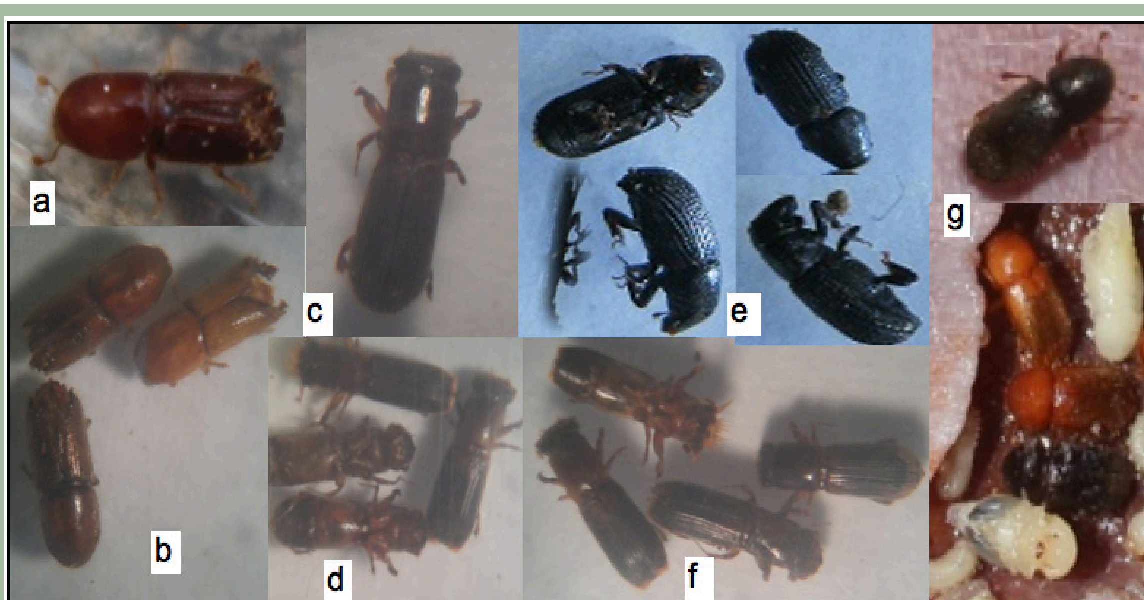

Figure 5. Bark beetles associated with Benguet pine trees: (a) five spine *I. grandicollis*, (b) six spined *I. calligraphus*, (c) Southern pine beetle or *D. frontalis*, (d) *Platypus sp.* 1, (e) black turpentine beetle *D. terebrans*, (f) *Platypus sp.* 2 and (g) *Dendroctonus sp.*

(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 $100cm^2$ 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.

Figure 6. Evidence of early onset of bark beetle infestation: (a) pitch tube and (b) yellowing and browning of tree crown.

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 (>21cm ≤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

Bark beetle stages average counts per 100sq.cm bark samples of pine

Life Stages	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8
Adult	11	2	43	2	1	11	+	0
Larvae	20	13	235	-	-	40	-	0
Egg	-	-	18	-	-	-	-	0

Note: - indicates absence; + bark beetles presence were observed outside the bark, but were absent in inside bark

Figure 7. Factors contributing to pine tree health (a) close spacing and root grafting (b) altered soil and vegetation condition (c) pine stem damaged due to grass cutter and (d) diseases brought by bark damages

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 4.

Risk rating for beetle spot growth and control priorities (Swain and Remion, 2012)

Plot number	Presence of fresh attacks	No. of trees with developing broods (ha^{-1})	Average size class of Timber	Stand Density	Risk Rating Points
1	30	8 = 0	10	10	50
2	30	24 = 20	10	0	60
3	30	99 = 40	10	10	90
4	30	38 = 20	10	20	80
5	30	22 = 20	10	10	70
6	30	50 = 20	10	10	70
7	0	0	10	0	10
8	0	0	10	0	10

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.

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References

Anonymous. (1989). Insects and Diseases of Trees in the South. USDA Forest Service. Protection Report R8-PR16. 98 p. Southern Pine Beetle (*Dendroctonus frontalis*). https://wiki.bugwood.org/Archive:South/*Dendroctonus_frontalis* and *Ips* Engraver Beetles (*Ips avulsus, Ips grandicollis* and *Ips calligraphus*). https://wiki.bugwood.org/Archive:South/Ips_Engraver_Beetles

Armendariz-Toledo, F. & Zuniga, G. (2017). Illustrated Key to Species of Genus Dendroctonus (Coleoptera: Curculionidae) occurring in Mexico and Central America. *J Insect Sci.* 2017 Mar; 17(2): 34.

Beaver R.A. & Liu, L.Y. (2010). An annotated synopsis of Taiwanese bark and ambrosia beetles, with new synonymy, new combinations and new records (Coleoptera: Curculionidae: Scolytinae). Zootaxa 2602: 1–47

Berryman, A.A. (1987). The Theory and Classification of Outbreaks. In: Insect outbreaks. Barbosa, P. and J. C. Schultz (Ed.). pp 3-27.

Center for Agriculture and Bioscience International (CABI). (2007). *Monochamus alternatus*. Crop Protection Compendium. Accessed October 10, 2009 from: http://www.cabi.org/cpc.

Calora, F.J., Parao, M.R., Malamug, J.J.M., Batani, R.S. and Gapasin, M.D. (2012). Benguet State University. 2012. BSU Synthesis Report. Biophysical Characterization and Socio-Economic Profiling in Benguet, Philippines. https://issuu.com/mdgf1656/docs/ bsu_synthesis_report_final

Chang, R. T., Duong, A., Taerum, S.J., Wingfield, M.J., Zhou, X., and de Beer, Z.W. (2017). Ophiostomatoid fungi associated with conifer-infesting beetles and their phoretic mites in Yunan, China. MycoKeys. 28:19-64.

DeMars, C. J. Jr., & Roettgering, B.H. (1982). Forest and Insect Diseases Leaflet. USDA Forest Service. pp. 1-3. https://www.forestpests.org/acrobat/fidl1.pdf

Dixon, W.N. (1984). *Ips* engraver beetles. FDACS, Division pf Forestry. Forest and Shade Tree Pests Leaflet. No. 2. 2p.

Dumlao, A. (2013). DENR OKs felling of 136 dead pine trees in Baguio. The Philippine Star. https://www.philstar.com/nation/2013/08/15/1094801/denr-oks-felling-136-dead-pine-trees-baguio

Eusebio, M.A. (1998). Pathology in Forestry Ecosystems. Research and Development Bureau, Department of Environment and Natural Resources. College, Laguna. 502p.

Food and Agriculture Organization (FAO) of the United Nations. (1982). Philippine Multiple Use Forestry: Possibilities for control of *Ips calligraphus* (Germar) in the Philippines. FAO, Manila. Vol. 1. Project Working Paper No.7. ERDB, College, Laguna.

Food and Agriculture Organization (FAO) of the United Nations. (2009). Global Review of Forest Pests and Diseases: A Thematic study prepared in the framework of Global Forest Resources Assessment 2005. FAO Paper No. 156. pp

Frank, S., Baker, J. & Bambara, S. (2016). Southern Pine Beetle: Entomology Insect Notes. NC State Extension Publication. https://content.ces.ncsu.edu/southern-pine-beetle

Franklin, J.F., Shugart, H.H., & Harmon, M.E. (1987). Tree Death as an Ecological Process. The causes, consequences, and variability of tree mortality. BioScience 37:8 pp 550-556. https://andrewsforest.oregonstate.edu/sites/default/files/lter/pubs/pdf/pub79.pdf

Guerard, N., Dreyer, E., & Lieutier, F. (2000). Interactions between Scots pine, *Ips acuminatus* (Gyll.) and *Ophiostoma brunneo-siliatum* (Math.): estimation of the critical thresholds of attack and inoculation densities and effects on hydraulic properties in the stem. Ann. For. Scie. 57:681-690.

Gullan, P.J. & Cranston, P.S. (2014). The Insects: An outline of Entomology. 5th Edition. Wiley-Blackwell. 624p

HARRDEC. (2003). Benguet Pine Tree Technology Manual. Highland Agriculture and Resources Research and Development Consortium (HARRDEC), Ecosystems Research and Development Services (ERDS), Department of Environment and Natural Resources (DENR) – CAR. Techno-CD Series.

Hain, F.P. (2002). Chapter 6 Sampling and Predicting Population Trends. In: The Southern Pine Beetle. (Ed.) Thatcher, R.C., Searcy J.L., J.E. Coster and G.D. Hertel https://www.barkbeetles.org/spb/spbbook/Index.cfm

Kirisits, T. (2007). Fungal Associates of European Bark Beetles with special emphasis on The *Ophiostomatoid* fungi. In: Lieutier F., KR Day, A Battisti, JC Gregoire and HF Evans (Eds.) Bark and Wood Boring Insects in Living Trees in Europe, A Synthesis. Springer, Dordrecht.

Lapiz, E.B. (1982). *Dioryctria rebella* Hamps. and *Petrova cristata* Wals. Moths infesting young Benguet (*Pinus kesiya* Royel ex Gordon), Mindoro (*P. Merkusii* Jungh. and de Vr.) and Caribbean (*P. caribaea* Royle ex Gordon) pine trees in the Philippines. *Sylvatrop Philippine Forestry Research Journal* 7(2): 79-82.

Lapiz, E.B. (1986a). Observation on the seasonal distribution of *Ips calligraphus* Germar, Baguio City, Philippines. *Sylvatrop Philipp. For. Res. J.* 11 (1 & 2): 61-68. College. Laguna.

Lapiz, E.B. (1986b). Some ecological studies on the six-spined engraver beetle, *Ips calligraphus* (Germar), infesting *Pinus kesiya* (Royle ex Gordon) in the Philippines. UP Los Baños.

Leatherman, D. A., Aguayo, I., & Mehall, T.M. (2011). Colorado State University. Mountain Pine Beetle Fact Sheet No. 5.528

Lee, J.S., Haack, R.A., and Choi, W.I. (2011). Attack pattern of *Platypus koryoensis* (Coleoptera: Curculionidae: Platypodinae) in relation to crown dieback in Mongolian oak in Korea. Environ. *Entomol*. 40(6):1363-1369; https://www.nrs.fs.fed.us/pubs/jrnl/2011/nrs_ 2011_lee-j_001.pdf

Min Lu, Zhou, X.D., De Beer, Z.W., Wingfield, M.J. & Sun, J.-H. (2009). Ophiostomatoid fungi associated with the invasive pine-infesting bark beetle, Dendroctonus valens, in China. Fungal Diversity 38: 133-145.

Moore, G.W., Bond, B.J., Jones, J.A., Phillips, N. & Meinzer, F.C. (2004). Structural and compositional controls on transpiration in 40 and 450-year-old riparian forest in western Oregon, USA. *Tree Physiology*. Vol 24. pp 481-491 Heron Pub. Victoria, Canada.

Nagpala, A.L. & Balinsoy, A.G. (2016). Fungi associated with pine trees (*Pinus kesiya*) infested by bark beetles in Camp John Hay In: Terminal Report on Prevention and control of pests and diseases infestation/infection within Camp John Hay Watershed.

Nair, K.S. (2007). Tropical Forest Insect Pests: Ecology, Impact and Management. Cambridge University Press

National Oceanic and Atmospheric Administration (NOAA). (2007). National Centers for Environmental Information, State of the Climate: El Niño/Southern Oscillation for Annual 2007, published online January 2008, Retrieved on October 11, 2019 from https://www.ncdc.noaa.gov/sotc/enso/ 200713.

Payne, T.L. (2006). Bark and wood boring insects of the world. Bugwood Network in cooperation with USDA Forest Service. Texas Agricultural University of Georgia (TAES #15693). http://www.barkbeetles.org/spb/spbbook/chapt2.html

Paine, T.D., Raffa, K.F. & Harrington, T.C. (1997). Interactions among Scolytid bark beetles, their associated fungi and live host conifers. Annual Reviews Entomology 42:179-206.

PCARRD. (1995). Pests and Diseases of Forest Plantation Trees in the Philippines: A Guidebook. Book Series No. 154. PCARRD and DENR, Los Baños, Laguna

Rick, R.H. Jr. (2002). Chapter 4: Climatic, Site and Stand Factors. In: Chapter 6 Sampling and Predicting Population Trends. In: The Southern Pine Beetle. (Ed.) Thatcher, R.C., Searcy J.L., J.E. Coster and G.D. Hertel https://www.barkbeetles.org/spb/spbbook/ Index.cfm

Schowalter, T. D. (2012). Ecology and Management of Bark Beetles (Coleoptera: Curculionidae: Scolytinae in Southern Pine Forests. *Journal of Integrated Pest Management*. 3(2): pp1-7 https://academic.oup.com/jipm/article-abstract/3/2/A1/877214

Self, A.B., Floyd, J.D. & Riggins, J.J. (2019). *Ips*: The Other Pine Bark Beetle. In: Forestry, Forest Pests. Missipi State Extension Service. Publication 2876. http:// extension.msstate.edu /sites/default/files/publications/publications/P2876_web.pdf

Sun, J., Lu, M., Gillette, N.E., & Wingfield, M.J. (2013). Red Turpentine Beetle: Innocuous Native Becomes Invasive Tree Killer in China. Annual Review of Entomology. 58:293-311. ento.annualreviews.org

Swain, M.S. & Remion, M.C. (2012). Direct Control Methods for the Southern Pine Beetle. Agriculture Handbook No. 575. http://www.sbpinfodirect.ento.vt.edu/Hndbk575/575.html#Introduction.

Taylor, E.L. (2015). Field Guide for the Eastman nature Trail. pp 12. https://texas4-h.tamu.edu/wp-content/uploads/2015/09/Eastman_Trailguide.pdf

Thatcher, R.C. & Conner, M.D. (1985). Identification and biology of southern pine bark beetles. USDA Forest Service, Washington D.C. Handbook 634. pp 14.

Thatcher, R.C., Searcy, J.L., Coster, J.E., & Hertel, G.D. (1980). The Southern Pine Beetle. USDA, Expanded Southern Pine Beetle Research and Application Program. Forest Service, Science and Education Administration, Pineville, LA. Technical Bulletin 1631. 265 pp

Villanueva, L.M. & Pascua, M.S. (2016). Plant parasitic nematodes associated with infected pine trees in Camp John Hay In: Terminal Report on Prevention and control of pests and diseases infestation/infection within Camp John Hay Watershed.

Zamora, R.A. & Lapiz, E.B. (1980). Five year national *Ips* infestation control program. IAGFRA. 110p.

Zamora, R.A. & Lapiz, E.B. (1987). The life history of *Ips calligraphus* Germar in Benguet Province. *Philippine Technology Journal*. 1987. 12:2 pp 43-60.

Wilson, F.L. (1977). A Guide to Insect Injury of Conifers in the Lake States. USDA Forest Service Agriculture Handbook No. 501. https://naldc.nal.usda.gov/download/ CAT87208650/PDF

Van Driesche, R.G., LaForset, J.H., Bargeron, C.T., Reardon, R.C. & Herlihy, M. (2013). Forest Pest Insects in North America: A photographic guide. UMASS AMHERST. FHTET 2012-02. 722p. https://www.fs.fed.us/foresthealth/technology/pdfs/Forest_Pest_Insects_Photo Guide_508.pdf