Mechanism of human-hornet conflicts in an urban ecosystem

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ABSTRACT

Conflict with wildlife in urban areas is not a unique issue in Japan. According to the statistics reported by Ministry of Health, Welfare and Labor of Japan, hornets, bees and paper wasps are top insects that have been related with several death reports in the country. The sting caused by these stinging insects such as hornet may be fatal only through single sting, commonly when combined with previous health complications suffered by the victims. In order to cope with wildlife conflict, the government of Japan had provided consultation and technical assistance to remove the unwanted pest in the urban area. According to statistics provided by previous report, consultation of stinging insect was showed as the highest pest group Tokyo. The demand for the consultation was overwhelmed and increased temporally especially for hornet. With the increased of these consultations demand, the financial and technical support provided by the government has also significantly afflicted. Therefore, efforts to understand the increase of the consultations might help to reduce the conflict between the residents and this stinging insect. While there are several factors that can influence the increase of this conflict, this study will focus on understanding human and hornet dimension. The question that rose in this study is whether these demands were driven by hornet numbers or human tolerance. Hornet adaptability in urbanized areas might have increased due to several factors that beneficial for hornet such as high temperature that increase their hatching rate and small habitat requirement of these insects. However, in the meantime, acceptability of human towards wildlife might also decrease. Lower tolerance towards wildlife has consistently been showed by the elder generations in previous studies, partly due to their limited physical abilities that induce their vulnerabilities on the wildlife. Nonetheless, lack of nature interactions among urban dwellers caused by limited time

spend near nature could have also contributed to the lower tolerance level towards wildlife.

To address this issue, this study first examined hornet's suitable environment based on their abundance correlation within green spaces and hornet's species-specific response towards green spaces. There are eight hornet species known to inhabit Japan which are; *Vespa mandarinia, V. analis, V. ducalis, V. crabro, V. simillima, V.flaviceps* and *V. dybowski*. With difference level of poison and aggressive levels, understanding their specific response towards environment is beneficial for human safety precaution purposes. Dataset that contained eight years of abundance data for four hornet species at 11 sites in Nagoya city were used. The levels of greenness around the hornet sampling points were measured using averages from the Normalized Difference Vegetation Index (NDVI) with radiuses of 0.1 – 10.0 km retrieved from Landsat-8 satellite. The relationship between abundance and species composition of hornets and NDVI were analyzed at different spatial scales using generalized linear mixed models(GLMM). Higher NDVI values positively affected the abundance of all the hornet species except *Vespa analis*. The abundances were estimated most effectively using the NDVI average with a 1–2 km radius for all species. The species composition of hornets drastically changed along the gradient of NDVI values; *V. mandarinia* was dominant in greener areas (over 0.2–0.3 NDVI average with a 2 km radius) and *V. analis* in less green areas (below 0.2–0.3 NDVI average). Our study showed that the abundance and species composition of hornets were both strongly associated with the level of urban greenness. This suggests that the increase in the urban greenness can increase hornet abundance and alter the species composition of hornets; a more aggressive species, *V. mandarinia*, may also increase in urban areas. This study also suggests that *V. crabro* might also depend on green spaces but not *V. analis* and *V. ducalis* due to their inconsistent trend of abundance near green spaces.

In second dimension of this study, the trend of removal demand by the resident was examined as indicator of human-hornet conflict. With limited attention been given on conflict between human and insect in human-wildlife studies, this dimension investigate the spatial and temporal pattern of conflict with hornet in urbanized setting. Land use patterns of grasslands, residential areas, forests, agricultural lands and parks were used as natural environment combined with elder generation and women proportion that particularly known to have different level of tolerance towards wildlife as social environment. The relationship of these environments and intensity of the hornet conflict were analysed from 1990 to 2005 in Nagoya city. Number of removals was found highly associated with forested areas for almost all hornet species including the *V. analis*, species that previously was found not abundantly associated with forest extent. Intensity of human wildlife conflict in this study was suggested to be determined by the level of human and wildlife interactions in natural environment. The sharing of these environments that is suitable for hornets as well as human can be the source of conflict between human and wildlife that interact. This suggests the impact of land use management in helping to control the conflict. In order to put the conflict in control, natural regulation is one of the alternatives to control hornet population especially at high intensity conflict areas like forest. Continuous risk communication and environmental education remain as one of the keys to promote urban biodiversity by improving human tolerance.

Balancing ecosystem services and disservices has become crucial for the planning and management of green spaces, particularly when urban green space increases. This study demonstrated how human tolerance towards wildlife may have to be improved in order to live in greener environment where wildlife can be expected. Although studies have examined the ecosystem services provided by natural environments in urban areas, they may have overlooked the capacity for humans and wildlife to coexist. This study suggests the impact of combination between ecology and social dimension in urban planning especially in green spaces development to control the intensity of human wildlife conflict within communities.

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Chapter 1

General Introduction

1.1 Green spaces as solution for urbanization problem

United Nation had projected that due to global impressive transformation towards urbanization, 66% of the world's population would become urban in 2050 (United Nations 2014). Modification of natural landscapes to make way for urbanization and agricultural activity had affected ecological processes heavily. Increase in temperature or commonly known as 'heat island effects' in larger cities tended to increase relatively with the increase of impervious surfaces such as buildings and roads(Gaston et al. 2010). Indirectly, usage of air conditioning is likely to increase these heat effects contributing to the rise of carbon dioxide(CO_2), making the environment even hotter(Akbari et al. 1997). Environmental pollution in urban areas although was suggested to have decreased recently however is still above desirable standards, affecting human health physically and spiritually. Transformation of natural vegetation to anthropogenic landscapes not only caused extinctions of animals but also human-nature experience. Deficiency of human contact with nature had contributed to limited general knowledge and benefits acknowledgement on natural elements such as animal and plants let alone sense of gratitude towards them(Miller 2005).

Negative impact of urban heat effects was suggested to decrease relatively with more green spaces (Tsilini et al. 2015). Vegetation planting help to reduce fossil fuel consumption and resultant carbon dioxide (Akbari et al. 1997) besides shadiness effect that act as natural sun protector. Improvement of physical health contributed by green spaces was also suggested through the physical activities (Lee and Maheswaran 2011). Besides providing walking opportunities for urban dwellers through existence of tree streets, green spaces that are located within proximity from residential areas tend to be more convenient for them to be active physically (Cohen et al. 2007). Green space has also been suggested as effective mitigate for air pollution (Nowak et al. 2006) where risk of stroke mortality was also suggested to be higher at environment of low exposure to green spaces particularly contributed by higher pollution level (Hu et al. 2008).

1.2 Human wildlife interaction

The benefits provided by green spaces in the city has contributed to the increase of urban green infrastructures development strategies in many cities. Public green spaces such as parks and reserves, sporting fields, streams, community gardens, green alleyways provide opportunities for human interactions with nature besides serving purpose for social gathering as well as physical activities setting for family (Wolch et al. 2014). These purposes therefore allow urban green spaces to be included as one of the sources for tourism attractions of several countries(Dwyer and Edwards 2000). Nature-based tourism that most significantly related with high biodiversity species-human interaction is potential for revenue increment since tourists are willing to invest financially to be closer to nature especially rare one (Naidoo and Adamowicz 2005).

Previous studies had shown that increase of wildlife species richness in urbanized areas especially birds and arthropods besides plants are related with their small habitat requirement and high adaptability in urbanized building structure through utilization of human element for food sources and habitats(McKinney 2008). This is good news for those who are fond of wildlife, being closer to wildlife in residential environments seems to be an enjoyable experience to some residences (Dandy et al. 2011; Hedblom et al. 2014). The existence of wildlife in human environment has often been related to with positive effects towards mental health and psychological benefits including species that plausibly harmful for human (Soulsbury and White 2015). Listening to bird song for example is associated with relaxation that contributes contributes to positive attitude although it may be related with interest in music that already existed(Hedblom et al. 2014).

1.3 Emergence of urban wildlife conflict

Animal communities that utilize human dominated ecosystems are called urban wildlife. They can be potential source of conflicts towards human when their existence cause complications and adverse effects especially the one that threatens lives. Human-wildlife conflict (HWC) can occur directly and indirectly. Direct effect can be observed when their existence cause harm or difficulties towards human such as through properties damages, health complications and trauma (Herr et al. 2010; Poessel et al. 2013). The increase of urban wildlife conflict has been affiliated with the increase of human population itself besides rapid development of residential sizes and green spaces (Soulsbury and White 2015) and modifications of natural habitat of the wildlife. The conflict that commonly associated with wildlife is through attacks, problematic behavior besides secondary impact by spread of diseases or parasites. Conflict among human towards wildlife is another type of HWC that can be observed. Different interpretation towards wildlife management and conservation can also affect HWC (Redpath et al. 2013).

In Japan, serious HWC that can be observed is between human and stinging insects such as bees, paper wasps and hornets. The average of death rate caused by stinging insects is three times higher compared to snake related causes based on statistics reported by

Ministry of Health, Welfare and Labor of Japan from 2005-2014. Although not all wasp attacks can cause death, fatal attacks that reported were mainly through single sting usually when combined with already existed health complications such as high blood pressure, respiratory-related diseases and venom allergies. High number of reports were found mainly during summertime coincided with period where peak numbers of foraging workers can be found due to their food searching and nest protection activities.

1.4Wildlife conflict in Japan: High pest consultations demand

Several methods have been used to control urban wildlife, this includes trapping, translocation of smaller animals, repellents, frightening devices, physical exclusion, and last but not least hunting (Hadidian 2015). Due to the well-known danger with regards to these stinging insects, pest consultation and removal assistance for residence had been provided by some local governments such as in Japan to eliminate wasp's unwanted nest. In Nagoya city government for example, consultation was provided for the residence who was mostly disturbed by the existence of the hornet, however priority was given more given to species that was more aggressive such as *V. mandarinia* and *V. simillima* (species characteristics are discussed in next chapter). The demand for pest consultation was overwhelming and increasing temporally. For example, in Tokyo the demand for consultation has shown increased significantly from 1995-2003 especially for paper wasps (r_s=0.51*) and hornets (r_s=0.83**)(Fig. 1.1).

The economy impacts caused by urban wildlife conflicts is quite minor but still valuable to be evaluated. Estimation of the costs of wildlife damages is beneficial to suggest alternative management strategies (White et al 2003). The highest costs from wildlife conflicts are mostly contributed by the wildlife diseases in covering treatment expenditures as well as loss of opportunity through sickness (Soulsbury and White 2015). Costs that are required for trapping nuisance animals in Chicago for example was also worth $1 million in 1999 (Gehrt 2004). In Japan, approximately half of the local governments (excluding the isolated islands) had covered between $100-500 US per nest removal from private homes. Therefore identifying the drivers of such conflicts can help to reduce the conflicts between human and wildlife.

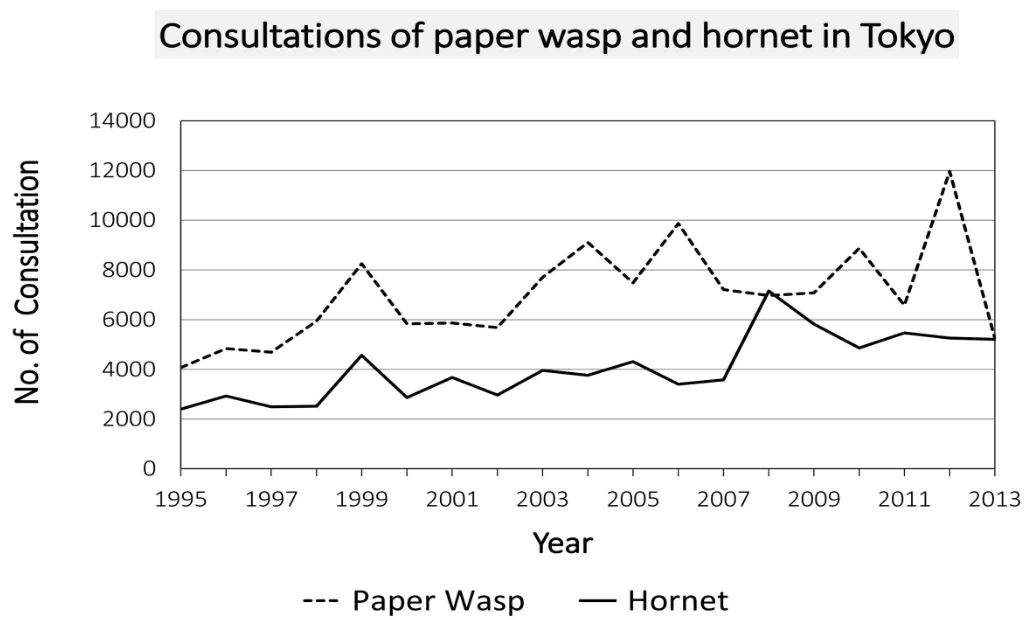


Figure 1.1 Temporal trend for paper wasp and hornet consultations in Tokyo from 1995-2013

1.5Aim of research

This study focuses on hornet-human conflict in Japan due to the intensity of conflicts perceived based on the high removal rate of the species. Although hornet has been listed as urban nuisance species in many previous studies, the drivers of conflicts between human and hornet were still under studied. Therefore, this study aims to investigate the factor that influences conflict between human and hornet and indirectly propose recommendations and measures for human-hornet coexistence. With main study area in Nagoya city, the hornet nest removal report from government of Nagoya was used as indicator of conflict. The first dimension that I focused is the location of the conflict. The main research question that I put forward is whether removal demand is high at human or hornet environment. To answer this, I first identified the dominant living location of community of hornet and human. Two studies were dedicated to investigate this first dimension with objectives; 1) To understand hornet adaptable environment using greenness level and 2) To investigate the spatial pattern of environment prone for human – hornet conflict.

1.6 Outline of chapters

In the first chapter of the thesis, background of urban wildlife conflict was introduced as negative side effects from human and wildlife interactions in urban green space. The statement of problem and objectives of the study were also introduced.

The second chapter is the materials and methodologies section. Study area in Nagoya city was introduced as well as characteristics of data such as hornet sampling and hornet nest removal. Normalized difference vegetation index that was used to represent urban greenness level was defined including the validations of the values with land use type.

In the third chapter, hornet specific response towards green spaces was discussed. The data analysis used and results were shown. In this chapter I showed how hornet response can be characterized by greenness level with different responses by species.

For fourth chapter, factors that influence human-hornet conflict in Nagoya city were discussed. I investigated the impact of natural environment that consist of grasslands, residential areas, forests, agricultural lands and parks. Social environments were also observed using elder generations and women proportion and population to understand how they affect the nest removal trend. Conflict was shown highly associated with forested areas.

The fifth chapter summarizes the whole thesis chapters from the beginning and recommends future improvements for urban planning as well as aspects for improvement towards wildlife for urban communities.

Chapter 2

Materials & Methodologies

2.1Study site

Nagoya city is the largest city in Chūkyō Major Metropolitan Area of Japan with approximately 2.29 million inhabitants (Statistics Bureau 2010). At the time of the 10th meeting of the Conference of the Parties for the Convention on Biodiversity (CBD COP10) held in Nagoya, Nagoya city established "The 2050 Nagoya Strategy for Biodiversity". The strategy for Nagoya acts as a guideline for the development of a sustainable city that supports biodiversity to conserve and revitalize the environment within the city. It includes support for an increase in green spaces (from 25 to 40% by 2050), improvement in the quality of each green space as a habitat for native species, and the creation of green networks (Nagoya 2010). Nagoya government had classified green land coverage of the city into 4 types which are forest, grassland, agricultural land, and water. Based on green land cover distribution provided by Nagoya city, forest constitute the largest part of the green land cover with 10.7%, followed by grassland(5.1%) and agricultural land(3.3%), with water surface(2.9%) (Nagoya 2015a). In total, residential size covered 28.66% of Nagoya city in 2007, followed by forest (11.3%), grassland (6.5%), park (5.5%) and agricultural land (4%). Population density data from a Nagoya demographic report (Nagoya 2015b) was used where the population was classified into three age groups: 1–14 (young), 15–59 (adult), and over 60 years (aging) based on working age limit.

2.2 Hornet characteristics

2.2.1 Life cycle of hornet

As shown in Fig. 2.2, similar life cycle was also observed among Vespa spp. where most queens will undergo to start new colonies. Beginning with pre-nesting stage, it is a recovery stage after long hibernation around 6-9 months. Impregnated queens will come out from the hibernation place and feed on tree sap sources to regain their strength before finding sites for new nest development (Matsuura and Yamane 1990a). Preemergence is the stage where nest foundation is set up and number of workers begin to emerge. Nest was built after the queen had inspected the areas. It then built the nest until certain shapes before stopping. Before the emergence of workers, all food hunting, nest structuring and protecting was conducted by queen alone. Queen began to slow down its extranidal activities except for oviposition during cooperative period due to the increase number of workers who continue working on food collections and nest maintenance. In polyethic stage, the behaviour of workers are now more active with some of them are more oriented towards queen. The stage of nest is also ready for acceptation of new queens. It's the end of polyethic stage with the death of queen (Matsuura 1984). The reproductive stage starts when the new queens and adult males were prepared by workers for reproduction process outside the nest. Declining numbers of workers and death of larva were also found during this stage since more attention were given to 'reproduction group'. However, there are also cases where queens become workers due to an insufficient supply of food. Matured males and new queens leave the nest for copulation. Hibernation stage started after the completion of copulation. Vespa hibernate in the soil and rotten wood on the ground usually in near distance from the nest since their physical strength are kept since no feeding activity were suggested after leaving the nest (Matsuura and Yamane 1990a). Hibernation sites that are preferred are often dim and high in moisture where effects of temperature changes can be controlled.

2.2.2 Species-specific ecology

Seven *Vespa* species are known to live in Japan (Matsuura and Yamane 1990b). My study put focus on four species that were abundant in the samples: *V. crabro, V. mandarinia, V. ducalis,* and *V. analis.* These four species differ in size, preference for nesting sites and prey, aggressiveness towards human, and quantity of poison in their stings (Table 1). *V. mandarinia* is the largest in body size, is the most aggressive, and releases the greatest amount of poison. This species is also a predator of other hornet species. *V. analis* frequently builds nests on tree branches of home gardens and buildings and thus is the primary species of conflict with residents in Nagoya city; 92% of the 12,898 nest removals in 1983–2007 in Nagoya belonged to colonies of *V. analis* (Yamauchi H 2009a). *V. crabro* preys mainly on cicadas (95% of total preys) while *V. ducalis* is a specialist predator that hunts pupae and the larvae of paper wasps (*Polistinae* spp.)(Matsuura 1984).

2.2.3 Benefits of hornet in urban ecosystem

Existence of hornet in our urban environment always been perceived as threat to the community, partly due to the negative portray of this species based on its venomous stings. Empirical studies actually are lacking in showing how hornet is beneficial towards human. This, contributes to less exposure of human to perceived hornet as a positive normal insect in the urban space. Although the sting is painful, hornet actually can be source of good protein for human being. Some countries in Southeast Asia even perceive this insect as exotic food supply (Matsuura and Yamane 1990a). Chinese medicine also has been identified to utilize wasps nest as herbal medicine along with the larvae. Although the consumption should be taken in certain limitation, wasps nest can be useful for sterilization detoxification and anti-inflammatory treatment (Yamauchi). Apart from these benefits, hornet is also known as effective pest control due to the varieties of preys. Hornet is useful in agriculture sectors to help controlling insect pest that negatively affect vegetation production as well as control in unsanitary pest such as flies (Matsuura 1984; Matsuura and Yamane 1990a).

2.3 Hornet sampling

Experienced government staff sampled hornets at 11 sites throughout Nagoya city (Fig. 1) from 2007 to 2014, but only from 2013 to 2014 for one location. All of the sampling sites were located in parks except for one located in a cemetery. The staff set two funnel traps containing an attractant liquid (made up of 40% water and 60% fermented milk drink) at a height of 3 meters in each park. They collected the hornets from the traps and renewed the attractants every week from April to November, covering the entire active period of hornets in the region (Matsuura 1984). All of the hornets sampled were identified, classified by species, and counted by the staff.

2.4 Hornet Removal data

After the government introduced removal to eliminate unwanted hornet nests, there was an increase in removal demand by locals from 1983 to 2005 in Nagoya (Nagoya, 2012). This approach was used in private and public spaces; however, due to an increase in demand for these services, the government limited the free-of-charge removal service to public spaces in 2006–2007 before stopping the service entirely. Removal report compiled by the Environmental Health Center of Nagoya was used for this study to investigate hornet removal trends. The data were comprised of annual removal data from 16 wards and included species identifications. The trends of free-of-charge removals were examined from 1990 to 2005 for publically owned (e.g., public parks) and privately owned (e.g., home gardens) spaces. All removals were conducted after confirming safe conditions but were passed to experts in cases of unreachably high nests requiring specialised equipment. Operations were not biased by ward, since the same institution oversaw all removals. Seven hornet species were identified in the report: *Vespa mandarinia* (oosuzumebachi), *V. analis* (kogatasuzumebachi), *V. ducalis* (himesuzumebachi), *V. crabro* (monsuzumebachi) and *V. simillima* (kiirosuzumebachi).

2.5 Vegetation indices

The amount of green space in Nagoya was quantified using Normalized Difference Vegetation Indices (NDVI) derived from satellite images which has the lowest effect of cloud (< 25%). The satellites used were OLI 14 on Landsat 8(Roy et al. 2014) and Landsat 5 Thematic Mapper (Small et al., 2001). These images were acquired using a 30 meters spatial resolution during the summer when vegetation coverage was at its maximum. These images that taken in September 1985, August 1995, 2000, 2005 and 2015 were level 1 product downloaded from the U.S. Geological Survey (https://lpdaac.usgs.gov). The validity of the images was crosschecked with aerial photos of the region (Google earth 2012) showing major green areas to confirm that the projection used WGS 1984 as a spatial reference. NDVI values range from -1 to 1; positive values indicate vegetated areas with values within 0.5-0.8 suggested for dense vegetation and negative values non-vegetated areas, such as water, clouds, and bare land (-0.1-0.2)(Carlson and Ripley 1997). NDVI is a common tool used for vegetation dynamic monitoring where NDVI pattern fluctuated according to vegetation greenness such as forest density (Sun et al., 2011). The amount of green space was estimated using NDVI averages at 12 different radii from 0.1 to 10.0 km from each sampling site using ARCGIS software based on 2013 image (ESRI ver. 10.0). The green space of each ward was estimated using images from 1985, 1995, 2000 and 2005.

2.5.1 NDVI validity

The validity of NDVI values in representing Nagoya greenness level were tested, by comparing correlation between the actual size of land cover types with NDVI values. The ward-level size of landuse which comprised of 5 types (Forest, Agricultural, Grassland, Water surface, Total and Total without water surface) in Nagoya based on 5 years survey from 1990 – 2010 were compared with 5 images retrieved from the satellite using NDVI values using Spearman’s rank correlation test. The analysis showed that the greenness coverage excluding water surfaces is highly correlated with NDVI values (Fig. 2.4). This suggests NDVI values represent Total of Forest, Agricultural and Grassland coverage in Nagoya.

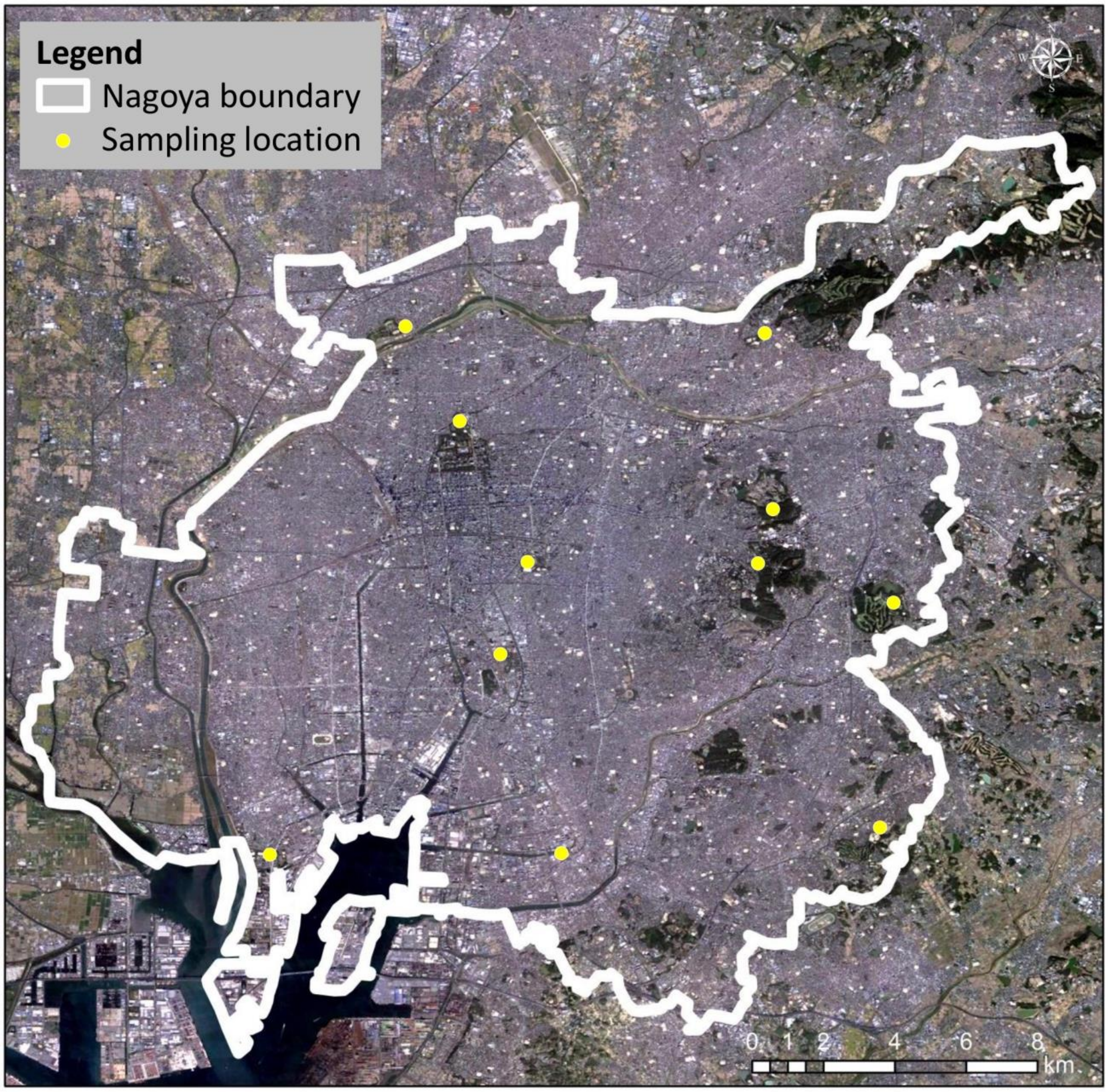


Figure 2.1 Location of hornet sampling sites in Nagoya city, Japan using Google Map 2016 view

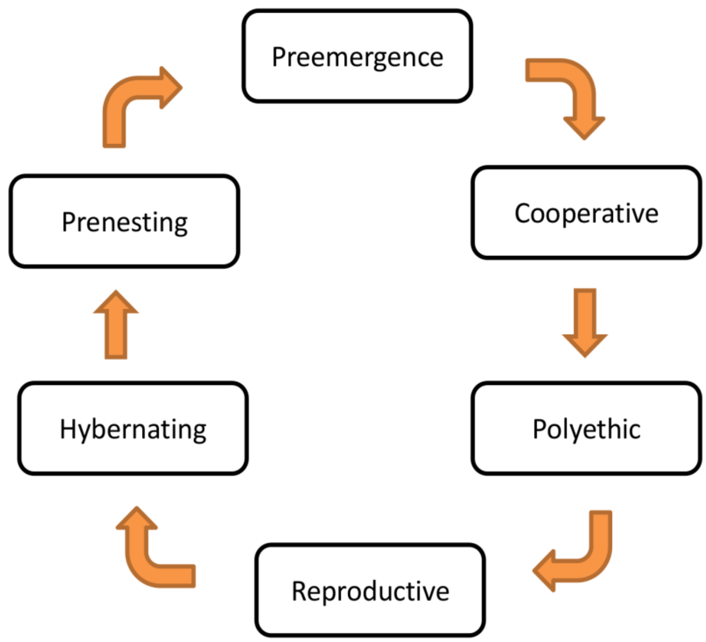


Figure 2. 2 Life cycle of polistine wasps proposed by Yoshikawa (1959)

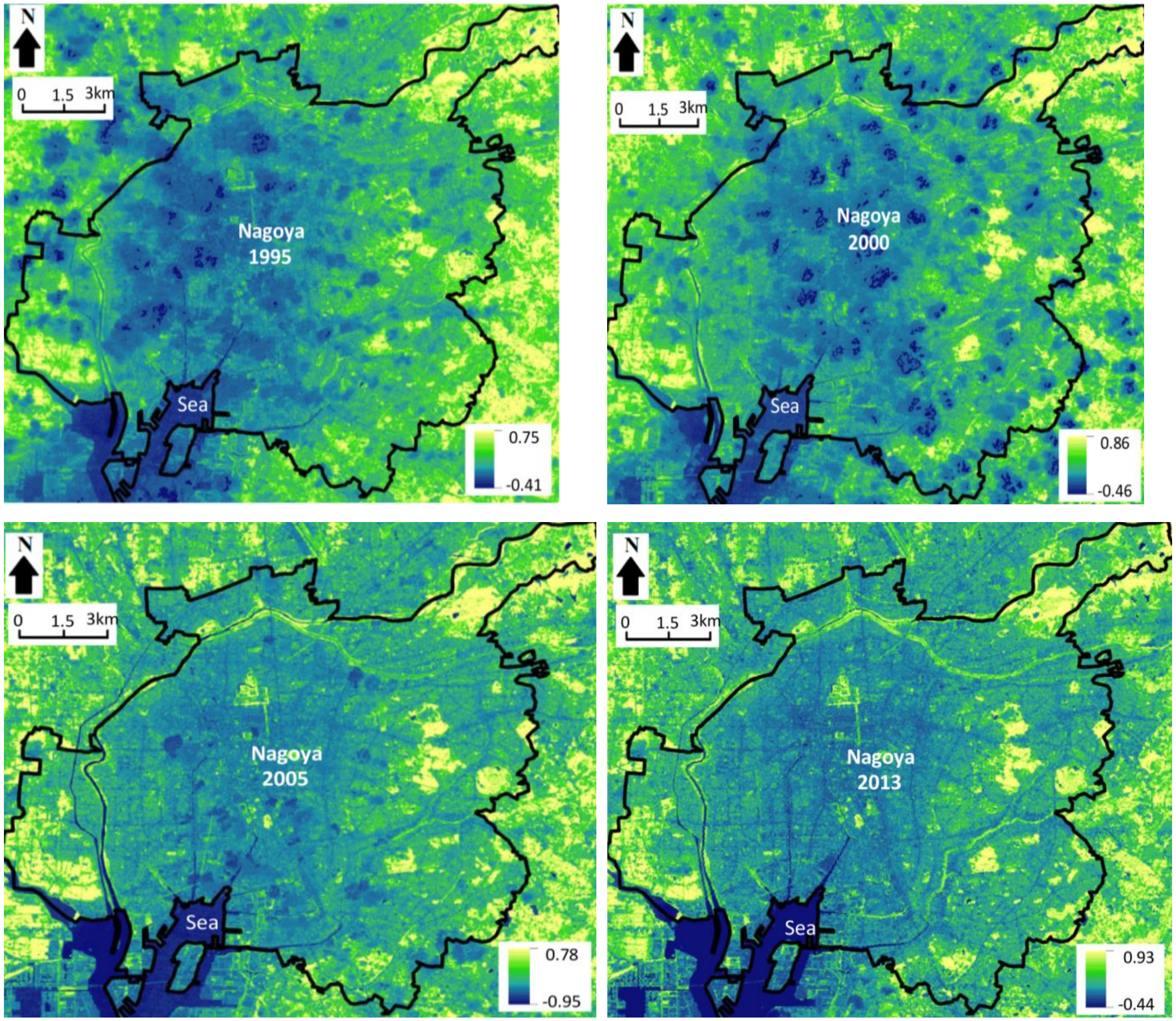


Fig. 2.3 Temporal distribution of greenness level based on NDVI values

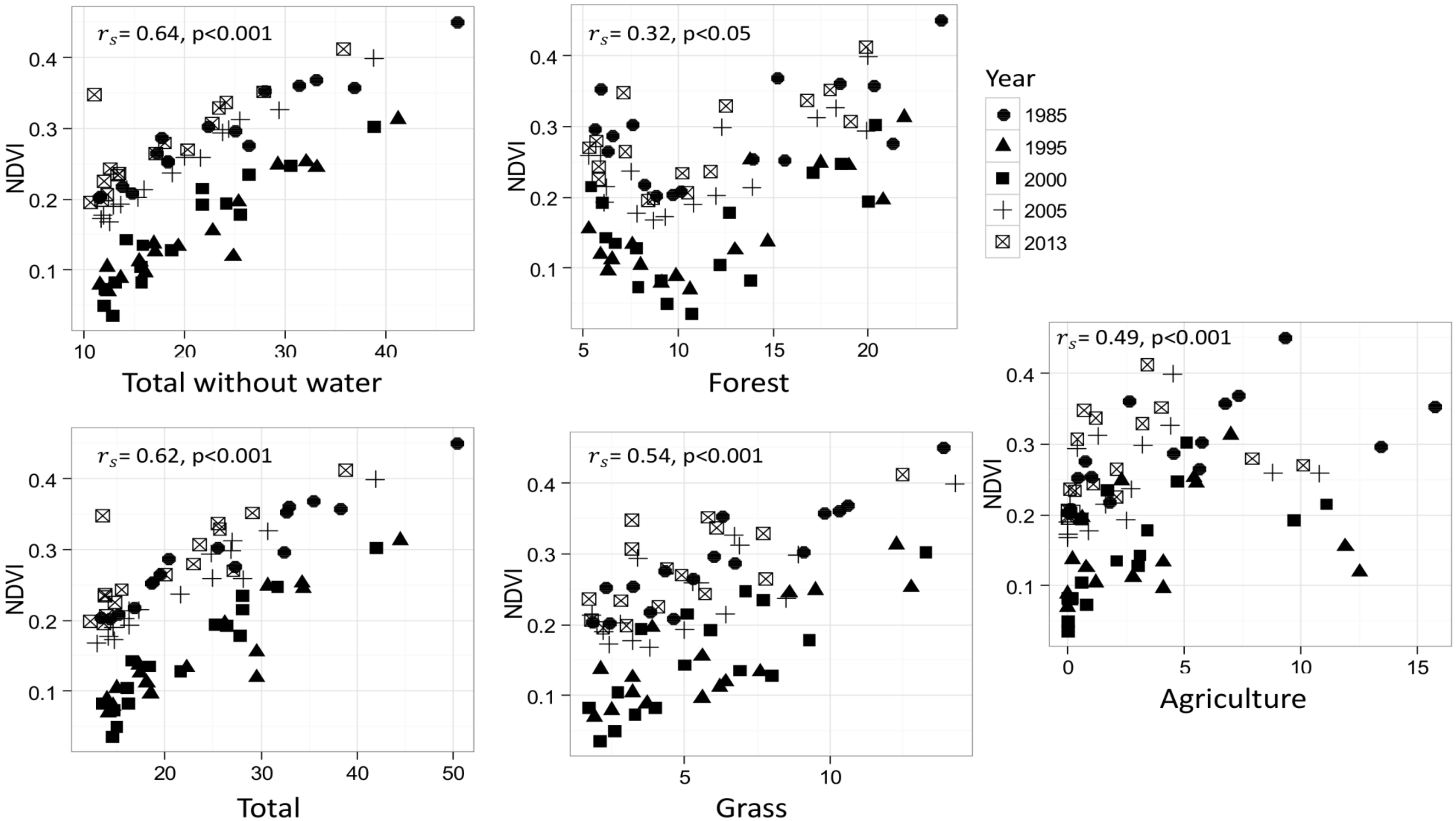


Fig. 2.4 Scatter plot of NDVI values versus percentage of land use type

Table 2.1 Differences in body size of workers, preference for nesting sites and prey, aggressiveness towards humans, and the amount of poison released per individual worker among four hornet species (Vespa spp.) based on Matsuura 1984. The level of aggressiveness and the amount of poison of the five species are ranked, with 1 being the highest level and 5 the lowest.

Features	**Species**				
	V. mandarinia	*V. simillima*	*V. crabro*	*V. analis*	*V. ducalis*
Body size (mm)	27-38	20-28	21-28	22-28	24-37
Nesting site	underground, tree hollow	underground, tree hollow, building eaves	attic, underground, tree hollow	tree branch building eaves, rock wall	attic, underground, tree hollow
Prey	various insects including other hornets	various insects and spiders	mainly cicadas	various insects and spiders	paper wasps
Aggressiveness	← Increasing				
Poison	← Increasing				

Table 2.2 Spearman's rank correlation test between NDVI and percentage of land use type; Forest, Grassland, Agriculture, total and total without water surface areas.

Year of NDVI	Total	Total without water	Forest	Grassland	Agriculture
1990	$\boldsymbol{r_s}$**= 0.97**	r_s= 0.94	r_s= 0.26	r_s= 0.93	r_s= 0.83
	p<0.0001	p<0.0001	p= 0.3262	p<0.0001	p<0.0001
1995	r_s= 0.88	$\boldsymbol{r_s}$ **=0.92**	r_s= 0.56	r_s= 0.73	r_s= 0.56
	p<0.0001	p<0.0001	p= 0.02488	p<0.001	p= 0.0229
2000	$\boldsymbol{r_s}$**= 0.95**	r_s= 0.93	r_s= 0.3	r_s= 0.73	r_s= 0.78
	p<0.0001	p<0.0001	p= 0.2583	p= 0.0018	p<0.001
2005	r_s= 0.95	$\boldsymbol{r_s}$**= 0.98**	r_s= 0.47	r_s= 0.73	r_s= 0.70
	p<0.0001	p<0.0001	p= 0.0679	p= 0.0018	p=0.0027
2010	r_s= 0.71	$\boldsymbol{r_s}$**= 0.76**	r_s= 0.40	r_s= 0.69	r_s= 0.66
	p=0.0022	p=0.0011	p=0.12	p= 0.0033	p= 0.0053
Whole years	r_s= 0.62 p<0.001	$\boldsymbol{r_s}$**= 0.64** **p<0.001**	r_s= 0.32 p= 0.003917	r_s= 0.54 p<0.001	r_s= 0.49 p<0.001

Chapter 3

Response of hornet towards greenness level

3.1Introduction

Green spaces are crucial elements in cities, providing several ecosystem services such as the mitigation of heat island effects, the reduction of pollutants in the air, and the improvement of health conditions for urban residents (Lee and Maheswaran, 2011; Gómez-baggethun et al., 2013; Tsilini et al., 2015). At the same time, the spaces can provide valuable habitats for diverse plants and animals, organisms which otherwise would be unable to survive in cities (Melles et al. 2003; McKinney 2008; Jones and Leather 2012). These benefits are well known as ecosystem services, and this issue has brought global awareness to the importance of urban biodiversity conservation. As a result, the amount of urban green space in various cities around the world is increasing or will increase in the near future (Secretariat of the Convention on Biological Diversity 2012).

This increase in urban green space, however, does not always provide benefits for urban dwellers. Many of the characteristics of urban green spaces are also perceived as negative, particularly for human wellbeing, such as allergen emission, damage to infrastructure and people by plants and animals, fear and stress in dark green areas, and an increase in unwanted species, such as pests and nuisance animals. These negative effects have recently been termed ecosystem disservices (Lyytimäki and Sipilä 2009). In contrast to ecosystem services, ecosystem disservices are rarely discussed in green space management and biodiversity conservation (Lyytimäki and Sipilä 2009; Lyytimäki

2015), with limited quantitative evaluation of these disservices (von Döhren and Haase 2015). Particularly, the possible increase of unwanted wild species due to increase in green spaces have not been demonstrated.

In Europe, East Asia, and Southeast Asia, hornets (Hymenoptera: Vespidae: *Vespa* spp.) create conflicts with urban residents (Choi et al. 2012a). Although they play an important role in ecosystem services, such as pollination and the regulation of pest abundance, they are well known for their poisonous sting, which can sometimes be fatal to humans (Xuan et al., 2010; Kularatne et al., 2014). In Japan from 1983 to 1999, the number of hornet consultations increased in many major cities, including Tokyo, Yokohama, Hiroshima, Sendai, Sapporo and Nagoya (Nakamura 2007). The number of hornet consultations was greatest among pest consultations for local governments over the past 10 years and has increased 2–3-fold over 20 years in Tokyo (T. Hosaka, unpublished). However, due to a lack of long-term data on hornet abundance, it is not known whether the recent increase in the number of consultations is due to an increase in hornet abundance or due to a decrease in public tolerance for hornets in urban areas.

All of the 24 species of *Vespa* hornets are exclusively distributed throughout Asia, except for one found also in Europe (Ono 2007). The ecological characteristics (e.g., preferences for food and nesting sites) and harmfulness to humans of *Vespa* hornets can differ among species (Matsuura 1984, Table 1). Therefore, it is extremely important to understand the factors that affect the abundance of each hornet species in urban environments. The amount of green space, particularly forest space, is one such important factor. Hornets feed on many forest insects, such as caterpillars and cicadas, and build nests in tree hollows (Matsuura 1984; Ono 2003). Some hornet species have also become well-adapted to urban areas, as they use garden trees and buildings for nesting places and use human waste as their food source (Ono 2003; Choi et al. 2012a). Understanding the landscape requirements for each hornet species is necessary to predict changes in hornet abundance in changing urban environments, particularly when there is an increase in green space.

Therefore, the aim of my study is to investigate the effect of urban greenness on the abundance of each hornet species. Hornet abundance data of eight years of was used from 11 sites in Nagoya city and Normalized Difference Vegetation Indices (NDVI) for measuring the level of greenness around the sites. Specifically, we addressed five research questions: 1) does the abundance of hornets increase during these years?, 2) does species composition of hornets differ among sites?, 3) do NDVI values correlate with the abundance and species composition of hornets?, 4) are responses to NDVI values different among hornet species?, 5) which spatial scale is the most effective at predicting hornet abundance and species composition? By answering these questions, our study aims to demonstrate the relationships between the level of greenness (NDVI) and abundance of hornets as one of the examples of ecosystem disservices.

3.2 Data Analysis

To answer the first question, the correlation coefficients for the abundance of hornets and the calendar year of the sampling was examined using Spearman's rank correlation. Abundance data at all of the sites were combined for this analysis. For the second question, non-metric multidimensional scaling (NMDS) was performed using the Bray-Curtis method (Faith et al. 1987) based on the abundance data to examine the dissimilarity of the hornet population compositions. The abundance data for each site and each year were regarded as one sample (i.e., eight samples for each site) for this and the following analyses. The significance of the differences in species composition among sites and years was examined using nonparametric analysis of variance using distance matrices (ADONIS) with 10000 permutations. To examine the effect of NDVI values on the abundance and species composition of hornets, for the third and fourth questions, generalized linear mixed models (GLMMs) were constructed using the hornet abundances (for the total number and for each species) or NMDS1 or NMDS2 scores as the response variables and NDVI values as a fixed effect. Since repeatedly collected data from the same park was used, the park ID was assigned as random effect in the GLMMs. For the last question, models using average NDVI values at 12 different radii were compared. GLMMs based on the Akaike information criterion (AIC) (Guisan et al. 2002) were compared and the model with the lowest AIC was identified as the best spatial-scale model to estimate hornet abundance. However, this also also decided that GLMMs with AIC < 2 from the best models are also substantially supported (Burnham and Anderson 2002). Identity link function and a negative binomial error structure were used for the GLMMs on abundance, while log-link functions and Gaussian error structures were used for the GLMMs with NMDS scores (Zuur et al. 2009). All analyses were implemented using R 3.2 (R Core Team, 2015). NMDS analysis was conducted using the 'vegan' (version 2.2–1 (Oksanen 2015)) package, while GLMMs were analysed using the glmmadmb()function from the 'glmmADMB' package (version 0. 8.0, (Skaug et al. 2014)), respectively.

3.3 Results

3.3.1 Spatial and temporal patterns of hornet species composition

A total of 52,411 hornets were collected from 2007 to 2014, of which 23,162 were *V. mandarinia*, 15,935 were *V. analis*, 8,019 were *V. crabro*, and 5,259 were *V. ducalis* (Fig. 3.1). The correlation coefficients between abundance and calendar year were positive for all of the species, except for *V. crabro* and all species combined, but none were significant. $\text{Total: } \rho = 0.45, V. mandarinia\text{: } \rho = 0.62, V. analis\text{: } \rho =$

0.17; $V. ducalis$: $\rho = 0.36$; $V. crabro$: $\rho = -0.31$. The species composition of hornets was significantly different among sites ('Adonis', F = 15.62, p < 0.001, Fig. 3.2) but not among years ('Adonis', F = 0.85, p = 0.44). Scores for both NMDS1 and NMDS2 were positively related to the abundances of *V. mandarinia* and *V. crabro*, while they were negatively related to the abundances of *V. analis* and *V. ducalis*.

3.3.2 The effect of NDVI on hornet abundance and species composition

NDVI was obviously higher at forest areas than other landscapes (Appendix 3,4). The abundance of hornet was higher at areas with higher NDVI values. NDVI average values at all radii had positive values, except 100 m radius value had a significant positive effect on total hornet abundance (Appendix 1a), suggesting that hornet abundance increases with the amount of green space. Among GLMMs for total abundance, the model using NDVI values for a 2 km radius had the lowest AIC values. At the species level, the abundances of *V. mandarinia* and *V. crabro* were also positively affected by the NDVI average at all radii except 100 m (Appendix 1b, c). NDVI averages of 1.5–5.0 km had a significant or marginally insignificant (p < 0.1) positive effect on the abundance of *V. ducalis* (Appendix 1d). In contrast, the abundance of *V. analis* was not affected by the NDVI average at any radius (Appendix 1e). Based on the AIC values, the abundance of *V. mandarinia* was best predicted by NDVI averages of 1–2 km, while those of *V. ducalis* and *V. crabro* were best predicted by NDVI averages of 1.5–2.0 km. The estimated coefficients for the NDVI were also considerably different among species in the same radius; the coefficients at 2 km were highest for *V. mandarinia*, followed by *V. crabro*, *V. ducalis*, and *V. analis* (Fig. 3.3), suggesting that *V. mandarinia* was the most dependent on green space and *V. analis* the least. NMDS1 scores were positively affected by NDVI averages within all of the radii from 100 m to 10 km. The AIC value was lowest at a 1 km radius (Appendix 2a). The dominant species drastically changed along the gradient of NDVI; *V. mandarinia* was found dominant at sites with an NDVI higher than 0.2–0.3, while *V. analis* was dominant at sites with an NDVI lower than these values (Fig. 3.4). The NDVI average had no significant effect on NMDS2 (Appendix 2b).

3.4 Discussion

3.4.1 Spatial and temporal trends of species composition

Since the numbers of nest removals and consultations have increased across large cities in Japan (Nakamura 2007), the abundance of hornets might be increasing in urban areas. In this study, significant increase in hornet abundance during these years was found for *V. mandarinia* but not other species. Therefore, we cannot conclude that hornets are increasing in urban areas, although the sample size may be too small to obtain significant results (n = 8). Since the abundance of hornets can fluctuate due to temperature and rainfall year by year (Kanayama et al. 1997), long-term monitoring is crucial to understanding temporal patterns of hornet abundance.

3.4.2 The response of hornets to green spaces

The level of landscape greenness was strongly affected by amount of forests. Therefore, as expected, the landscape greenness level positively affected total hornet abundance. However, the strength of the responses to the amount of greenness differed among species. The differences are likely related to the species-specific ecological characteristics discussed earlier (Table 1). The abundance of the largest-sized species, *V.*

mandarinia, increased the most among the four species with increasing NDVI values. *V. mandarinia* prefers to build closed nests (Matsuura and Sakagami (1973)) in forest undergrounds around rotten tree roots, cavities left by snakes and rodents, subterranean tree hollows. Also, *V. mandarinia* preys on a great number of large insects in forests (Matsuura 1984). These characteristics would be reasons for the higher abundance of this species near forests.

The abundance of *V. crabro* had the second strongest positive correlation with increasing NDVI values. *V. crabro* colonies prefer to build nests in tree hollows and underground, and they largely prey on cicadas (~95%) among other species such as honeybees and grasshoppers (Matsuura 1984). Cicadas were mostly discovered near forested areas due to their underground activities in soil with low compaction (Moriyama and Numata 2015). Thus these hornets would be more abundant in forest areas. On the other hand, the abundance of *V. ducalis* increased weakly with NDVI values. Since its prey (paper wasps) are also available in semi-urban environments (Michelutti et al. 2013), they are not necessarily restricted to green spaces or forest. Abundance of *V. analis* was not affected by NDVI values. *V. analis* are generalists in regard to prey species and nesting sites, which means they utilize buildings and garden trees (Matsuura, 1984; Choi et al., 2012) and thus can become a dominant hornet species in urban areas. Interspecific interactions among *Vespa* species may also be important to understanding their responses to green spaces. Since *V. mandarinia* is a predator of *V. analis*, the latter may favour urban areas with low greenness where *V. mandarinia* is absent.

The hornet species composition differed spatially but not temporally, suggesting it was strongly determined by spatial environmental factors, such as the amount and quality of green space, rather than temporally fluctuating factors such as temperature and rainfall. It was clear that the dominant hornet species composition changed dramatically with the level of greenness; *V. mandarinia* is dominant in greener areas (NDVI > 0.2–0.3) and *V. analis* in less green areas. The areas with values of 0.2-0.3 NDVI at 2 km contained 5–

10% green space, which was mainly forest. Therefore, even a small increment in green space in urban areas can increase the abundance of *V. mandarinia* and *V. crabro*, which are more aggressive and harmful to humans than are *V. analis*.

The suitable spatial scale for measuring NDVI to estimate hornet abundance was 1–2 km for all of the species. This is reasonable considering the home range of hornets is a few kilometres (Matsuura 1984). The performance of models using NDVI values at smaller spatial scales (100 m or 500 m radius) was lower. For example, NDVI values with a 100 m radius were higher than 0.3 for all sites (Appendix 3), since the hornet sampling was conducted in parks. However, the level of greenness at such a small spatial scale has little power to determine the abundance and species composition of the hornet populations. Therefore, it is obviously important to consider the greenness level of landscapes rather than that of each land use element (e.g., parks and forest patches) to understand the spatial distribution pattern of hornets.

3.4.3 Green space and conflicts with hornets

Many modern cities now try to increase their amount of green space to provide urban residents with ecosystem services and to provide diverse animals and plants with habitats in urban areas (Secretariat of the Convention on Biological Diversity 2012). With more green spaces expected in the cities, urban dwellers had more opportunities to interact with nature (Kansky and Knight 2014). However, the benefits conferred to wild animals sometimes conflict with the interests of human populations. This study showed that three of the four common hornets were more abundant in areas with more green spaces including *V. mandarinia*, the largest and aggressive species. The increases of the species might induce fear in these green spaces by nearby users and residents (although this species does not make nests on garden trees and buildings as does *V. analis*). Although some studies had demonstrated human willingness to coexist with wildlife based on long history of conflict (Inskip et al. 2016), there are more studies that shows low human wildlife acceptance due to risks and damages expected in the future(Linnell et al. 2003; Dickman 2010). Some studies also showed that human tended to exaggerate the losses due to wildlife such as sharks and bears even though the risk of attack is minimal (Dickman 2010). This suggests that the level of conflicts with hornets (e.g., the number of consultations and nest removal requests) are likely to increase if human-hornet interaction increases.

Notably, our previous study found that the number of hornet consultations per population in each district increased with the proportion of green spaces (particularly forest areas) in Tokyo (Hosaka and Numata 2016). Similarly, wasp nest removal by 119 rescue services in Seoul, South Korea was concentrated around green spaces (Choi et al. 2012a). In Tokyo, approximately half of the 53 local governments (excluding the isolated islands) financially or technically support nest removal from private homes, which normally costs between $100–500 US per removal. Therefore, an increase in hornet consultations may lead to an increase in financial and labour costs for governments. Loses due to the damage caused by wildlife was sometimes more severe than the cost of preventive measure in solving human-wildlife conflict (HWC) such as in United States(Messmer 2009). Direct compensations method to recover communities economic loses, however, also may not be practical due to limited human-power and finance of local governments. Coexistence between human and nuisance wildlife may not be simply solved. Increasing public acceptability towards wildlife may help to reduce conflict in urban environment.

Studies on ecosystem services and biodiversity conservation in urban areas are growing, but they often focus only on the positive effects for residents while ignoring the negative effects (Nakamura 2007). It is key to note that an increasing abundance of hornets would also have positive effects on residents, such as preventing outbreaks of tree pests. However, since negative perceptions have a greater influence on public attitudes towards wild animals than do positive perceptions (Kansky and Knight 2014), ecosystem disservices, including increases in animals causing conflicts, should also be identified and considered before developing greener urban landscapes. For this purpose, it is key to develop an understanding of the spatiotemporal dynamics of not only species for conservation and ecosystem services but also species causing conflicts and disservices in urban areas.

Since hornets are becoming the one of the most important nuisance animals in the number of consultations in Japan, hornet abundance can be one of the relevant measures of ecosystem disservices. The abundance and species composition of hornets were showed dramatically changed with the NDVI. Thus, this study would be useful for urban planners to understand and predict how much and what kind of hornets will be in problem when the greenness level changes. If increase in urban green spaces aim to increase biodiversity and human-wildlife interactions, promotion of understanding how to coexist with not only likeable animals (e.g., butterflies and small birds) but also towards nuisance animals such as hornets would be important. For example, since hornets are only become aggressive when they felt threat, e.g., direct disturbance on their nests (Matsuura 2000), they are usually not dangerous unless human attack or scare them (e.g. flapping hands). Such information is useful as safety precaution during hornet encounter situations which might as well reduce fear towards them.

3.5 Concluding remarks

This study showed how the hornet abundance was not temporally increase plausibly due to limited temporal pattern observed. However, as expected, the species compositions of the hornets were different spatially but not temporally. This is suggested due to consistent spatial environment at the hornet sampling locations. As I showed that NDVI was significantly correlated with abundance and species compositions of the hornet, the responses of each species towards NDVI however are different. Their responses can be related with the ecological characteristics such as nesting and prey preferences which were exclusive by species. Effective range to predict the abundance and species composition of the hornets is within 1 – 2 km radius. This study demonstrates how hornets respond to the urban environment based on nature elements such as green spaces. Since hornets can be dangerous to human being, the side effect of ecosystem disservices partly was highlighted in this study. However the impact of hornet does not totally harmful to human being unless they were distracted or threatens.

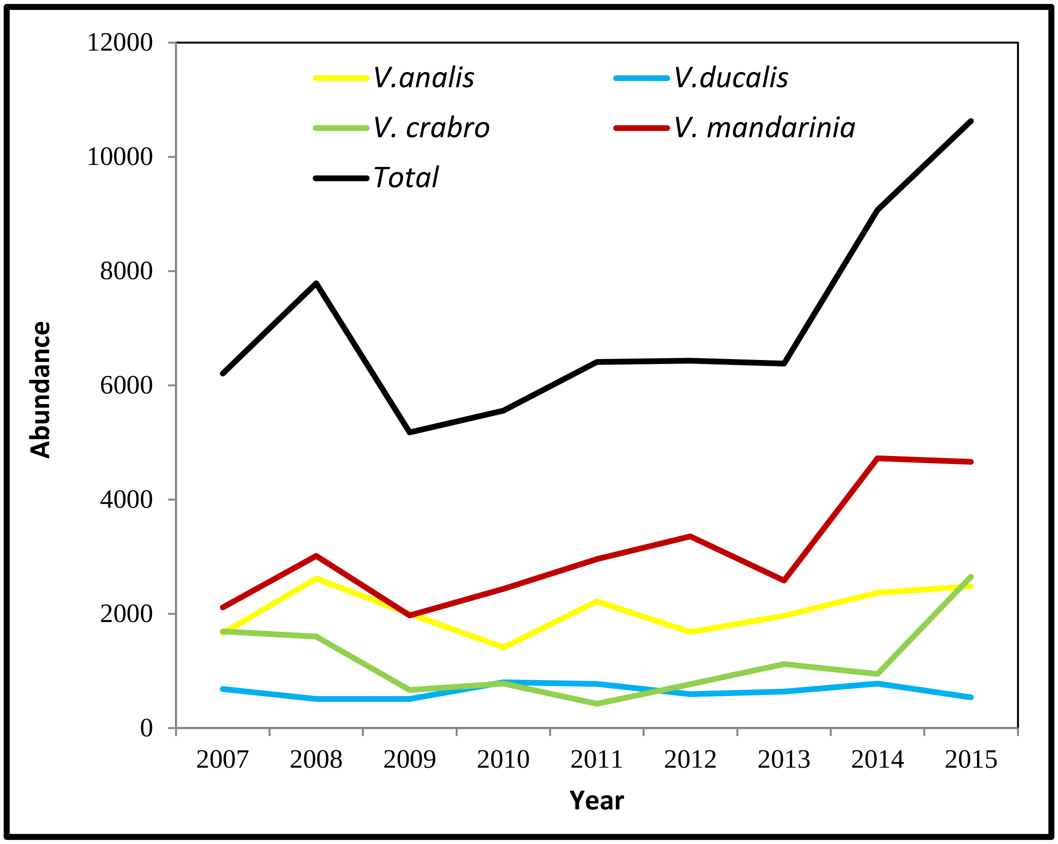


Fig. 3.1 Temporal patterns of hornet abundance with species identification

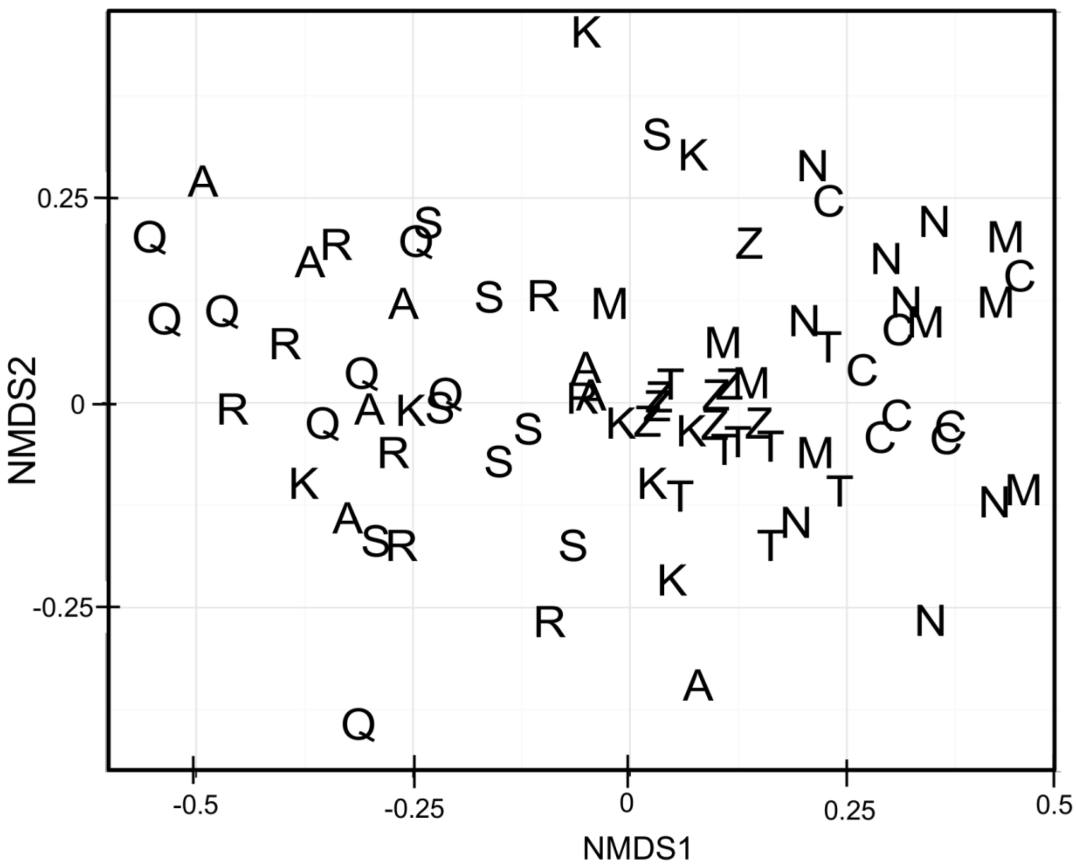


Fig. 3.2 Nonmetric multidimensional scaling (NMDS) ordination based on hornet species composition at 11 sites from 2007–2014. Letters represent trapping sites.

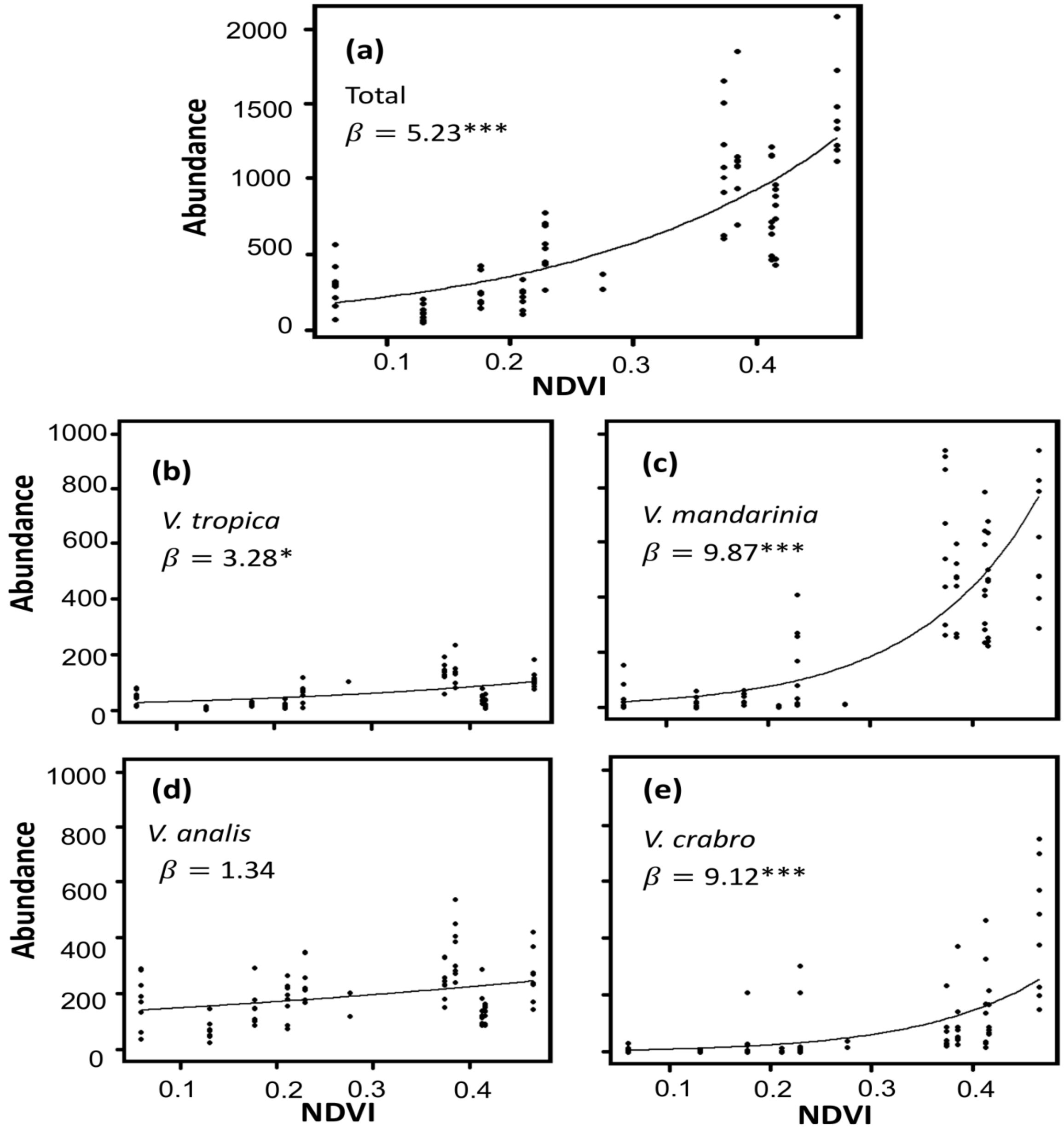


Fig. 3.3 The relationship between hornet abundance and NDVI averages within a 2 km radius. Each regression line was based on the GLMM without a park ID as a random effect for the purpose of visualization. * and *** indicate significant parameter estimates of the GLMMs at $p < 0.05$ and $p < 0.001$, respectively.

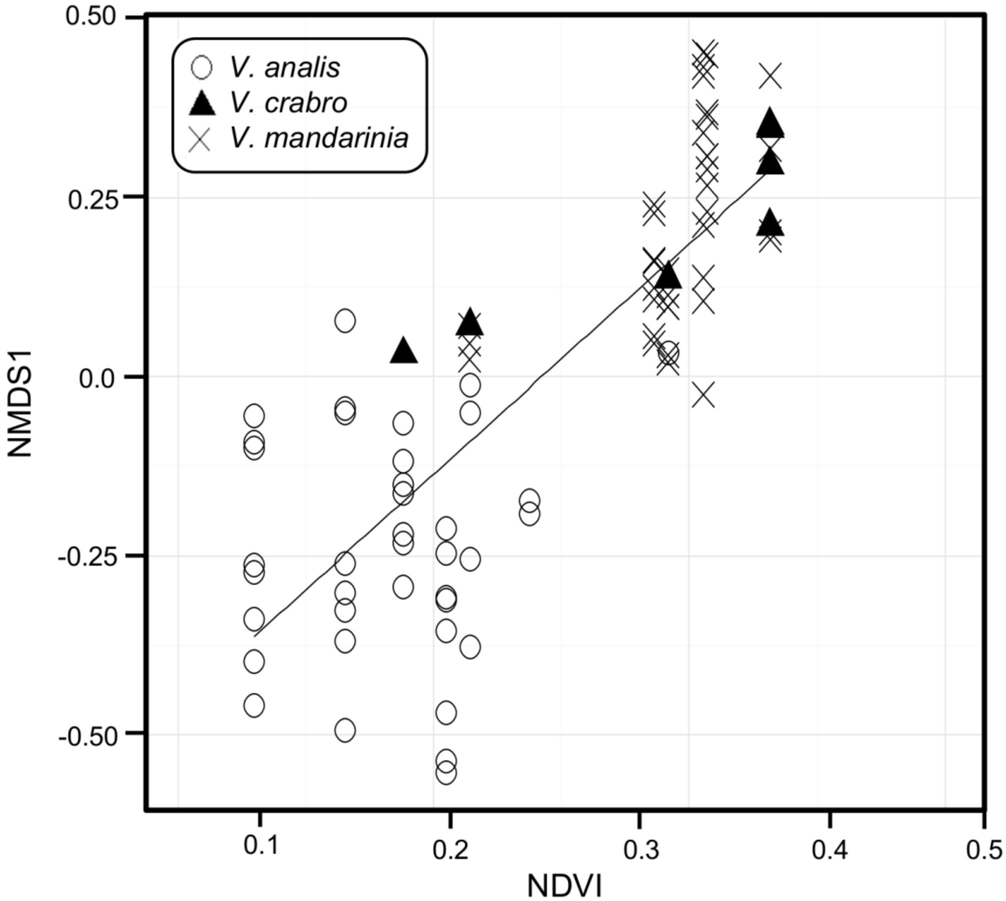


Fig. 3.4 The relationship between species composition at sites (NMDS1) and NDVI averages within a 2 km radius. Symbols represent a site's annual dominant species in 2007–2014. The regression line was based on the GLMM without park ID as a random effect for the purpose of visualization.

Appendix 1 Relationship between NDVI average and hornet (Vespa spp.) abundance with species diversity

GLMMs result using negative binomial error structure. Response and explanatory variables were species abundance and NDVI average within 0.1-10 km radius respectively, while identities of sites are used as random effects. Highlighted AIC values indicate the optimum GLMMs model that describes species abundance.

Species abundance	Parameter estimates	z	p	AIC
1.a) Total				
NDVI 100 m	1.74	0.65	0.52	1131.1
NDVI 500 m	3.61	2.76	<0.001	1125.7
NDVI 1km	5.20	4.54	<0.001	1119.9
NDVI 1.5km	5.14	4.51	<0.001	1120
NDVI 2km	5.23	5.65	<0.001	1116.6
NDVI 3km	5.73	4.42	<0.001	1120.3
NDVI 4km	6.63	4.59	<0.001	1119.8
NDVI 5km	7.57	4.72	<0.001	1119.4
NDVI 6km	6.35	2.65	0.008	1126.1
NDVI 7km	7.09	2.84	0.005	1125.5
NDVI 8km	7.83	3.02	0.003	1124.8
NDVI 9km	8.30	2.96	0.003	1125.1
NDVI 10km	9.19	2.93	0.003	1125.2

Appendix 1 Relationship between NDVI average and hornet (Vespa spp.) abundance with species diversity

Species abundance	Parameter estimates	z	p	AIC
1.b)*V. mandarinia*				
NDVI 100 m	2.99	0.53	0.59	988.6
NDVI 500 m	7.68	2.97	0.003	982.5
NDVI 1km	10.89	5.10	<0.001	976.1
NDVI 1.5km	10.49	4.56	<0.001	977.5
NDVI 2km	9.87	4.45	<0.001	977.9
NDVI 3km	10.78	3.62	<0.001	980.4
NDVI 4km	12.43	3.71	<0.001	980.2
NDVI 5km	14.11	3.74	<0.001	980.1
NDVI 6km	11.29	2.13	0.033	985.1
NDVI 7km	12.78	2.31	0.021	984.6
NDVI 8km	14.50	2.54	0.011	983.9
NDVI 9km	15.42	2.51	0.012	984
NDVI 10km	16.94	2.46	0.016	984.1
1.c) *V. ducalis*				
NDVI 100 m	-0.98	-0.35	0.72	771.6
NDVI 500 m	1.51	0.90	0.37	771.0
NDVI 1km	2.91	4.26	0.099	769.3
NDVI 1.5km	2.89	4.38	<0.001	769.5
NDVI 2km	3.28	2.09	0.04	768.1
NDVI 3km	3.53	1.84	0.07	768.8
NDVI 4km	4.24	1.96	0.05	768.4

NDVI 5km	4.97	2.06	0.04	768.2
NDVI 6km	3.55	1.21	0.23	770.4
NDVI 7km	4.01	1.29	0.20	770.2
NDVI 8km	4.45	1.35	0.18	770.1
NDVI 9km	4.80	1.36	0.17	770
NDVI 10km	5.46	1.39	0.16	770

Appendix 1 Relationship between NDVI average and hornet (Vespa spp.) abundance with species diversity (cont.)

Species abundance	Parameter estimates	z	p	AIC
1.d) *V. analis*				
NDVI 100 m	-0.28	-0.19	0.85	953.8
NDVI 500 m	0.24	0.27	0.78	953.7
NDVI 1km	0.78	0.78	0.43	953.2
NDVI 1.5km	0.95	0.98	0.33	952.9
NDVI 2km	1.34	1.52	0.13	951.7
NDVI 3km	1.34	1.25	0.21	952.3
NDVI 4km	1.54	1.26	0.21	952.3
NDVI 5km	1.79	1.3	0.19	952.2
NDVI 6km	1.23	0.78	0.44	953.2
NDVI 7km	1.46	0.87	0.38	953.1
NDVI 8km	1.65	1.89	0.38	960.3
NDVI 9km	1.79	0.94	0.35	952.9
NDVI 10km	2.10	0.99	0.32	952.8
1.e) *V. crabro*				
NDVI 100 m	5.09	1.10	0.27	837.7
NDVI 500 m	7.75	3.99	<0.001	828.9
NDVI 1km	9.57	5.03	<0.001	825.6
NDVI 1.5km	9.31	4.84	<0.001	826.3
NDVI 2km	9.12	5.43	<0.001	824.6
NDVI 3km	10.12	4.44	<0.001	827.6
NDVI 4km	11.99	4.99	<0.001	825.9
NDVI 5km	13.79	5.26	<0.001	825

NDVI 6km	14.44	4.46	<0.001	827.5
NDVI 7km	15.75	4.71	<0.001	826.6
NDVI 8km	17.31	5.16	<0.001	825.1
NDVI 9km	18.61	5.20	<0.001	825
NDVI 10km	20.68	5.13	<0.001	825.2

Table 2.3 Relationship between hornet species composition (NMDS1 and NMDS2) with NDVI.

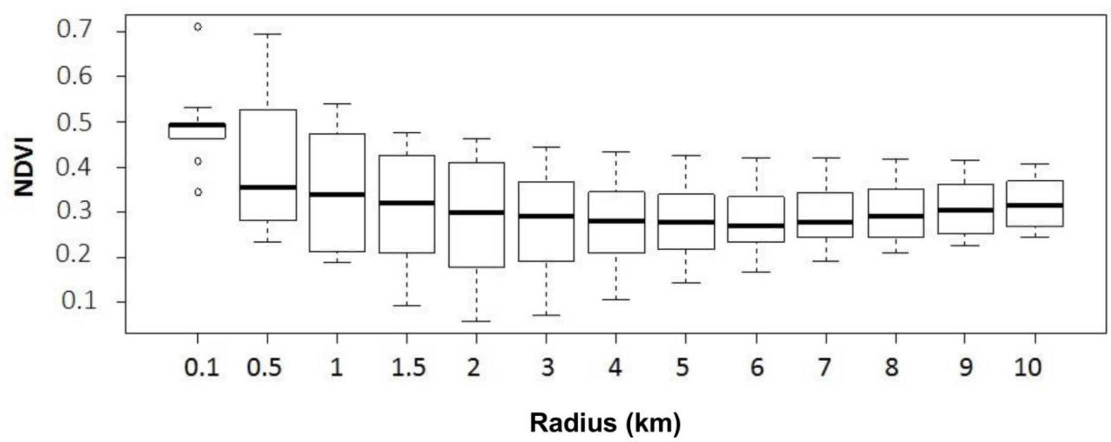
Result of GLMMs with Gaussian error structure using locations species composition and NDVI average in 100m-10km radiuses as response and explanatory variables respectively. Site identities are used as random effect. Bold AIC values indicate the optimum GLMMs.

a) NMDS1	Estimates	z	p	AIC
NDVI 100 m	1.004	1.28	0.20	-66.5
NDVI 500 m	1.455	5.90	<0.001	-77.0
NDVI 1km	1.836	13.3	<0.001	**-90.8**
NDVI 2km	1.614	6.60	<0.001	-79.0
NDVI 3km	1.809	5.25	<0.001	-75.4
NDVI 4km	2.084	5.45	<0.001	-75.9
NDVI 5km	2.361	5.49	<0.001	-76.0
NDVI 6km	2.205	3.50	<0.001	-69.9
NDVI 7km	2.413	3.67	<0.001	-70.5
NDVI 8km	2.667	3.99	<0.001	-71.5
NDVI 9km	2.832	3.90	<0.001	-71.2
NDVI 10km	3.100	3.74	<0.001	-70.7

b) NMDS2	Estimates	z	p	AIC
NDVI 100 m	0.235	1.22	0.22	-68.4

NDVI 500 m	0.111	0.94	0.35	-67.8
NDVI 1km	0.079	0.58	0.56	-67.3
NDVI 2km	0.074	0.58	0.56	-67.3
NDVI 3km	0.089	0.59	0.56	-67.3
NDVI 4km	0.104	0.60	0.55	-67.3
NDVI 5km	0.127	0.65	0.52	-67.4
NDVI 6km	0.249	1.16	0.25	-68.3
NDVI 7km	0.270	1.18	0.24	-68.3
NDVI 8km	0.294	1.20	0.23	-68.4
NDVI 9km	0.320	1.22	0.22	-68.4
NDVI 10km	0.356	1.22	0.22	-68.4

Appendix 3 NDVI average values at 0.1 – 10 km radius from hornet sampling sites



Chapter 4

Impacts of environment on human - hornet conflict in urban ecosystem of Nagoya

4.1 Introduction

The human–wildlife conflict (HWC) is a current issue in urban environments worldwide, as more animals have adapted to areas densely populated with humans (McDonald et al. 2012; Soulsbury and White 2015), in particular due to increased development of green infrastructures to improve biodiversity (Goddard et al. 2009). HWC can be divided into two which first deals with direct impact between human and wildlife such as residential damage, diseases and mortality(Inskip and Zimmermann 2009), second is the conflict between human towards wildlife such as different goals in wildlife conservations (Young et al. 2010). Both conflicts however are potentially detrimental towards emotion, physical and even financial of well-being and communities (Dickman 2010). Combination of increased human population in urbanized environment with human dynamic attitude, induce challenge for urban planners and wildlife managers in solving HWC (Jochum et al. 2014). Preventative measures that are often considered as effective measures in overcoming HWC are not always effective without good measures design, degree of tolerance and strict management of local people (Pettigrew et al. 2012; Inskip et al. 2016). Effectiveness of campaign and education as alternative tools to improve human acceptance towards urban biodiversity (Spencer et al. 2007; Hockings and Humle 2009; Tsuchiya et al. 2014) were not always approved in promoting tolerance towards wildlife (Baruch-Mordo et al. 2011). Limited quantitative information to measure the intensity of wildlife prone areas might hinder the effectiveness of these strategies(Messmer 2009). Spatial and temporal comparison of different conflict intensities areas can suggest us how conflict can be reduced or mitigated using the common pattern that was showed in areas with low HWC.

Urban wildlife studies also have focused mainly on carnivores, birds, and large mammals, where limited attention had been given on fish, herpetiles, and arthropods (Magle et al. 2012). Therefore, there is a lack of understanding on human responses towards the latter groups, even though they are important indicators of urban biodiversity due to their high adaptability to anthropogenic environments (McIntyre 2000). In Japan, existence of stinging insects in urban environments is considered as dangerous pest since approximately 30 people on average died annually from 1979 to1998, due to insect stings (Matsuura 2000). To minimize the dangers of the insects towards the residence, government of Japan has provided consultation and assistance in exterminating unwanted insect nest. The conflict however arises when the number of exterminations demand increased gradually such as in city of Tokyo and Nagoya especially hornet wasp. With technical and financial effort required for exterminations, understanding the drivers of this demand is beneficial to reduce the impact of this conflict. Based on extermination reports of Nagoya city as conflict indicator, this chapter aims to examine the relationship between spatial environment and the intensity of human-hornet conflict in urbanized setting.

The intensity of the conflict in this city was hypothesized to be driven by two factors: (1) rising abundance of hornets due to convenient urban environments, and (2) decrease in human tolerance towards hornets. The first factor was hypothesized based on the minimal habitat requirements of hornets (McKinney 2008) and high temperatures that positively induce hatching rate (Sirassmann and Orgren 1983), which can be found in cities. Moreover, greenness area is a strong abundance factor of some hornet species in urban areas (Azmy et al. 2016). In addition, low human tolerance is a possible factor that promoting this conflict (Dickman 2010). Perceptions of elder generations are generally more negative towards animals that were considered vulnerable towards human, partly due to their inability in defending themselves from dangers due to their limited stamina (Bjerke et al. 1998; Røskaft et al. 2007).

Spatial environmental factors that are plausible in driving human–hornet conflict that was indicated by number of hornet extermination using natural and social environment in Nagoya, Japan, based on ward characteristics were examined. Human-hornet conflict by species distribution was also observed in this chapter since response of hornet towards the environment can be differentiated according to their preferences of nesting, food and prey (Matsuura and Yamane 1990a; Azmy et al. 2016). The influence of land use type of natural environment using areas of grassland, agricultural land, forest, residential and parks were put to test. For social environment, we used ratio of elder generation, women proportion and populations as suggested by previous studies (Røskaft et al. 2007; Xiao and McCright 2015). Consideration on the impact of population in this study is necessary since higher human population would drive higher rate of extermination. The objective is 1) To identify the temporal pattern of human-hornet conflict 2) To examine the effect of natural and social environments on intensity of human-hornet conflict.

4.2Data analysis

Spearman's rank correlation test was used to investigate temporal trends of hornet extermination by species where total exterminations for all wards in Nagoya were combined. To test the second objective, generalised linear mixed models (GLMMs) was used to identify the effects of the land use categories and social characteristics on the number of exterminations. Number of exterminations, including five species distributions, was used as the response variable. The explanatory variables were comprised of percentage of grassland, agricultural land, residential areas, parks, forest, women proportion, elder generation proportion and number of population. Element of year was also used as one of the explanatory variables to control the effect from year since rapid temporal increase of extermination was shown from 1983-2005. The explanatory variables were standardized for standardized regression coefficients comparison. Ward ID was used as random effect because of repeated data that was used from the same ward. The identity link function of negative binomial error structure was used for the GLMMs due to the count data used as the response variable. GLMMs were conducted using the glmmadmb() function from the 'glmmADMB' package for R (ver. 0. 8.0, (Skaug et al. 2014)).Stepwise elimination method was used to choose the best model to describes the extermination. Akaike Information Criteria(AIC)<2 was used to choose the best model to be supported (Burnham and Anderson 2002) and zero-inflated model to overcome the impact of too many zero in the models (Zuur et al. 2009).

4.3Results

4.3.1 Trends of extermination

In general, the number of exterminations increased significantly from 1990 to 2005 (Spearman's; rs = 0.86; p < 0.001) (Fig. 1). The species that accounted for the most exterminations was *V. anal*is (92%), followed by *V. ducalis* (3%), *V. crabro* (2%), *V. simillima* (2%), and *V. mandarinia* (1%). Temporal increases in exterminations were observed for *V. analis* (r_s = 0.85; p < 0.001), *V. ducalis* (r_s = 0.46; p =0.0755), *V. crabro* (r_s = 0.72; p < 0.01), and *V. mandarinia* (r_s = 0.95; p < 0.001), but not *V. simillima* (r_s =-0.43; p = 0.0959).

4.3.2 Impact of spatial environment

Forested areas comprised most of the land, ranges from 5 - 21 % of the ward size after residential areas which ranges from 15 - 41 % (Fig. 2). Agricultural lands were not widely distributed in this city as it holds only up to 10.9 - 11.5% on average in two wards that occupied high agriculture industries, whereas the remaining other wards constituted less than 8% agricultural lands from 1990-2005. Trend for elder generations population was increased steadily in the city ($r_s = 1$, $p < 0.001$), similar with woman proportion that was significantly increased ($r_s = 0.97$, $p < 0.001$) (Fig. 3). High correlations between residential and commercial land suggested that both values were highly dependent ($r_s = 0.88$, $p < 0.001$).

Comparison of GLMMs (Table A1) showed that the exterminations were strongly affected by forest size followed by year and residential sizes compared to other variables (Table 1). Since V. analis was the majority species exterminated, the effect of environment on extermination was largely contributed by this species extermination. All species exterminations were strongly associated with forest areas except for V. ducalis whose extermination was negatively affected by the proportion of elder generations (Table 1). Association of woman proportion, residential and park sizes with exterminations were not relevant. Exterminations were consistently shown low at agricultural land and lower commercial value land based on the negative coefficients in all the models although significant level was not consistently shown.

4.4 Discussion

4.4.1 Removal trends

The temporal increase in the number of hornet exterminations in this city indicates the increase in human–hornet conflict in Nagoya especially for *V. mandarinia* and *V. analis*. Since *V. mandarinia* is the most aggressive and venomous among five hornet species in this study, (Matsuura 1984), understanding the increasing factor of this species in this environment is crucial. The conflict with *V. mandarinia* might have increased accordance to the abundance. I suggest that numbers of the species have increased since the species from the sampling in Nagoya city was relatively increased in 2007-2014 based on our previous study (Azmy et al. 2016) although the trend was not significant partly due to limited sample size.

Interestingly, between two generalist species that we studied, extermination of *V. simillima* was significantly decreasing unlike *V.analis.* High extermination of *V. analis* in this city was expected due to the generalist characteristics of this species on prey and nesting habitat enabling this species to adapt easily into urban environment. *V. simillima* had almost similar characteristics with *V. analis*, it even capable to change nesting sites and occupied both closed and open spaces unlike other species (Matsuura 1984), so why does this species extermination trend declining? We suggested that there is possibility of competition between *V. analis* and *V. simillima*. Based on personal observation, *V. analis* was consistently been found dominant at area with less number of *V. simillima* and vice versa for *V. simillima.* This phenomenon is still yet to be explored.

Majority species that was exterminated in this study, *V. analis* was as expected. Insignificant relationship between the abundance of the species with green spaces in our previous study suggested that this species might be available at green and non-green areas (Azmy et al. 2016). *V. analis* that opted for various kinds of prey and preferences for open nesting spaces such as buildings and gardens (Matsuura and Yamane 1990) might be more adaptable to the urban environment which directly increase their exposure towards human compared to other species. In addition, the increases in exterminations were possibly related to an increased awareness on the dangers of hornets due to media reports and improved technologies in communications (Choi et al. 2012a). Sensitivity towards dangers of hornet in Japan are possibly provoked by the media such as TV and radio services who often emphasized on the dangerous nature of hornet wasps(Nakamura 2007).

4.4.2 Impact of environment

In total, trend of extermination was strongly associated with the natural environment mainly forest areas for all species except *V. ducalis*. This finding was consistent with previous studies that indicated green spaces as potential factor that contribute to higher conflict between stinging insect and human (Choi et al. 2012a; Hosaka and Numata 2016). The trend of exterminations for *V. mandarinia* and *V. crabro* that were highly associated with forest distribution was not surprising since our previous study showed that these species was abundant at greener spaces (Azmy et al. 2016). Availability of prey and habitat for this species in the forest was suggested to assist them in maintaining thecolonies in the forest. The increased number of this species in forested environment plausibly induce human-hornet encounter which indirectly lead to increase of the extermination.

High associations between forest areas and extermination demand including *V. analis* species was not consistent with our previous study since the species abundance was found not related with green spaces using greenness level detected via remote sensing (Azmy et al. 2016). However, different observed factor between the current and previous studies can be related with this distinctive result. Greenness level detected in our previous study using NDVI also involved vegetation covers on grassland other than forested areas (Tucker et al. 1981; Wang et al. 2005) unlike specific forest sizes observed in this study. Higher intensity of conflict with this species in ward with large forested areas suggested the availability and higher dependency these species might be available and dependent Nevertheless, effect of different forest characteristics and building structures might also influent the intensity of species extermination since hornet species were different in terms of nesting and prey preferences affecting their adaptability in forest (Matsuura 1984). Spatial environment near forested areas in this study area might better accommodate the habitat of *V. analis* securing their survival thus, increasing human-hornet interactions.

Hornet exterminations were negatively associated with agricultural areas. I suggest either the agricultural environment was unsuitable for the survival of hornets or high tolerance towards them due to its ability in controlling pests in these areas. Since lower extermination of three species was found associated with agricultural areas, further quantitative analysis might be required to understand the impact of specific agricultural activities that causing such trend. Unlike existence of carnivores and mammals at agricultural areas that mostly perceived as nuisances by farmers (Treves and Karanth 2003; Sakurai and Jacobson 2011) due to the damage caused by the species, existence of insects at agricultural lands might not necessarily be damaging. Removal of agriculture pest by natural enemies was suggested as environmental and economic friendly compared to chemical pesticide used (Matsuura and Yamane 1990a; Bianchi et al. 2006).

Lower conflict can be driven by lower interactions with hornet as most conflict were most affected by the level of human interactions with the observed wildlife (Goulart et al. 2010; Poessel et al. 2013).The limitation of the data that was ward-based however could hinder the effect of social dimension on extermination since impact from individual might be different than the whole community contributing to the factor of irrelevant impact of gender on this conflict. However, although previous studies suggested low tolerance of elder generations on wildlife (Røskaft et al. 2007),my study showed the opposite pattern. Future research can evaluate relationship between the extermination at higher spatial scale such as individual level or specific residential community to provide more understanding on the drivers of extermination decision, such as different tolerance level of urban dwellers that live near forested areas and agricultural areas which likewise can affect the intensity of the conflict.

4.4.3 Recommendations for future implementation

Extermination of hornet in the future is plausibly increasing as shown in this study. However, due to the change of government's policy by limiting free of charge service extermination towards the residents, the trend is expected to be different starting 2006. This showed that the spatial pattern of the exterminations which was different by species might plausibly be associated with the abundance of the species since three out of five species exterminations were highly associated with forest areas that match the species ecological characteristics.

Suggesting drivers of extermination trend in urbanized setting is not simple. While extermination can be dependent on the number of nest, the colony mortality at the nest can be affected by various factors such as loss of queens, climatic factors, not just human interference. Although this study does not show the impact of extermination by level of hornet abundance, human tolerance or human-hornet interaction directly, I showed how conflict between hornet and human can arise in various environments at different hornet species. Since different level of aggressiveness can be expected by each species (Matsuura 1984), conflicts prevention towards each species is crucial to avoid further damage such as fatal encounter.

Land modification had relatively shifted the natural habitats of wildlife (Threlfall et al. 2012; Fortel et al. 2014), probability of human and wildlife encounter will definitely increase in the future especially at human dense areas. Greater food availability from human food waste and fewer predators in urban areas helps in promoting wildlife populations such as hornet(Choi et al. 2012a). By considering benefits of urban biodiversity like hornets as pest control and exotic food sources (van Huis 2011; Choi et al. 2012b), the effects of vulnerability and cost associated with wildlife that strongly determining human negative attitudes towards wildlife during conflicts (Kansky and Knight 2014) might be reduced. Effective campaign and scientific education were recommended to help in promoting biodiversity can be achieved by targeting the areas with high intensity of conflicts such as the areas closer with forested areas. Providing guidelines and examples of how human and hornet can coexist might help to increase awareness on the risk and opportunities available in dynamic urban ecosystems.

Since exterminations were strongly associated with forest areas, conflict resolvement is suggested to be improved at this area. Besides extermination technique to control the number of hornet or conflict, introduction of natural enemies to control the pest such as parasitism and honey buzzard was also found useful (Matsuura 1984; Moriya et al. 2002). Planning of urban development especially residential or community based areas should consider the range of forested areas distribution that is wildlife-conflict potential as consistent with previous studies (Teixeira et al. 2015; Hosaka and Numata 2016).

4.5 Concluding remarks

This study showed the increased of extermination demand from 1990 – 2005. However, although conflict with all species were temporally increased, the increased of *V. simillima* removal was not significant. Competition between *V. simillima* and *V. analis* might contribute to this finding. Removal of hornets in this city was consistently showed high at wards with high forest areas suggesting that this area as the main drivers of conflict. It could be due to the availability of the food and suitable habitat for the hornets in the forest. Increased abundance of them in the forest plausibly increased human-hornet interactions which contributed to higher removal of them near these areas. However, since *V. analis,* the species that was suggested adaptable to urbanized area whose removal was associated with forested areas, this study suggested that urban residents with low tolerance towards hornet might be living near forest environment causing higher removal near forest. With the comparison of human and hornet conflict intensity in accordance to natural and social environment, this study demonstrates risk of conflict with hornet spatially within urban environment especially forested areas.

Hornets as an urban nuisance have been discussed in several previous studies (Matsuura and Yamane 1990a; Nakamura 2007; Yamauchi H 2009b); however, the drivers of this conflict are still blurred as various factors can be associated. However, understanding environment prone for conflict can prepare us for preventive measure. Strong association between forest and high intensity conflict areas suggested us that ecological-based urban planning can be useful to control the negative impact of human-wildlife interactions. However, considering the positive impact of urban biodiversity for livelier city communities improving human acceptance towards wildlife is also important to reduce the conflict. Highlighting benefits of wildlife existence (ecosystem services) during campaign of urban biodiversity conservation might improve human tolerance towards wildlife.

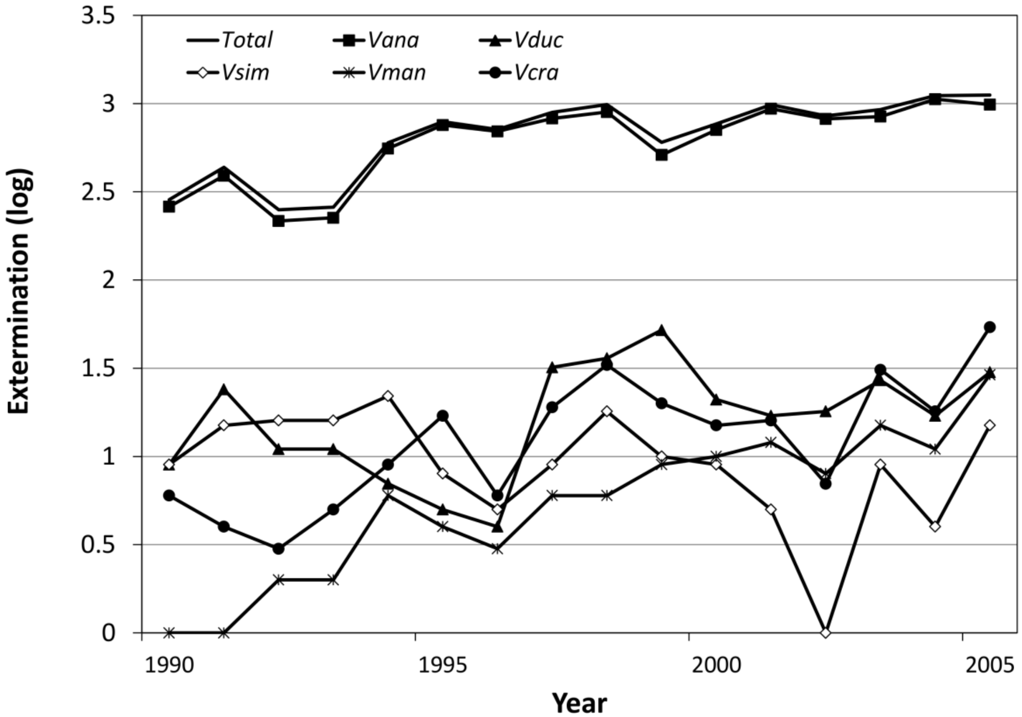


Figure 4.1 Temporal trends of removals from 1990 to 2005 for five hornet species.

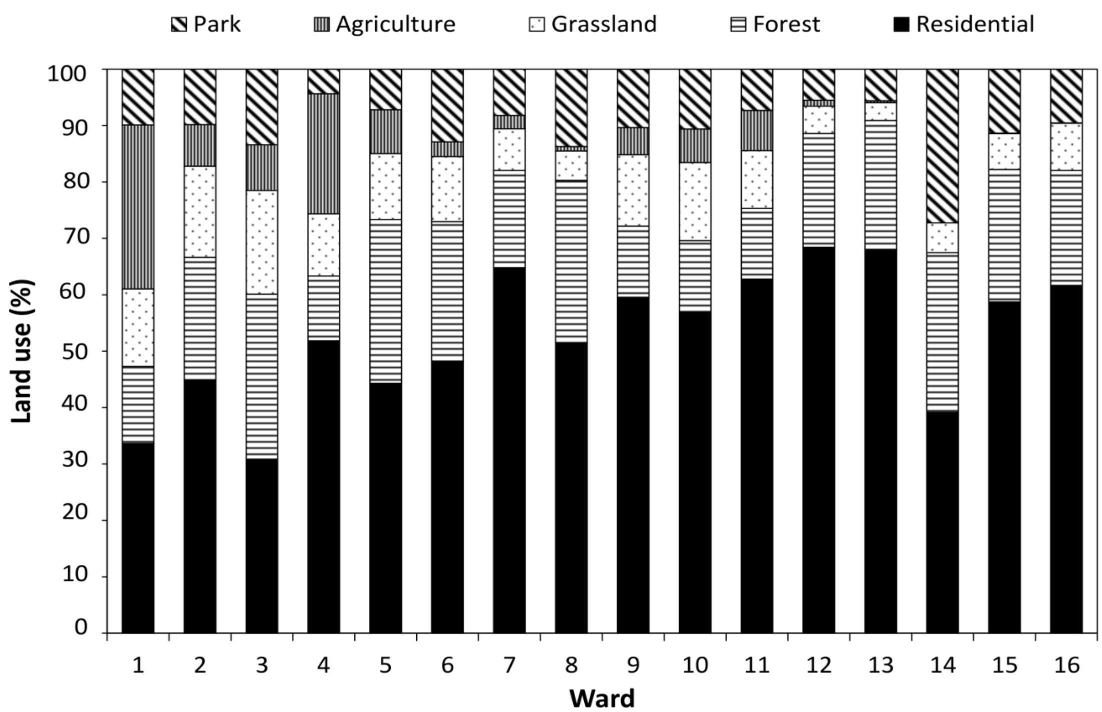


Figure 4.2 Ratio of land use types at ward in Nagoya city where number of ward represents the rank of ward's size starting from the largest.

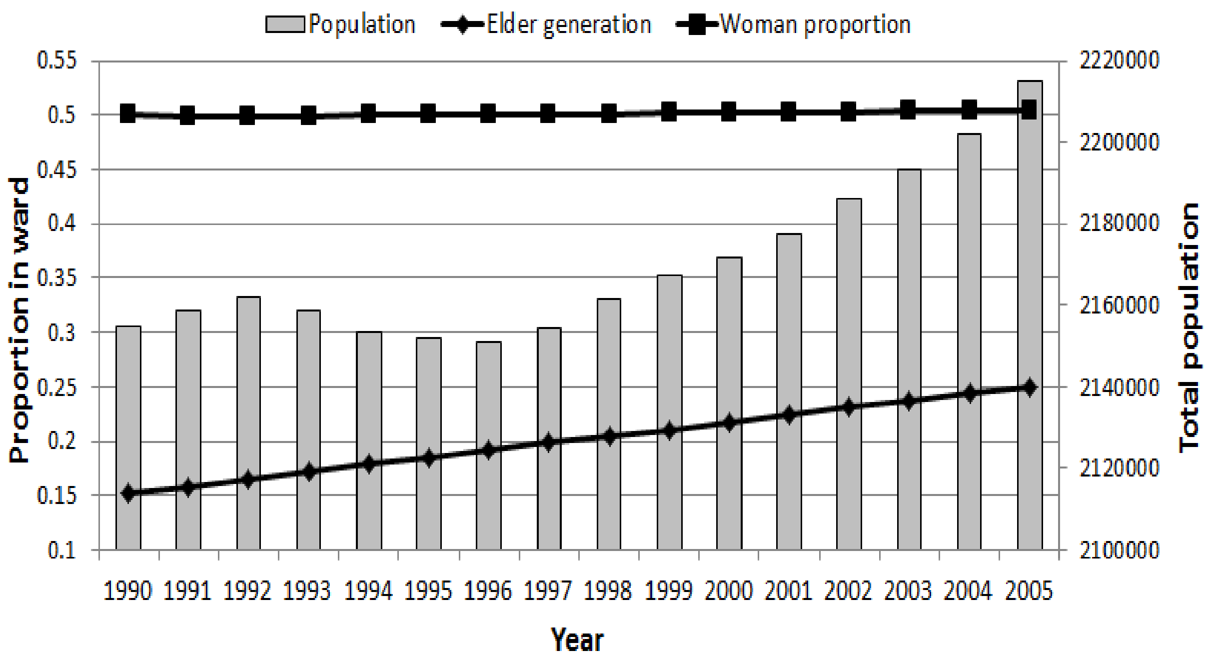


Figure 4.3 Temporal trend of population, proportion of woman and elder generation**.**

Table 4.1 Parameter coefficients of generalized linear mixed models on hornet (Vespa spp.) removals including specific species differentiation based on nine explanatory variables.

	Total	*V. analis*	*V. mandarinia*	*V. crabro*	*V. ducalis*	*V. simillima*
Forest	0.69***	0.64***	1.06***	1.34***	0.66***	1.65***
Year	0.45***	0.44***	0.79***	0.96***	0.68***	-0.33
Grass	0.29***	0.29***			0.34***	0.70**
Residential	0.28***	0.29***			-0.28	-0.70
Elder generation			-0.23	-0.45***	-0.59***	0.13
Agriculture			-0.66*		-0.96**	-1.3*
Population			0.41*	0.40**	0.81***	0.75*
Parks					-0.025	0.15
Woman					-0.08	-0.45

Standardized parameter coefficients of the GLMMs are significant at *p < 0.05, ** p < 0.001and *** p < 0.001, respectively.

Appendix

Appendix 4A Trend of hornet nest removal spatiotemporally from 1990-2005

a) Ward-based temporal trend using spearman rank's correlation test

Ward	Removal					
	Total	*V. analis*	*V. mandarinia*	*V. ducalis*	*V. crabro*	*V. simillima*
Atsuta	r_s=0.84***	r_s=0.84***	NA	r_s=0.20	NA	NA
Chikusa	r_s=0.82***	r_s=0.83**	r_s=0.65***	r_s=-0.13	r_s=0.83**	r_s=0.65**
Higashi	r_s=0.83***	r_s=0.84***	r_s=0.33	r_s=0.20	NA	r_s=0.33
Kita	r_s=0.68**	r_s=0.66***	NA	r_s=0.11	r_s=0.41	NA
Meito	r_s=0.61*	r_s=0.60**	r_s =0.52*	r_s=0.09	r_s=0.37	r_s=0.52*
Midori	r_s=0.83***	r_s=0.85***	r_s =0.66**	r_s=0.36	r_s=0.51*	r_s=0.66**
Minami	r_s=0.74**	r_s=0.71**	r_s =0.40	r_s=0.32	NA	r_s=0.40
Minato	r_s=0.73**	r_s=0.73**	NA	r_s=0.41	r_s=0.49	NA
Mizuho	r_s=0.44	r_s=0.40	r_s=0.44	r_s=-0.08	r_s=0.42	r_s=0.44
Moriyama	r_s=0.87***	r_s=0.87***	r_s=0.64***	r_s=0.67**	r_s=0.46	r_s=0.64**
Naka	r_s=0.71**	r_s=0.72**	r_s=0.36	r_s=0.08	r_s=-0.01	r_s=0.36
Nakagawa	r_s=0.62*	r_s=0.57*	NA	r_s=0.60*	NA	NA
Nakamura	r_s=0.69***	r_s=0.66***	r_s=0.03	r_s=0.41	r_s=0.25	r_s=0.03
Nishi	r_s=0.59*	r_s=0.61*	NA	r_s=0.16	r_s=-0.20	NA
Showa	r_s=0.87***	r_s=0.85***	r_s=0.62*	r_s=0.12	r_s=0.37	r_s=0.62*
Tenpaku	r_s=0.82***	r_s=0.84***	r_s=0.67**	r_s=0.22	r_s=0.67**	r_s=0.67**

Correlation coefficients of the GLMMs are significant at *p < 0.05, ** p < 0.001and *** p < 0.001, respectively.

Ward	Removal ratio	Elder gen.	Population	Woman proportion
Atsuta	r_s=0.85***	r_s=1***	r_s= -0.88***	r_s= 0.81***
Chikusa	r_s=0.82***	r_s=1***	r_s= -0.29	r_s= 0.94***
Higashi	r_s=0.81***	r_s=1***	r_s= -0.23	r_s=-0.11
Kita	r_s=0.69**	r_s=1***	r_s= -0.94**	r_s= 0.99***
Meito	r_s=0.6*	r_s=1***	r_s=0.22	r_s= 0.99***
Midori	r_s=0.77***	r_s=1***	r_s=1***	r_s= 0.94***
Minami	r_s=0.74**	r_s=1***	r_s= -0.99***	r_s= 0.96***
Minato	r_s=0.69**	r_s=1***	r_s=0.99***	r_s= 0.91***
Mizuho	r_s=0.45	r_s=1***	r_s= -0.96**	r_s= 0.95***
Moriyama	r_s=0.87***	r_s=1***	r_s=0.99***	r_s= 0.91***
Naka	r_s=0.70**	r_s=0.97***	r_s= -0.30	r_s= -0.77***
Nakagawa	r_s=0.58*	r_s=1***	r_s=0.997***	r_s=0.99***
Nakamura	r_s=0.7**	r_s=0.98***	r_s= -0.99***	r_s= -0.77***
Nishi	r_s=0.61*	r_s=1***	r_s= -0.37	r_s= -0.71***
Showa	r_s=0.87***	r_s=1***	r_s= -0.69***	r_s= 0.90***
Tenpaku	r_s=0.79***	r_s=1***	r_s=0.99***	r_s= 0.93***

Correlation coefficients of the GLMMs are significant at *$p < 0.05$, ** $p < 0.001$and *** $p < 0.001$, respectively.

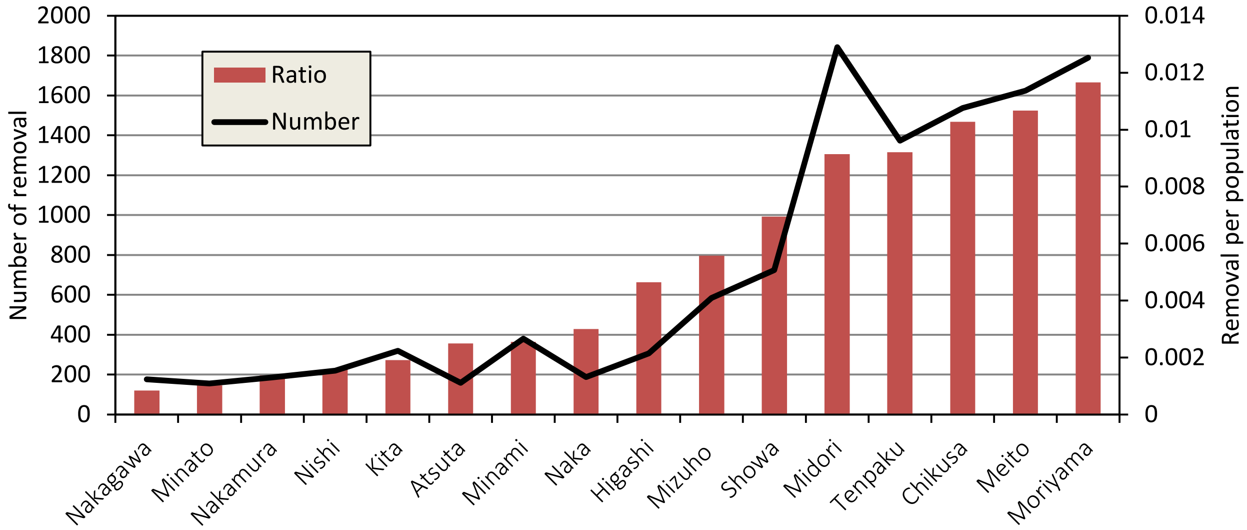


Figure A1 Spatial trend of average number and ratio of removal 1990-2005

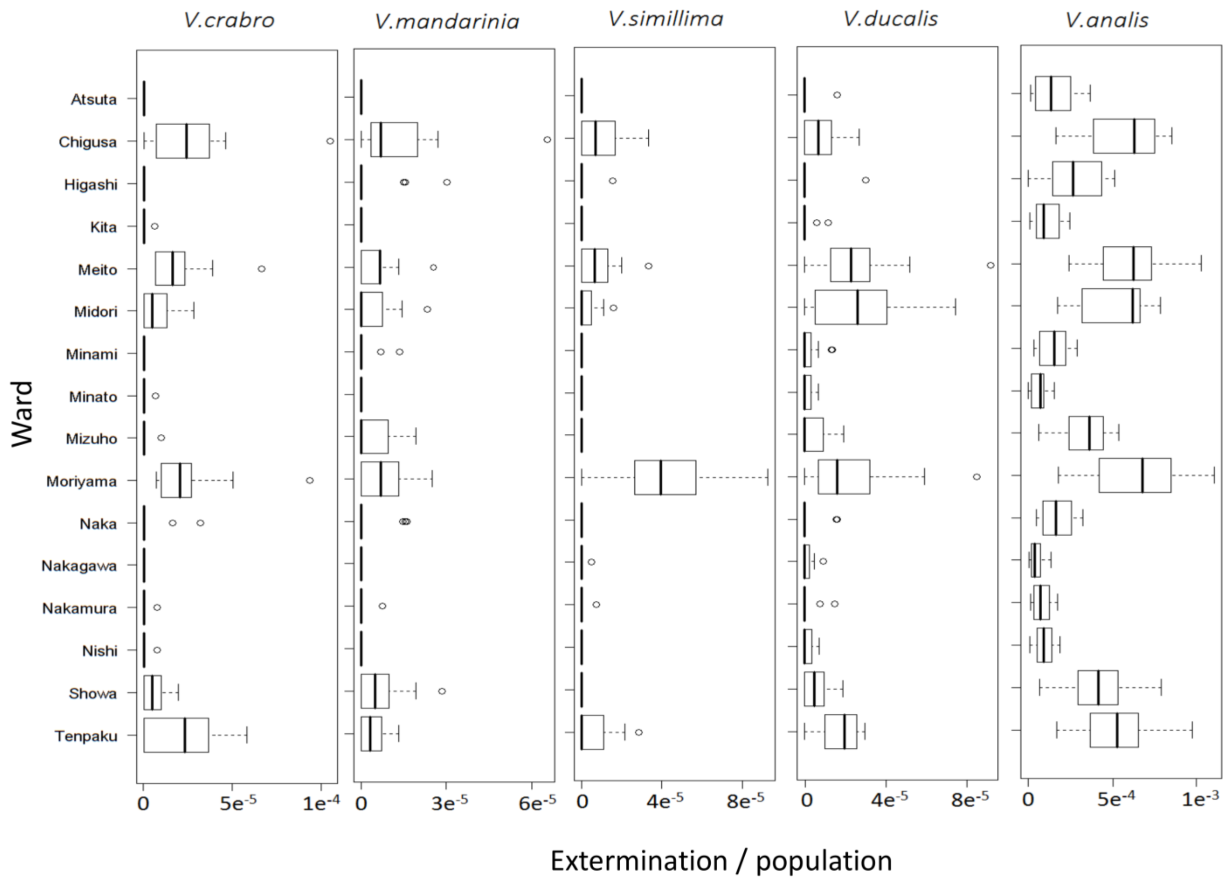


Figure A2 Ratio of hornet (Vespa spp.) extermination (removal) by population at Nagoya wards

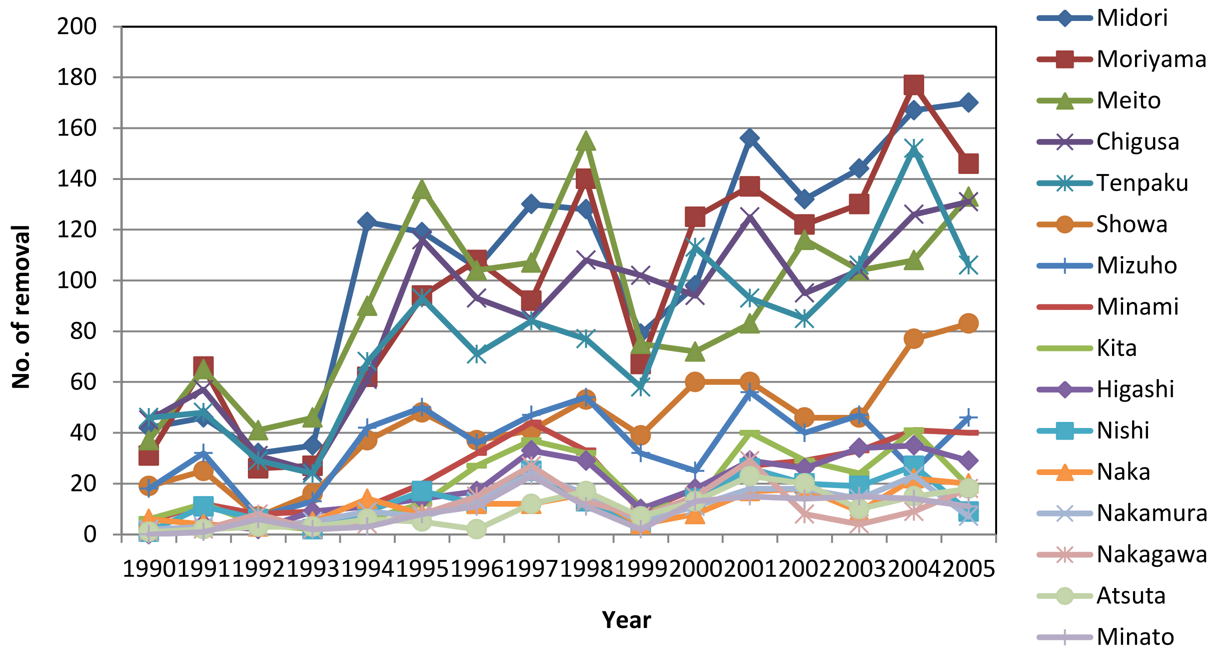


Figure A3 Spatiotemporal pattern of *V. analis* removal

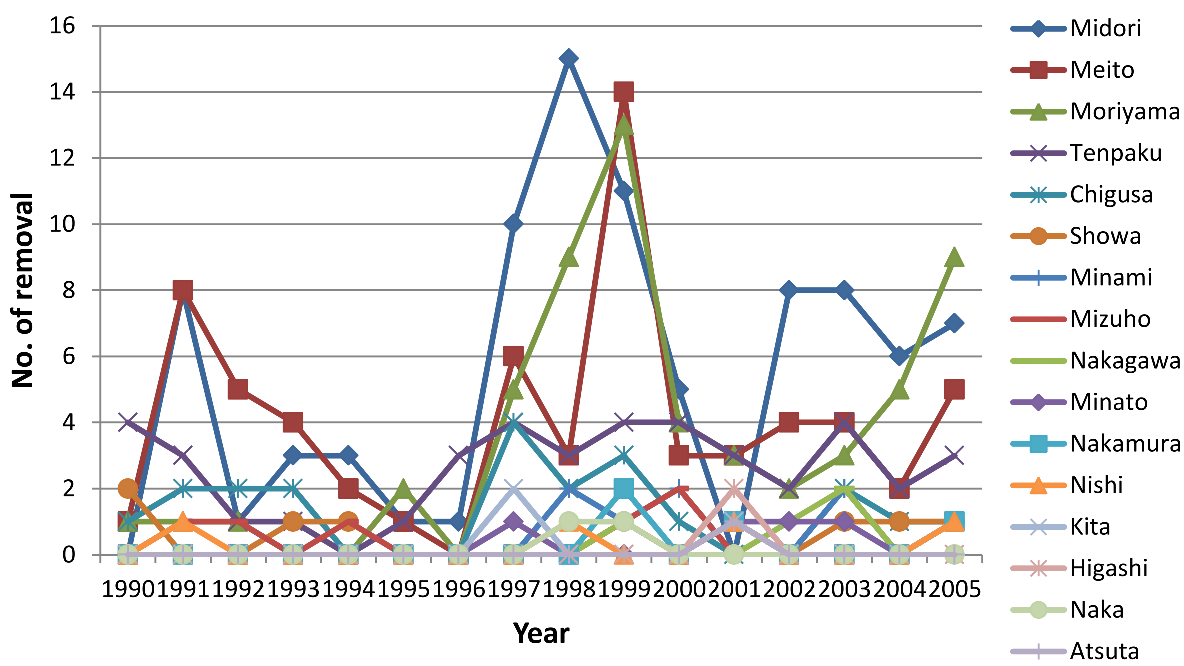


Figure A4 Spatiotemporal pattern of *V. ducalis* removal

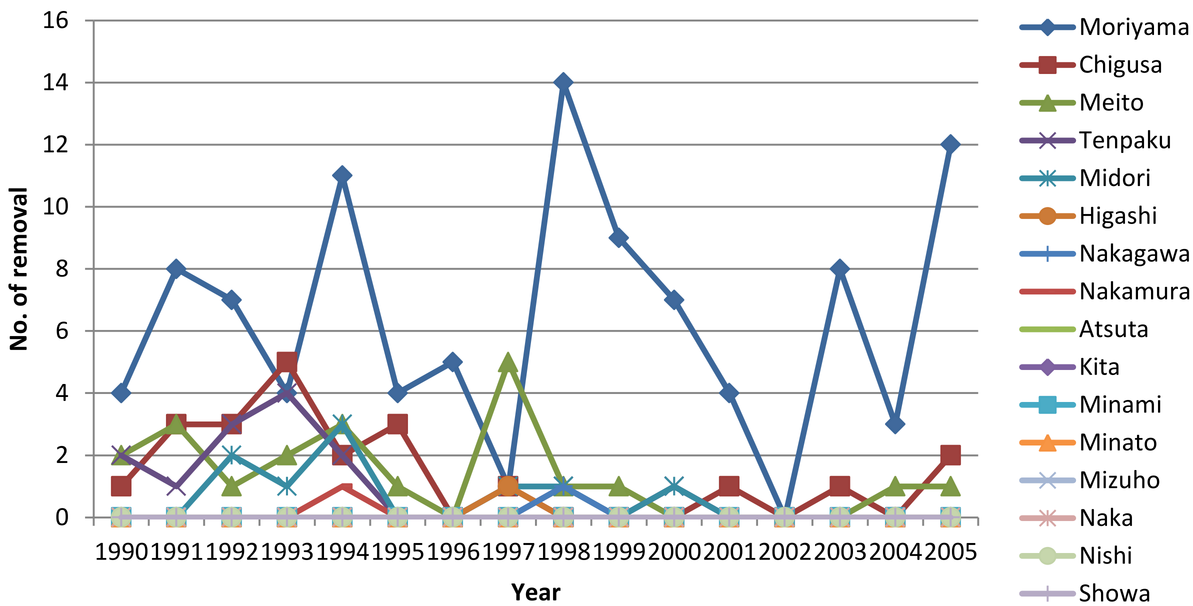


Figure A5 Spatiotemporal pattern of *V. simillima* removal

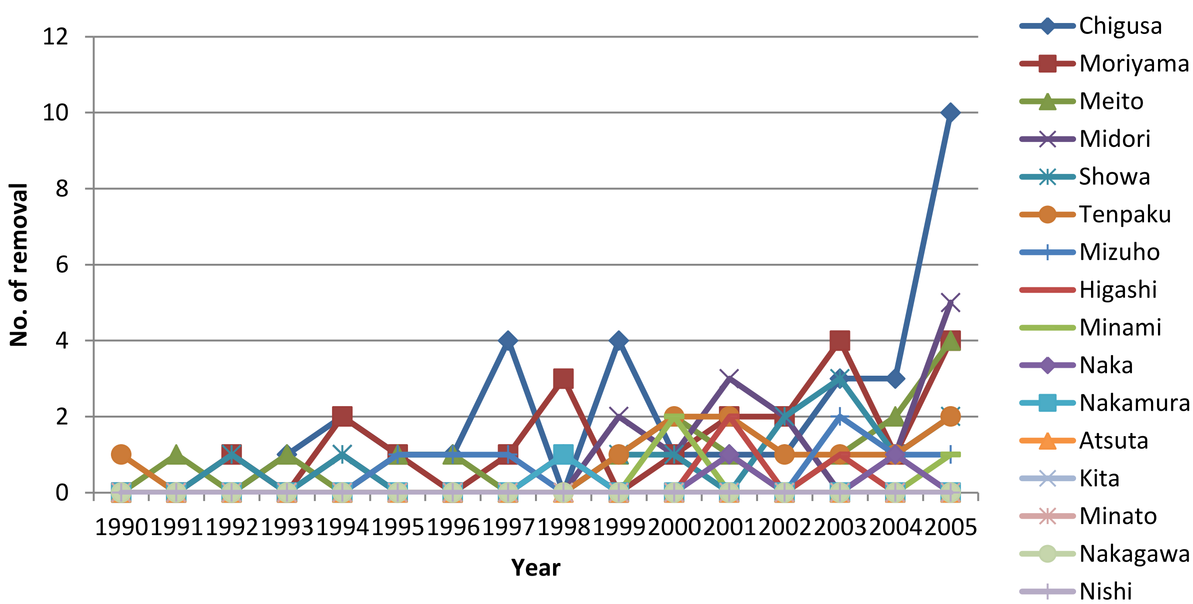


Figure A6 Spatiotemporal pattern of *V. mandarinia* removal

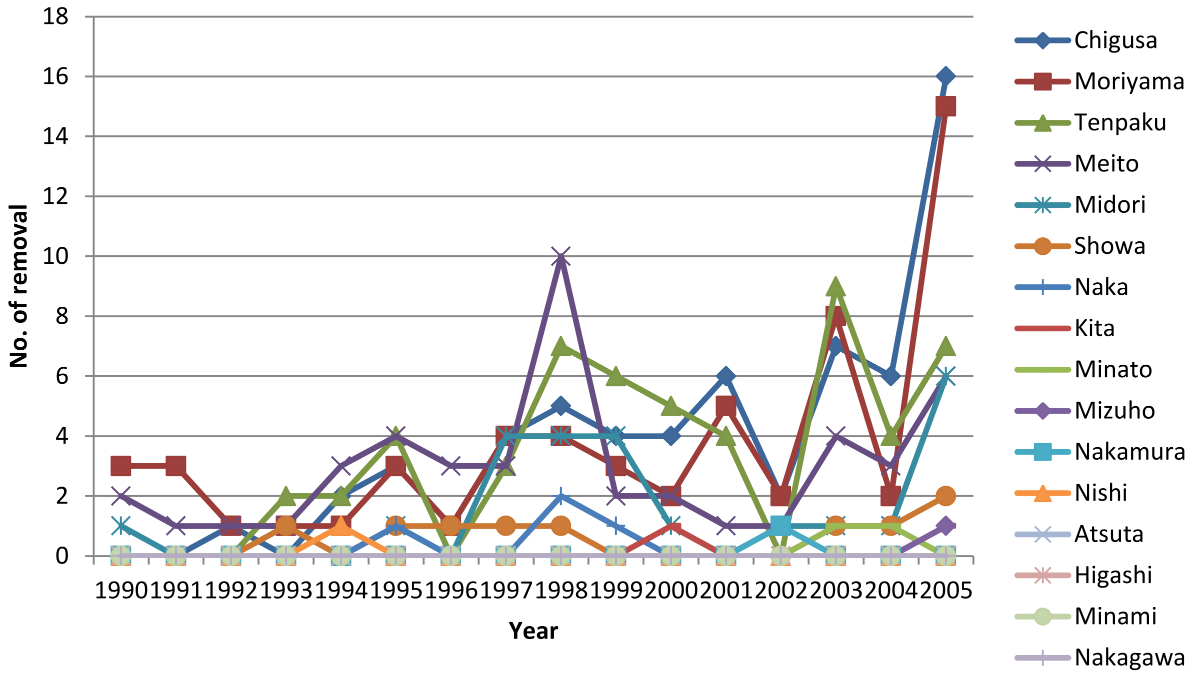


Figure A7 Spatiotemporal pattern of *V. crabro* removal

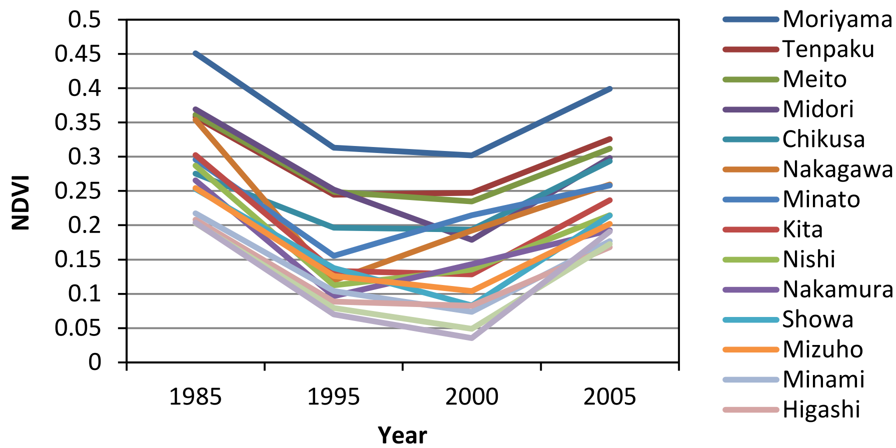


Figure A8 Spatiotemporal pattern of NDVI

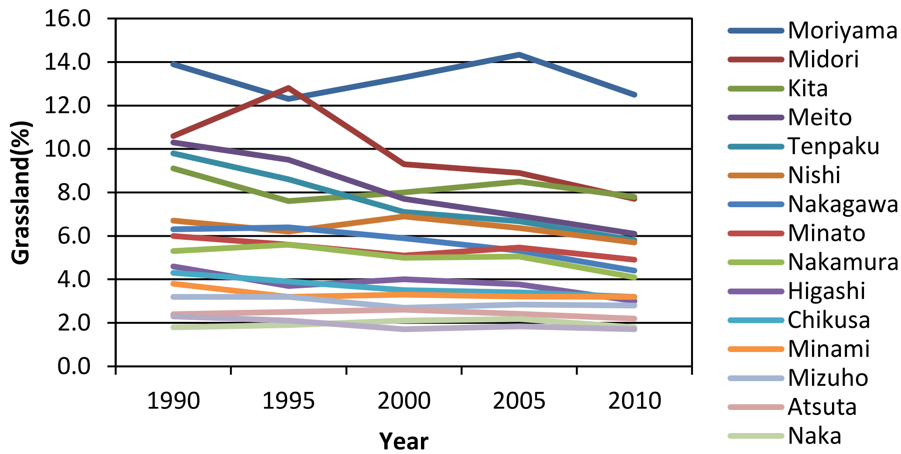


Figure A9 Spatiotemporal pattern of grassland

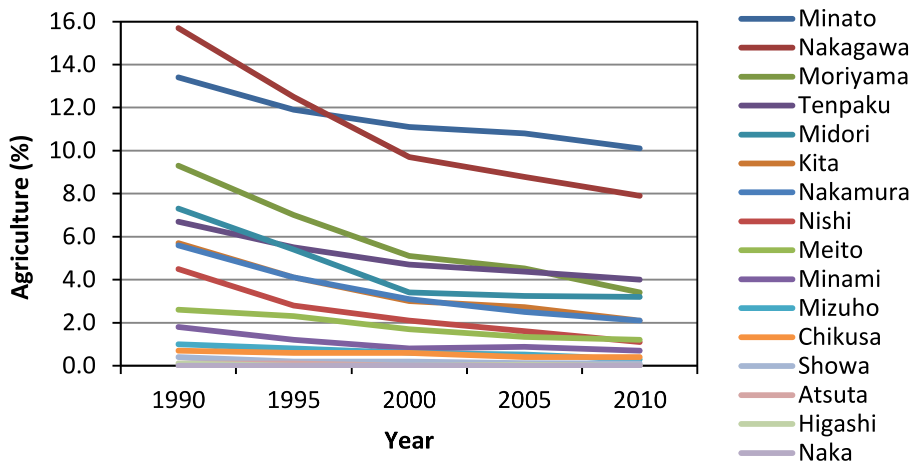


Figure A10 Spatiotemporal pattern of agriculture land

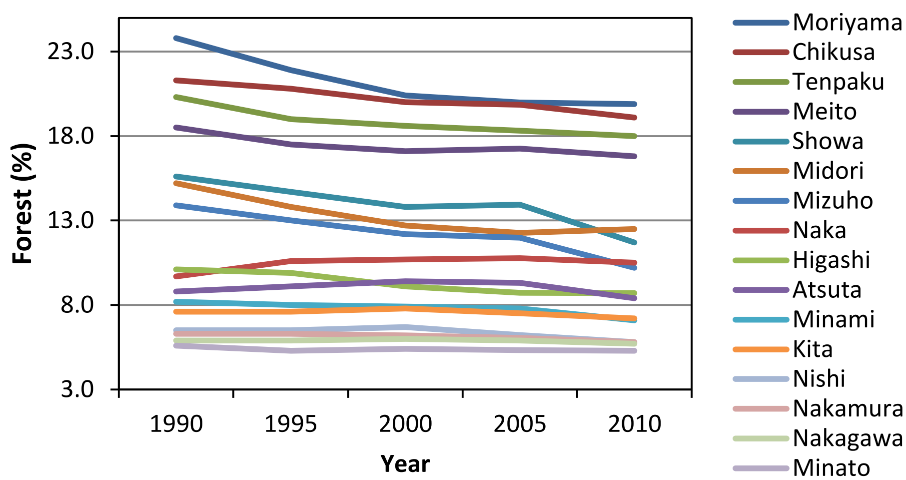


Figure A11 Spatiotemporal pattern of forest

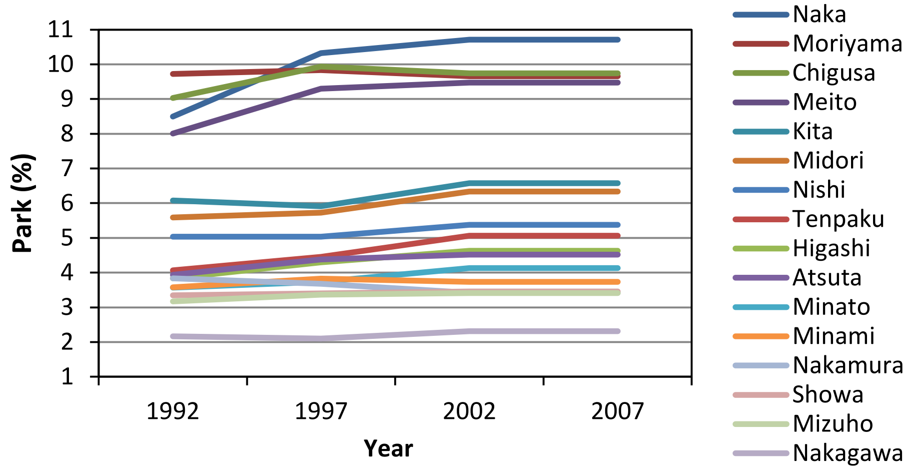


Figure A12 Spatiotemporal pattern of park

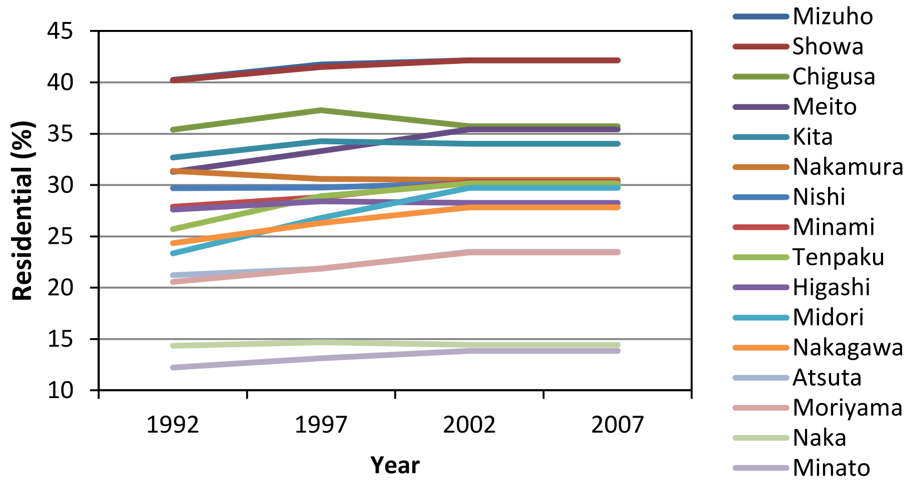


Figure A13 Spatiotemporal pattern of residential

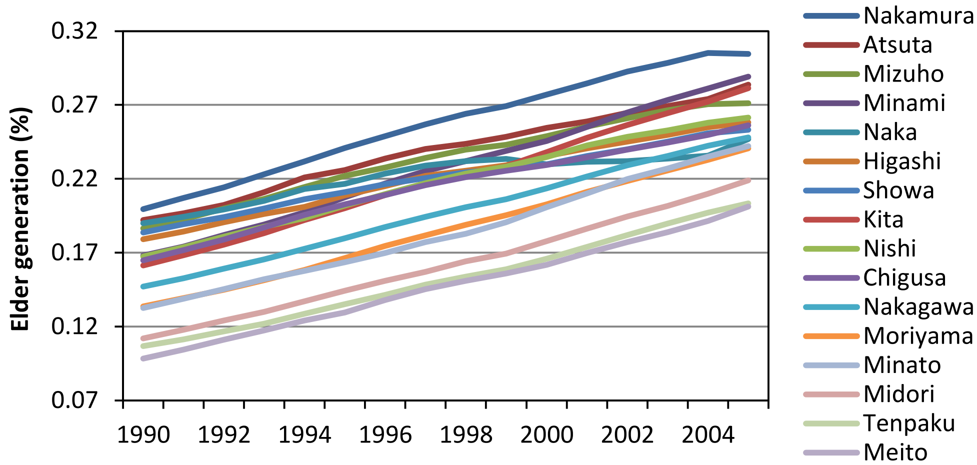


Figure A14 Spatiotemporal pattern of elder generation proportion from 1990-2005

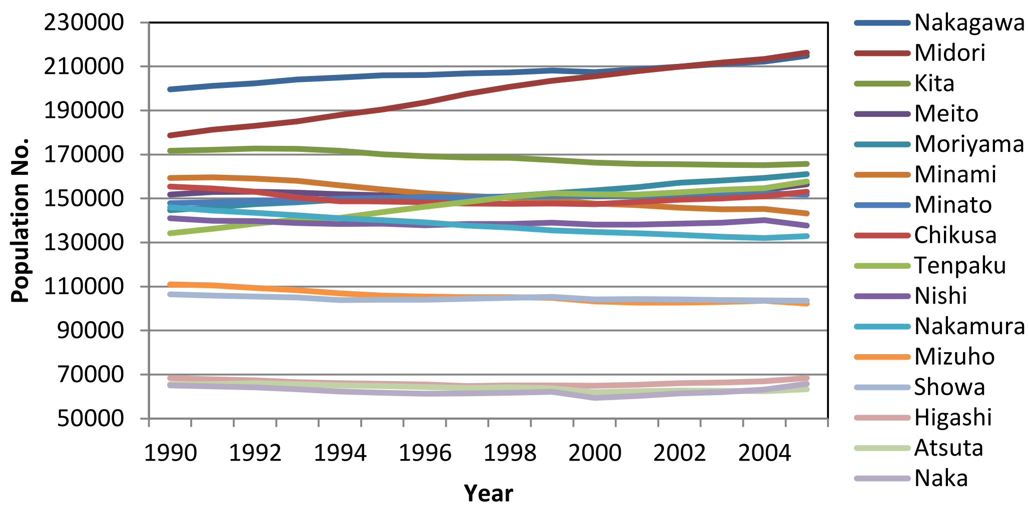


Figure A15 Spatiotemporal pattern of population from 1990-2005

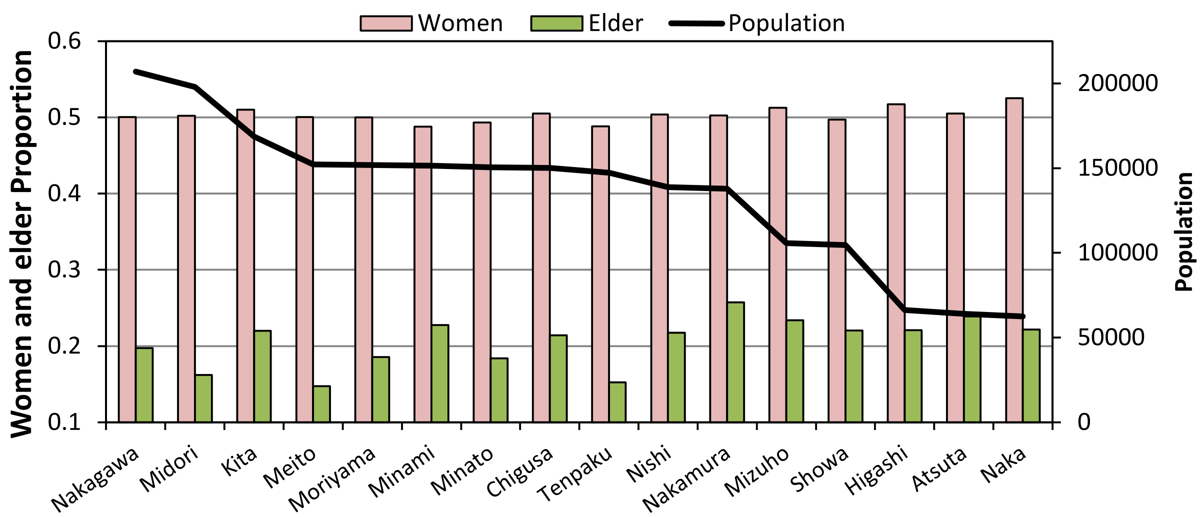


Figure A16 Proportion of elder generation and women proportion with number of population by ward

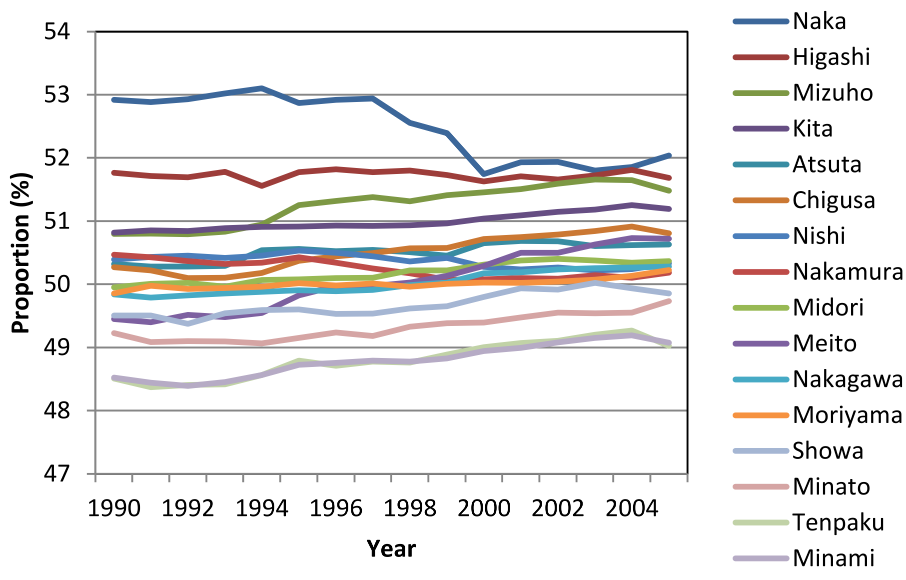


Figure A17 Spatiotemporal pattern of woman proportion from 1990-2005

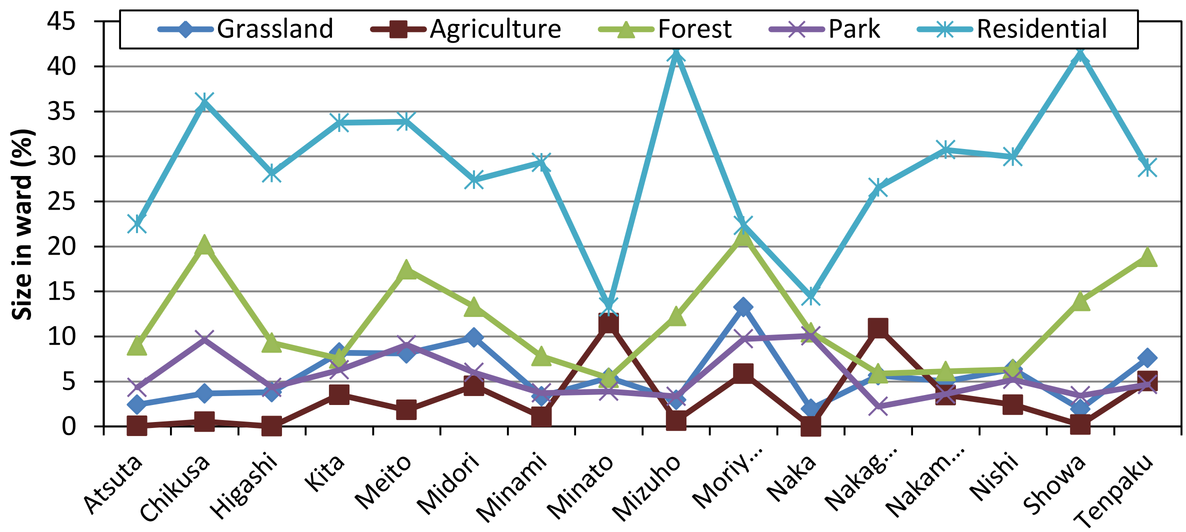


Figure A18 Land use distribution in Nagoya city from 1990-2005

Chapter 5

General Discussion

The existence of wildlife within urbanized ecosystems was well acknowledged. Various daily activities and historical background of urban dwellers shaped different response towards problem solving including situations during wildlife encounter. Although attitudes were not consistently shown depend on education, economic situation, family status and others(Teixeira et al. 2015; Inskip et al. 2016), the variation of response towards wildlife from fear to enjoyment affect conflict management in various ways. With the increase of urbanization that contributes to various other conflicts economically and socially, reducing conflict between human and wildlife is one of the crucial actions to be taken. Mechanism of human and wildlife conflict should be understood, so that the positive effects of human interaction can be increased and at the same time reduce the negative effects.

5.1 Understanding how wildlife responds in urban environment.

As I showed earlier in the introduction, green urbanization is one of the solutions to improve the environment that is dense with human activities. So, cities are the location where ecosystem productivity is at the peak with various types of ecosystems functions can be found. It is able to support biodiversity naturally (McKinney 2008) although the landscape of cities are often highly altered and pressured by human activities that can threat biodiversity. This allows biodiversity to flourish in the growth of urbanizations (Nielsen et al. 2014). Studies have shown that wildlife has well adapted to the human areas partly due to their improvement in adaptive reaction to use elements in human areas as their food sources and habitat. Animal species mostly find their habitats in open spaces where large amount of vegetation and water can be found. Urban parks has been shown to be the most well-known element in the cities that provide best spots for them (Tonietto et al. 2011). Understanding how the animals are able to live in our urbanized environment can assist us to understand how our environment can be worth for sharing without compromising each other's life requirement.

Although there are many positive outputs from urban green spaces for urban dwellers, the negative effects of green spaces are often overlooked. Limited studies have been done to highlight how the ecosystem can be harmful toward urban dwellers (Lyytimäki 2015; Hosaka and Numata 2016). One of the chapters of this study looked at the negative impact of ecosystem using hornet's abundance as the element. Since hornets can cause harm to human through its venomous stings, I showed how this species can respond towards green spaces. Although looking only at four species, understanding how each of these species reacts to our environment can help us to prepare ourselves when associating with community during outdoor activities especially near green areas. This study demonstrated that abundance of hornets would increase if the amounts of green spaces increased in the urban area. However, the increase in hornet abundance may not necessarily result in increase of conflicts or disservices since the level of conflicts is determined by the amount of conflict sources (e.g. hornet abundance) and the level of acceptability among people toward animals causing problems.

5.1.1 Understanding how wildlife conflict took place in the urban environment

With increase of human-wildlife interactions, conflict associated with them is undeniably increased. Solving the conflicts however requires diverse efforts when it comes to dealing with conflict associated with human especially in urbanized environment where various environments and historical backgrounds are shaped individuality. Fortunately, there has been increased numbers of studies that has looked into the spatial environment associated with human-wildlife conflict although the numbers of the studies are still limited. This at least helped us to understand how the conflict could occur in our environment (Poessel et al. 2013; Magle et al. 2014). For this study I showed how the conflict with hornet mostly occurred at wards with large forested areas. This study was also consistent with previous study that showed high associations of urban forests with other types of wildlife conflicts (Hosaka and Numata 2016). This situation demonstrated how green spaces could be detrimental on human tranquillity in the urbanized environment. However, studies using higher resolution of data would improve our understanding to understand how conflict can occur at closer location especially when involving different communities and individuals. Since our study used ward-based characteristics data, dynamic mechanism of individual or micro environment associated with the conflict might be different.

5.1.2 Key to solve wildlife conflict

With increased strategies to improve green environment (Secretariat of the Convention on Biological Diversity 2012), increased number of urban green spaces is expected in the future. Therefore, if we aim to benefit through positive human-wildlife interactions in urban areas by increasing green spaces, it is a key to increase public acceptability for the animals or reduce the number of negative perceptions. For public acceptability, I suggest the primary method to improve human acceptance using knowledge and education (Baruch-Mordo et al. 2011) as the efficient method. Especially with improvement of technologies through media, informative knowledge on benefits of wildlife and importance of biodiversity can be circulated more efficiently. Improving the sharing of knowledge method through working community group would also be beneficial(Tsuchiya et al. 2014) to sustain the knowledge sharing environment. Targeting the group that mostly showed negative attitudes towards wildlife such as older generation is also helpful to assist them in accepting wildlife in their environment. Examples of how human can coexist with hornet in agricultural environment (Matsuura 1984) might improve their tolerance towards the hornets. Identification of risks that plausibly relatable to urban dweller is also important aspect to be considered. Various risks and hazards can be associated within our urban environment which partly shaped by different regional, physical, cultural, political, economic and social components (Fitzpatrick and LaGory 2002). Human- wildlife conflict is one of the elements of risk that need to be considered especially when importance of aspect of biodiversity is encouraged in the society.

In order to reduce the negative interaction between human and wildlife, I suggest that using the environment where human and wildlife often interact as the place to start. As I shown in this study on forest and urban green spaces as prone environment for hornet-human conflict, I recommend that the management of these spaces should be efficiently designed. Since I showed that the hornet abundance could be affected within 1 - 2 km radius in green environment this suggests that higher level of management should be provided within these areas in terms of safety and regulations. Awareness of dangers towards hornet for example should be well-informed to the public within this range such as putting up sign or wall information. In terms of urban planning, the forest sizes within urbanized location should be controlled to further reduce conflict. Allocating forest into other locations might not be efficient in the case of hornets and wasps for example since the insect can adapt to even fragmented environments compared to bees (Fortel et al. 2014) including other wildlife (Linnell et al. 1996). Building residential areas near forested areas should also be carefully designed to avoid the conflict between human and hornet that mostly inhabit these areas. Assuring the potential residents at residential areas near forested areas might also be beneficial to prepare them on future conflict.

5.2 Conclusion

Despite the negative effects of human wildlife conflict shown near urban environment such as forest, I still underline the importance of greenness in the urbanized setting. This is because of the various positive effects provided by green spaces that mostly benefit us spiritually, physically even if not financially. With the recommendations and suggestions in this study, I suggest human can coexist with hornet as well as other wildlife if human can tolerate with wildlife disadvantages and improve the planning of the urban environment more proactively in order to minimize the potential of human-wildlife conflict.

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