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REVIEW

IPS INFESTATION – A GLOBAL PROBLEM FOR CONIFEROUS IN THE FACE OF CLIMATE CHANGE

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Abstract: Bark beetle infestation *(Coleoptera: Curculionidae, Scolytinae)* is a relevant issue for forestry sector at global scale. In Europe, the average wood lost because infestations was approximately 2.9 million m3/year in the last half of the twentieth century. In present, at a global scale, insects affect 30 million hectares of forest annually. The intensity of the bark beetle attack increases in temperate forests worldwide, in Europe, Asia, in southern parts of North America and in the north of the continent. In Alaska, during the period 1990-2000, spruce mortality was spread over an area of 1,19 million hectares. From 1990 to 2000, in Tatra Mountains, in Poland and Slovak Republic (Central Europe), more than 118,000 m^3 of trees were damaged by Ips typographus infestation. Although it is the most important agent of tree mortality, bark beetle is considered a secondary pest because it has favorable conditions for development only in damaged trees. Climate warming and drought conditions have led to an unprecedented intensity of infestation. The spatial and temporal dynamics of bark beetle population outbreaks varies according to host species and insect aggressiveness. In this study, 112 articles were analyzed to discover the conditions favoring outbreaks and the severity of damage caused by bark beetle infestations.

Keywords: *bark beetle, climate changes, coniferous, infestation, pollution*

INTRODUCTION

Insects influence the function and structure of forest, being a major component of these ecosystems [1]. Forest insects can be grouped into bark beetles (xylophagous), defoliators (folivorous insects) and fluid-feeders (mucivores insects) [2]. Bark beetles are the most economically important pests of coniferous [3]. These pests regulate the size, abundance and distribution of trees. The bark beetle plays an important role by promoting changes in the forest structure and natural regeneration [4]. Disturbances reduce biomass and regulate energy and material through forest ecosystems [5]. Coniferous mortality is resulting from changes in functions and structure of the ecosystem [6]. Indirect interactions between species are essential to their proper functioning [7]. Forest structure or function and species composition are influenced by natural and human disturbances [8]. The most common salvage method of spruce forests infested by Ips typographus is to clean the forest by cutting the damaged trees [9]. Some aggressive bark beetle species, including Ips typographus, are directly favored by warming temperatures [10]. Between 1950 and 2000, storms caused more than 50 % of the damage attributed to all disturbance factors, in Europe [11]. Land managers face difficult decisions about the land management strategies and the use of limited resources [12, 13]. Windfalls and drought stress are the major factors increasing the susceptibility of coniferous to attacks by Ips typographus [14]. Biotic factors such as bark beetles (Ips typographus) and abiotic factors such as windstorms can cause forest disturbances [15]. The biotic and abiotic disturbances increase forest heterogeneity [16]. The exponentially increase of bark beetle infestations is due to climatic factors which favors both bark beetles development as well as hosts disposition [17]. The main factors that influence the coniferous death are: the spatial arrangement of infected coniferous, age trees, site quality, crown and stand density, size class, soil depth, species composition etc. [18]. Slash management is recognized as an important instrument for reducing Ips typographus attacks on affected trees stands [19]. Disturbances may affect coniferous forests over various temporal and spatial scales, from landscape scale to the level of tree functional elements [20]. To limit the potential size and severity of drought, wildfires and bark beetle outbreaks, in many cases fuel treatments was required as a quick and efficient solution [21]. Bark beetle populations can attack and kill any host tree over extensive areas, whether the trees are infected or not with other pathogens [22]. From an ecological perspective, dead wood is considered an important component of forest ecosystems due to their role facilitating tree regeneration and providing habitat for various animals and plants [23]. More than a third of animal and plant species in temperate forests depend on keeping in the ecosystem the fallen and dead wood, for their survival [24]. Many species of bark beetle cause timber sapstain, with economic loss because affect the esthetic quality of the wood [25].

FACTORS INFLUENCING BARK BEETLE-CONIFER INTERACTION

Life cycle and infestation process

Also, bark beetle species are associates with external microbes which include algae, bacteria, viruses, and fungi [26]. Microbes can be transported inside the body or on beetle body surfaces [27]. Fungal associates have an economic impact affecting the wood industry by causing discoloration [27, 28]. Many bark beetles live in association with fungi [29] being commonly associated with ophiostomatoid fungi or Geosmithia genus [30]. Informations about bark beetle associated with Geosmithia genus are limited. Until 2010 only four published studies described these fungi on Pinaceae in Europe: Kirschner, 2001; Kolarık et al. 2008; Jankowiak & Kolarık in 2010 [31]. Bark beetles are the most common insect associates of Leptographium ssp. These fungi are capable of causing considerable losses on coniferous [32]. The beetles stand under the bark where they dig the galleries to lay their eggs.

The importance of abiotic and biotic factors in the infestation process

Temperature, water, nutrients, sunlight, oxygen and carbon dyoxide are growth factors that individual trees utilize until one of these factors become limiting (Figure 1) [33].

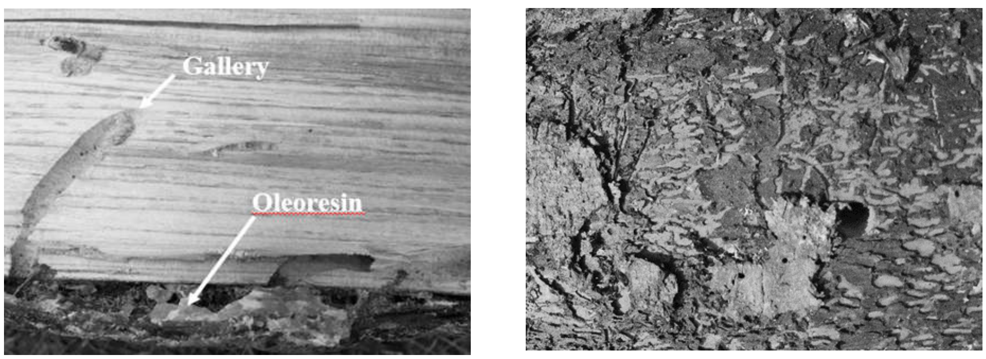

Figure 1. *The appearance of an infested spruce with Ips typographus: a) resin production for protection and digging galleries for egg deposition, and b) the inner bark aspect after beetle colonization*

Growth is generally reduced under these stress factors [34]. Disturbances such as prolonged drough can alter the coniferous vigor and allow the bark beetle to attack. Climate change may have negative effects on coniferous growth but also several biotic and abiotic disturbances (Figure 2) are expected to increase in intensity and frequency [35 – 37]. Of all the climate factors, temperature is the most important. Several specific and host factors as relief, tree competition, soil type [38] or weather conditions play an important role in Ips infestation [39]. Weather phenomena such as storms, snow, drought or forest management are considered the principal factors causing forest damage [40]. All these extreme weather events weaken the trees and can serve as favorable conditions for Ips outbreaks [41]. Increasing winter temperatures favor bark beetle survival and low humidity during the growing season decreases plants resistance [42]. Increasing summer temperature can increase the generation number per year from 1 to 2.

Features such as high density, tree diameter or pure spruce stands can increase the susceptibility of Ips infestations [43]. Low precipitates have also a very important role in plant growth and their vigor, the ability to protect against herbivores and diseases (production of secondary metabolites and in many coniferous, resins). Climatic conditions that favor harmful insect persistence in temperate regions are higher seasonal temperatures and longer vegetation periods that allow mass attacks and the successful development of more generations per year [14, 45].

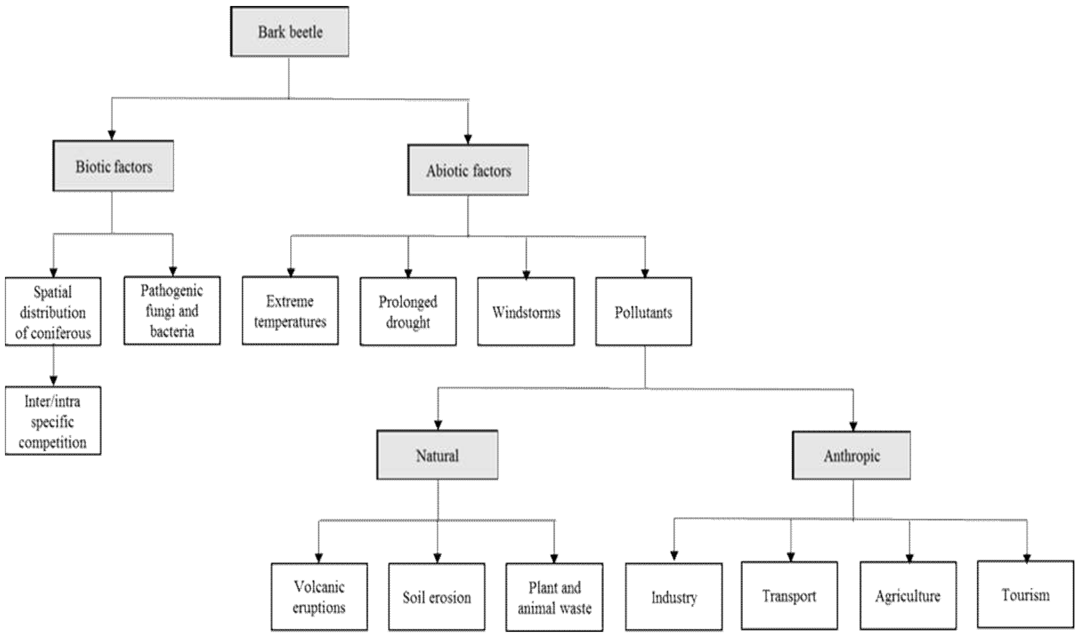

Figure 2. *The influence of biotic and abiotic, natural and anthropic factors on bark beetle infestation of coniferous*

Canopy closure can influence the susceptibility of bark beetles infestation, studies showing that a low canopy closure may favor the development of beetles. These factors are important because they allow bark beetles to infect host trees easily [46]. Forest carbon emissions are affected by the intensity of infestation and the spatial extend of disturbance [47]. Coniferous forest contains more than 35 % of terrestrial carbon and account more than 25 % of the global forested area. Data provided from NASA – GLOBAL CLIMATE CHANGE shows an unprecedented increase of temperatures and CO_2 concentrations at global scale.

In Figure 3, the evolution and dependence between temperature and CO_2 are presented. In 2100, the concentration of CO_2 will increase to at least 486 ppm, compared to 280 ppm in the pre-industrial period [48].

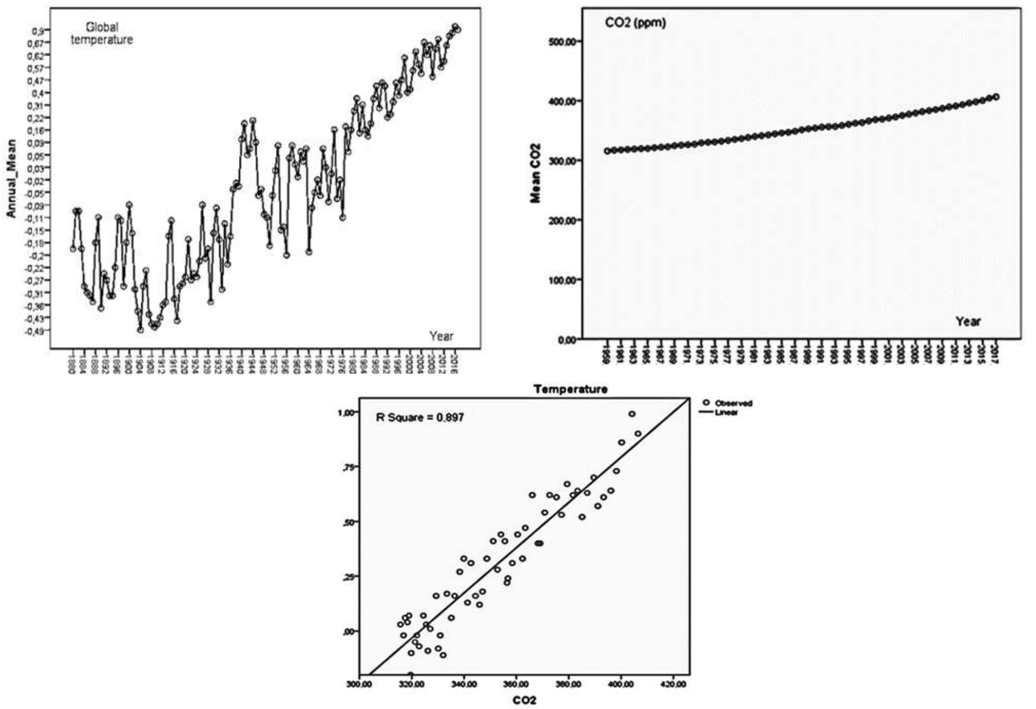

Figure 3. *The evolution of a) global temperature (1880-2017), b) global CO_2 values (1959-2017) and c) the dependency curve between the two variables (1959-2017)*

Spatial and temporal distribution of bark beetles

The dynamics of bark beetle and their temporal and spatial distribution are not yet well understood [49, 50]. The process of host tree colonization is complex and insufficiently understood, but it is generally known that bark beetle performs a series of consecutive activities before accepting a host tree [51]. The main characteristics associated with Ips infestation are stand density, basal area and tree diameter [52]. A single generation is enough to destroy the habitat because of the mass attack [53]. This species, at high population densities, is capable of infesting healthy trees if the forests are not properly managed. As long as the wind is missing, they seem to choose a random flight [51]. The spatial spread of bark beetles is ensured by host trees susceptibility and population variations determined by volatile attractants [51, 54]. The habitat availability in combination with host trees selection and flight capacity determine the spatio-temporal factors. The experiments using pheromone traps are the basis in many dispersion gradients development studies that help to understand the outbreaks orientation in space and time parameters [55]. Outbreaks cause not only economic damage regarding timber production, but also generate planting and forest maintenance costs [56]. At high population densities, this bark beetle species are capable of attacking healthy trees and can give rise to large areas of infested trees that die if the forests remain unmanaged. Generally, a single generation exhausts the entire habitat because of the mass attacks resulted from the pheromone attraction [57]. The juveniles are then forced to adapt to new hosts. Insect disorder plays an important role in forest ecosystems dynamics by renewing old and sensitive forests, recycling nutrients, and feeding wildlife. Aerial detection studies are used in order to detect bark beetle outbreaks as well as damage assessment and tree mortality: Angela Lausch, 2013; Ionuţ Barnoaiea, 2011; Sarah J. Hart, 2015, etc. Remotely sensed data is used to characterize disturbance events in drying coniferous forests [58]. Quantification of presence patterns and dispersion of bark beetle allows a better understanding of its distribution pattern on landscape scenery. Although biology and ecology have extensively investigated coniferous infestation with bark beetle, there is no satisfactory understanding of the long-term dynamics and space-time dispersion [59]. A better understanding of temporal and spatial patterns of bark beetle infestation is the key to understand and predict the transitions between different conifer infestation states [59 – 62]. Bark beetles cause widespread disturbances that have important consequences for wildlife, forest structure, wood production and water resources [63].

BARK BEETLE – A PEST WIDESPREAD IN THE WORLD

In the last decades, extended bark beetle outbreaks have been a significant problem for forest health in Europe and North American [64]. Bark beetle outbreaks occurred in Central Europe and USA over 20 years ago [65]. Because of a warming tendency, boreal forests from Alaska have been subjected to stress and morphological changes. From Alaska (south-central region) to Arizona Ips infestation caused tree mortality during the last 20 years. During this time, more than 90 % of trees with diameter at breast height bigger than 11 cm were affected by bark beetles [66]. In 2003, Ips infestation only affected 37,000 ha of spruce forest (Table 1), active outbreaks being on the decline [66]. In Alaska bark beetles colonize all species of spruce and the infestation varies with climatic conditions, host tree chemistry and growth. In Romania, the largest infested areas with bark beetles, primarily including Ips typographus, are located in the Oriental Carpathians (70 %), in Meridional Carpathians where these attacks represent 20 % of the affected area and in Occidental Carpathians (10 %) (Poliță et. al., 2014). In 1980s, almost 5800 ha of Bavarian Forest National Park from Germany were affected by Ips infestation [67]. Since then, there have been numerous investigations of the temporal and spatial outbreaks distribution. In 1983 and 1984, the severe thunderstorms destroyed 173 ha of forest. This violent episode of the weather allowed bark beetle infestations to increase considerably. About 150 species of bark beetles infests different species of trees in Europe. Therefore they are considered to be secondary pests [67]. The most destructive bark beetle infesting spruce in Scandinavia and Central Europe is Ips typographus. In the last two decades, in Austria the infested area increased from 0.6 to 3 million m3, because of the bark beetle infestan. From 1958 to 2001, in Europe bark beetle infested approximately 2.9 million m^3 of timber. The attack increased with 5.31 % each year during this period [68]. Bark beetle infestation is extremely relevant for the European forestry sector, where the estimated average volume of lost wood due to infestations was about 2.9 million m^3 / year in the second half of the 20th century. Pest attacks have been recorded with the introduction of forestry and modern agriculture, with millions of dollars invested annually in control measures. It has been calculated that harmful insects affect 30 million hectares of forest annually (FAO, become a highly relevant topic in forest policy 2010). Since 2004, the Plešné Lake - Czech Republic, has been subject to a bark beetle (Ips typographus) outbreak. The highest intensity of infestation was reached in 2008. Ips typographus is the major bark beetle which infests spruce in Eurasia [69]. Since the 1990s, in Europa, sustainable forest management has [70]. In 1996, more than 47 % of the residual spruce trees near Granite Creek on the Kenai Peninsula became infested with bark beetles Ips tridens and Ips perturbatus [71]. Since the 1990s, the rich structural diversity within the Bavarian Forest Park is caused by infestation with Ips typographus [72]. The character of abiotic disturbances determines host availability and the possibility of bark beetle outbreaks [73]. Between 1950 and 2000, an annual average of 35 million m3 of wood was damaged by disturbances such as storms and fire [74]. As an effect of global climate change many species increase the rate of population dynamics because of extinction risks [75]. Norway Spruce is the most important forest tree species in Central Europe [76]. Moraal L et al. mentioned that below 650 m, the Norway Spruce is outside of its natural range [77]. Between 1850 and 1935 the majority of forest has been planted in The Netherlands. Furthermore, new pests invaded The Netherlands, including Coleoptera such as Ips typographus [78]. In 2009, in Australia nearly 38 % (760,500 ha) of the two million hectares of forest included the exotic pine species, was affected. In subalpine forests of Europe, North America, and Japan [79] various ecosystems of Picea genus depends on seedling recruitment from dead wood [80]. In Asia (Japain, China, South Korea) the main agent of infestation is the pinewood nematode Bursaphelenchus xylophilus, but the infection is facilitate by the bark beetle. In China, the Chinese white pine beetle is a serious pest of coniferous forests which can kill large areas of white pine [81]. Low mountain areas cover more than half of Central Europe. These forests contain areas that are important for nature conser [82] vation such as national parks, natural parks, special protected areas and nature protection areas [83]. As a result of beetle infestations and prolonged drought, many regions have experienced on a large scale historically unprecedented mortality of coniferous [84]. In old-growth forests is generally recognized that large-scale disturbances such as wind or fire are sometimes needed to allow the light to pass through the trees [85]. Millions of hectares in western North America have been affected and killed (to 70 - 90 % of trees in some areas) by recent infestations with bark beetles [86]. In Scandinavia, the amount of dead wood because of bark beetle infestations has dramatically decreased due to the intense management of the boreal forest [87]. The chronic bark beetle infestations in nearly all forest types has reached an unprecedented level not seen in 125 years [88] due to warming winter and summer temperatures, hotter summer droughts and earlier springs [89]. In the last decades, bark beetle outbreaks (Ips typographus) and windstorms have caused changes in the forest structure of Bavarian Forest National Park [69]. In the Czech Republic, the decline of Norway spruce was first observed in the late 1990s when 32,000 hectares of forest were affected [90]. In British Colombia, bark beetles have infested 173.5 million m^3 of lodgepole pine which is very commercially valuable and prevalent tree species. Bark beetles infestations have expanded considerably in temperate and boreal coniferous forests in Central Europe and North America [65]. Mexico has a long and extensive history regarding coniferous forests and their infestation with bark beetles [91, 5]. The severe storms between 2005 and 2007 have allowed the spruce bark beetle to infest large areas of coniferous forest in Sweden, northern Europe [92]. In the south of the Bavarian Forest Park, due to extensive infestation of bark beetles, the structure of the canopy varies from dense stands to open forests [93]. The outbreak of Ips typographus was documented in Bavarian Forest National Park for the first time in 1988. Since then, the amount of dead wood caused by bark beelte infestations has increased rapidly [94]. A winter storm in Germany caused in January 2007 26.5 million m^3 of timber damage [75]. In the USA, bark beetles influence the nutrient cycling, ecological succesion and certain aspects of primary productionIn North America, a grup of insects are noted as the most important mortality agent of coniferous. This group is large and diverse and consists of approximately 550 species [52]. In spruce forests of Alaska and the Rocky Mountains has seen unprecedented levels of coniferous mortality [45]. A high level of mortal [95] ity has also been observed in forests of western Canada (Pinus contorta). Forests in North Carolina, South Carolina, Tennessee, Florida and Kentucky are also affected by bark beetle infestation. In California and Arizona forests the pine ponderosa was attacked by bark beetle contributing to tree mortality. In Europe, coniferous forests cover about 88 million hectares, compared to deciduous forests which cover 65 million hectares [96]. The Bayerischer Wald National Park offered in 1983 the first data about the development of spruce forests after large-scale natural disturbances (windstorms) [97]. Even if they are less aggressive, tree mortality due to bark beetles infestation leads to the loss of millinos of dollars every year in US [64]. In recent epidemics from northern Mexico to Alaska, bark beetle has killed billions of coniferous [98]. In 2015, in the Western United States, more than 50,000 km^2 of forest was affected by bark beetle outbreaks [99, 100]. In Table 1 are presented a big part of bark beetle damages in coniferous forests from Europe, America and Asia.

Table 1. *Over time bark beetle damages in coniferous forests worldwide*

Period	Area	Damages	Source
1920 to 1989	Alaska	847,000 ha	[65]
1990 to 2000	Alaska	1.19 million ha	[65]
1990 to 1996	From Alaska (south-central region) to Arizona	30 million trees / year - 930,000 ha	[65]
In 2003	Kenai Peninsula (Alaska)	37,000 ha	[65]
In the last two decades	Austria	From 0.6 to 3 million m^3	[107]
The second half of the 20th century	Europe	1.75 billion m^3 of timber	[95]
In 1950-2000	Europe	2.9 million m^3 annually	[40]
From 2009 through 2014	Colorado	46,000 ha in 2009 - 196,000 ha in 2014	[61]
From the late 2000s–2014,	Tatra Mountains, Poland	170 ha	[101]
In 1999-2007	British Columbia, Canada	11 million ha	[67]
In 1990-2000	Tatra Mountains in the Slovak Republic and Poland	90,000 m^3 of trees	[58]
Between 1985 and 2010	Beskid Mountains, Poland	56,000 ha	[47]
In 2004	Tatra Mountains	12,000 ha	[58]
In 1868	Bavarian Forest NP	11,000 ha	[56]
In 2014	Mexic	4,3 million m^3 of trees	[38]
Since 1996	Western North America	600,000 km^2	[45]
2002	Colorado	16,000 km^2	[45]
Late 1980s	Markagunt Plateau, southern Utah, USA	>250 km^2	[57]
Between 2002 and 2003	USA	From 1.6 to 4 million ha	[102]
In 2008	USA	3.6 million ha	[102]
Between 1990 and 2001	USA	400,000 ha	[102]
In 1999	British Columbia, Canada	164,000 ha	[102]

From 2004 to 2006	British Columbia, Canada	From 7 to 9.2 million ha	[67]
In 1975	Quebec, Canada	35 million hectares	[86]
In 2008	Berchtesgaden Park, Germany	400 ha	[100]
In recent years	North America	100,000 km^2	[103]
In 2000–2004	Colorado Plateau and southwest United States	over 1 million ha	[21]
From 1988 to 2010	Bavarian National Park	5800 ha	[23, 66]
For the last twelve years	British Columbia, Canada	10.1 million ha	[104]
In 2011	British Columbia, Canada	175,000 km^2	[64]
In recent years	Japan	*700 000 m3	[81]
In recent years	China	*1 million ha	[81]
Since 1995	United States	> than 17 million ha	[54]
Since 1996	Colorado	13,300 km^2	[61]
In 2004	SE Alps	8 100 m^3	[105]

*as an indirect pest

STUDIES OVER TIME OVER CONIFEROUS INFESTATION WITH BARK BEETLE

Bark beetle attack is a factor that acting in the final stages of drying trees. Thus, other factors that cause destabilization of forest ecosystem must be considered. In Table 2, important results obtained over time by researchers studying bark beetles infestation of coniferousare presented. Some studies focus on climate, especially on temperatures and precipitation. These studies involve interactions assessing between drought stress and bark beetle infestation, and how these factors affect radial growth, water efficiency and tree mortality [52, 66]. The researchers conducted over time and the experimental works aimed to establish relations between the general characteristics of the trees and bark beetle infestation process. The spruce, under physiological stress, such as drought conditions, fungal diseases [107] or intense competition among individuals, is considered a propitious habitat for bark beetle. In the experimental studies conducted by Becker and Schroter, 2000 and Fettig et al., 2007, it was noted that the space-time availability of trees may increase the risk of infection and the intensity of damage [108]. In order to develop ueful forest management tools, since 1990s many studies have been focused on factors that favor infestation as well as spatio-temporal dynamics of the outbreaks [6]. Numerous studies focus on semi-aridity forests destabilization, bark beetle infestation and its dynamics [108]. During the last 40 years, various studies dealing with vegetation indices have been published [109]. Over time, studies have shown that there is a link between forest stand attributes and bark beetle outbreaks [110]. Many researches are studying the dispersion dynamics within a short timeframe, only a few studies analyzed bark beetles dispersion for a period of 7 - 11 years [67]. Recently, more and more serious outbreaks have motivated researchers to study local topography, extension and attack stages using remote detection data [62]. Investigations in space and time of the infestations focused mainly on parameterization of the shape and size of infested plots and assessing the risk of further infestation on the landscape scale [57, 110]. Insect outbreaks monitored through remote sensing can help to understand spatially and temporally causes of disturbance caused by conifers infestation with bark beetle [111]. These studies aim to determine the spectral-temporal trajectories for mapping the dynamics of bark beetle [112].

Table 2. *Important results obtained over time by researchers studying bark beetles infestation of coniferous*

Period	Authors	Results
1758	Linnaeus	Concluded that in Eurasia, the major insect pest is the spruce bark beetle Ips typographus
1925-1926	Craighead and Miller	Demonstrated for the first time that slower growing coniferous is due to bark beetles attack
1928-1931, 1936	Person Keen	Developed a classification system for rating the possibility of bark beetle infestation
1954	Massey and Wygant	Reported the diameter of attacked spruce decreased
1971	Sartwell	Suggested that slow growth was indicative of nearly all trees killed by mountain pine beetle
1977	Amman et al.	Summarized factors influencing the susceptibility of lodgepole pine forests to mountain pine beetle attack and demonstrated that trees older than 60 years and larger than 25 cm in diameter are more vulnerable
1978	Cahill	Suggested the use of clearcutting and partial cuts to manage mountain pine beetle infestations with the primary objective of removing larger diameter trees
1982	McCambridge	Suggested a higher probability of tree mortality caused by bark beetle infestation is correlated with dense pine forests
1983	Larsson et al.	Observed that ponderosa pine vigor decreased as stand density increased
1985	Waring and Pitman	Observed that trees with low vigor were more heavily attacked by mountain pine beetle and some produced no resin
1988	Christiansen and Bakke	Concluded that I. typographus is the most destructive Scolytid in the spruce forests of the palaearctic region
1989	Schulze	Identified a variety of human and natural stress factors (air pollution, pathogens) that cause forest damage in Europe
1989-1991	Materna and Kubikova	Described the relation between forest decline and air pollution or wet deposition
1996	Olsen et al.	Concluded that active management through thinning is critical to maintaining healthy trees that are less susceptible to mountain pine beetle attack
1998	Feeney	Assessed the effects of coniferous thinning and initial results suggest that restoration treatments decreased Ips attacks on coniferous
1998	Kolb et al.	Compared measures of tree susceptibility to bark beetle attack in thinned ponderosa pine
1999	Shore et al.	Reported that infested groups of trees were positively correlated with mean dbh, tree height, age, bark and phloem thickness and poor growth
1999-2001	Coulson and Negron	Reported that conifer mortality caused by bark beetles outbreaks exhibits spatial patterning in forest stand
2003	Perkins and Roberts	Collected data from white bark pine, Pinus albicaulis Engelm., stands in central Idaho to estimate the probability of attack by mountain pine beetle
2004	Negron and Popp	Reported that plots infested by mountain pine beetle had significantly higher total basal area
2005	Zausen et al.	Investigated the effects of thinning and prescribed fire, on ponderosa pine: water stress, oleoresin exudation pressure, phloem thickness, and radial growth
2006	Lindenmayer and Noss	Concluded that forest ecosystems may be more strongly affected by salvage logging than by the initial natural disturbance
2006	Orwig	Contrasted ecological effects of windstorms, invasive pests and pathogens with the impacts of salvage logging
2007	Schroeder	Concluded that ecological and economical importance of large-scale disturbances in forests might become larger in the future

FUTURE CHALLENGES

There is more and more evidence that human management and climate change have altered the interactions between insects and forests, resulting in more outbreaks. The bark beetle impact on forest environment is affecting the ecological, economic and social environment and is even greater as past management practices have been more flawed. Managing and estimating the bark beetle impact on forests requires a normal understanding of forest health state as an ecosystem, but also at an individual level. The most important factors are natality, rhythm of growth, mortality and renewal. To predict bark beetle future infestations, required to understand their spatial and temporal dynamics. Long-term monitoring and dendroecology allow for an historical view on Ips infestations, but do not show the spatial parameters needed for understanding the patterns of infestation at the landscape scale. With climate change projections, current research indicates that outbreaks will become more frequent in the future which will have significant consequences on the carbon balance in forest environment. Saving the forest from bark beetle attack depends on the management activities and outbreak dynamics. To apply a correct managerial activity, a good understanding of outbreak dynamics is needed. Ips attack stressed or dying coniferous, but at 30 to 50 years intervals bark beetles experience periodic outbreaks during which they can affect or kill also healthy trees. The interaction between several factors such as host suitability and susceptibility and climate conditions are decisive in controlling the degree of bark beetle infestation. To understand the long-term outbreaks, it is necessary to study the bark beetle infestation development in epidemic and non-epidemic conditions.

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