An analysis of the influence of land use and selected land cover parameters on the distribution of certain longhorn beetles (Coleoptera: Cerambycidae) in Sweden

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Master Thesis no. 243

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ABSTRACT

The longhorn beetles, LHBs, belonging to the *Family Cerambycidae* constitute an important part of the biodiversity spectrum in Swedish forests. The LHB community signifies high relevance of biodiversity and conservation status of several specific habitats as well as at the landscape level, owing to their ecological position in a variety of habitats across the landscape. The current study focused on LHBs, since there exists with well-organized and structured data sets on their distribution and abundance over the last two hundred years. The present study focused on discerning the influence of different land uses and land cover parameters on the distribution of certain long horn beetles over different landscapes in Sweden. The main objective was to understand the different aspects to be considered in suggesting inputs for biodiversity conservation in the Swedish forest landscape. The study is based on spatially explicit analysis methods to discern the distribution of selected species of LHBs both at individual and group levels by studying a grid network of 10x10km representing the different supporting habitat factors. The analysis was performed with the support of data already available in SMD - Swedish land cover data base, KNN forest data and Key biotopes data. Variables for prediction were selected based on the assumption that they should influence the distribution of LHBs. A combined LHB records over 65 years from Lindhe *et al.* 2010 and artportalen records were considered in this study as response variables. The geospatial analysis to quantify the predictors and response variables were accomplished with ArcMap 10.2.2. However, the influence of land use and land cover parameters on the distribution of LHBs were assessed with binary logistic regression models by considering predictor variables both individually and also in combined models. The results of the study indicate that among landscape variables considered in the study general structures such as arable land and pasture land exhibited consistently high statistical power in predicting the presence of most groups of LHB across the landscapes, whilst the area of nominal habitat was observed with very limited predictive power to explain the distribution of LHBs. However, the exception of general pattern is represented by LHBs breeding in oak habitat substrate, which had a relatively strong relation to deciduous forest cover when predictor variables were studied individually. Volumes of specific categories of trees as predictors were found to contribute significantly for the occurrence of particular beetles in respective forest habitats. Key biotope small scale owner area revealed positive significant relation with the occurrence of almost all species in both individual and combined models. In contrast key biotope large scale owner area showed negative relation with almost all of the species' occurrence. Only one exception for conifer breeding beetles in individual model both key biotope area as predictors exhibited the opposite response pattern. No group of LHBs exhibited strong threshold effects but some individual cases, *Trogosoma depsarium, Monochamus galloprovincialis,* revealed threshold effects of nominal habitat area as well as volume and below that area or volume the existence of these particular beetles almost absence. *Xylotrechus antelope* showed to have strong threshold effect of coniferous forest area although it's breeding substrate is oak habitat. It is concluded that among the land use and land cover parameters arable land, pasture land and clearcut area were represented to have higher relative contribution in regard to the distribution of most of the LHBs. Volume of respective nominal habitat as well as key biotopes also contributed to influence the distribution of LHBs. Therefore for biodiversity conservation we observe that indicators of general management and landscape factors appear to contribute equally much or more towards sustainable forest management than nominal habitat resources in the landscape.

Key words: Long horn beetles, land use and land cover parameters, management approaches, biodiversity conservation

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1 INTRODUCTION

1.1 Background

The decade 2011-2020 has been declared as the international decade on biodiversity by the Convention on Biodiversity (CBD). Conservation of forest biodiversity is one of the seven identified thematic programs of implementation in the decadal action strategy. The action plan calls for coordinated action across Europe, since forests covers a variety of landscapes with biodiversity values highly influenced and modified by human interventions. It is reported that land use supporting forests and woody vegetation cover nearly 176 million ha of the land area (app. 42 %) in the European Union. However, land use conversions, modifications, unsustainable resource use and developmental interventions have often altered or facilitated erosion of biodiversity at different spatial and temporal dimensions. Therefore the scenario calls for evidence-based sustainable measures and interventions to conserve the existing biodiversity as well as to restore lost biodiversity values in the European landscapes (Naturvårdsverket, 2015-02-09). The European Union has also emphasized the need for protection of biodiversity as well as to stop biodiversity loss within the union by 2020 (European Commission, 2015). The strategy is further supported by the EU Vision for 2050 which provide protection, upholding the values and appropriate restoration of the intrinsic value of the biodiversity for human wellbeing and economic prosperity.

Two particular threats have been reported to undermine the biodiversity in Europe: 1) Ill-considered land use and development and 2) Increasing impacts of climate change on biodiversity. However the solutions to the problems lie in improved planning, reconciling land use and developing the requirements for the conservation of biodiversity and maintenance of ecosystem services (Commission of the European communities, 2006). In contrast to the traditional approach of restricting nature and biodiversity conservation to certain areas carved off from the production concerns; the recent approaches strongly argue for integrated landscape level strategies. Such strategies are generally anchored on securing various ecosystem services in the landscapes without compromising the concerns of timber production or biodiversity conservation (Millennium Ecosystem Assessment, 2005). However, integrated landscape level biodiversity conservation approaches best support the promotion of biodiversity conservation on a multiscale approach, at different spatial levels (Lindenmayer *et al.*, 2006). Nevertheless, functional performances of the approaches are critically dependent on the natural forest characteristics, as well as practices targeted on improvement of the landscape matrix quality.

Reviews of the literature in this domain strongly indicate that multi scale approaches are fast expanding their coverage across different forest biomes (Lindenmayer *et al.*, 2006; Fimbel *et al.*, 2001). However, the efficiency of such approaches is highly influenced by the spatial planning as well as by the dynamic components adopted in such strategies. The researchers in the domain have suggested integration of flexible and innovative strategies to mitigate and adapt to the risks of biodiversity erosion due to intensified forestry as well as due to the emerging new risk of climate change.

1.2 Biodiversity Conservation in Sweden

It is often reported that matrix level biodiversity management and conservation has a pivotal role to play in integrated biodiversity conservation, considering the scale and intensity of forest management in Sweden. Sweden has 62 % of its geographic area under forest cover, and is one of the most forested countries in the European Union. The forests in Sweden are represented by semi natural or highly modified forest lands and plantations of more or less even aged stands, monocultures or limited multispecies models etc. (Fern, 1995). These landscapes have changed drastically over the centuries, resulting in biodiversity displacement and erosion due to intensive promotion of commercial production forestry, unsustainable practices of modern agriculture etc. The competing land uses are reported to have led to shrinkage of the area of natural forest and is estimated now to be about 4 % of the total forest area in Sweden. Nevertheless biodiversity conservation in Sweden has been given considerable focus through the network of nature reserves and national parks covering nearly 5% of the total forest area of Sweden.

The forest policy of Sweden provides for landscape level strategies to address various factors which are important for biodiversity such as deciduous trees, old growth forests, dead wood etc. It also provides for continued action under holistic approaches to maintain ecological processes, and to ensure species survival as well as long term productivity of the ecosystems by safeguarding different habitats and landscapes ((Naturvårdsverket, 2014(a)). However, it is indicated that 90% of the area under production forestry in Sweden is benefited by integrated models touching upon the biodiversity concerns, irrespective of the ownership pattern (viz. private forest owners, forest companies and other forest owners). The latest study by the Swedish Forest Agency, recommends standing tree retention in production forest areas (particularly regeneration felling areas) as well as maintenance of a threshold level of volume of dead wood left in forests. But it is also reported that the majority of the trees left for conservation are thinner than 30 cm DBH though there has been a slight increase in the number of large tress of conservation value (mostly Scots pine and Birch) and wood volume in production areas in the landscape. The statistics for productive forest land which underwent logging in Sweden indicate that only less than 0.5 ha/ property is left on an average for conservation purposes in such areas (Swedish forest agency, 2015).

It is also widely observed that in production landscapes of Sweden, the distribution of natural and semi natural forests is very scattered and represents only a small part of the forest landscape. The area concerns expressed about the capability of such forested landscapes / patches to support and maintain biodiversity (Götmark *et al.*, 2011). However species diversity is reported to be often limited by the interplay of biotic and abiotic elements and the species richness is also reported to be highly influenced by spatial-temporal aspects such as landscape quality and configuration, habitat or stand quality (Franc *et al.,* 2007). Several ecological attributes like population size and species richness are also reported to be highly influenced by the dependence on landscape characteristics as well as the characteristics of the surrounding landscapes.

1.3 Landscapes and Biodiversity Conservation

The dynamics of species population change are reported to be regulated by several factors but population declines are often attributed to reduction or degradation of the supporting habitat. The population declines are also associated with spatial reduction of the spread of the species (Gaston, 1994). It is also suggested that from a habitat perspective, it can be predicted that as populations increase, less-common species should expand their range more than common species (Freckleton *et al.*, 2005). Therefore gathering knowledge on the relationship between changes in population size and range can have important implications for species conservation. It is also widely accepted that the causes for population reductions are not mutually exclusive; instead they may follow temporal co working behaviour (Hanski and Gaggiotti, 2004). This leads to the prediction that range contractions are more likely to be linked to population declines in rare species but not necessarily in common species. This is greatly influenced by the degree of habitat specialization (Ewers and Didham, 2006).

However, it is widely perceived that small natural forest patches, key woodland habitats etc., may complement relatively larger patches (Götmark *et al.*, 2011). Such dynamic complementation at spatial levels has been identified as areas of synergy for conservation as well as for enhancing availability of ecosystem services (Götmark *et al.*, 2011). It is therefore important that habitat area, isolation and quality are considered in the development of conservation strategies (Franc *et al.*, 2007). In recent times, it is much reported that the biodiversity significance of buffer areas /strips have been undervalued and there exists very little quantitative data on their potentials. An understanding of the factors which influence distribution of species communities in small conservation forests will contribute to evolve strategies for biodiversity monitoring. However, it is also reported that efforts to assess the population changes of the species are fraught with a shortage or non-availability of long term time series data on the population status (Shaw *et al.,* 2004; Vik *et al*., 2008).

1.4 Conservation Monitoring of Forest Biodiversity

In old growth forests in Sweden, insect communities constitute a biodiversity-rich group with several specialized taxa which includes many red listed species as well. However, such invertebrate assemblages are often reported to be highly indicative of environmental disturbances, alterations and modifications in the landscape. The saproxylic beetles represent an important part of this spectrum of biodiversity and in temperate regions beetles are reported to be important part of the natural enemy assemblages and ecosystem integrity at surrounding landscape level (Økland *et al.*, 1996). Wood volume in the natural forests constitutes a species rich substrate to support this biodiversity. However, such substrates are reported to be diminishing in production forests over the period and thereby proving disadvantageous for the insect biodiversity dependent on such forest patches (Christensen *et al.,* 2005).

Earlier studies in this domain identified several factors such as continuity of forest or substrate, quality and quantity of wood in local stands and the composition of the landscape to influence species richness of saproxylic beetles (Gärdenfors, 2005). Therefore an understanding of the interplay between habitat type and landscape structure is expected to enhance our capacity to manage the ecosystems for securing biodiversity and different ecosystem services. However several factors are reported to influence species richness of saproxylic beetles in the old growth forests, such as forest cover continuity, forest patches / substrates, quantity of wood in the stands, surrounding landscape composition, etc. The earlier researchers reported strong relationships between landscape factors and species richness of saproxylic beetles (Götmark *et al.*, 2011). In case of saproxylic beetle communities the qualities of the surrounding landscapes are also reported to be significantly important for the local species richness (Götmark *et al.*, 2011). The most recent research focuses on stand quality and its importance for supporting insect species distribution and richness, besides distinguishing key habitats for species diversity. High species richness of longhorn beetles supports high nature conservation values and reflects on the density of wood substrate in the large surrounding landscapes. The key biodiversity habitats which are of high conservation value help to monitor biodiversity at local as well as landscape levels.

It is established that determination of sites of high conservation values could be accomplished with approaches based on representative diversity (Cousins, 1991; Webb, 1989). Such approaches integrate across representative species assemblages with combinations of habitats and ecological factors. Hence, it is highly important that the best possible set of representative species is selected for nature monitoring, conservation and management for different habits (Dufrêne and Legendre, 1997). However, the approach is based on representative species in broadleaved forests, and is focused on the quantity of dead wood as a reflecting parameter without the inclusion of species composition (Christensen *et al., 2005;* Lachat *et al.*, 2012). It is also reported that the Natura 2000 network defines a few insect species as relevant for evaluation of conservation values of a site, this varies from the localities as well. It is often criticized that such selections have been much based on expert ideas and needs further validation through analysis of comprehensive data sets for different habitats in the broadleaved forests. Therefore, there is an urgent requirement for filling such gaps with specific representative species approaches for different habitats such as oak, pine, spruce and other deciduous and coniferous forests. In this regard it is also reported that saproxylic beetles have been focused upon as a suitable group for biodiversity studies in mixed forests (Brunet *et al., 2010*).

1.5 Application of Databases on Biodiversity

Datasets concerning Swedish landscapes that are relevant in the context of the current study include Svensk Marktäcke data, KNN forest data, Key biotope data and long horn beetle (LHB) databases from Lindhe *et al*. (2010) and Artportalen records. As per reports, around fifty species belonging to the LHBs (approx. 45% of the Swedish species) are currently listed on the databases supporting Swedish Red List (Gärdenfors, 2005), out of which 22 are categorized as threatened (VU, EN or CR) and 5 as Regionally Extinct (RE). The databases reflect details on population distribution, geo spatial spread, distribution of substrates quantity and key habitats. They also provide platforms to analyse and develop models for the conservation monitoring of biodiversity at landscape level. However, it is highly important to investigate the efficacy of these data bases to explain the factors responsible for the distribution of biodiversity components at landscape level and to assess their potential for developing strategies for landscape level biodiversity management and protocols for monitoring of biodiversity resources.

Reports based on the analysis of the biodiversity databases state that on average 20-25% of the forest living insects in Sweden thrive on saproxylic substrates and the availability of knowledge on population trends over time may be indicative of other taxa sharing the utilization of the same substrates. The studies at macro landscape level also indicate the changes in land use patterns in forested areas as well as the agricultural landscapes (Axelsson *et al*., 2002; Linder and Ostlund, 1998; Ostlund *et al*., 1997; Siitonen, 2001& Jeppsson *et al.,* 2010). Such macro level land use changes have been reported to affect the quantity and quality of wood substrates available in the habitats due to highly intensified forestry practices. The previous studies also reported that population of several LHB are in decline on account of perceived threats due to habitat destruction and degradation (Ehnström and Holmer, 2007).

In the above context, the current study has been devised to explore the distribution as well as to quantify the influences of habitat parameters such as wood volume, ground cover type, key habitat and other landscape variables, on the occurrence (presence/absence) of LHB associated with different substrate types in Sweden. The study aims to understand the different aspects to be considered in suggesting inputs for biodiversity conservation in the

Swedish forest landscape. A central concern considered in the study is whether the available landscape data on species are sufficient for development of predictive models at larger spatial scales in the context of biodiversity conservation and monitoring. The major outcomes of the study are expected to lie in complementing the efforts on large scale surveys to be attempted in future, to explore for validated databases, to develop pragmatic management models to provide a fair deal between production concerns and biodiversity conservation at landscape level.

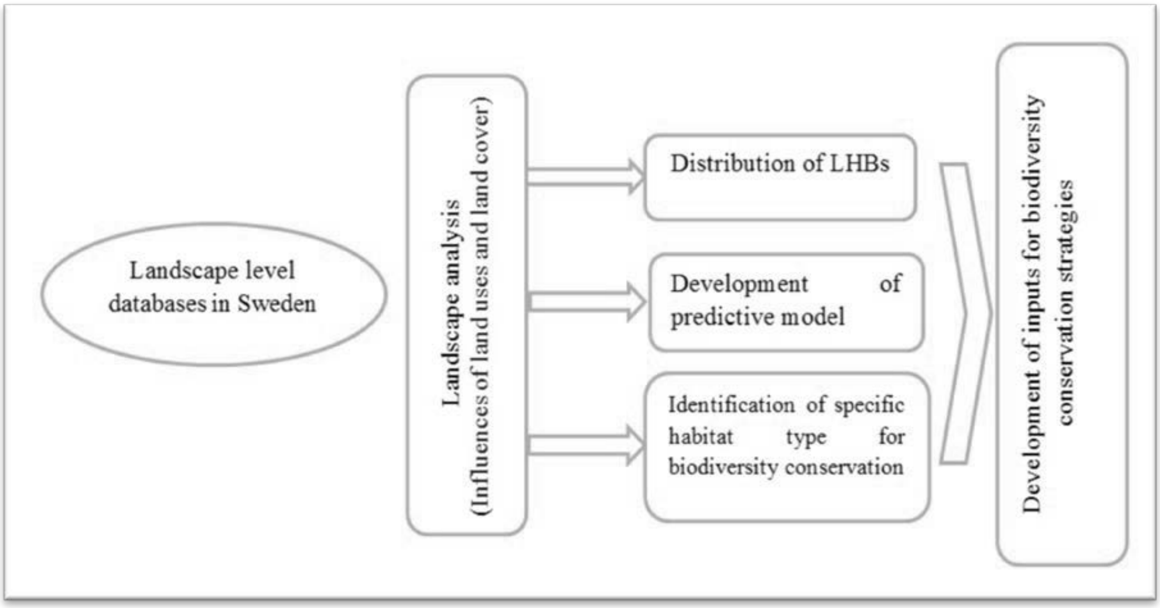

Fig.1. A conceptual framework for assessment of biodiversity databases considered in the study (Source: Own elaboration)

1.6 Objectives / Goals of the current research

The overall objective of this study was to identify landscape parameters that could be utilized in further projects to develop management approaches for biodiversity conservation. The main objectives of this project are

1. To explore factors that can explain occurrence of selected LHBs considering different land use management regimes in Sweden
2. To utilize the available landscape level data bases developed for Sweden giving information on species distributions and landscape variables
3. To explore spatial scales that are relevant to be used in landscape analysis by taking into consideration species distributions and landscape variables
4. To investigate various landscape parameters which can potentially contribute in the development of comprehensive land use management approaches for biodiversity conservation at landscape level

1.7 Research Questions

Current forestry management models are aimed at increasing the resources available for biodiversity in the forest landscape, e.g. by increasing the amount of deciduous forest in areas dominated by coniferous forest. Is it possible to use existing regional information about saproxylic insects and corresponding landscape parameters to provide meaningful guidelines for minimal levels of specific habitat types that should be retained at the landscape level, in order to provide sufficient resources for saproxylic insects? In order to provide a meaningful guideline for conservation biodiversity the following research questions are set in the current study:

1. Which spatial scales are relevant to use in a landscape analysis?
2. Which are the factors that can explain presence or absence/distribution of selected groups of longhorn beetles under different land use management regimes, based on currently available landscape level data bases developed for Sweden?
3. Is it possible to provide reasonable threshold values for habitat retention for individual species or groups of species?

2 MATERIALS & METHODS

Swedish long horn beetles (LHB) that are highly relevant to biodiversity conservation are considered in this study within a spatial scale of 10x10 km grid network. A combined LHB dataset from Lindhe *et al*. 2010 and artportalen records over the last 65 years were considered in this study as response variables. 65 years of combined records of LHBs are divided into five different groups based on their habitat preference and some individual LHBs of three groups are also demonstrated as response variables. For this study three different levels of land use and land cover datasets are considered; SMD - Swedish land cover, KNN forest data and Key biotopes data. These three forest datasets are considered as predictors for the occurrence of different LHB groups as well as individual species. In order to quantify the predictors and response variables, geospatial analyses were done using ArcMap 10.2.2. Binary logistic regression models were used to analysis the influence of land use and land cover parameters on the distribution of LHBs. Parameters were estimated using the statistical program Minitab 17. Study species, different predictor variables and their analytical procedures within the spatial scale are discussed below.

2.1 Description of Study Species

Longhorn Beetles (Cerambycidae, Coleoptera), represent an important group of insects which are known to be conspicuous and easy to identify. During the 19th to 20th century around 117 species of LHB were observed in Swedish landscapes (Ehnström and Holmer, 2007; Jeppsson *et al.,* 2010). The longhorn beetles (Family Cerambycidae) represent an important part of the biodiversity spectrum in Swedish forests with a high relevance in conservation of biodiversity in specific habitats / landscape level and moreover, well-organized and structured data sets are available for the distribution and abundance of LHBs over the last two hundred years; these are the main reasons for choosing this particular insect group for this study.

Most of the LHB species are saproxylic and some of the species depend on other substrates such as living trees, herb roots or litter etc, (Jeppsson *et al.*, 2010). Their spatial range is different in order to respond to forest habitat (Holland *et al.*, 2004) although they are the members of same family Cerambycidae. Some species of insects may be dependent on habitat density at small spatial scales, whereas for other species the availability of habitat at large spatial scales, restrict their occurrence (Holland *et al.*, 2004; Kinnunen *et al.*, 2001).
In the current study, comprehensive data sets on Swedish LHB, over the last 65 years were considered in order to investigate changes in population occurrence in the context of changing quality parameters of habitats in Sweden. In the analysis, yearly records of all study species are used in an effort to calculate species occurrence. The study also attempts to comprehend the broad contours of species range and occurrence patterns for the study area. In the current study five species group of LHBs are distinguished based on their substrate requirements: oak forest beetles, pine forest beetles, spruce forest beetles, deciduous forest beetles and conifer forest beetles. Furthermore individual species of three groups based on habitat preference are studied for assessment of distribution and accordingly development of management approaches.

The pine beetle group comprise species which mainly depends on pine as their habitat. From the pine beetles group we considered the following individuals for this study; *Tragosoma depsarium, Acanthocinus aedilis, Arthopalus rusticus, Asemum striatum, Monochamus galloprovincialis, Nothorhina muricata, Pogonocherus decorates, Spondylis buprestoides, Pedostrangalia pubescens*.

The spruce beetles group consists of LHBs with preference of spruce. The individual beetles of this group are *Tetropium castaneum, Semanotus undatus, Pachyta lamed, Molorchus minor, Judolia sexmaculata, Gaurotes virginea, Callidium coriaceam, Callidium aeneum, Tetropium fuscum, Obrium brunneum*.

The oak beetles group has preference for oak as larval substrate. The individual study species are *Pyrrhidium sanguineum Grammoptera ustulata Poecilium alni Rhagium sycophanta Anoplodera sexguttata Anoplodera sexguttata, Plagionotus arcuatus, Xylotrechus antelope, Anaesthetis testacea, Exocentrus adspersus, Strangalia attenuate.*

2.2 Study Area

This study in principle took into account the whole area of Sweden (62° N to 15° E). The study area is represented with different land uses, different forest types' volumes of different tree species and key habitat at national level. The study area is shown in Figure 2.

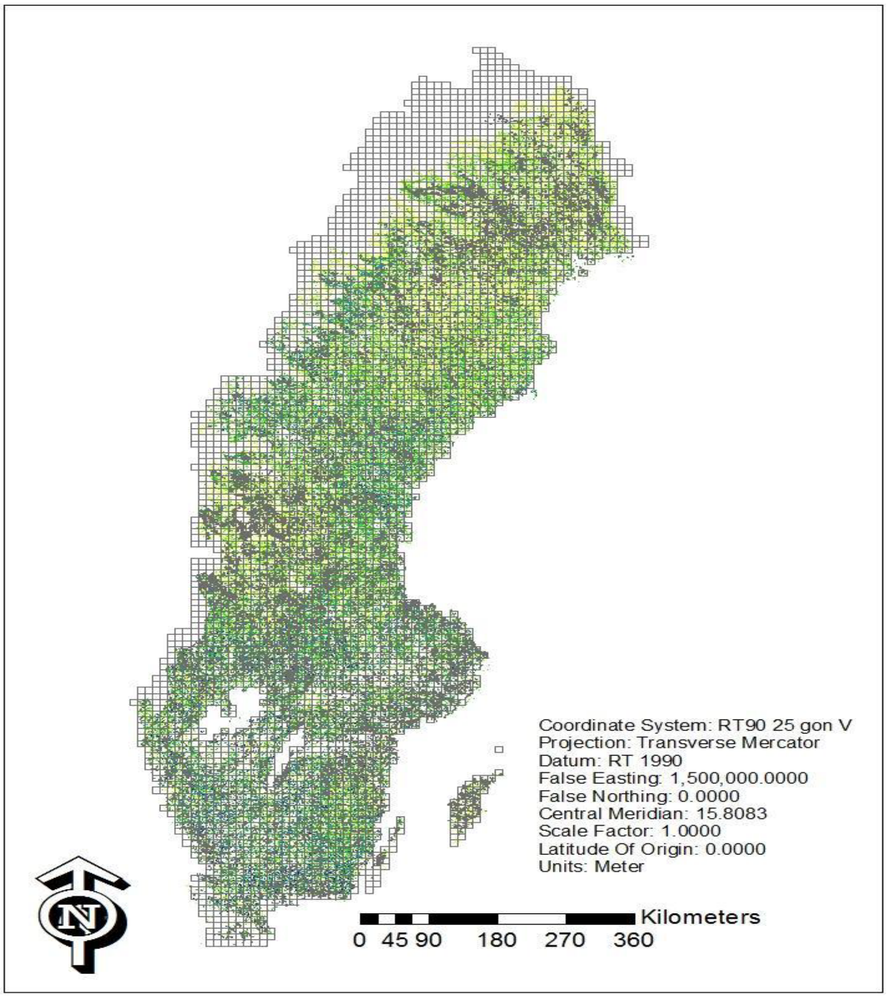

Figure 2. Land cover map of Sweden with study area of assessment of distribution of LHB along with different habitat

2.3 Description of dataset considered for this study

1. SMD - Swedish land cover, 2. KNN forest data & 3. Key biotopes data are considered as predictor variables which influence the distribution of LHBs. A combined LHB records over 65 years from Lindhe *et al.* 2010 and artportalen records were considered in this study as response variables. Both predictors and response variables are discussed below-

2.3.1 Svensk Marktäckedata (SMD - Swedish Land Cover)/CORINE Data

CORINE/SMD is a nation-wide land use and land cover data holding developed by the European Environmental agency (EEA) under the agreements of the European Union (EU) from 1985, covering different European countries. The database was developed with Co-ordination of information on the environment (CORINE) program supported by CORIEN land cover (CLC) dataset. The SMD for Sweden combines National Forest Inventory (NFI) data, meteorological and hydrological data from the Swedish Meteorological and Hydrological Institute (SMHI), general statistical features on the landscape's Statistics Sweden (SCB), geological data on the landscape components, Sweden Geological survey (SGU), data on environmental parameters Environmental Protection Agency and general administrative data on the administrative units in the land parcels the County Administrative Board environmental devices ; all configures on geo spatial platforms.

The Swedish land cover data has been developed based on land cover classification and interpretation of Landsat TM data from year 2000. The database reports on vegetation and land use further supported with classified output based on the EU classification on land cover; landscaped areas, farmlands, forest and natural lands, wetlands and water etc. In the database considered in the current study reported 58 land cover classes with differential geographical extents for the cover classes considered in the database (Naturvårdsverket, 2014(b)).

In the current study, the CORINE land cover data (SMD) was considered for the analysis of the land classes in the landscapes across Sweden. This data set consists of information on different land cover classes, land features, etc. The database which was initially developed on a raster platform based on classified satellite imageries with a spatial resolution of 25x25 m (Landsat TM from year 2000) provided details over 58 land cover classes. The land cover classes in the database were coded following a three digit CORINE Land Cover (CLC) code system for facilitation of analysis and interpretation. The instant database which was originally developed with a pan European perspective was further adapted to the context of the land cover classes found in Sweden and a comprehensive database on Swedish Land cover data (SMD) was developed. The codes were further sub coded according to various land cover sub classes. In the current research work the certain local modifications were also adopted in the framework of the database by grouping the closely related sub components to facilitate the analysis at the landscape level. This data set was in Swedish Reference Frame 1999 Transverse Mercator (SWEREF 99 ™) co-ordinate system but most of the insect data was in RiketsNät, RT 90, so in order to harmonize all the dataset in one coordinate system, the raster environment was converted into the RT 90 coordinate system.

2.3.2 KNN Forest Data

KNN-Sweden is developed and produced by the Remote Sensing Laboratory, Forest Resource Management, Swedish University of Agricultural Sciences in Umeå, Northern Sweden with a spatial resolution of 25x25 m. The basic constitution of the database was built up on National Forest Inventory (NFI) data along with satellite images for Sweden. It provides data on spatially explicit countrywide estimators of various forest attributes like standing wood volume by the tree species, mean stand age, stand height, total biomass per unit areas, etc. (Reese *et al*., 2002; Hultberg, 2015).

In the current study three individual tree species: pine, spruce and oak along with two group of species: the deciduous groups and the conifer group were considered with the objective to estimate the standing volume of wood in respect of each species/group of species in order to further infer about the influence of standing volume on the occurrence (presence/absence) of host specific LHB species.

2.3.3 Key biotopes data

Key biotopes are forest areas with potentially high conservation values for endangered and threatened species to survive and colonize. These biotopes are independent of size and depend on the biodiversity value it supports and it can be represented by even a single old growth tree. Since 1990, key biotopes records are reported during forest inventories.

In the current study, we considered only geographical areas of small scale owner biotope area which is limited from 0.5ha upto 60 ha forest land, large scale owner biotope area which has more than 60 ha of forest land as well as combined area of these two landscapes to find out their influence of LHB species/groups' occurrence and distribution. Large scale owner biotope area covers more areas as it is situated on the forest area owned by large forest companies and small scale owner biotope area covers small area as it is situated on the private forest. In order to include both small and large areas the landscape area were further combined and was taken as a parameter (Swedish forest agency, 2014).

2.3.4 Datasets on Swedish Longhorn Beetles

The Swedish longhorn beetles' database signified one of the best organized and systematically collected biodiversity databases in Sweden. This data has a history of over 200 years, and has been logged into the database form different data collection sources. The major sub groupings of the main database are described below;

*Lindhe et al. in 2010***.** The database is unique in representing the most extensive collection of LHBs data with 1 km spatial scale at RT90 coordinate system in Sweden. In the current research work we took the records of LHB considered in the study for the period from the year 1951 up to 2000 in connection with the analysis of the species distribution within the grid network and their relations with the different land use classes as well as with key potential habitat areas.

Artportalen records: Artportalen (species gateway) is a Swedish electronic site which provides information as well as observations on Swedish flora and fauna. In the study, we accessed the data of Swedish saproxylic longhorned beetles for the period from year 2000 to 2015 at RT 90 coordinate system to find out the presence /absence of long horned beetles in the Swedish landscape (Artportalen, March, 2015).

In order to develop a complete dataset of LHB we combined all the records that were collected from different sources by Lindhe *et al*. in 2010 during the year 1951 upto 2000 with the artportalen records from year 2000 to 2015. In order to carry out the assessment of distribution of LHB, a 10x10 Km spatial scale was considered within which habitat variables limit the occurrence of LHBs. We grouped all the insect species based on their habitat preference for the period form year 1951 to 2015. In the present study, we took individual LHB species which are mostly associated with pine, spruce and oak trees and subsequently grouped them as oak beetle group, pine beetle group, spruce beetle group, deciduous beetle group and conifer beetle group after combining the insect species corresponding to their habitat.

2.4 Description of the spatial analysis in ArcMap

2.4.1 Grid network

In order to carry out spatially explicit analysis on the distribution of the study species of LHB species groups and individual insects as well as the supporting habitat factors, a grid network of squares 10x10km was considered. For making the grid network at first Sweden is divided into 10x10 km square using the fishnet function of ArcMap 10.2.2 (ESRI, 2014) following the RT90 coordinate system. Unwanted cells containing more than 70% coverage of irrelevant land classes - mainly water bodies - were pruned from the attribute table. The remaining grid cells were used for the quantification of amount of contents in other layers

2.4.2 Quantification of SMD - Swedish Land Cover data

In order to quantify the land cover classes within the grid network, the SMD information was subject to feature class analysis using ArcGis functions on spatial analyst tools. The land cover tabulated data generated through the analysis was represented by 58 land cover classes and were further grouped under 12 major land use classes to facilitate the analysis. Modified land cover classes are shown in Table 1.

Table 1.: Land use classes in Sweden (Naturvårdsverket, 2014(b)- Modified and translated)

Code	Code CLC	Code SMD	Class Name	Grouping class with code*
1	111	111	Dense urban areas	Urban area(1-20, 31)
2	112	11211	Towns>200 inhabitants and little green areas	
3	112	11212	Towns>200 inhabitants and much green areas	
4	112	1122	Towns <200 inhabitants	
5	112	1123	Single houses and back yards	
6	121	121	Industry public buildings etc	
7	122	122	Roads and raiload areas	
8	123	123	Harbour areas	
9	124	124	Airport	
10	131	1311	Quarry	
11	131	1313	Mine	
12	132	132	Garbage dumps	
13	133	133	Constructionsites	
14	141	141	Urban parks and nature areas	
15	142	1421	Sport and athletics playground	
16	142	1422	Grass landing strip	
17	142	1423	Ski slope	
18	142	1424	Golf course	
19	142	1425	Non-urban park	
20	142	1426	Camping and summer houses	
30	211	211	Arable land	Arable land(30)
31	222	222	Orchards	
32	231	231	Pastureland	Pasture land(32)
40	311	3111	Deciduous forest, not on wetland or bedrock	Deciduous forest(40, 41, 42)
41	311	3112	Deciduous forest, on wetland	
42	311	3113	Deciduous forest, on bedrock	

Continue Table 1				
Code	Code CLC	Code SMD	Class Name	Grouping class with code*
43	312	31211	Coniferous forest, on lichen-rich ground	Coniferous forest(43, 44, 45, 46, 47, 56)
44	312	312121	Coniferous forest, not on lichen 7-15 meters	
45	312	312122	Coniferous forest, not on lichen >15 meters	
46	312	3122	Coniferous forest on wetland	
47	312	3123	Coniferous forest on bedrock	
48	313	3131	Mixed forest not on wetland or bedrock	Mixed forest (48, 49, 50)
49	313	3132	Mixed forest on wetland	
50	313	3133	Mixed forest on bedrock	
51	321	321	Natural grasslands	
52	322	322	Heathland (not grassland)	
53	324	3241	Bushes and brushland	
54	324	3242	Clearcuts	Clearcut (54)
55	324	3243	Young forest, plantation	Young forest(55)
56	312	31212	Coniferous forest, not on lichenous ground	
58	331	331	Beaches, dunes sand fields	
59	332	332	Bedrock	Bedrock with little vegetation (58-62)
60	333	333	Areas with little vegetation	
61	334	334	Burned areas	
62	335	335	Glaciers, permanent snow fields	
63	321	3211	Heath, Grassland	Grassland(51, 52, 53, 63, 64)
64	321	3212	Meadow	
70	411	411	Limnic wetlands	wet land (70,71, 73, 74)
71	412	4121	Wet mire	
72	412	4122	Other mires	
73	412	4123	Peat quarry	
74	421	421	Salt marshes	
80	511	511	Running water	water sources(80- 86)
81	512	5121	Lakes and ponds, open water	
82	512	5121	Lakes and ponds, overgrowing	
83	521	521	Estuaries	
84	522	522	Estuaries	
85	523	523	Coast and oceans, open water	
86	523	5232	Coast and oceans, overgrowing	

*Indicates that this group is developed only for the current study in order to facilitate the analysis

2.4.3 Quantification of KNN Forest Data

In order to carry out the volumetric analysis, the shape files of each tree species and group of tree species considered in the study were exported to Arcmap (ArcGis10.2.2., ESRI, 2014) for the necessary analysis of the data using zonal statistics. The outputs of the results were exported as excel files and were subjected to further analysis to extract the sum of standing volume of tree species within each 10x10 km grid cell.

2.4.4 Quantification of Key biotopes Data

The dataset so adapted was considered for analysis of key habitat areas within the each grid cells using the intersect geoprocessing analyst to derive the extent of such key habitats in the grid network. Thereafter the cumulative key habitat areas within each grid cell were assessed using the dissolve function under the geoprocessing domain in ArcGis.

2.4.5 Databases on Swedish Longhorn Beetles

After making a group of LHB based on the habitat preference shape files were prepared in ArcCatalog, displaying every individual observation from each group and/or every individual LHB species at RT90 coordinate system. Observations were joined with the grid network in the ArcMap environment for all the insect groups and individual insects considered in the study in order to find out the presence and absence of LHB groups or individual species within each grid cell. After making quantification of the forest data as available from Marktäcke, KNN and as well as key biotope databases, each of the dataset are joined with the grid cells in order to assess their capability to support determination of the presence/absence and their relation to ground cover classes, wood volume as well as variables relevant to the key biotopes for rare and / endanger saproxylics considered.

2.5 Statistical analysis

Analysis of the amounts of wood volume, area of ground cover classes and key habitat area, in relation to the distribution of individual species or species groups within the 10x10 km grid network, was accomplished with binary logistic regressions. Both individual and combined binary logistic regression models were developed for the species groups and individual species with respective databases by using Minitab 17. Land use classes, volume of different tree species and key biotope areas were considered as predictors and insect groups, as well as individual LHBs were considered as response variables in individual binary logistic regression model. In order to find out the responsive predictor, binary fitted line plots were developed for each individual case. For the combined binary logistic regression model the land use classes and key habitat areas as a whole were considered as predictors and insect species, both individual species and grouping into LHB groups according to breeding substrates, were considered as response variables. The relations between land cover class, standing volume, geographical area of key habitat and species distribution were inferred through verified models with chi square value at 0.05, 0.01 and 0.001 level of P value. For distribution of LHB in relation with different land use classes, volume of different habitat substrate and within potential key habitat areas histogram was developed. Thereafter, determinations of the degree of influence of the stand volume, land use class and key habitat area on the distribution of the coleopterans considered in the study were carried out.

3 RESULTS

The results of the individual and combined binary logistic regressions between predictor and response variables are presented in this chapter. In the binary logistic regression we considered first group beetles as response variables and after that some individual LHBs of three groups was demonstrated in order to see how they are influenced for their occurrence by different predictor variables. Binary fitted line plot are considered of each individual relations in order to verify the strength of the logistic regression model. Distributions in relation with different predictors are presented in the histogram.

3.1 Observations of LHB considered in the Study Area

The observations on the distribution of LHB groups and selected LHB species in the different habitat types were analysed in the GIS environment based on the combined LHB data of Lindhe *et at.* 2010 and artportalen data for the study area following grid network and the results are presented and depicted in the maps given below at Figure 3

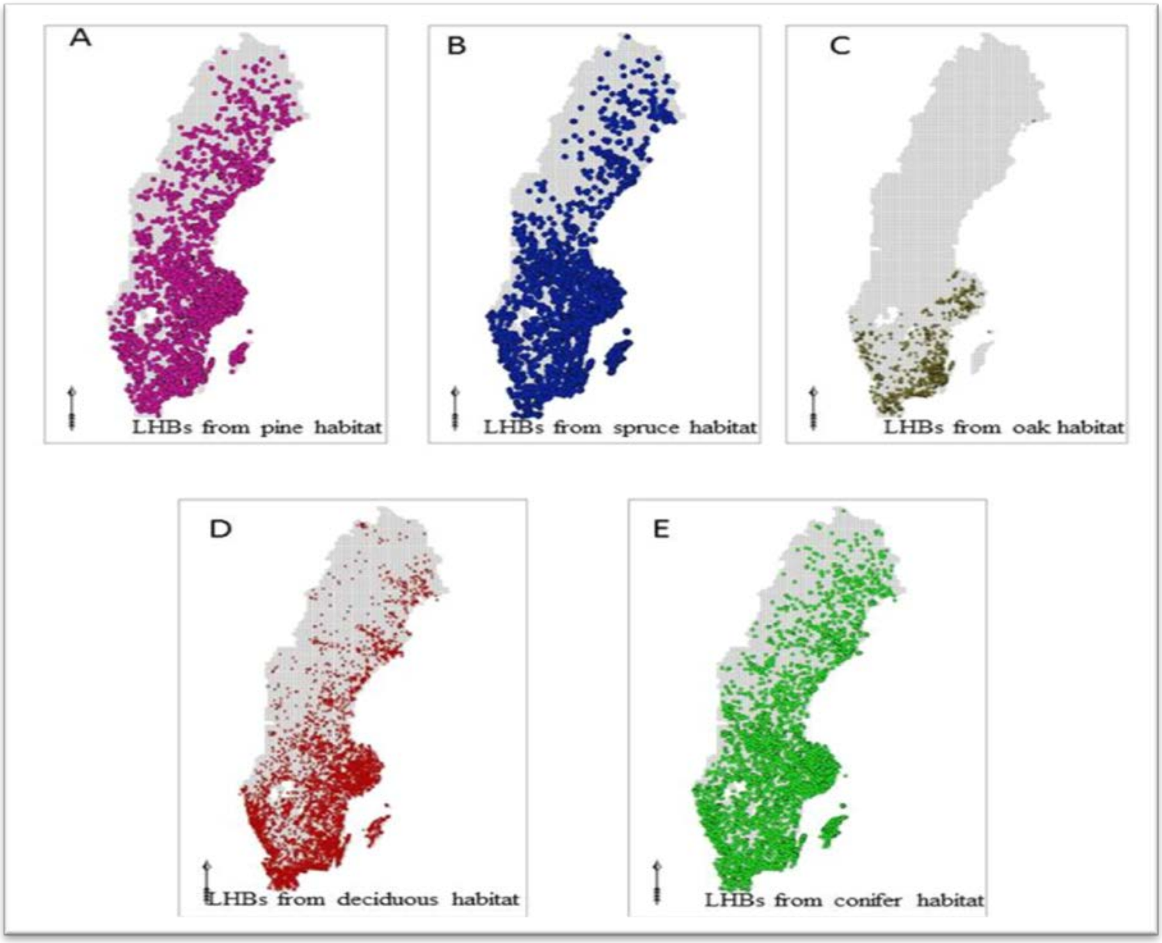

Figure 3. Observations on LHB groups using different breeding substrates within the 10x10 km grid network over Sweden for the period 1951 to 2015. The Map A, B, C, D and E indicate the observations of LHBs breeding in pine habitat, LHBs breeding in spruce habitat, LHBs breeding in oak habitat, LHBs breeding in deciduous habitat, LHBs breeding in conifer habitat respectively.

As could be perceived from results, the different LHB groups considered in the study are observed to be located over the study area (Map A, B, D and E), except the LHB Group breeding in oak habitat (Map C), which is restricted mostly to the southern parts of the country. The nature of occurrence of oak breeding beetles may be restricted by their dependency on oak substrate for survival and completion of their life cycle (Figure 3). It may also be assumed that the occurrence of LHB groups is found to be following the general distribution pattern of pine, spruce, coniferous and deciduous forests and the substrates available in such habitats in the landscape.

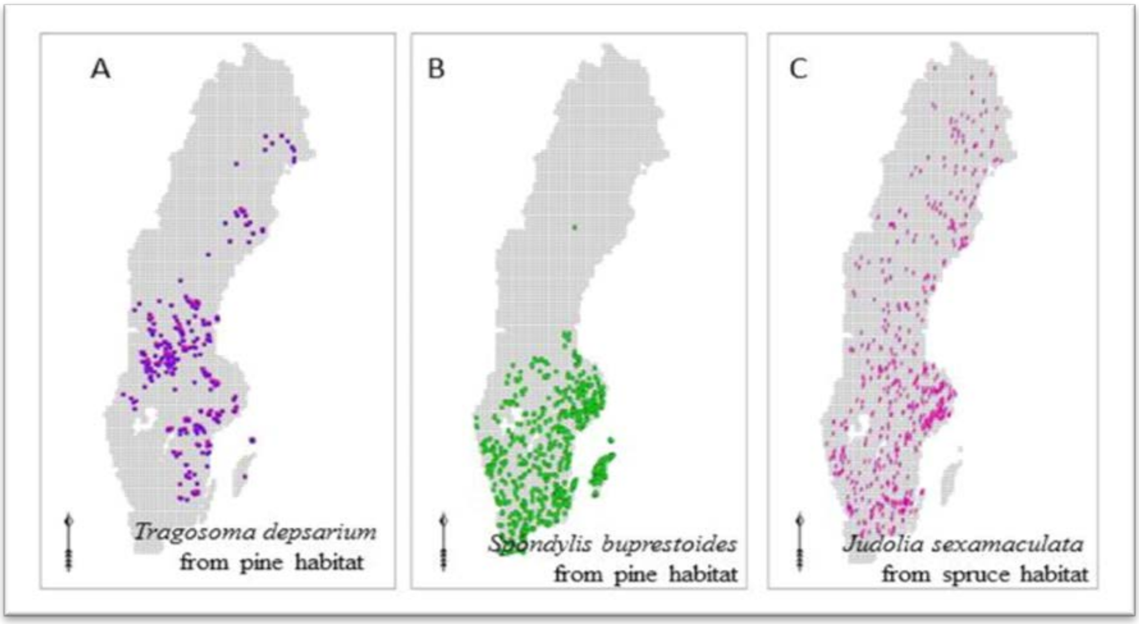

Figure 4. Observations on individual LHB species using different breeding substrates within 10x10 km the grid network over Sweden for the period 1951 to 2015. The maps A, B and C, indicate individual observations of individual LHB of *Tragosoma depsarium* (associated with pine habitat), *Spondylis buprestoides* (associated with pine habitat) and *Judolia sexmaculata* (associated with spruce habitat), respectively.

The map shows that observations of individual LHBs of each groups, are not akin to the pattern revealed by the analysis as group of LHB. Some individual species like *Tragosoma depsarium* (Figure 4A), *Judolia sexmaculata* (Figure 4C) are observed to cover whole area and some others are observed to cover some or part of the country. For instance *Spondylis buprestoides* is observed in the southern part of the country (Figure 4B) although their main habitats are found throughout the whole study area.

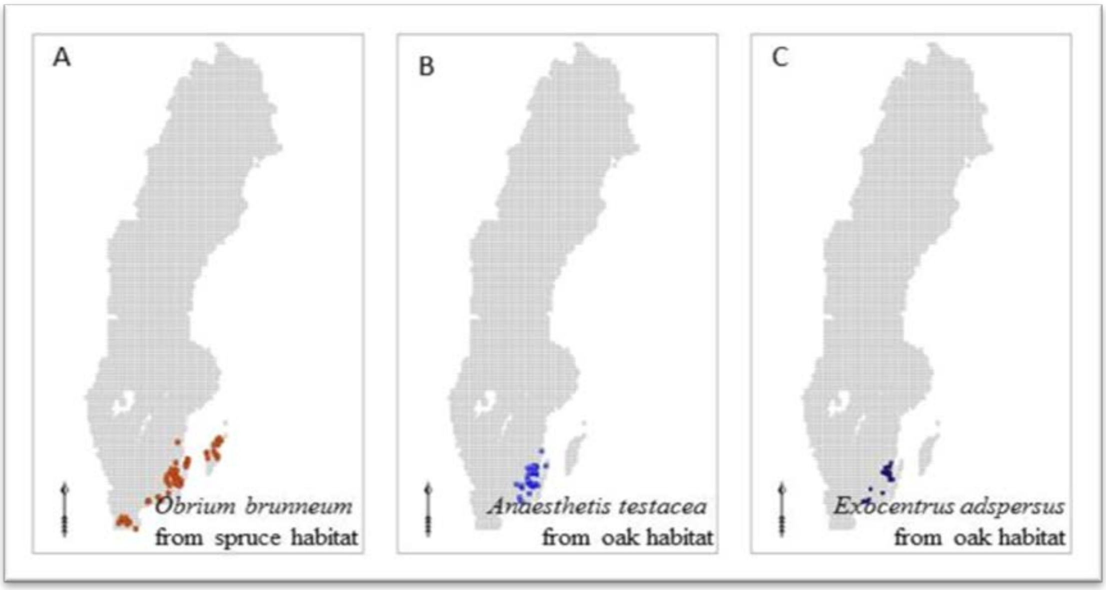

Figure 5. Observations of individual LHB species using different breeding substrates within 10x10 km grid network over Sweden for the period 1951 to 2015. The Map A indicates the observations of *Obrium brunneum*, breeding in spruce in the southeast part of Sweden and Map B and C indicate observations of *Anaesthetis testacea* and *Exocentrus adspersus* in Kalmar län and their main habitat is oak substrate.

From the Figure 5 it could be revealed that the observations of some individual LHBs are very restricted to specific locations. They are considered as endangered individuals, for instance: the observations of *Obrium brunneum* (Map A) covering south the eastern part of the country though their main habitat substrate, e.g. spruce is widespread. However, other individual LHBs like *Anaesthetis testacea* (Map B) *Exocentrus adspersus* (Map C), *etc.* covered only one specific area, i.e., Kalmar and Blekinge counties. The probable reason for the restricted occurrence in the area may be subject to climatic variations.

3.2 Binary logistic regression model

In the study two types of binary logistic regression model were considered; 1. individual binary logistic regression model where all the forest type classes, other land cover classes, volume of different tree species and key biotope areas were considered individually to show their influence on the occurrence of both individual beetles and as well as group of LHBs. A total of 7 land cover classes, volume estimations of 5 different tree species and groups of tree species (deciduous and coniferous) and 3 key biotope areas were found on influence the occurrence of five major groups of LHB and 29 individuals among three groups individually. In order to compare the strength between predictor and response variables in different cases, the chi square value were considered in addition to different levels of significance ($p<0.05$, $p<0.01$ and $p<0.001$). Each individual relations was shown in a binary line plot in order to further, verify the strength of the model and in order to check the threshold effect in regarding to distribution of LHBs. 2. A combined binary logistic regression model where all the predictors; forest type classes, other land cover classes and key biotope areas were considered as combined to show their responses on the occurrence of both individual beetles and as well as group of LHBs. A total of 12 land cover classes were influencing the occurrence of LHBs both major groups and individuals. In order to find out the relationship between predictors and response variables chi square values were taken at different $p<0.05$,

$p<0.01$ and $p<0.001$ level of significance and variance inflation factor (VIF) was considered to find out the collinearity among different predictors for the occurrence of response variables. High values of collinearity indicate that a variable co-varies along with one or more other variables, making it difficult to assign a causal relationship to any specific variable.

Table 2. Logistic Binary Regression Individual Model of LHB species/categories with different Land Cover Classes

Species/ Category	Present/ Total Sq.	Arable land	Pasture land	Deciduous forest	Coniferous forest	Conifer with lichen and bedrock	Mixed forest	Clear-cut
Chi-Square								
Deciduous beetles	1902/ 4294	452.54***	724.72***	-0.1	0	-57.15***	-27.24 ***	8.71 **
Conifer beetles	1987/ 4294	168.36***	343.81***	-4.81*	4.35*	-20.14***	-9.85**	13.77 ***
Spruce beetles	1536/ 4294	62.25***	161.46***	-0.38	4.86*	-36.81***	-3.31	18.64 ***
Pine beetles	1313/ 4294	99.78***	257.94***	-9.81**	0.79	-5.85*	-17.92***	7.39**
Oak beetles	445/ 1663	1.55	38.79***	51.36***	-18.99***	-17.45***	-2.63	-19.92***
Individual LHB species of Pine group								
Tragosoma depsarium	229/ 4294	-9.72**	-0.39	-36.4***	48.18***	16.3***	-0.23	53.93***
Acanthocinus aedilis	542/ 4294	53.4***	85.05***	-7.11**	6.69**	-0.57	-2.7	9.2**
Arthopalus rusticus	531/ 4294	104.39***	190.72***	-10.64***	-5.22*	-2.73	-16.05***	-2.83
Asemum striatum	547/ 4294	42.21***	72.74***	-1.46	1.25	-3.09	-4.03*	3.01
Monochamus galloprovincialis	68/ 4294	0.88	2.88	-0.18	0.24	5.98*	-3.65	0.02
Nothorhina muricata	146/ 4294	2.72	0.86	-0.49	-9.39**	-0.01	-25.45***	-2.2
Pogonocherus decorates	170/ 4294	18.74***	49.39***	-7.91**	-2.31	1.57	-6.32*	-0.93
Spondylis buprestoides	449/ 1979	12.58***	59.76***	17.26***	-30.04***	-1.58	-1.81	-56.46***
Pedostrangalia pubescens	28/ 1116	-26.94***	-17.65***	-6.42*	5.7*	3.77	0.12	10.68 ***

Continue Table 2.

Species/ Category	Present/ Total Sq.	Arable land	Pasture land	Deciduous forest	Coniferous forest	Conifer with lichen and bedrock	Mixed forest	Clear-cut
Chi-Square								
Individual LHB species of Spruce group								
Tetropium castaneum	546/ 4294	122.41***	185.19***	0.02	-0.31	-21.77***	-2.11	-0.04
Semanotus undatus	274/ 4294	3.44	0.33	-7.68**	0.33	3.42	-8.37**	0.33
Pachyta lamed	207/ 4294	-6.95**	-11.91***	-0.03	3.11	-0.2	-0.51	1.89
Molorchus minor	593/ 4294	112.11***	139.81***	-0.23	-1.34	-41.52***	-1.25	3.07
Judolia sexmaculata	473/ 4294	14.84***	33.68***	-0.02	0.51	-10.46***	-0.07	1
Gaurotes virginea	621/ 4294	43.35***	124.22***	-1.75	3.39	-28.68***	5.62*	13.43***
Callidium coriaceam	453/ 4294	-1.38	-0.3	-0.95	7.9**	1.47	-0.8	8.12**
Callidium aeneum	112/ 4294	8.21**	11.05***	-0.01	-2.77	-1.83	-0.88	0.03
Tetropium fuscum	112/ 4294	8.21**	11.05***	0.01	2.77	-1.83	0.88	0.03
Obrium brunneum	30/ 695	-10.44***	-7.1**	0.01	1.71	0.01	15.91***	3.41
Individual LHB species of Oak group								
Pyrrhidium sanguineum	115/ 1663	-1.61	8.9**	21.86***	-0.85	-16.91***	1.7	-0.33
Grammoptera ustulata	97/ 1663	0.06	4.11*	7.39**	-5.18*	-8.27**	-0.52	-0.47
Poecilium alni	50/ 1663	-0.74	2.89	7.57**	0.59	-11.46***	1.58	2.34
Rhagium sycophanta	64/ 1663	3.28	17.92***	19.36***	- 29.36***	-8.37**	-12.75***	-13.63***
Anoplodera sexguttata	85/ 1663	1.54	15.26***	54.54***	-11.48***	-19.74***	-0.27	-8.88**
Plagionotus arcuatus	321/ 1663	15.42***	50.12***	30.75***	-44.29***	-18.09***	-7.42**	-41.39***
Strangalia attenuate	58/ 1663	-5.85*	-1.33	4.88*	2.19	0.02	5.59*	4.41*
Xylotrechus antelope	47/664	-28.78***	-38.99***	-4.76*	33.62***	11.6***	21.72***	104.89***
Anaesthetis testacea	25/599	-8.51**	-13.52***	-0.11	2.98	4.89*	9.2**	26.69***
Exocentrus adspersus	19/434	-9.53**	-15.87***	0	1.41	12.47***	7.38**	17.98***

*, ** and *** indicate significant at P <0.05, P<0.01 and P < 0.001level respectively

3.2.1 Analysis of presence of species/ group of LHBs within grid network

Observations of individual LHB species considered in the study may not be found covering the whole area of the study. However, the LHB groups which consisted of species resident in or breeding to a particular type of habitat were observed with greater spread in terms of geographic distribution. It may also be inferred that the presence of LHB within the total grid doesn't indicate the true presence / absence ratio. The instant presence is based on the observations with different survey reports. The observations on of LHBs groups were found to cover more grids compared to individual LHBs.

3.2.1.1 Observations of group LHBs

The LHB group that depends on habitat of conifer substrates was found covering larger number grids in the network. Throughout the entire grid network of 4294 cells, this group of LHBs covered 1987 grids, followed by deciduous forest beetles group (1902 cells), spruce forest beetles group (1536 cells) and pine forest beetles group (1313 cells) respectively. However, the oak beetle group was observed only in 445 cells against 1663 cells considered in the study, based on the combined survey records of Lindhe *et al*., 2010 and artportalen records. The low frequency of observations on oak group LHBs may be attributed to the restricted distribution of oak habitats in Southern Sweden (Table 2).

3.2.1.2 Observations of Individual LHBs

As for the observations on selected individual beetles considered within pine beetles, spruce beetles and oak beetles; *Gaurotes virginea* inhabiting spruce habitat was found with the maximum frequency of observations covering 621 grid squares out of 4294 grids. It was also observed that most of the individual LHB species considered in pine and spruce forest beetle groups covered more cells in the grid network and this may be linked to the distribution of these two habitats across the country. Some of the LHBs among the groups like *Pedostrangalia pubescens*, *Obrium brunneum*, *Exocentrus adspersus* were observed with low frequencies of observations in the grid network as they covered only 28, 30, 19 cells respectively (Table 2).

3.2.2 Influence of landscape data

3.2.2.1 Influence of landscape data on occurrence of LHB group

Overall, the area of nominal habitat, represented by land cover classes obtained from the Swedish Land Cover map, had very limited predictive power regarding the distribution of LHBs. Most groups of LHB, defined according to their substrate preferences, exhibited very little significant positive relationships with the land cover area of their nominal habitats, when different land cover variables were studied individually (Table 2). Conifer-breeding beetles and spruce-breeding beetles exhibited a significant but weak relationship with the cover of conifer forest. In contrast, the landscape variables Arable land and Pasture land exhibited consistently high statistical power in predicting the presence of most groups of LHB (Figure 6). The only exception to this general pattern is represented by LHBs breeding in oak, which had a relatively strong relation to deciduous forest cover (Figure 7), with a somewhat weaker relation to Pasture Land and no relation to Arable Land.

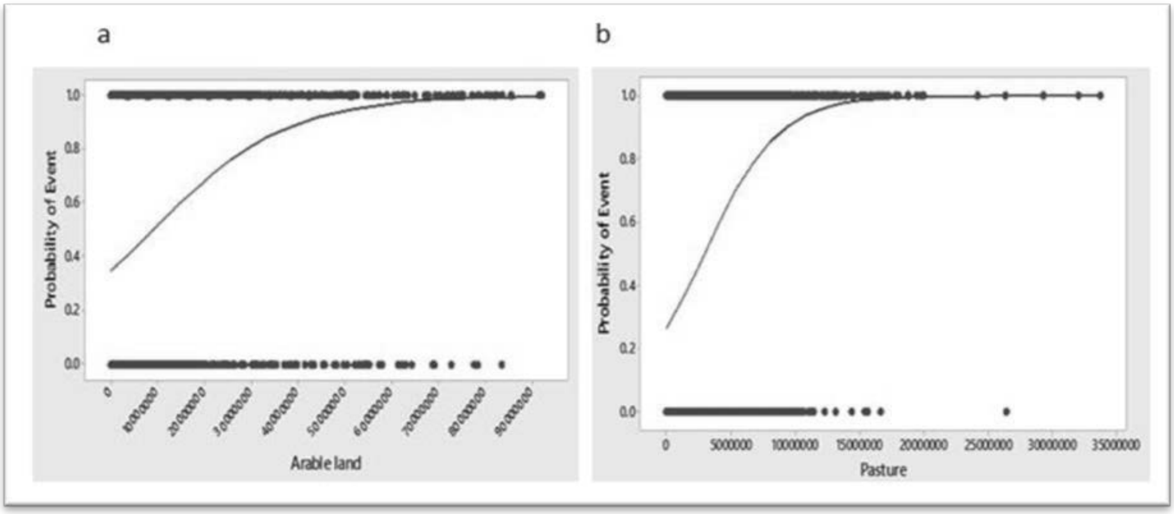

Figure 6. Binary fitted line plots of deciduous forest beetles within the areas (m^2) of (a) arable land and (b) pasture land. Here probability of event 0 indicates absence and 1 indicates presence of deciduous habitat preference of LHB

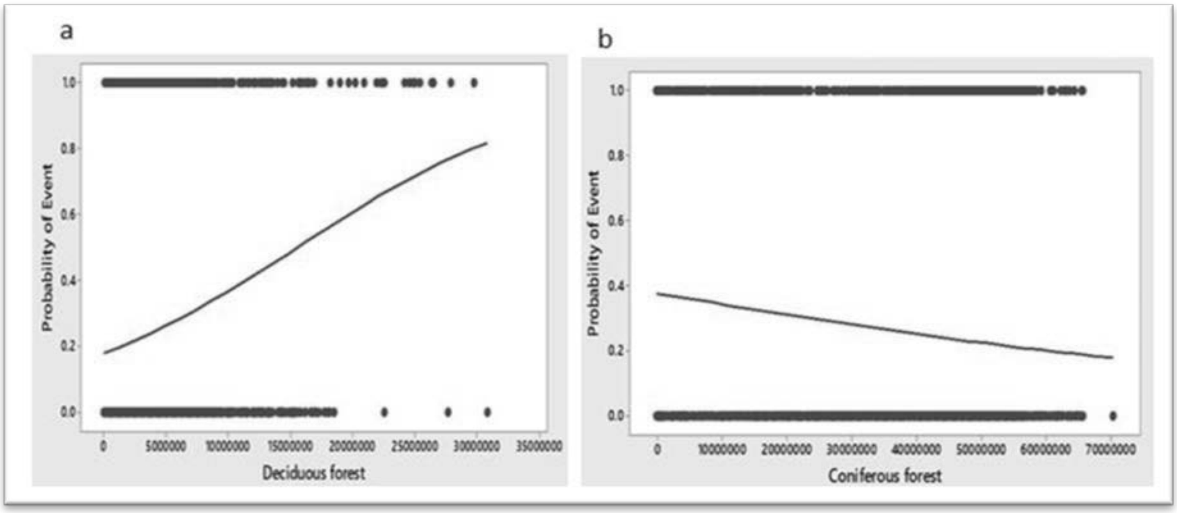

Figure 7. Binary fitted line plots of oak beetles within the areas (m2) of (a) deciduous forest and (b) coniferous forest. Here probability of event 0 indicates absence and 1 indicates presence of oak habitat preferring LHBs

No group of LHBs exhibited strong threshold effects, with presence mainly at higher amounts of any variable (Figures of plots showing this in Figure 6 & 7). For their presence they don't require certain amount of breeding habitat.

Results from the combined model where variables were taken together contrasted quite strongly with the results from the individual variables. The area of expected breeding habitat had some predictive power regarding the distribution of LHB groups, but many other variables had equally strong or stronger influences (Table 3). Most groups of LHBs yielded positive significant relationships with habitat of deciduous forest, coniferous forest, mixed forest, etc. regardless of their expected breeding habitat, except pine breeding beetle group showed no relation with deciduous forest and oak breeding beetles didn't show positive relation with mixed forest. However, young forest had strong predictive power regarding the distribution of LHBs breeding in deciduous and oak substrates. The analysis of the data flagged that landscape area yielded predictive power for the distribution of LHB group when variables were contributing together but didn't show a strong relationship when variables were tested individually. The pasture land was observed to contribute more as a predictor for the occurrence of different group LHBs followed by clearcut, urban and arable land as predictors. Water source confined a good predictor for the occurrence of all of the group LHBs. However wetland showed positive but weak relationship in regarding the distribution of LHB. In the case of oak forest beetle occurrence in relation to different types of landscape areas as predictor generally showed high multicollinearity.

3.2.2.2 Influence of landscape data on occurrence of individual LHBs of pine group

Among the nine individual study species of pine breeding LHBs considered in the study, very few exhibited strong relationships with their expected breeding habitat as an individual variable. Whilst, nominal habitat type of coniferous forest and clearcut area showed predictive power regard to the distribution of pine breeding LHBs of T*ragosoma depsarium* and *Pedostrangalia pubescens* and these pine breeding individual beetles flagged strong threshold effect of nominal habitat of coniferous forest (Figure 8) regarding their distribution. Five species; *Acanthocinus aedilis, Arthopalus rusticus, Asemum striatum, Pogonocherus decorates and Spondylis buprestoides*) revealed significant and strong relationships at $p<0.001$ level of significance with predictor variables such as arable land and pasture land (Table 2) when landscape variables were tested individually.

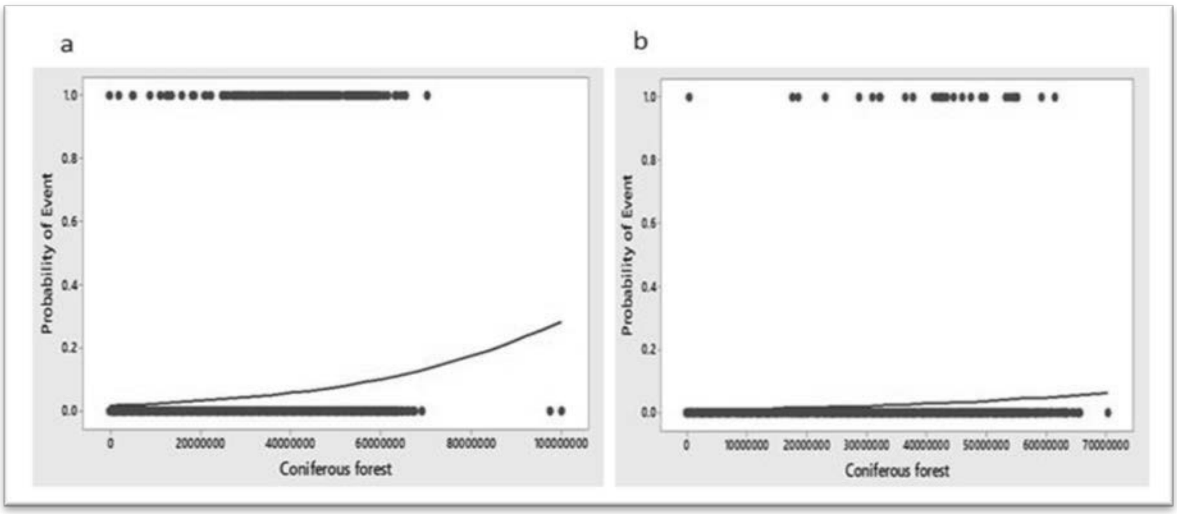

Figure 8. Binary fitted line plots of pine beetles; *Tragosoma depsarium* (a) and *Pedostrangalia pubescens* (b) within the areas (m^2) of coniferous forest. Here probability of event 0 indicates absence and 1 indicates presence of pine habitat preferring respective LHBs

When all the landscape variables were studied together, the area of expected breeding habitat variables, viz. coniferous forest showed significant positive relationship in regard to the distribution of most of the individual pine breeding beetles. However, other landscape variables such as Urban, Arable land, Pasture land, and to some degree also clearcuts often yielded higher statistical power in predicting the presence of most of the pine breeding individual LHBs (Table 3). The exception to the general pattern was represented by *Pedostrangalia pubescens* which has no relationship with the landscape variables as well as nominal habitat type. Probable reasons may be that these particular beetles cover small area. The predictor variables showed higher multicollinearity. Water sources were represented to have high predictive power in regarding the distribution of *Arthopalus rusticus*, *Spondylis buprestoides*, etc.

Table 3. Logistic Binary Regression Combined Model of LHB species/categories in relation to SMD variable as well as key biotopes

Species/Category	Present/Total Sq.	Deciduous forest		Conifer forest		Mixed forest		Young forest	
		Chisq	VIF	Chisq	VIF	Chisq	VIF	Chisq	VIF
Deciduous beetles	1899/4289	13.34***	1.98	13.49***	4.53	24.26***	1.45	32.08***	2.38
Conifer beetles	1983/4289	4.48*	1.92	16.79***	4.64	17.51***	1.48	1.27	2.45
Spruce beetles	1533/4289	10.44***	2.03	14.98***	5.45	9.08**	1.54	0.34	2.59
Pine beetles	1310/4289	1	1.91	18.82***	5.77	14***	1.54	4.45*	2.48
Oak beetles	445/1660	38.5***	5.47	21.26***	67.75	0.47	2.99	30.83***	3.5
Individual LHB of Pine group									
Acanthocinus aedilis	541/4289	1.79	2.01	24.69***	4.46	3.32	1.35	7.51**	1.92
Arthopalus rusticus	530/4289	0.91	1.96	31.82***	6.41	0.05	1.56	10.6***	2.08
Asemum striatum	547/4289	5*	2.05	18.71***	3.89	4.69*	1.37	0.75	1.95
Monochamus galloprovincialis	68/4289	1.1	2.2	4.66*	4.09	3.72	1.45	1.36	2.1
Nothorhina muricata	146/4289	0.01	1.75	0.31	3.25	15.44***	1.6	0.06	2.23
Pogonocherus decorates	170/4289	0.13	1.73	7.24**	6.84	0.37	1.61	2.58	2.51
Tragosoma depsarium	229/4289	5.73*	1.41	7.98**	1.9	6.99**	1.25	0.16	1.66
Spondylis buprestoides	448/1976	16.38***	3.43	46.53***	38.12	10.12***	2.32	6.8**	2.9
Pedostrangalia pubescens	28/1113	0	4.13	0.42	64.66	0.25	3.63	9.72**	3.73
Individual LHB of Spruce group									
Tetropium castaneum	545/4289	18.96***	2.55	39.21***	5.92	0.33	1.45	2.69	2.04
Semanotus undatus	274/4289	1.22	1.69	2.49	3.07	5.61*	1.43	5.05*	1.98
Pachyta lamed	207/4289	0.14	1.85	1.1	2.49	2.45	1.35	0.12	1.94
Molorchus minor	593/4289	17.88***	2.6	17.27***	5.64	0.35	1.45	0.09	2.17
Judolia sexmaculata	473/4289	3.75	2.01	7.62**	3.38	0.16	1.4	10.33***	1.93
Gaurotes virginea	620/4289	4.56*	2.03	11.56***	4.21	11.93***	1.44	9.4**	1.96
Callidium coriaceam	451/4289	0.1	1.79	0.38	2.54	5.84	1.31	2.54	1.85
Callidium aeneum	112/4289	1.2	2.11	0.02	3.98	0.06	1.51	1.11	2.15
Tetropium fuscum	112/4289	1.2	2.11	0.02	3.98	0.06	1.51	1.11	2.15
Obrium brunneum	30/693	0.02	13.63	0.43	133.44	14.89***	7.82	14.97***	8.75
Individual LHB of Oak group									
Pyrrhidium sanguineum	115/1660	28.05***	26.02	24.6***	203.21	13.11***	6	42.97***	9.9
Grammoptera ustulata	97/1660	18.88***	28.77	19.24***	249.97	7.56**	6.64	46.74***	12.67
Poecilium alni	50/1660	5.44*	16.32	6.07*	97.36	1.4	3.09	22***	5.56
Rhagium sycophanta	64/1660	6.07*	24.9	2.37	145.36	0.11	5.32	25.71***	10.85
Anoplodera sexguttata	85/1660	19.34***	22.52	8**	142.21	2.05	4.89	34.97***	8.27
Plagionotus arcuatus	321/1660	17.18***	7.97	11.57***	87.76	3.94*	3.66	14.16***	4.02
Xylotrechus antelope	47/662	1.55	11.91	3.09	98.96	4.97*	4.13	11.21***	6.38
Anaesthetis testacea	25/597	0.8	21.43	0.5	230.47	3.46	7.12	3.84*	12.25
Exocentrus adspersus	19/432	0.03	27	0.01	393	2.11	11	3.06	15.89

Continue Table 3

Species/Category	Present/ Total Sq.	Urban		Arable land		Pasture		Clearcut	
		ChiSq	VIF	Chisq	VIF	Chisq	VIF	Chisq	VIF
Deciduous beetles	1899/4289	1.23	1.37	16.7***	2.85	169.2***	2.04	54.9***	2.4
Conifer beetles	1983/4289	23.18***	1.34	5.37*	3.28	85.65***	2.09	21.4***	2.33
Spruce beetles	1533/4289	36.4***	1.39	2.6	3.82	47.09***	2.07	23.5***	2.43
Pine beetles	1310/4289	38.17***	1.41	2.98	4.13	78.7***	2.09	30.3***	2.47
Oak beetles	445/1660	40.18***	10.63	17.3***	57.04	21.53***	4.43	4.96*	6.26
Individual LHB species of Pine group									
Acanthocinus aedilis	541/4289	58.83***	1.45	12.8***	4.03	18.84***	1.74	20.4***	2.21
Arthopalus rusticus	530/4289	64.11***	1.56	29.2***	5.26	53.33***	1.69	16.9***	2.49
Asemum striatum	547/4289	39.93***	1.39	10.1***	3.37	17.73***	1.71	10.7***	2.22
Monochamus galloprovincialis	68/4289	12.69***	1.95	0.29	2.83	0.17	1.72	2.39	2.47
Nothorhina muricata	146/4289	8.91**	1.31	0.16	2.47	0.62	1.86	1.32	2.64
Pogonocherus decorates	170/4289	32.64***	2.27	5.49*	5.07	27.31***	1.8	1.02	2.47
Tragosoma depsarium	229/4289	0.95	1.21	7.62**	1.83	5.3*	1.86	14.2***	1.66
Spondylis buprestoides	448/1976	70.39***	5.61	37.4***	30.49	56.83***	3.54	2.26	4.47
Pedostrangalia pubescens	28/1113	0.39	1.67	0.12	8.02	0.05	3.4	1.47	9.6
Individual LHB species of Spruce group									
Tetropium castaneum	545/4289	73.35***	1.57	43.6***	5.42	42.52***	1.65	15.1***	2.37
Semanotus undatus	274/4289	7.3**	1.31	3.17	2.72	2.39	1.91	3.05	2.3
Pachyta lamed	207/4289	0	1.24	0.03	2.23	4.78	2.11	0.07	2.15
Molorchus minor	593/4289	65.68***	1.59	40.8***	5.51	22.54***	1.76	36.1***	2.43
Judolia sexmaculata	473/4289	54.51***	1.35	1.94	2.77	3.55	1.73	12.5***	2.27
Gaurotes virginea	620/4289	56.63***	1.42	7.09**	3.5	35.79***	1.71	40***	2.25
Callidium coriaceam	451/4289	3.83*	1.25	1.66	2.24	0.24	1.92	3.31	2.12
Callidium aeneum	112/4289	19.24***	1.81	1.55	3.49	1.16	1.75	3.52	2.38
Tetropium fuscum	112/4289	19.24***	1.81	1.55	3.49	1.16	1.75	3.52	2.38
Obrium brunneum	30/693	1.41	24.86	0.62	38	0.29	6.27	0.38	13.2
Individual LHB species of Oak group									
Pyrrhidium sanguineum	115/1660	33.24***	64.72	21.7***	127	19.52***	12.6	19.5***	14.9
Grammoptera ustulata	97/1660	32.48***	95.4	21***	207	18.46***	12	23***	21.3
Poecilium alni	50/1660	5.66*	12.71	4.72*	66	7.8**	6.88	7.31**	9.22
Rhagium sycophanta	64/1660	8.74**	58.63	4.67*	142	5.98*	12.9	6.67**	14.6
Anoplodera sexguttata	85/1660	9.78**	21.64	9.76**	131	6.3*	9.26	4.26*	11
Plagionotus arcuatus	321/1660	31.91***	15.72	14***	87	14.53***	5.45	3.24	7.09
Xylotrechus antelope	47/662	3.23	17.3	4.29*	87	0.69	3.82	17***	8.31
Anaesthetis testacea	25/597	1.26	36.4	1.3	128	0.01	6.13	7.25**	21
Exocentrus adspersus	19/432	0.25	41.59	0.11	111	0.46	7.37	5.72*	34

Continue Table 3

Species/Category	Key biotope small scale owner area		Key biotope large scale owner area		Wet land		Water source	
	Chisq	VIF	Chisq	VIF	Chisq	VIF	Chisq	VIF
Deciduous beetles	27.65***	1.08	1.5	1.13	6.03*	1.4	11.01***	2.88
Conifer beetles	43.06***	1.08	0.8	1.14	2.09	1.46	14.6***	2.84
Spruce beetles	17.8***	1.07	5.2*	1.18	6.58*	1.44	9.42**	3.3
Pine beetles	40.71***	1.07	0.67	1.17	7.78**	1.37	25.07***	3.71
Oak beetles	0.24	1.1	1.34	1.26	2.41	1.27	24.99***	55.47
Individual LHB of Pine group								
Acanthocinus aedilis	19.83***	1.05	2.05	1.12	2.34	1.26	7.5**	2.77
Arthopalus rusticus	51.65***	1.05	0	1.13	0.22	1.29	49.89***	4.75
Asemum striatum	11.86***	1.05	0.15	1.15	0.01	1.28	7.73**	2.37
Monochamus galloprovincialis	9.58**	1.06	1.01	1.22	0.22	1.21	2	2.54
Nothorhina muricata	9.34**	1.08	0.12	1.25	0.01	1.22	3.26	1.85
Pogonocherus decorates	16.9***	1.05	0.59	1.12	1.31	1.45	11.48***	4.86
Tragosoma depsarium	13.17***	1.05	0.25	1.14	4.06*	1.18	0.29	1.68
Spondylis buprestoides	5.66*	1.07	0.03	1.26	9.64**	1.15	46.8***	31.65
Pedostrangalia pubescens	0.25	1.2	0.79	1.21	1.49	1.55	1.73	115.68
Individual LHB of Spruce group								
Tetropium castaneum	22.15***	1.05	0.17	1.14	1.69	1.36	16.87***	3.45
Semanotus undatus	15.72***	1.07	0.01	1.14	1.65	1.26	0.86	1.8
Pachyta lamed	1.47	1.07	0.49	1.15	0.01	1.23	0.38	1.41
Molorchus minor	18.1***	1.05	0.73	1.17	0.4	1.36	31.35***	3.9
Judolia sexmaculata	14.6***	1.06	2.87	1.15	0.51	1.25	3.04	2.02
Gaurotes virginea	22.53***	1.05	6.96**	1.17	0.53	1.25	13.49***	2.83
Callidium coriaceam	12.7***	1.07	0.04	1.12	0.05	1.24	1.54	1.5
Callidium aeneum	9.16**	1.07	0.59	1.21	0.08	1.31	1.67	2.43
Tetropium fuscum	9.16**	1.07	0.59	1.21	0.08	1.31	1.67	2.43
Obrium brunneum	0.11	1.27	1.55	1.19	2.1	1.86	1.8	193.8
Individual LHB of Oak group								
Pyrrhidium sanguineum	0.11	1.1	14***	1.14	5.75*	1.68	27.81***	179.26
Grammoptera ustulata	0.27	1.1	6.82**	1.16	5.47*	1.8	28.64***	276.66
Poecilium alni	0.25	1.09	8.16**	1.14	2.9	1.68	6.96**	59.87
Rhagium sycophanta	2.5	1.13	3.68	1.16	2.08	1.72	7.56**	227.28
Anoplodera sexguttata	0.02	1.09	1.26	1.21	1.44	1.46	11.79***	142.85
Plagionotus arcuatus	2.6	1.12	15***	1.17	5.24*	1.39	13.78***	73.54
Xylotrechus antelope	5.87*	1.13	0.69	1.31	0.32	1.6	1.75	13.33
Anaesthetis testacea	0.02	1.16	1.73	1.26	1.17	1.95	1.58	215.96
Exocentrus adspersus	0.81	1.36	2.49	1.29	0.17	1.93	0.25	521.24

*, ** and *** indicates significant at P <0.05, P<0.01 and P < 0.001level respectively; VIF- Variance inflation factor

3.2.2.3 Influence of landscape data on occurrence of individual LHBs of spruce group

The individual regression analysis revealed that area of expected breeding habitat had no or very little predictive power for the distribution of most of the spruce breeding species except *Callidium coriacea*, whereas mixed forest showed a positive significant relationship for the occurrence of *Obrium brunneum*. In contrast, general structure viz., Arable land, Pasture land yielded consistently high statistical power in predicting the presence of most of the spruce breeding individual LHBs (Table 2, Figure 9b). Whilst clearcut area showed less predictive power for most of the spruce breeding LHBs considered in this study except *Gaurotes virginea* and *Callidium coriaceam* species, clearcut area showed a positive significant relationship.

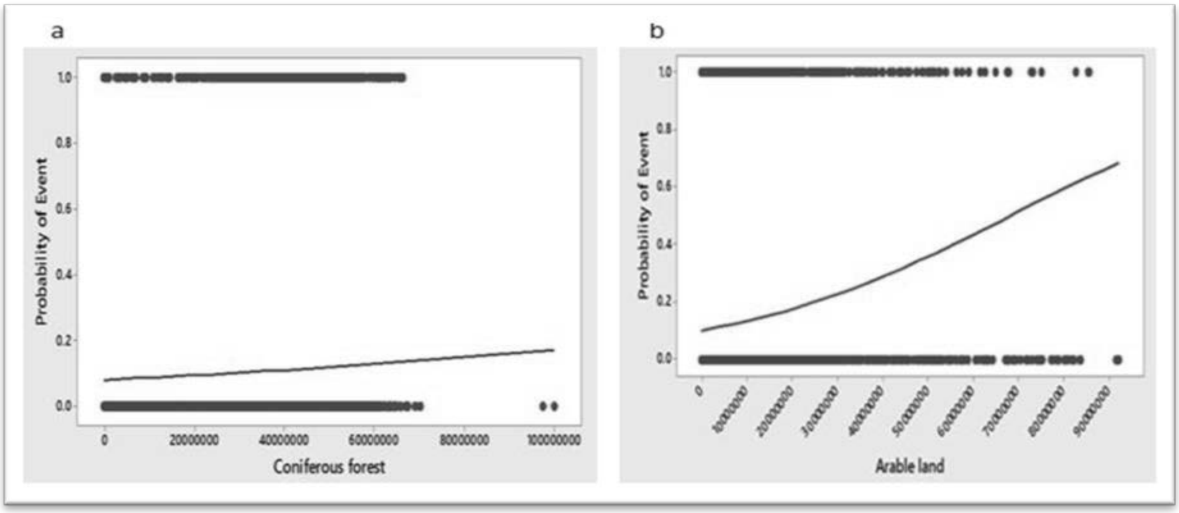

Figure 9. Binary fitted line plots of spruce forest beetles; *Callidium coriaceam* and *Tetropium castaneum* within the areas (m^2) of different land use classes of (a) coniferous forest and (b) arable land respectively. Here probability of event 0 indicates absence and 1 indicates presence of spruce habitat preferring respective LHBs

None of the spruce breeding species appeared to exhibit a strong threshold limit of expected breeding habitat type for their presence (*Callidium coriaceam* as the most pronounced example of a marginal threshold effect (Figure 9a))

On the other hand, in the combined model, it was observed that the different forest area considered in the study did not qualify as a good predictor for most of the individuals included in the LHB of spruce group. However, coniferous forest area showed significant relationship with *Tetropium castaneum, Molorchus minor and Gaurotes virginea;* though it's VIF value was higher as 5.92, 5.64 and 4.2 respectively for the species. On the other hand, mixed and young forest areas were observed to have predictive power for the occurrence of *Obrium brunneum* with high VIF values 7.82 & 8.75 respectively (Table 3). Whilst among the landscape variables Urban area presumed to have predictive power in regarding the distribution of almost all of the spruce breeding individuals (Table 4) with lower collinearity.

3.2.2.4 Influence of landscape data on occurrence of individual LHBs of oak group

Within the collective of oak breeding LHBs, the individual species exhibited very mixed and heterogeneous responses to different landscape variables, ranging from strongly negative to strongly positive effects. The individual regression analysis revealed that area of nominal habitat; deciduous forest presumed to have some predictive power for the distribution of most of the individuals of oak breeding LHBs: *Pyrrhidium sanguineum, Grammoptera ustulata, Poecilium alni, Rhagium sycophanta Anoplodera sexguttata Plagionotus arcuatus* etc. Note, however, that some predictions, although statistically significant, do not appear to provide a strong relation to the expected breeding habitat when the distribution of observations is visualized (Figure 10a). Also, coniferous forest as a predictor revealed significant relationship at $p<0.001$ level of significance in regarding the distribution of *Xylotrechus antelope* (Table 2) and this particular oak breeding species followed a strong threshold effect of coniferous forest for its distribution (distribution of individual presence and absence in the binary fitted line shown at Figure 10b). In contrast, other landscape variables were represented as no consistent influence regarding the distribution of most of the oak breeding individual species, although some variables had strong positive or negative effects in some cases. Pasture land showed positive significant relationship for the distribution of some oak breeding individuals and negative for others and clearcut area represented to have a good predictive power in regarding the distribution of some red listed species: *Xylotrechus antelope, Anaesthetis testacea* and *Exocentrus adspersus*, but negative for others.

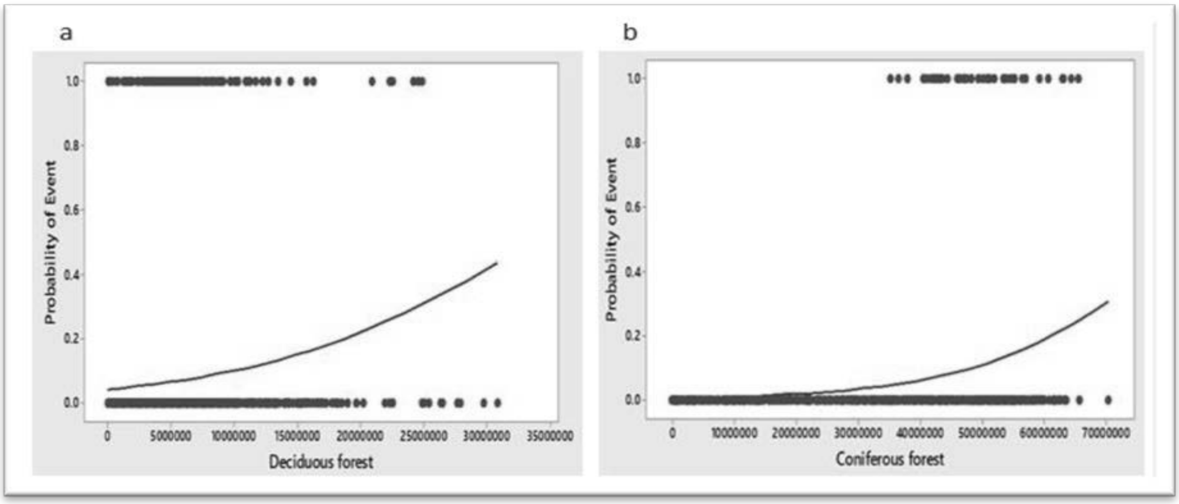

Figure 10. Binary fitted line plots of oak forest beetles within the areas (m^2) of different forest area where binary fitted line plot represents (a) *Pyrrhidium sanguineum* in deciduous forest and (b) *Xylotrechus antelope* in coniferous forest respectively. Here probability of event 0 indicates absence and 1 indicates presence of oak habitat preferring respective LHBs

When all the variables were studied together, all of the landscape predictors considered in the study recorded higher multicollinearity in regard of the distribution of individual oak breeding LHBs. Both general structural such as arable land and pasture land and area of nominal habitat types emerged to have strong predictive capabilities regarding the distribution of most of the individuals considered within oak group (Table 3). The only exception for those species which are found in a certain areas: *Xylotrechus antelope, Anaesthetis testacea* and *Exocentrus adspersus* had no strong influence of occurrence within different landscape area like Urban, Arable land, Pasture land as well as different nominal habitat type, deciduous forest, coniferous forest, etc. Water sources confined as good predictive capability for the occurrence of *Pyrrhidium sanguineum, Grammoptera ustulata*, etc. but recorded high VIF values.

3.2.3 Influence of KNN forest data

3.2.3.1 Influence of KNN forest data on occurrence of LHB group

In general, the volumes of different habitat type represented by standing volume of different tree species obtained from KNN forest data, had a strong predictive power than nominal habitat area regarding the distribution of LHBs. Most of the LHBs, defined according to their habitat preferences, yielded significant positive relationship at $p<0.001$ level of significance (Table 4) with all of the volume of their nominal habitat types when KNN forest data were studied individually. However, in many cases forest tree variables other than the nominal type also yielded strong relationships. Among the volume of different habitat, volume of deciduous habitat revealed to have the strongest predictive power regarding the distribution of most LHB groups. The only exception to this general pattern is represented by the oak breeding LHBs which had a strong significant relationship with only the volume of oak habitat substrate, and a non-significant relationship with deciduous volume.

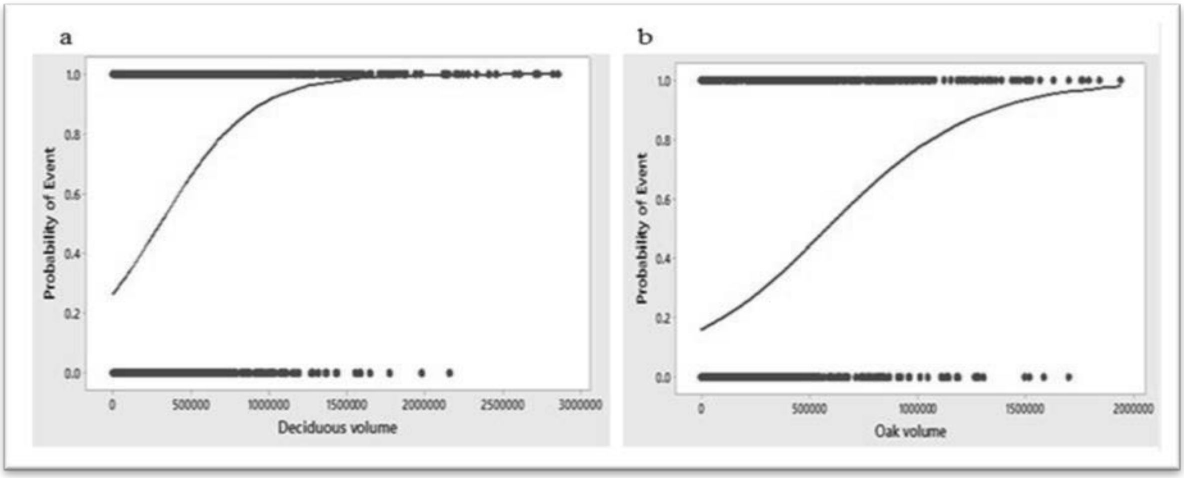

Figure11. Binary fitted line plots of deciduous and oak beetles within the volume (m^3) of different habitat where binary fitted line plot represents deciduous forest beetles in (a) volume of deciduous habitat, and oak forest beetles in (b) volume of oak habitat. Here probability of event 0 indicates absence and 1 indicates presence of respective LHB.

No group of LHBs revealed strong threshold effects of volume of different habitat substrate in regarding their distribution (See distribution of individual presences and absences in the binary fitted line plot representing at Figure 11).

3.2.3.2 Influence of KNN forest data on occurrence of individual LHBs of pine group

The individual regression analysis carried out between the 9 pine breeding individual species with volume of substrate in different habitats considered: pine volume, spruce volume, deciduous volume and conifer volume as predictor variables; revealed that all of the individuals considered in this group except *Spondylis buprestoides* species, demonstrated strong significant relationships at $p<0.001$ level of significance with pine and conifer habitat volume as predictors (Table 4). Therefore it may be presumed that volume of pine and conifer habitat substrates had strong predictive power regarding the distribution of pine breeding individuals. Some species also displayed strong effects from spruce and deciduous forest volume.

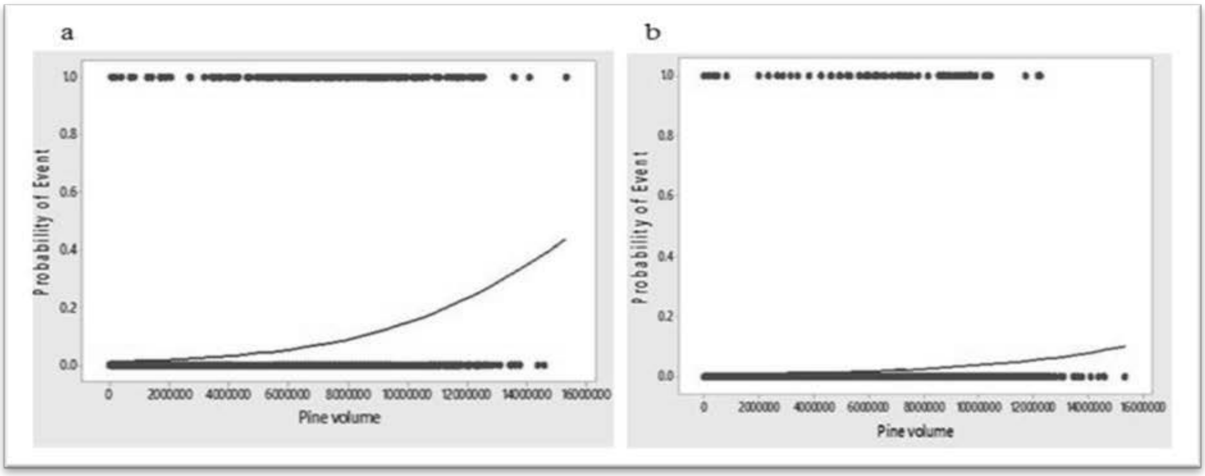

Figure 12. Binary fitted line plots of pine beetles; *Tragosoma depsarium* (a) and *Monochamus galloprovincialis* (b) within the volume (m^3) of pine habitat. Here probability of event 0 indicates absence and 1 indicates presence of pine habitat preferring LHBs

Some of the pine breeding individuals: *Tragosoma depsarium, Monochamus galloprovincialis,* etc. appeared to exhibit some threshold effect of pine habitat volume for their presence (distribution of individual presences and absences in the binary fitted line plot representing at Figure 12).

Table 4. Logistic Binary Regression Individual Model of LHB species/categories with Standing Volume of Different Tree Species

Species/Category	Oak volume	Pine volume	Spruce volume	Deciduous volume	Conifer volume
Chi-square					
Deciduous beetles		146.57***	264.24***	802.71***	306.08***
Conifer beetles		42.29***	94.03***	306.81***	99.65***
Spruce beetles		56.11***	108.07***	208.69***	122.17***
Pine beetles		93.23***	59.78***	161***	111.46***
Oak beetles	249.68***	-21.24***	-2.05	--1.98	-5.21*
Individual LHB species of Pine group					
Tragosoma depsarium		149.98***	4.59*	3.23	70.83***
Acanthocinus aedilis		51.84***	64.07***	33.15***	89.07***
Arthopalus rusticus		30.75***	31.78***	53.92***	47.35***
Asemum striatum		36.79***	32.39***	50.22***	52.05***
Monochamus galloprovincialis		25***	6.82**	2.65	21.34***
Nothorhina muricata		23.76***	-0.27	-3.78	6.01*
Pogonocherus decorates		11.29***	2.4	10.12***	8.58**
Spondylis buprestoides		-3.16	0.31	5.84*	-3.36
Pedostrangalia pubescens		23.9***	-0.22	0	5.48*
Individual LHB species of Spruce group					
Tetropium castaneum		7.44**	76.26***	99.27***	54.13***
Semanotus undatus		55.5***	6*	-0.46	34.43***
Pachyta lamed		19.09***	0.15	-7.16**	7.53**
Molorchus minor		15.7***	61.71***	96.34***	55.66***
Judolia sexmaculata		15.88***	45.88***	21.96***	45.73***
Gaurotes virginea		37.43***	170.46***	72.13***	150.21***
Callidium coriaceam		68.33***	12.14***	-1.17	49.1***
Callidium aeneum		5.31*	15.27***	6.34*	15.45***
Tetropium fuscum		5.31*	15.27***	6.34*	15.45***
Obrium brunneum		1.84	2.27	4.44*	3.08
Individual LHB species of Oak group					
Pyrrhidium sanguineum	130.51***	5.56*	1.06	0.34	-0.13
Grammoptera ustulata	63.17***	-0.03	-0.65	0.06	-0.24
Poecilium alni	49.37***	0.16	0.33	3.78	0.49
Rhagium sycophanta	72.49***	-36.99***	-18.84***	-22.2***	-32.07***
Anoplodera sexguttata	116.52***	-17.56***	0.04	-0.15	-3.03
Plagionotus arcuatus	120.68***	-23.98***	-0.33	-2.07	-6.75**
Strangalia attenuate	55.14***	13.11***	15.82***	23.53***	22.79***
Xylotrechus antelope	14.6***	71.68***	5.1*	57.38***	41.87***
Anaesthetis testacea	7.89**	8.27**	0.27	3.72	3.48
Exocentrus adspersus	8.17**	10.23***	0.16	3.45	2.9

*, ** and *** indicates significant at P <0.05, P<0.01 and P < 0.001level respectively

3.2.3.3 Influence of KNN forest data on occurrence of individual LHBs of spruce group

The individual regression analysis carried out between the 10 individuals of spruce group with volume of substrates in different habitats considered: pine volume, spruce volume, deciduous volume and conifer volume as predictor variables; revealed that all of the individuals showed significant positive relationship with volume of spruce habitat substrate and volume of conifer habitat substrate as well. Volume of spruce habitat substrate represented to have the highest predictive power for the distribution of *Gaurotes virginea* among the spruce breeding individuals as it generated highest chi- square value of 170.46 at p<0.001 level of significance. However, some species displayed equally strong or stronger relations to deciduous volume or pine volume. *Tetropium castaneum* showed the highest positive result with volume of deciduous habitat substrates followed by spruce and conifer volume at p<0.001 level of significant (Table 4).

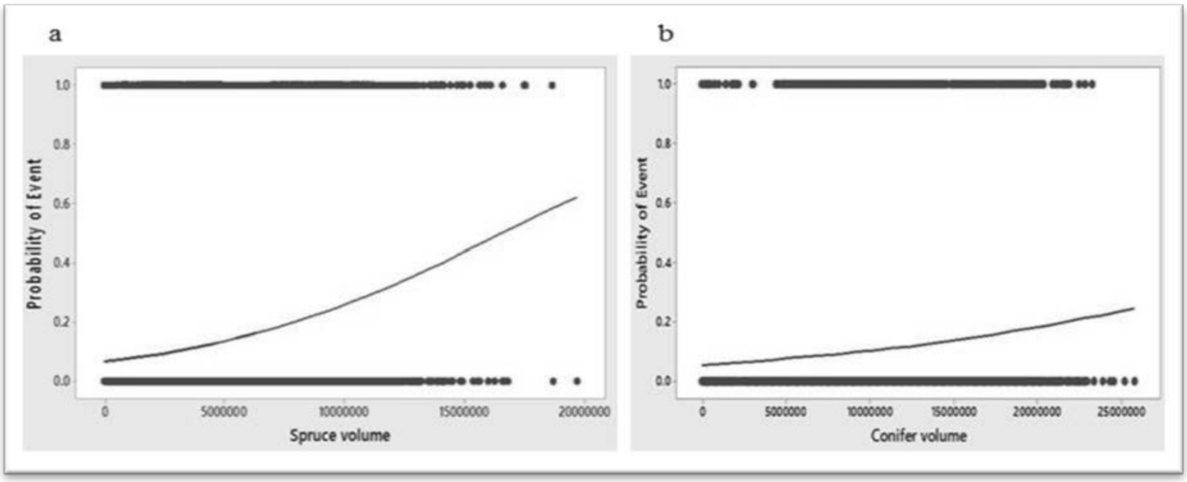

Figure13. Binary fitted line plots of individual spruce beetles, *Gaurotes virginea* and *Callidium coriaceam* within the volume (m^3) of spruce and conifer habitat respectively. Here probability of event 0 indicates absence and 1 indicates presence of respective LHBs.

Callidium coriaceam which had strong positive relationships with its own breeding substrate, spruce volume as well as other conifer species and followed a threshold level of volume of conifer habitat substrate (distribution of individual presences and absences in the binary fitted line plot representing at Figure 13) for its distribution.

3.2.3.4 Influence of KNN forest data on occurrence of individual LHBs of oak group

The individual regression analysis carried out between the 10 individuals of oak group with volume of substrates in different habitats considered: oak volume, pine volume, spruce volume, deciduous volume and conifer volume as predictor variables; revealed that all individual species demonstrated higher chi-square values (130.51, 120.68, 116.52, etc.) at p<0.001 level of significance with oak habitat volume as a predictor (Table 4). Therefore, it may be considered that volume of oak habitat substrate had strong predictive power for the distribution of oak breeding beetles. However, for the occurrence of some oak breeding individuals': *Strangalia attenuate, Xylotrechus antelope* all of the habitat substrate volume showed positive significant relations.

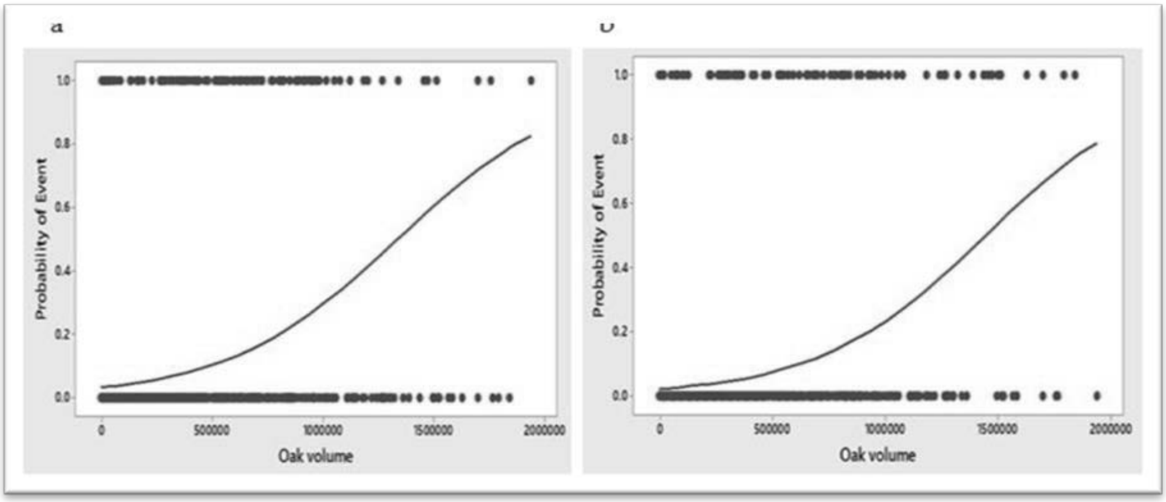

Figure 14. Binary fitted line plots of individual oak beetles; *Pyrrhidium sanguineum* (a) and *Anoplodera sexguttata* (b) within the volume (m^3) of oak habitat Here probability of event 0 indicates absence and 1 indicates presence of oak preferring respective LHB.

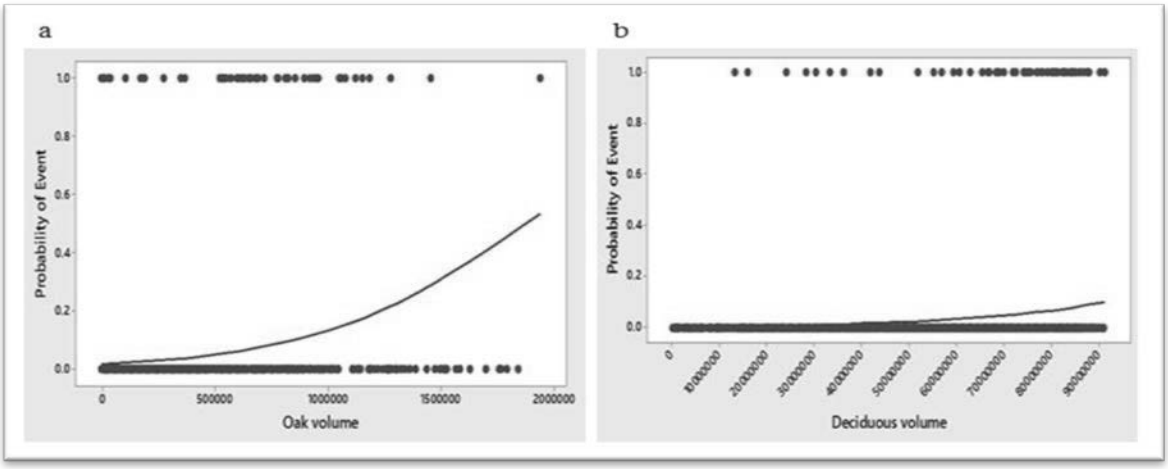

Figure 15. Binary fitted line plots of individual oak beetles; *Strangalia attenuate* within the volume (m^3) of oak habitat (a) and deciduous habitat (b). Here probability of event 0 indicates absence and 1 indicates presence of oak preferring respective LHB.

Some of the individuals of oak breeding LHBs exhibited threshold effects of volume of oak and deciduous habitat substrates. *Pyrrhidium sanguineum* (Figure 14a) *Anoplodera sexguttata* (Figure 14b) and *Strangalia attenuate* (Figure 15a) revealed a threshold level of volume of oak habitat substrate for their presence. Whilst, *Strangalia attenuate* (Figure 15b) demonstrates a threshold level of volume of deciduous habitat substrate.

3.2.4 Influence of Key biotopes

Key biotopes in small scale owner areas are concentrated in southern Sweden while the key biotopes in large scale owner areas are mostly concentrated in northern Sweden. The detailed outputs of the geospatial analysis carried out in Arc GIS are provided in Appendix.

3.2.4.1 Influence of Key biotopes on occurrence of LHB group

Overall, key biotope in small scale owner area, represented to have a strong predictive power regarding the distribution of most of the LHB groups, as it generated higher chi square values with the occurrence of LHBs when key biotope areas were studied individually (Table 5). However, key biotope large scale owner area revealed negative significant relationship for the occurrence of most of the LHBs. The only exception to this trend is demonstrated by LHBs breeding in conifer habitat, which generated a significant negative relation with key biotope small scale owner area and in contrast it yielded a significant positive relationship with large scale owner biotope area.

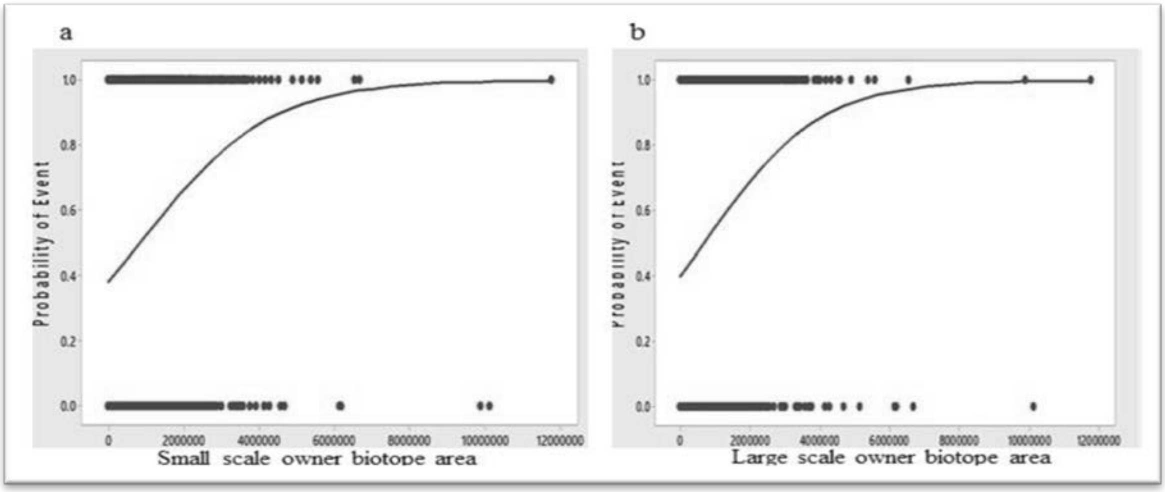

Figure 16. Binary fitted line plots of individual deciduous beetles and conifer beetles within the area (m^2) of small scale owner biotope area (a) and large scale owner biotope area (b) respectively. Here probability of event 0 indicates absence and 1 indicates presence respective LHBs.

No group of LHBs exhibited a threshold effect for their presence within the area of potential key biotopes (distribution of individual presences and absences in the binary fitted line plot representing at Figure 16).

Results from the combined model where variables were taken together contrasted quite strongly with the results from the individual variables in case of distribution of conifer breeding beetles. Key biotope small scale owner area flagged a positive significant relationship with the occurrence of conifer breeding LHBs (Table 3). However, key biotope large scale owner area generated no or little predictive power regarding the distribution of LHBs which is almost against the individual regression model.

Table 5. Logistic Binary Regression Individual Model of LHB species/categories with Key biotope area

Species/Category	Key biotope small scale owner area	Key biotope large scale owner area	Key biotope combined area
Chi-square			
Deciduous beetles	138.57***	-54.67***	-5.59**
Conifer beetles	- 146.52***	37.79***	-1.91
Spruce beetles	70.18***	-36.24***	-4.68*
Pine beetles	124.17***	-41.35***	-1.58
Oak beetles	3.09	-20.88***	-0.84
Individual LHB species of Pine group			
Tragosoma depsarium	18.33***	1.26	6.24*
Acanthocinus aedilis	54.76***	-3.69	1.49
Arthopalus rusticus	114.4***	-36.11***	0.01
Asemum striatum	36.51***	-9.65**	-0.02
Monochamus galloprovincialis	15.15***	-3.58	0.24
Nothorhina muricata	11.21***	-1.02	0.28
Pogonocherus decorates	32.75***	-1.82	1.72
Spondylis buprestoides	11.23***	-31.36***	-0.57
Pedostrangalia pubescens	0.1	4.88*	1.22
Individual LHB species of Spruce group			
Tetropium castaneum	65.18***	-30.67***	-0.69
Semanotus undatus	19.33***	-0.29	1.48
Pachyta lamed	0.5	0.14	0.37
Molorchus minor	60.34***	-28.86***	-0.89
Judolia sexmaculata	35.76***	-16.99***	-0.59
Gaurotes virginea	68.03***	-46.35***	-2.74
Callidium coriaceam	15.42***	0.18	3.1
Callidium aeneum	15.14***	-3.7	0.08
Tetropium fuscum	15.14***	-3.7	0.08
Obrium brunneum	2.46	4.98*	3.81
Individual LHB species of Oak group			
Pyrrhidium sanguineum	2.11	-25.08***	0.66
Grammoptera ustulata	1.86	-15.09***	-0.26
Poecilium alni	0.23	-8.31**	-0.77
Rhagium sycophanta	8.28**	-16.44***	1.38
Anoplodera sexguttata	2.54	-9.1**	0
Plagionotus arcuatus	11.42***	-61.12***	-0.24
Strangalia attenuate	8.85**	-3.08	3.74
Xylotrechus antelope	-3.15	8.27**	-1.06
Anaesthetis testacea	0.23	8.39**	1.17
Exocentrus adspersus	2.71	7.87**	4.64*

*, ** and *** indicates significant at P <0.05, P<0.01 and P < 0.001level respectively

3.2.4.2 Influence of Key biotopes on occurrence of individual LHBs of pine group

All of the individual breeding pine beetles considered for this study generated significant positive relationship at p<0.001 level of significance as they yielded higher chi square values such as *Arthopalus rusticus* (114.4), *Acanthocinus aedilis* (54.76), *Asemum striatum* (36.51) etc with key biotope small scale owner area, saving *Pedostrangalia pubescens* which recorded only a chi square value of 4.88 at p<0.05 level of significance with key biotope large scale owner area (Table 5). Therefore it may be presumed that key biotope small scale owner areas had strong predictive power regarding the distribution of most of the pine breeding LHBs. However, combined key biotope area only has significant but weak relationsip with the distribution of *Tragosoma depsarium*.

However, the combined regression model generated quite similar results of individual variables. Key biotope area of small scale owner showed a high predictive power regarding the distribution for the pine breeding individuals except *Pedostrangalia pubescens* (Table 3) with lower VIF values.

3.2.4.3 Influence of Key biotopes on occurrence of individual LHBs of spruce group

Most of the individual spruce breeding beetles considered in this study generated significant relationship at $p<0.001$ level of significance as it yielded higher chi square values such as *Gaurotes virginea* (68.03), *Tetropium castaneum* (65.18), *Semanotus undatus* (19.33) for the regression models fitted with key biotope small scale owner area as a predictor variable, except *Pachyta lamed. Obrium brunneum* which recorded only a chi square value of 4.98 at $p<0.05$ level of significance with key biotope large scale owner area (Table 5). Therefore it may be presumed that key biotope small scale owner areas may be the key potential area for most of the spruce breeding beetles and their relations can satisfactorily explain their predictive power regarding the distribution of spruce breeding LHBs.

In the combined regression model where all the landscape variables and key biotope areas were tested together, they yielded similar results to the individual variables. Only one exception is key biotopes large scale owner area showed a significant but weak relationship regarding the distribution of spruce breeding LHB, *Gaurotes virginea* (Table 3).

3.2.4.4 Influence of Key biotopes on occurrence of individual LHBs of oak group

The individual regression analysis revealed that key biotope of small scale owner area yielded a significant but weak relationship for the occurrence of the individual oak breeding LHBs: *Plagionotus arcuatus*, *Strangalia attenuate*, *Rhagium sycophanta* etc (Table 5). In contrast key biotope of large scale owner area revealed negative relationship for the occurrence of most of the oak breeding beetles. The only exception of the general trend of those oak breeding species which were found only in certain areas: *Xylotrechus antelope, Anaesthetis testacea* and *Exocentrus adspersus* showed a positive relationship with key biotopes of large scale owner area.

The combined regression model generated contrasting results with the individual variables. Here key biotope large scale owner area was revealed to have predictive power for the distribution of oak breeding LHBs: *Pyrrhidium sanguineum, Grammoptera ustulata, Poecilium alni, Plagionotus arcuatus,* etc. with lower collinearity. However, key biotope small scale owner area yielded a significant but weak relationship regarding the distribution of *Xylotrechus antelope*.

3.3 Landscape level analysis of the distribution pattern of LHB

As revealed by the analysis of binary logistic regression model and the binary fitted line plot area for the individual / group species considered in the study, it can be seen that both individuals as well as groups of LHB recorded very high chi-square value at different p levels with different land use classes, volume of different habitat substrates and with key habitat area and some of the fitted lines showed very good predictors for the occurrence of LHB. In order to find out the distribution pattern in relation with different land cover classes and habitat types, each individual relation were visualized in histogram. Some of the results (histograms) are presented in the figures given below;

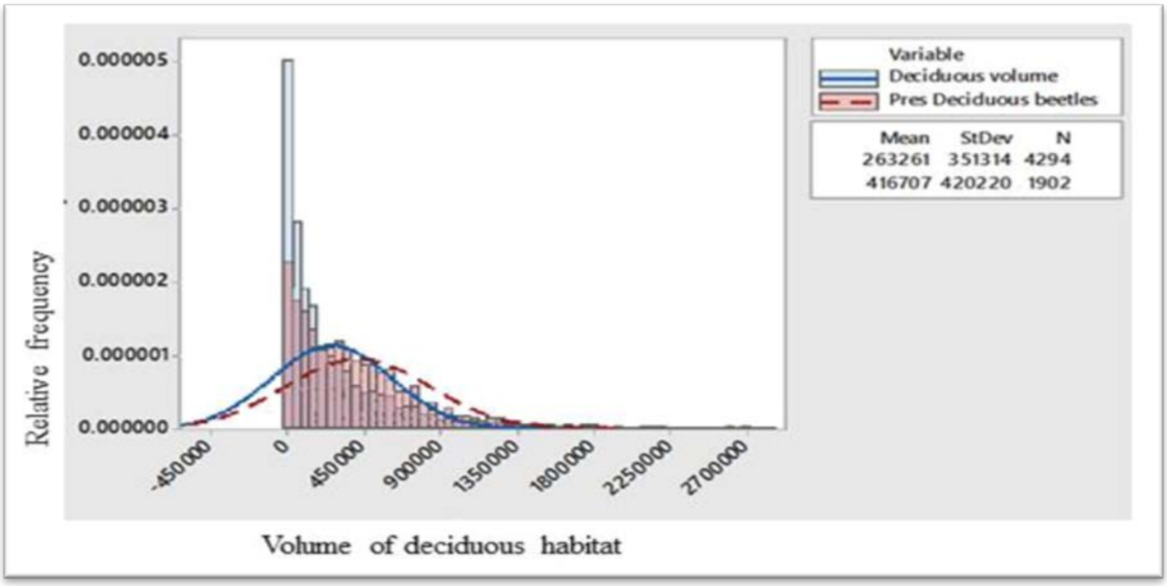

Figure 17. Distribution patterns of deciduous forest beetles and deciduous habitat volume (m^3)

As could be noted from histogram at Figure 17, it is observable that with the increasing volume of deciduous habitat, the frequency of occurrence of deciduous forest beetles increased and vice versa. The volume of deciduous habitat and beetles' mean distribution recorded peak values at around 450000 m^3 (volume of deciduous habitat). Therefore it may be observed that the relationship between volume of deciduous habitat and deciduous beetle distribution stands significant.

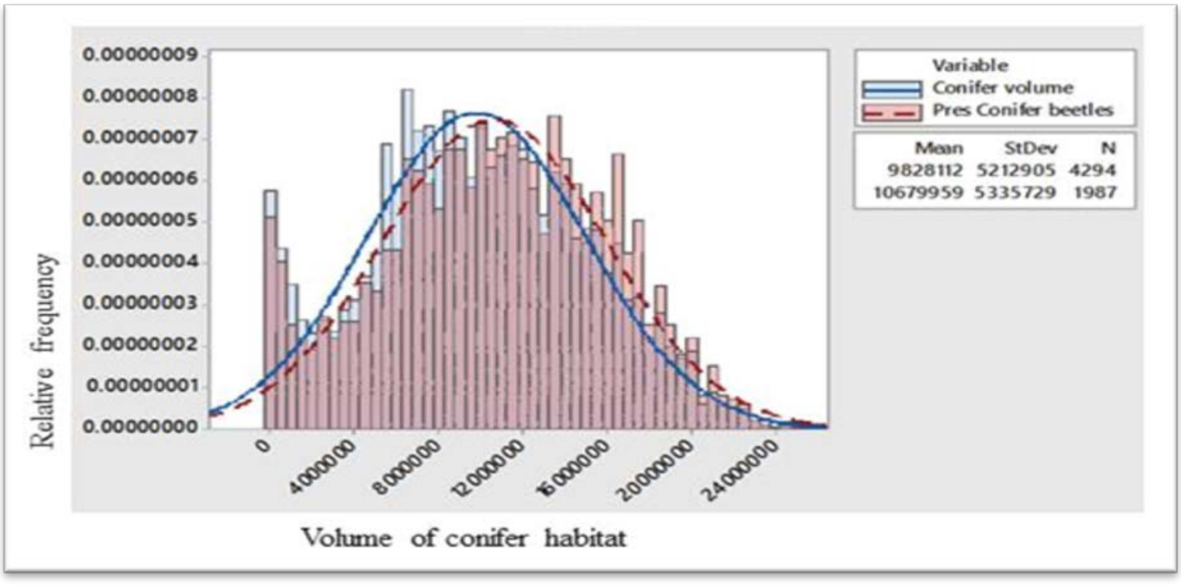

Figure 18. Distribution patterns of conifer forest beetles and volume (m^3) of conifer habitat

The analysis revealed that there is a significant relationship between volume of conifer habitat and conifer forest beetle distribution. Therefore it may be inferred that the frequency of occurrence of conifer beetle increases with increasing volume of conifer habitat and vice versa. It was also observed that both conifer habitat volume and conifer forest beetles' distribution peak was highest near around 12000000 m^3.

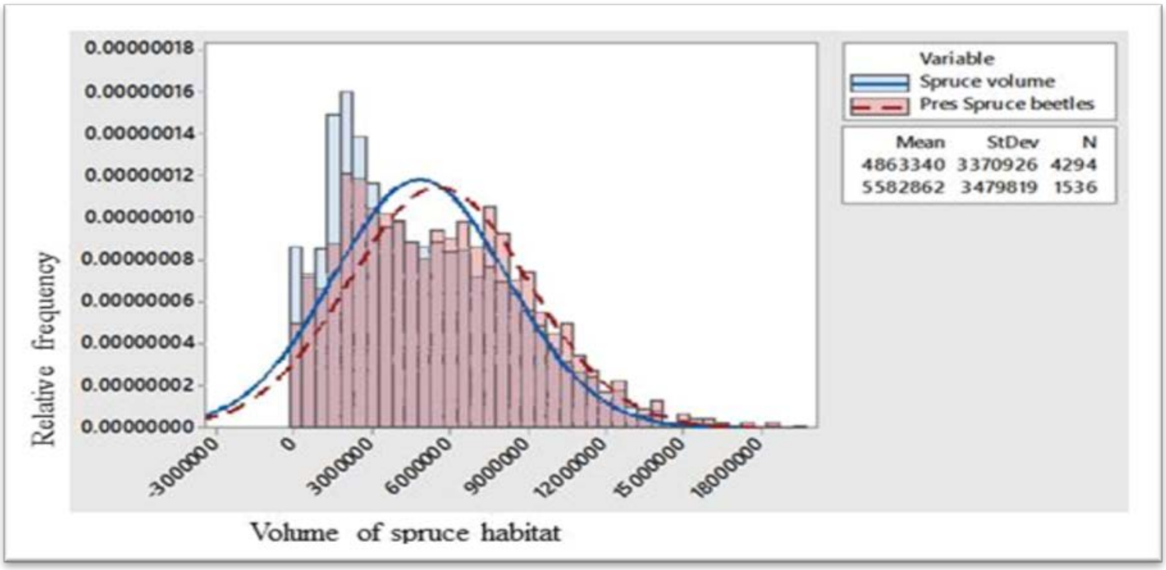

Figure 19. Distribution patterns of spruce beetles and volume (m^3) of spruce habitat

On a similar line of observations related to conifer volume; spruce volume also showed significant relationship with distribution of conifer forest beetles observed from Figure 19, it is clear that when the volume of spruce habitat has increased and vice versa. Both volume of spruce habitat and spruce beetles' distribution peak were observed to be highest around 6000000 m^3.

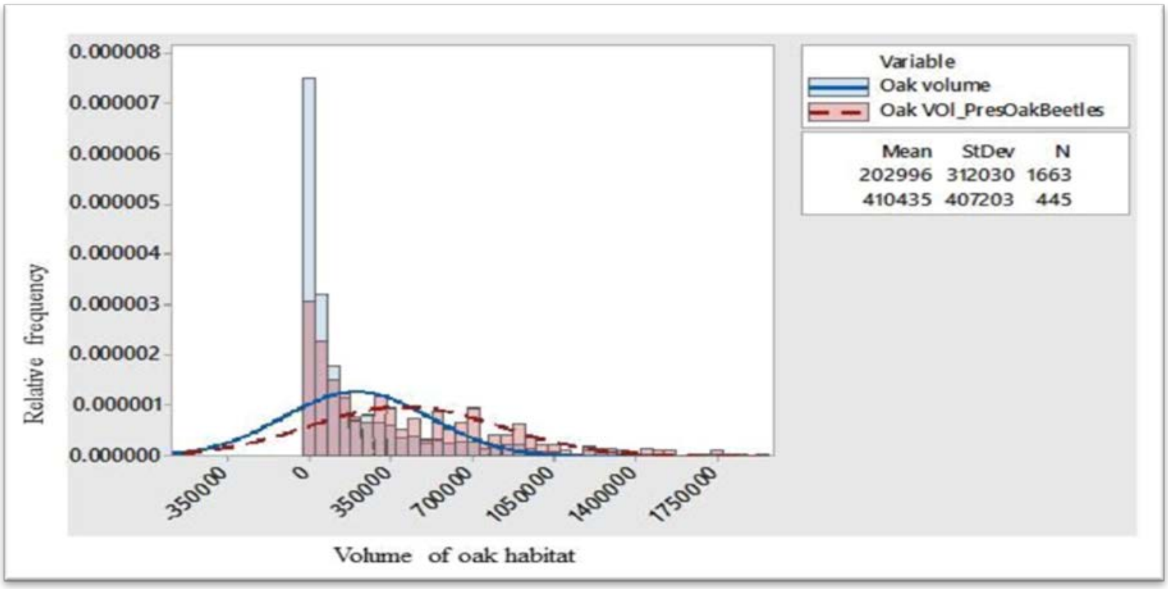

Figure 20. Distribution patterns of oak forest beetles and volume (m^3) of oak habitat

The analysis revealed that with the increasing of volume of oak habitat, the frequency of occurrence of oak forest beetles increases and vice versa. Therefore, we may infer that the relationship between volume of oak habitat and oak forest beetle distribution was significant as the chi square value recorded was higher at $P<0.001$ level of significance (Table 4).

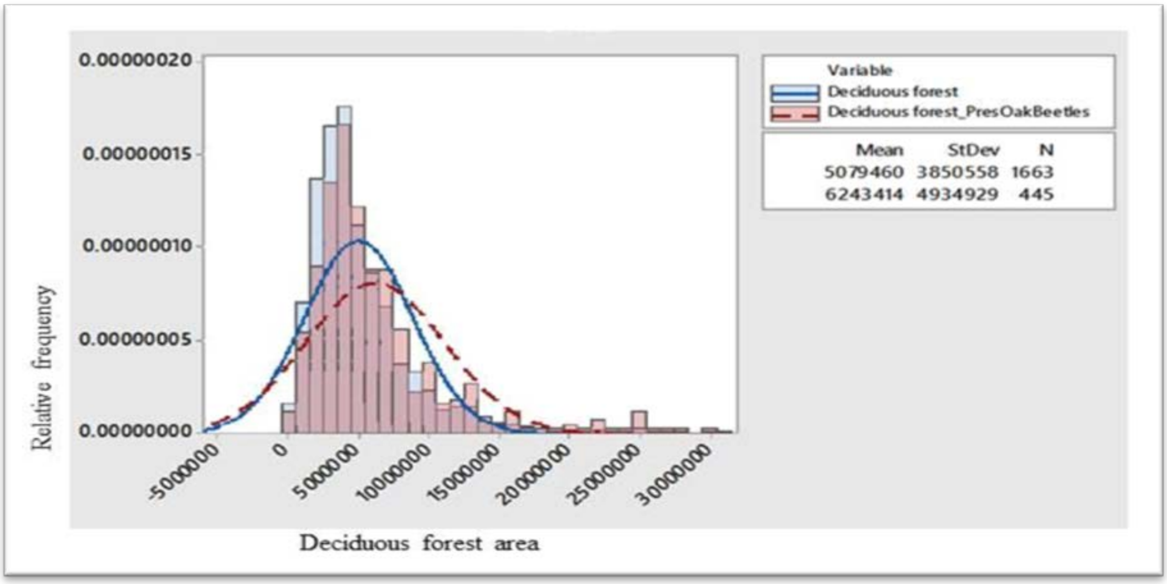

Figure 21. Distribution pattern of oak forest beetles within the deciduous forest landscape area (m^2)

As could be seen from Figure10a; we may infer that the area of deciduous forest as a parameter can qualify as a good predictor for the occurrence of oak forest beetles. The figure also shows a significant relationship with deciduous forest area and oak forest beetle distribution. It is also obvious from the figure that when the deciduous forest area increased, the frequency of occurrence of oak beetle also increased and vice versa.

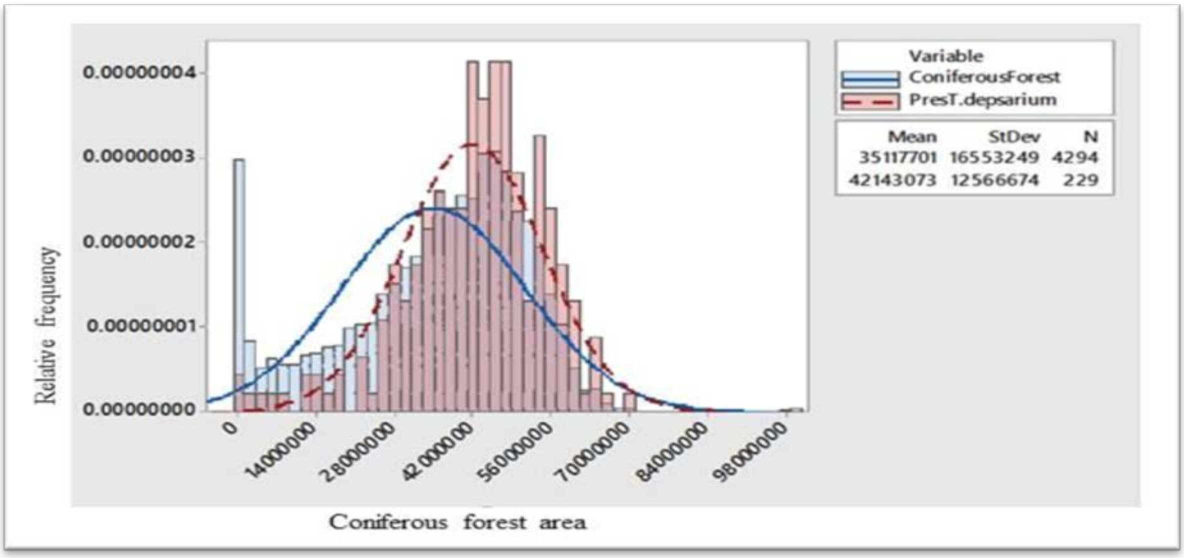

Figure 22. Distribution patterns of *Tragosoma depsarium* and coniferous forest landscape area (m^2)

However it is also observed that areas of coniferous forest as a parameter represent a good predictor for the occurrence of *Tragosoma depsarium* (Figure 11a). *Tragosoma depsarium* was observed to be influenced by a threshold limit of coniferous forest area and the distribution of the species was observed to be affected by sub threshold level. As could be seen from the histogram at Figure 22, that this particular pine species was found following a threshold value near to 30 million m^2 of coniferous forest area and after that it showed an increasing tendency for occurrence with increase in the area of coniferous forest for the species of *Tragosoma depsarium* and vice versa. Therefore it may be inferred that there is a significant relationship between coniferous forest area and distribution of this particular species as they revealed a high chi square value at $p<0.001$ level of significance.

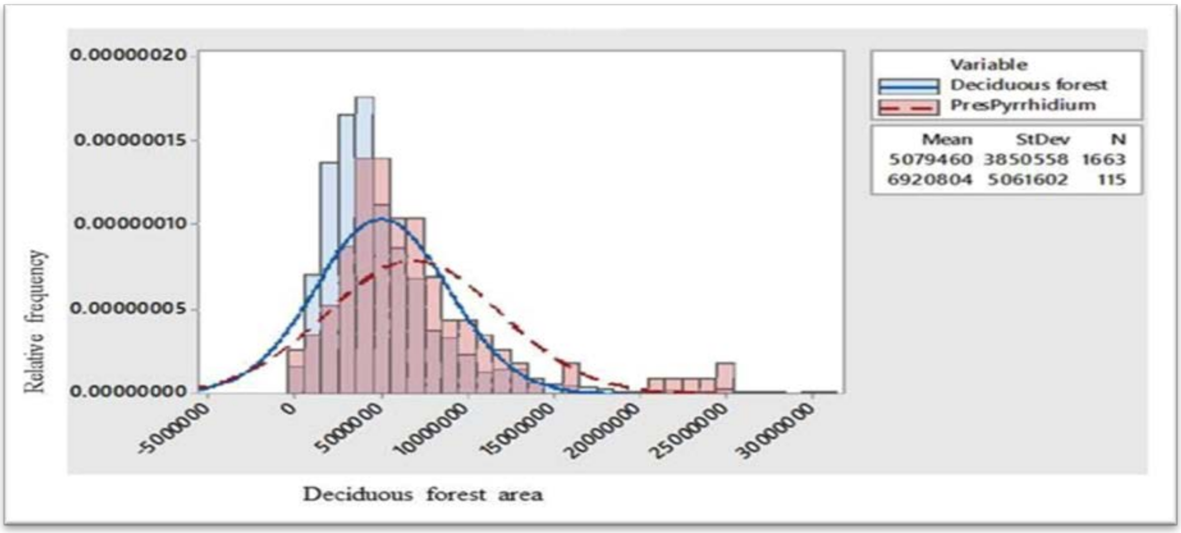

Figure 23. Distribution patterns of *Pyrrhidium sanguineum* and deciduous forest area (m^2)

The figure flagged a significant relationship with deciduous forest area and *Pyrrhidium sanguineum* distribution that supported the result in Table 2. It may also reveal that with the increasing deciduous forest area, the frequency of occurrence of this beetles increased and the increasing rate of frequency of this beetles is more compare to deciduous forest area increased. The probable reason may be attributable to deciduous forest as habitat substrate is preferable for these particular oak beetles.

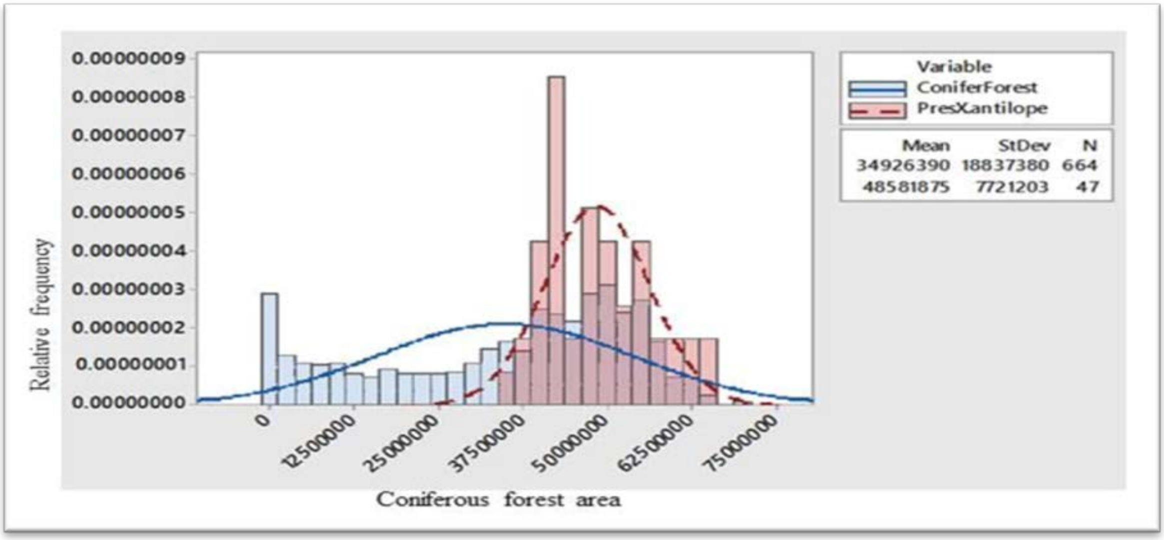

Figure 24. Distribution patterns of *Xylotrechus antilope* and coniferous forest area (m^2)

It is revealed from the Figure 24 that coniferous forest area has significant relationship with the occurrence of *Xylotrechus antelope* which is supported the binary logistic regression as well (Table 2). This particular oak breeding species followed an approximate threshold limit 37500000 m^2 of coniferous forest for their occurrence and below that limit it was found totally absent. After the threshold limit with the increasing of the area of coniferous forest frequency of occurrence of this LHB also increased and vice versa.

4 DISCUSSION

4.1 Influence of land use classes on occurrence of LHBs

The analysis of the observations of different beetles groups considered in the study revealed that in most of the cases, general structure of landscape area, Arable land and Pasture land showed positive significant relationship at $p<0.001$ level of significance when variables were studied individually. Whereas in the combined logistic regression model, Urban area and Pasture land yielded high chi square values at lower VIF. Arable land emerged to have high predictive power for the occurrence of deciduous beetles and oak beetles in combined model. The probable reasons for the same may be ascribed to the availability of different types of ground covers and element available in Urban area, Arable land and Pasture land or may be frequency of observations by the observers were relatively higher within these structures. Similar results were also reported by Laura *et al*. (2010) on staphylinids highlighting that regional richness of staphylinids in the landscape depended on vegetation cover and characteristics of landscape elements like fragment size, shape of the perimeter, isolation and type of edge etc.

Different expected breeding habitat types like deciduous forest, coniferous forest, mixed forest, young forest, etc. showed either low or negative chi square values for the occurrence of different forest LHBs groups such as deciduous breeding beetles, conifer breeding beetles, pine breeding beetles, spruce breeding beetles and oak breeding beetles in individual models. Therefore it may be assumed that nominal habitat types had less predictive power in regarded of the distribution of deciduous breeding beetles, coniferous breeding beetles, pine breeding beetles and spruce breeding beetles compare to general structures. The probable reasons for such a pattern of occurrence may be production forests may not provide sufficient habitat resources for occurrence and life cycle completion (Shafer, 1995; Turner and Corlett, 1996; Fischer and Lindenmayer, 2002; Götmark and Thorell, 2003; Ranius and Kindvall, 2006). However, deciduous forest was shown to have high predictive capability for the occurrence of oak breeding LHBs group and has been further supported by the high chi square values recorded by the individual species of beetles considered in the context of deciduous forest. It may be due to sufficient habitat substrate available in the deciduous forest landscape. However in the combined model, different habitat types contributed to the occurrence of beetles groups. Deciduous forest was also confirmed to have predictive power for the occurrence of all beetles group except pine beetles, though coniferous forest showed positive significant relations with all the groups. This may be possibly because, all of the predictor variables are acting together and they are influencing each other. However, young forest showed positive significant relations with the occurrence of deciduous and oak breeding beetles and the probable reasons may be due to the high stumps that have been left after logging which degrade slowly and therefore provide food resources for the beetles.

Clearcut area as a predictor, demonstrated significant positive relationship with the occurrence of LHB groups as well as some of the individuals species like *Tragosoma depsarium*, *Pedostrangalia pubescens*, *Gaurotes virginea*, *Xylotrechus antelope*, *Anaesthetis testacea*, *Exocentrus adspersus*, etc in both individual and combined model. These species may have been receiving their breeding substrates from the tree (Lindhe *et al.*, 2010) stumps left after harvest in the felling areas which can provide 3-5 times more coarse wood than what would have been available throughout the natural cycle of the species occurring in the habitat. These observations have a high relevance as most of the Swedish forests are managed for production of timber or pulpwood (Fridman and Walheim, 2000) besides retention of high stumps on clearcut areas may provide a very good environment for their living and completing their life cycles by utilizing the food from the stump substrate as approximately ¾ of Swedish LHBs prefer sun-exposed conditions (Lindhe *et al.*, 2010). Water source confined a good predictor for the occurrence of all of the group LHBs as well as most of the individual LHBs of three groups. However wetland showed positive chi square values but didn't yield impressive results. In the combined analysis, different land use classes, showed higher VIF value for the occurrence of almost all of oak forest beetles (both individual and group beetles). May be the predictor variables co-vary with others which may overweight the results as oak habitat is restricted to the southern part of the study area. The SMD map used for measuring different classes of land cover represents a snapshot of the situation in a single year, whereas the distribution of beetles represents observations from the last 65 years. Relatively ephemeral types of habitats and resources like young forest and clearcuts could only represent a small fraction of this time. Rather, we could perhaps expect that the situation captured by the SMD map represents management dynamics characteristic for a region that extend for much longer time than the individual snapshot represented here.

4.2 Influence of volume of different habitat substrates on occurrence of LHBs

It has been observed that volume of different habitat substrates exhibited high predictive power for the occurrence of all of the LHB groups' viz., deciduous beetles, conifer beetles, pine beetles and spruce beetles except oak beetles group in individual model. Among the volume of substrates considered in five different tree habitats (pine, spruce, oak, deciduous and conifer forest) the volume of substrate in deciduous habitat revealed highest chi square value for the occurrence among all four beetles groups. In the context, it may be reasoned that probably in the Southern Sweden, deciduous trees are planted in the conifer dominated production forests (Götmark *et al*., 2005) and the presence of deciduous forest may be representative of management regimes that are beneficial for the retention of all types of substrates – including coniferous substrates. Therefore deciduous habitat substrates may influence other breeding habitat to supply habitat substrate resources for the survival and completing of life cycle of LHBs. However, it may be presumed that as far as the occurrence of oak beetles group is concerned, volume of oak habitat may be good predictor in the oak dominated landscape. In this context, similar result was also reported by Franc *et al*. (2007)

The current study also revealed that pine volume as a predictor variable demonstrated significant relationship for the occurrence of five individual pine breeding species: *Tragosoma depsarium, Monochamus galloprovincialis, Nothorhinaa muricata, Pogonocherus decorates*, *Pedostrangalia pubescens*, among the species considered. However, spruce volume had high predictive power for the occurrence of spruce breeding beetle, *Gaurotes virginea;* while deciduous volume showed positive relation for the occurrence of spruce breeding *Tetropium castaneum* LHB. Whilst, volume of oak habitat substrate showed high predictive power for the occurrence of individual LHB of oak group is considered.

From this observation it can be presumed that volume of particular habitat substrate yields higher chi square values for the occurrence of those habitats preferring individual LHBs. But we can't conclude that by increasing production of particular habitat will increase the occurrence of that habitat breeding LHBs because production forest may not add sufficient habitat substrates for the survival and completing of life cycles of that particular habitat breeding LHBs. Therefore it may be empirically observed that conservation of biodiversity in both contemporary and commercial forest should be managed sustainably so that forests could provide sufficient food and environment for the species.

4.3 Influence of key biotope on occurrence of LHBs

As regards the geographic distribution of key biotopes, the geospatial analysis highlighted that most of the key biotope small scale owner areas are concentrated in southern Sweden while the key biotope large scale owner areas, mostly concentrated in northern Sweden. In this regard, it is also relevant to presume in this context that the conifer dominated forests owned by large forest company are situated in northern part of Sweden whilst the forest area owned by individual private owners mostly situated in southern part of Sweden in which, the oak forests are predominantly distributed.

It may also be noted that in the detailed analysis, the key biotope small scale owner area showed positive relation with the occurrence of almost all LHBs species group in both individual and combined models saving conifer group beetles in individual model. However, key biotope large scale owner area may be considered as a good predictor for the occurrence of conifer beetles as it revealed a high chi square value. The probable reasons that may be attributed to the realization of such result may be that their geographical locations are in the same geographic landscape in the North Sweden. The key biotope areas which are highly valuable for conservation biodiversity (Timonen *et al*., 2010; Paltto *et al*., 2006), can provide more support for the species assemblages than production forest, because of the presence of older trees and more dead wood material (Götmark *et al*., 2011) than contexts available with production forest.

Among the potential key biotope areas considered as the predictors for the test, key biotope large scale owner area revealed a higher negative chi square value and key biotope small scale owner area revealed a positive relationship with the occurrence of oak beetles group as well as individuals LHBs considered in this study in individual model. The probable reasons for this account may be geo spatial arrangement of oak habitats, key biotope small scale owner areas and key biotope large scale owner areas. In the southern Sweden, more than 25% oak habitats are found within 10000 woodland key habitats (Götmark *et al*., 2011). Therefore it may be evidenced that oak habitat can supply sufficient substrate resources for the LHBs which prefer oak habitat for their survival and completion of life cycle.

However it is also pertinent to mention that the combined model analysis of key biotope large scale owner area showed positive relations with the occurrence of some individual oak breeding beetles: *Pyrrhidium sanguineum, Grammoptera ustulata, Poecillium alni* and *Plagionotus arcuatus* with low VIF.

In both the individual and combined model, the analysis of observations on pine beetles, it is revealed that key biotope small scale owner areas generate high chi square values for the occurrence of all individual LHBs except *Pedostrangalia pubescens*. On the other hand, key biotope large scale owner areas generate negative chi square value despite the presence of large extent of pine forests in the region reflecting otherwise on the expected potential for occurrence of LHBs in substantial extent. It may be due to low dense productive forest in Northern part or lower key biotope area that is not sufficient for the long time protection of LHB (Franc *et al*., 2007). For the occurrence of spruce breeding individual LHBs key biotope small scale owner area may have good predictive power for the occurrence of these beetles.

4.4 Determination of threshold values for the LHBs

In contemporary forest management as well as in the context of commercial forests habitat threshold values are very important for biodiversity conservation (Müller and Bütler, 2010).

But it is difficult to estimate threshold value for single species as well as species assemblages in the managed production forest. In the managed production forests, threshold level may vary among different species (Ranius and Fahrig 2006). In the current study, no group of beetles showed any threshold effect on land cover classes, volume of different tree species and key biotopes. However, from distribution of individual presences and absences in the binary fitted line plot as well as in histogram it is revealed that some individual species from the pine group i.e., *Trogosoma depsarium*, *Monochamus galloprovincialis*, *Pedostrangalia pubescens;* the spruce group i.e., *Callidium coriaceam* and oak group i.e., *Xylotrechus antelope*, *etc* showed a threshold effect of coniferous forest in regarding their distribution. Whereas some other pine LHBs *Tragosoma depsarium* and *Monochamus galloprovincialis* showed a threshold level of volume of pine habitat substrates for their occurrence. *Callidium coriaceam* which is a spruce breeding LHB showing a threshold limit of volume of conifer habitat substrate for their occurrence. *Pyrrhidium sanguineum*, *Anoplodera sexguttata* and *Strangalia attenuate* which depend on oak habitat substrates have threshold limit of volume of oak habitat substrate for their occurrence. However that for the occurrence of oak habitat preferring LHBs i.e., *Strangalia attenuate* and *Anoplodera sexguttata* showed threshold level of volume of deciduous habitat substrate.

4.5 Spatial scale and landscape analysis

The limiting spatial factor in the present analysis turned out to be the available dataset of LHBs from Lindhe *et al*., (2010) which is represented with 1 km spatial resolution and considerable uncertainty, often based on older records. Modern records from Artportalen often have considerably higher resolution, down to tens or a few hundred meters. Other databases had much higher resolution, with SMD and kNN Skogsdata being limited to pixel resolutions of 25x25 m. Based on the resolution of the LHB observations, the study considered a scale at 10 times higher spatial scale in this landscape analysis in order to ascertain that virtually every observation would fall within the proper grid square. Based on the results obtained it may be presumed that the chosen scale has some relevance for making meaningful predictions regarding the occurrence of LHB within this grid network. However, it is likely a much larger scale than the characteristic scales of response at which most saproxylic insects interact with the landscape (Bergman *et al.,* 2013), and access to observation records with higher resolution would be desirable.

5 CONCLUSION

From the results it is revealed that 10x10 km spatial scales are relevant to be used in a landscape analysis, given the currently available information about species distributions and landscape variables. In individual model different land cover classes: arable land, pasture land, other than expected breeding habitat type showed positive significant relationship regarding the distribution of group LHBs but different habitat type: deciduous forest, coniferous forest, mixed forest, young forest, as predictive variable, contribute no or very little to explain the occurrence of LHB group. While in the combined model different habitat type confined to have predictive power for the occurrence of LHB groups as well as some individuals coniferous forests showed positive significant relation with the occurrence of individual pine beetles; *Spondylis buprestoides, Arthopalus rusticus, Acanthocinus aedilis,* etc. and individual spruce breeding beetles like *Tetropium castaneum, Molorchus minor, Gaurotes virginea,* etc. However, deciduous forest showed to have high predictive power in regard to distribution of oak breeding individual beetles like *Pyrrhidium sanguineum, Anoplodera sexguttata, Plagionotus arcuatus*, etc. Other landscape predictors like urban area, pasture land showed significant relationship for the occurrence group beetles and most of the individual beetles. Clearcut area as a predictor, demonstrated significant relationship with the occurrence of LHB groups as well as some of the individuals species like *Tragosoma depsarium, Pedostrangalia pubescens, Gaurotes virginea, Xylotrechus antelope, Anaesthetis testacea, Exocentrus adspersus*, etc in both model

Volume as a predictor was found to contribute significantly for the occurrence of particular beetles in respective forest habitats. Volume as a predictor in deciduous forest was observed to contribute significantly for almost all species.

Key biotope small scale owner area revealed positive significant relation with the occurrence of almost all species in both individual and combined models. Key biotope large scale owner area showed negative relation with almost all of the species' occurrence. Only one exception for conifer breeding beetles in individual model both key biotope area as predictors responded inversely. From the distribution of presence and absence of species in binary fitted line and also from histogram some threshold values of habitat for some species like *Trogosoma depsarium, Monochamus galloprovincialis, Xylotrechus antilope* etc. could be observed.

In the combined model, different land use classes showed higher VIF value for the occurrence of almost all of oak forest beetles (both individual and group)

Suggestions on aspects to be considered in development of biodiversity conservation strategies

In the context of the above discussion we may suggest the following aspects which may potentially contribute towards the development of land use based management approaches for biodiversity conservation-

- Increasing the amount of deciduous forest patches in areas already dominated by coniferous forest
- Retention of specific habitat types in landscapes in order to provide sufficient resources for saproxylic insects and for the monitoring of the spectrum of biodiversity components associated with the species
- Maintenance of threshold level of volume of wood left in forest to provide sufficient habitat substrates for the beetles to survive and colonize.
- Keeping matured tree in the harvested area to facilitate biodiversity values.
- Conserving biotopes and providing for other natural reservations in the forested landscapes for biodiversity conservation.

Areas required for further study

- From the above discussion in results and discussion chapter, it is revealed that both ILBRM and CLBRM differ to show predictive power of different landscape variable in regarding the distribution of LHBs. So further study is needed regarding the models.
- In the study for the facility of analysis we modified the 58 Swedish land cover classes (LCC) into 12 classes. It is necessary to demonstrate it again how the 58 LCC influence for the occurrence of the LHBs both group and individuals.
- Here we considered only the volume of habitat substrates from the KNN forest data, there remains other estimators which can influence for the occurrence of the beetles. So further investigation in this regards is necessary.
- For the key biotope as a predictor we only considered geographical area of two types i.e., key biotope small scale owner area and key biotope large scale owner area and combined area of this two types. Further research is needed for specific key biotopes.
- Overall, LHB we only grouped based on the habitat coverage and individual species are chosen based on the habitat preference. Further analysis are needed for individual species.

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Appendix

1. Geographic distribution of key biotopes

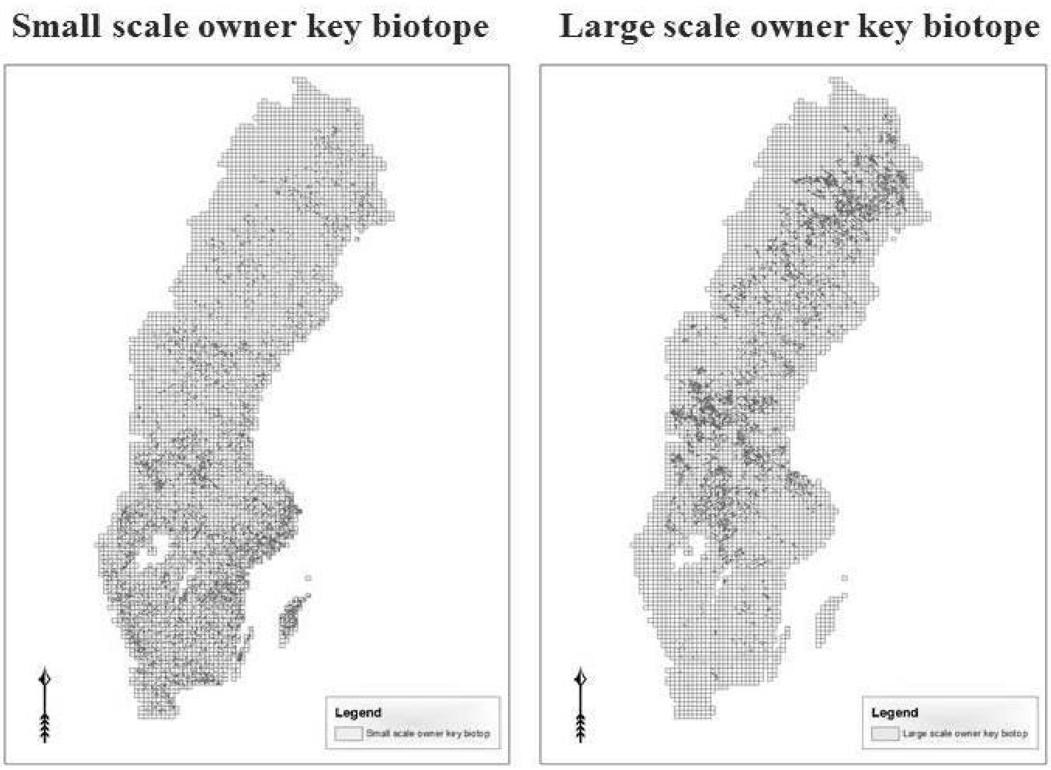

Figure 25. Geographical distribution of key biotope areas within the grid network

2. Observations of LHBs within different habitats at 10x10 km grid network over Sweden

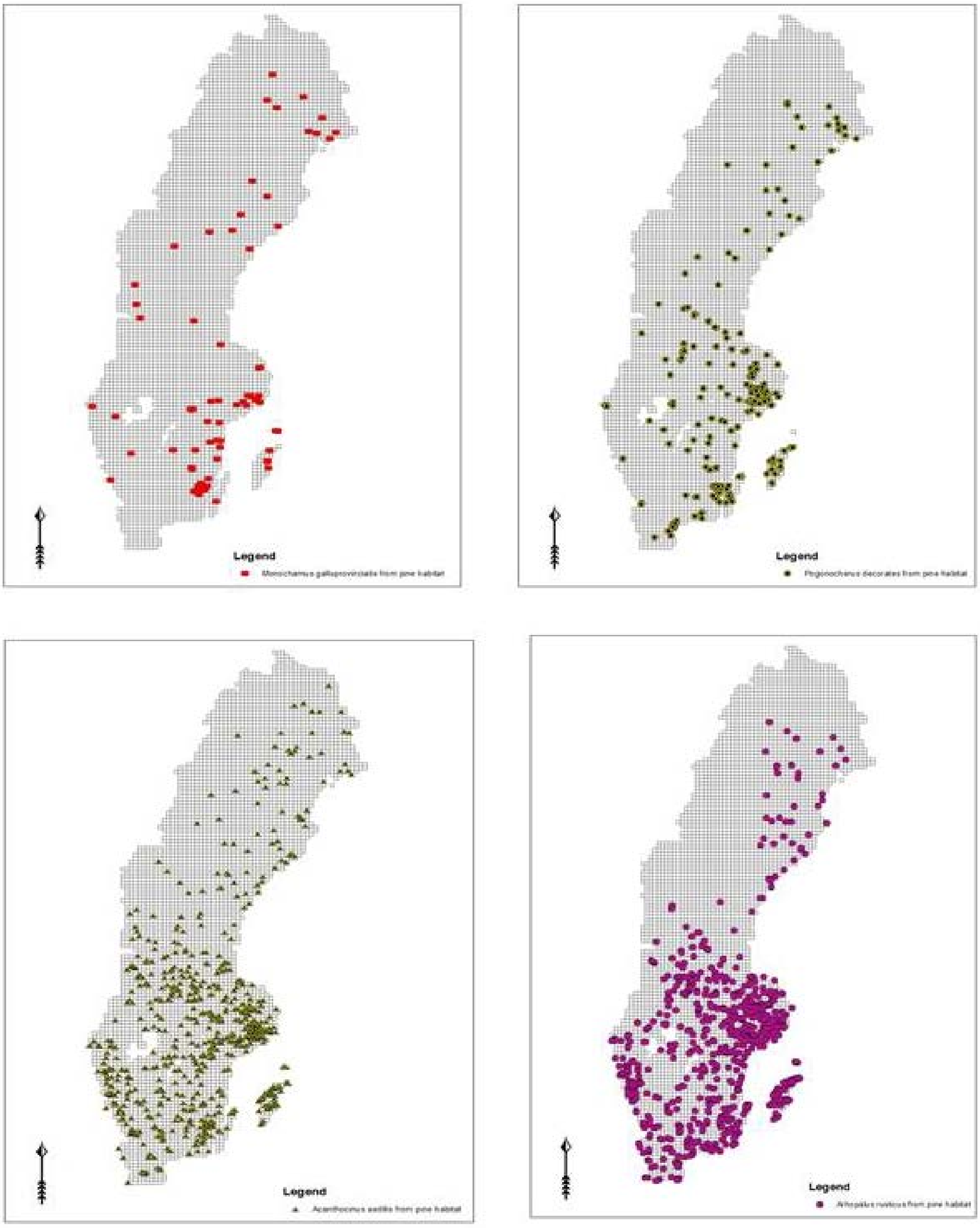

Figure 26. Observations of pine beetles within pine habitat at 10x10 km the grid network over Sweden for the period 1951 to 2015

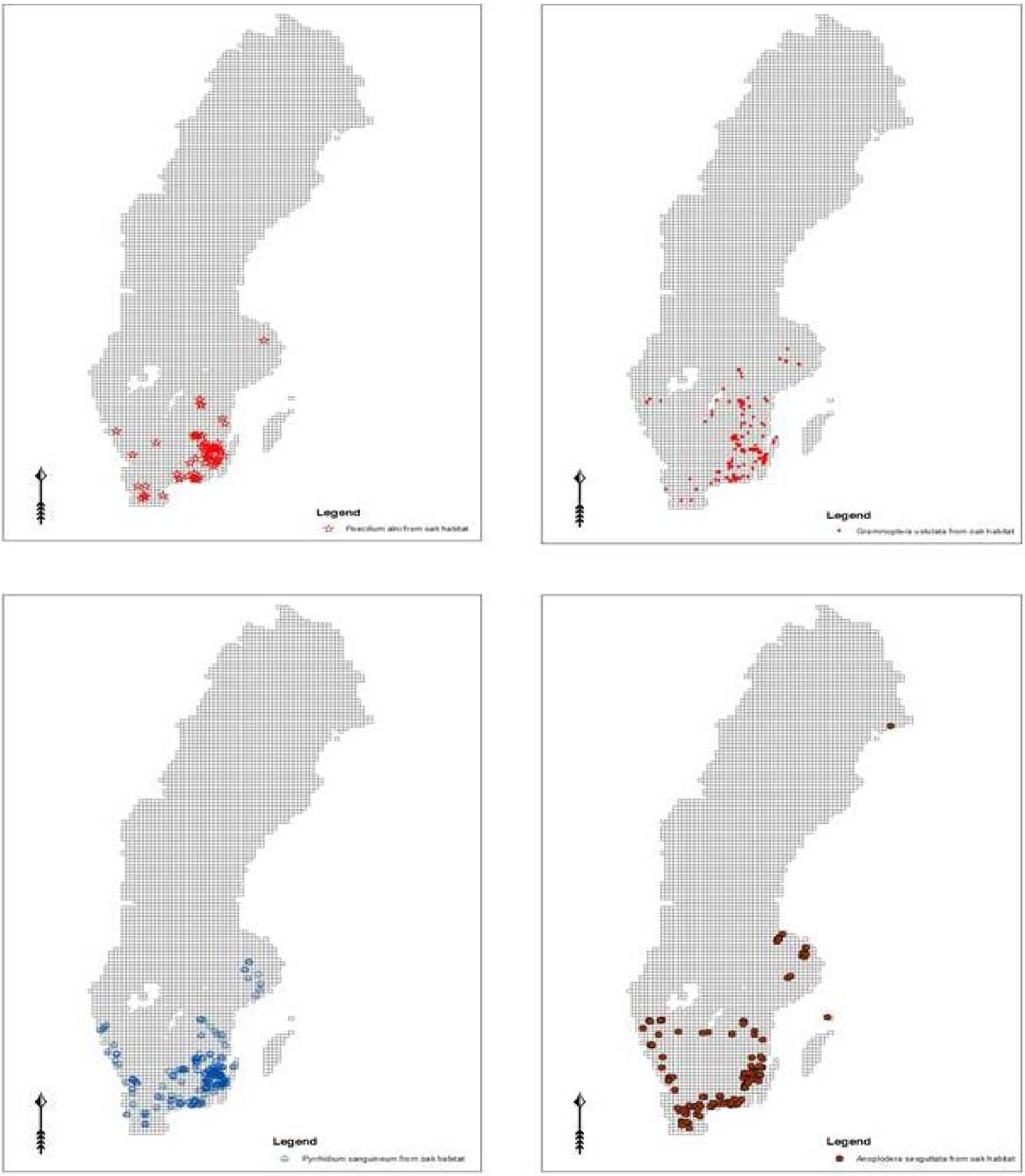

Figure 27. Observations of oak breeding beetles within oak habitat at 10x10 km the grid network over Sweden for the period 1951 to 2015

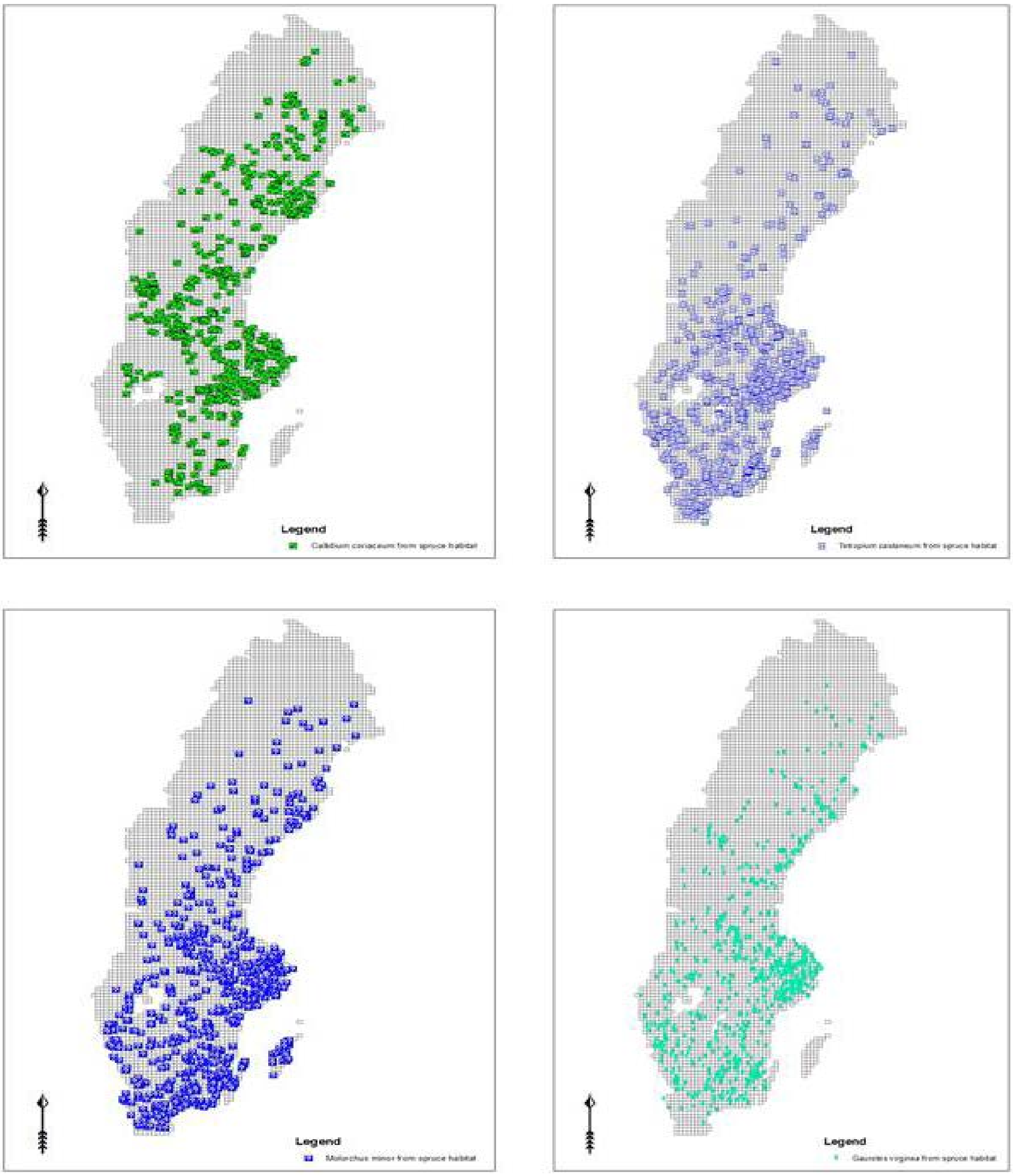

Figure 28. Observations of spruce breeding beetles within spruce habitat at 10x10 km the grid network over Sweden for the period 1951 to 2015

3. Distribution of presence and absence of LHBs within binary fitted line plots areas of landscape variables

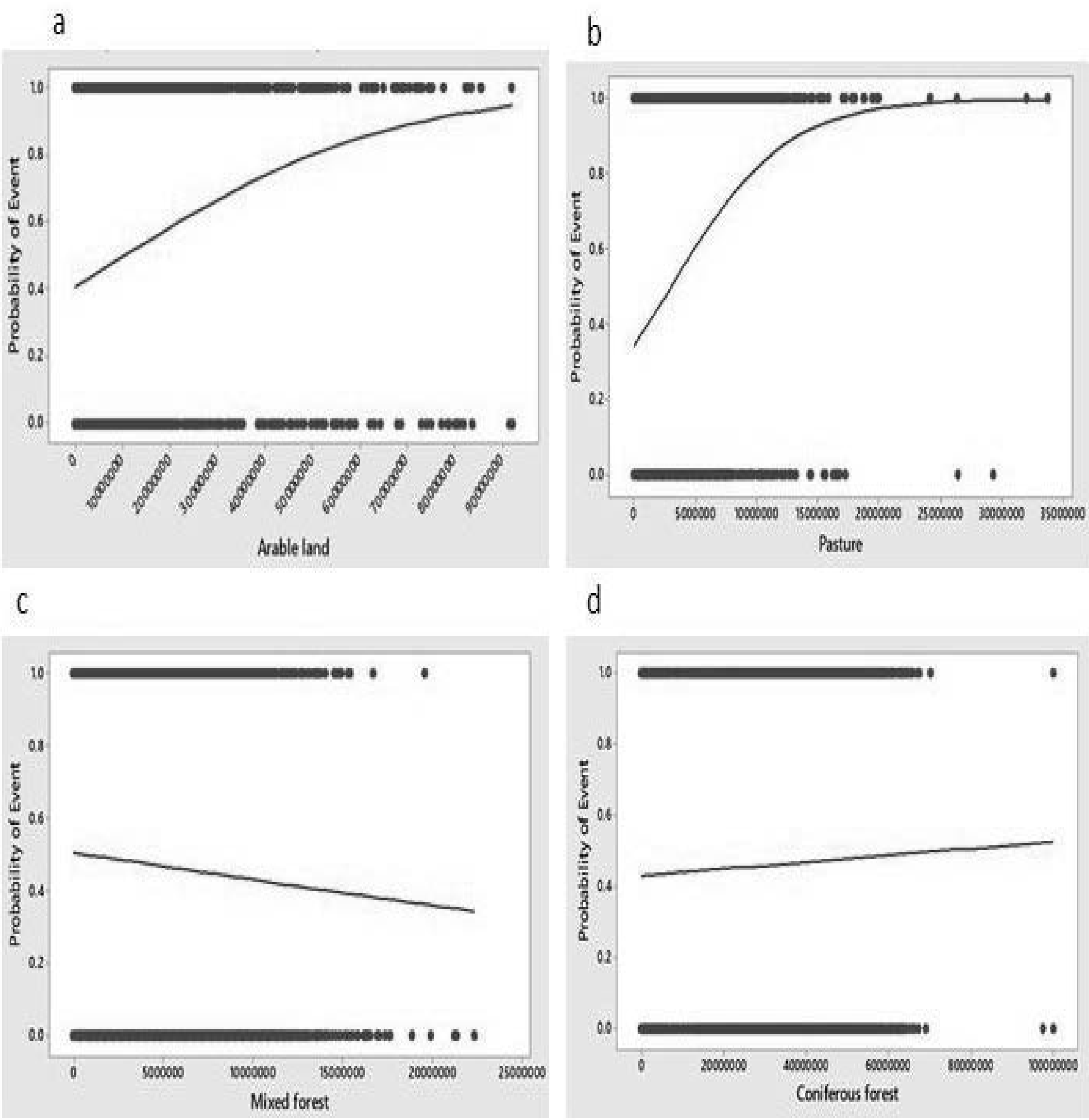

Figure 29. Distribution of presence and absence of conifer breeding beetles within binary fitted line plots areas (m^2) of landscape variables (a) arable land (b) pasture land, (c) mixed forest and (d) coniferous forest. Here probability of event 0 indicates absence and 1 indicates presence of conifer beetles

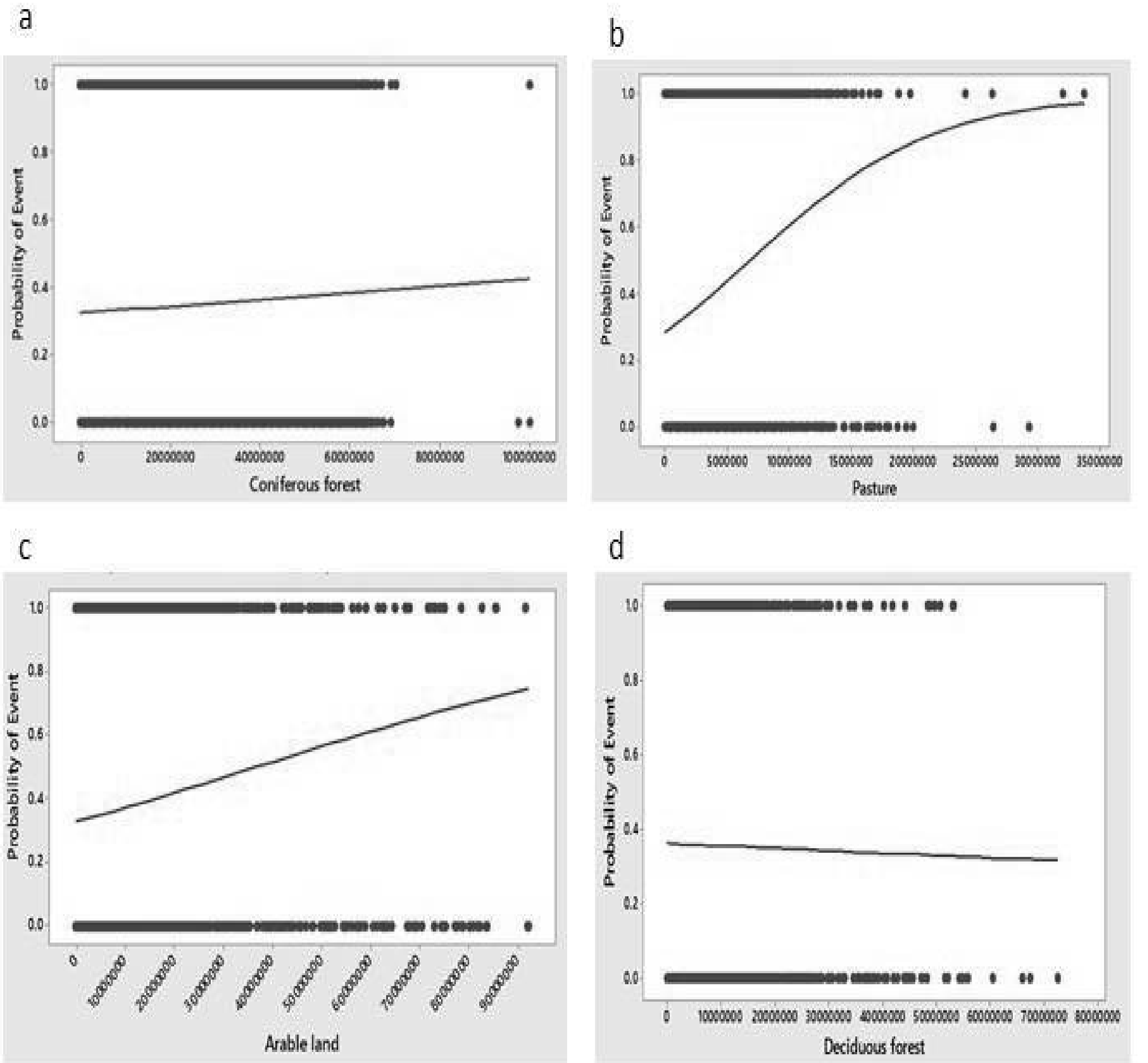

Figure 30. Distribution of presence and absence of spruce breeding beetles within binary fitted line plots areas (m^2) of landscape variables (a) coniferous forest (b) pasture land, (c) arable land and (d) deciduous forest. Here probability of event 0 indicates absence and 1 indicates presence of spruce beetles

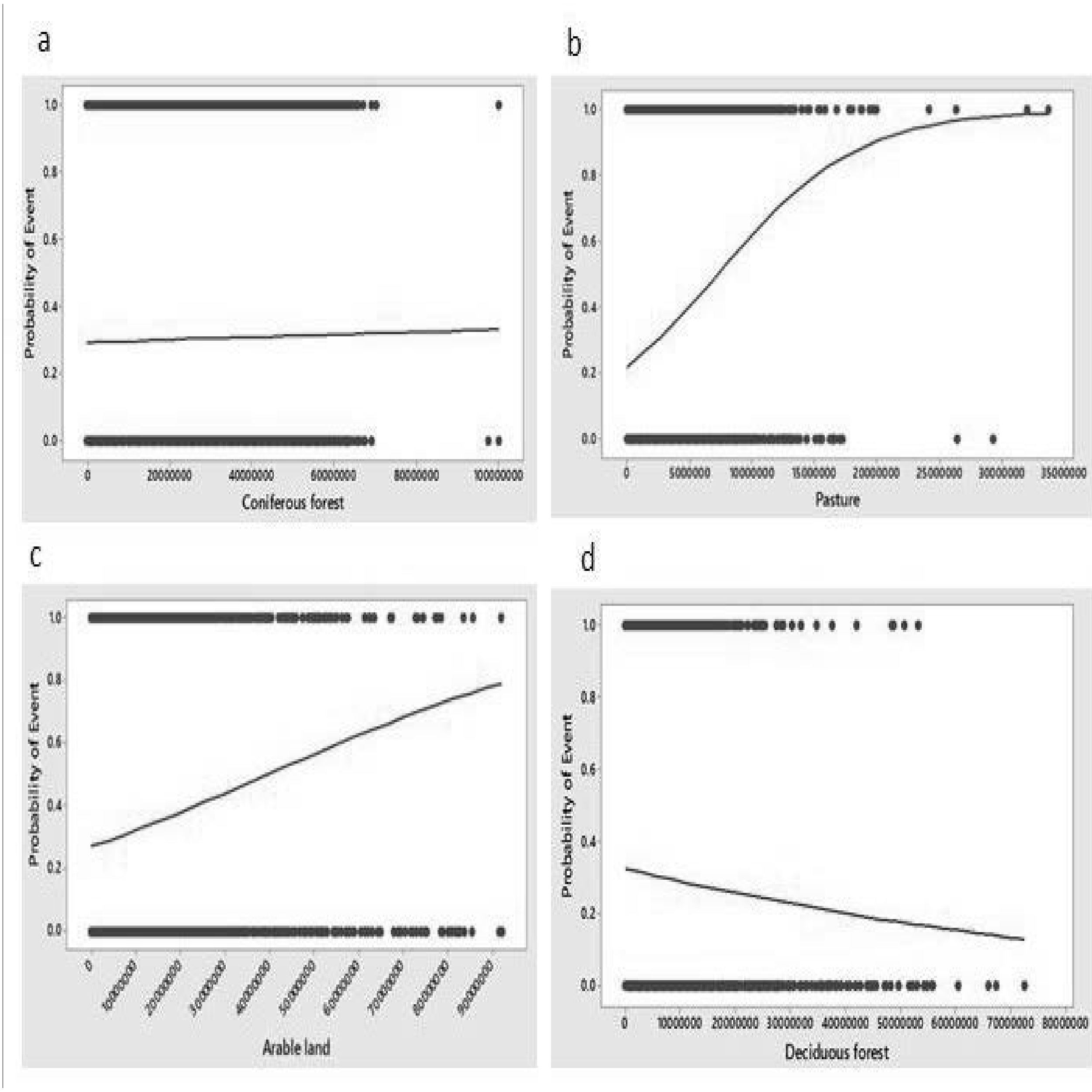

Figure 31. Distribution of presence and absence of pine breeding beetles within binary fitted line plots areas (m^2) of landscape variables (a) coniferous forest (b) pasture land, (c) arable land and (d) deciduous forest. Here probability of event 0 indicates absence and 1 indicates presence of pine beetles

4. Distribution of presence and absence of LHBs within binary fitted line plots of volume of different tree species

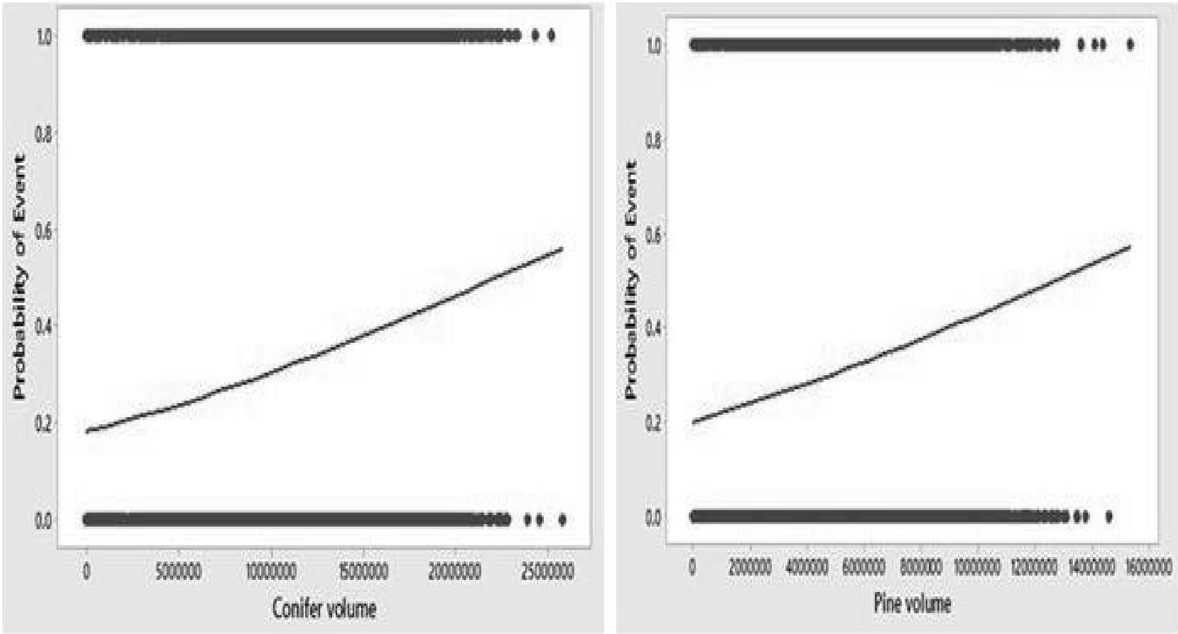

Figure 32. Binary fitted line plots of pine beetles within the volume (m^3) of conifer and pine habitat. Here probability of event 0 indicates absence and 1 indicates presence of pine habitat breeding beetles

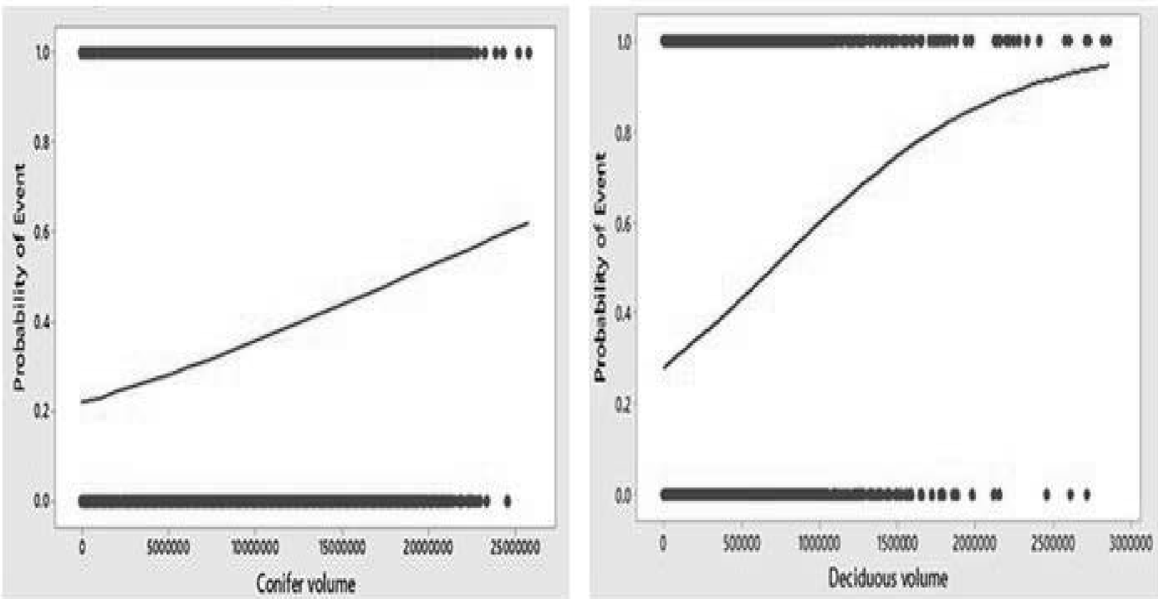

Figure 33. Binary fitted line plots of spruce beetles within the volume (m^3) of conifer and deciduous habitat. Here probability of event 0 indicates absence and 1 indicates presence of spruce habitat breeding beetles

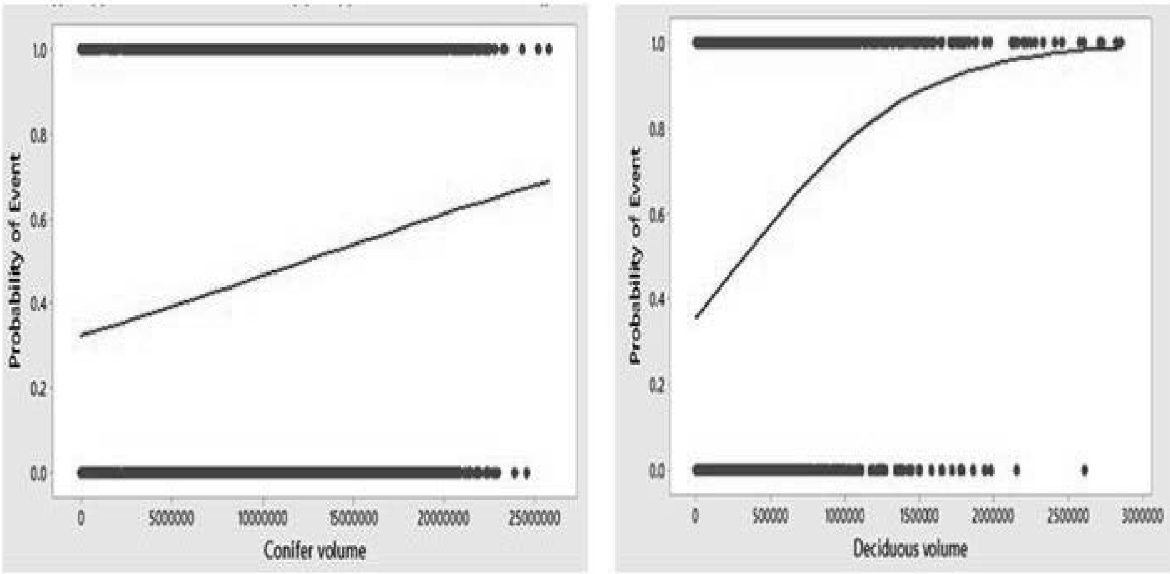

Figure 34. Binary fitted line plots of conifer beetles within the volume (m^3) of conifer and deciduous habitat. Here probability of event 0 indicates absence and 1 indicates presence of coniferous habitat breeding beetles