POPULATION ECOLOGY AND THE HABITAT SUITABILITY OF NORWAY RAT (*Rattus norvegicus*) IN SELECTED URBAN AREAS OF PENANG, MALAYSIA

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UNIVERSITI SAINS MALAYSIA

2013

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By

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Thesis submitted in fulfilment of the requirement
For the degree of
Master of Science

June 2013

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful. All praise due to Allah s.w.t for His bless and grace, ultimately I successfully completing this research. This research would not have been possible without the guidance and the help of several individuals who in one way or another contributed and extended their valuable assistance in the preparation and completion of this study.

It's my honour to express the heartiest gratitude and deep sense of obligation to my respectable and considerate supervisor Assoc. Prof Dr. Shahrul Anuar Md Sah, School of Biology Sciences, University Science Malaysia, Penang for his keen interest and propitious for the successful accomplishment of the present study. I am thankful to my co-supervisor, Dr Nurul Salmi Abd Latif, School of Biology Sciences for her valuable suggestions during this project. I feel great pleasure to express deep sense of thanks to Dr. Wan Mohd Muhiyuddin Wan Ibrahim, School of Humanities, for his encouraging attitude, sympathetic and inspiring guidance, and constructive criticism for the accomplishment of this manuscript.

Exclusively thank is also given to my dearly loved husband, Mohd Fadzly bin Hj. Ahmad Sukor for his endless love, patience and support throughout the study. Not to forget, to my cunning and adorable son, Muhammad Al-Fateh Immamuddin for giving me strength to complete this research. Finally, I would like to say million thanks to my parents, Khairuddin Jauhar and Kamaliah Ibrahim, parents-in-law, as well as all members in my family, biologi staff and zoology lab's friends Juliani, Nur Munira and Bidarulmunir. I am so grateful to have them in my life and I will never forget their sincere support, sacrifice and encouragement. Only Allah S.W.T can repay their contributions and prayers.

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LIST OF ABBREVIATIONS

AHP	Analytical Hierarchy Process
CI	Consistency Index
CR	Consistency Ratio
GIS	Geographical Information System
HM	Harmonic Mean
MCDA	Multi Criteria Decision Analysis
MCP	Minimum Convex Polygon
RI	Random Index
SPSS	Statistical Package for Social Science

EKOLOGI POPULASI DAN KESESUAIAN HABITAT TIKUS NORWAY (*Rattus norvegicus*) DI KAWASAN BANDAR TERPILIH, PULAU PINANG, MALAYSIA

ABSTRAK

Satu kajian mengenai ekologi populasi dan ramalan tentang kesesuaian habitat tikus Norway (*Rattus norvegicus)* telah dijalankan di kawasan yang terpilih di Georgetown, Penang. Kajian tersebut melibatkan tiga kawasan penempatan utama; kawasan dalaman bandar (Kawasan A), kawasan penempatan bercampur (Kawasan B) dan kawasan komersial (Kawasan C). Dalam kajian populasi pula, 42 lokasi perangkap telah dipilih di tiga kawasan penempatan utama, yang mana setiap kawasan terdiri daripada 14 lokasi perangkap. Sebanyak 786 ekor tikus telah ditangkap dalam tempoh persampelan selama 10 bulan, dimana *R. novergicus* merupakan spesis tikus yang mendominasi dengan jumlah 748 ekor. Kawasan dalaman bandar menunjukkan penangkapan paling tinggi iaitu sebanyak 321 ekor tikus diikuti dengan kawasan penempatan bercampur dan kawasan komersial; 306 ekor tikus dan 159 ekor tikus masing-masing. Kajian mengenai pemilihan umpan untuk menangkap tikus menunjukkan bahawa mentega kacang bersama roti adalah pilihan yang paling tepat c^2(3, N=163) = 13.04, $p < 0.05$. Taburan *R. norvegicus* di Georgetown tidak sekata tetapi secara berkelompok. Tikus jantan dan tikus betina menunjukkan saiz julat kawasan rayau yang kecil dengan pergerakan yang terhad diantara sarang dan lokasi makanan. *R. novergicus* bergerak aktif pada awal waktu malam sehingga tengah malam antara jam 2100 – 2300 dan jam 0300 – 0400. Peta kesesuaian habitat mempunyai kemampuan

untuk mengenalpasti dan meramal kawasan yang mempunyai kadar infestasi yang tinggi. Data dari hasil tangkapan digunakan untuk proses validasi peta. Berdasarkan jumlah tikus yang telah ditangkap di setiap tiga kawasan penempatan dan peramalan HSI (Indeks Kesesuaian Habitat), menunjukkan bahawa terdapat populasi tikus yang tinggi di bandar Georgetown. Justeru itu pengawalan dan pengurusan tikus ini harus dijalankan oleh pihak berwajib untuk menurunkan bilangan tikus ini di bandar Georgetown.

POPULATION ECOLOGY AND THE HABITAT SUITABILITY OF NORWAY RAT (*Rattus norvegicus*) IN SELECTED URBAN AREAS OF PENANG, MALAYSIA

ABSTRACT

A study regarding the population ecology and prediction on habitat suitability of Norway rat (*Rattus norvegicus*) was carried out in selected urban areas of Georgetown, Penang. The study areas involve three major settlement areas; inner city area (Site A), mixed settlement area (Site B) and commercial area (Site C). In the population study, 42 trapping locations were selected in three major settlement areas, with each area constituent 14 trapping locations. A total of 786 individual rats were caught in 10 months sampling period, with *R. norvegicus* was the dominant rat species; 748 individuals. Inner city area shows the highest captured of 321 rats followed by mixed settlement area and commercial area; 306 rats and 159 rats respectively. Study concerning the bait selection for rat capture shows peanut butter with bread was the best choice of bait c^2(3, N=163) = 13.04, $p < 0.05$. The distribution of *R. norvegicus* in Georgetown is not evenly distributed but in patches. Adult male and adult female show small home range size and the movement is limited between nest and food location. *R. norvegicus* was confirmed to be active during early night towards mid nights, 2100 - 2300 hours and 0300 - 0400 hours. Habitat suitability map has the ability to identify and predict area with high degree of infestation. The map was validated using an independent set of trapping data. Based on the number of rats that had been caught at the three major settlement areas and HSI (Habitat Suitability Index) prediction, it shows that

there is high population of rat in Georgetown city. Thus control and management of this rat should be done by the local authorities to lower the number of this rat in Georgetown city.

CHAPTER ONE

Introduction

1.1 Background of the study

Geographical structures of the habitats that exist in the cities are usually having limited composition in terms of species diversity compared to those in the natural habitats (McKinney, 2002). Many studies have found out that the number of non native species tends to increase toward the urban centre (McKinney, 2002). In relative, only a few species are able to exploit the urban environment that is the result of urbanization. The peculiarity of an urban environment compared to other natural habitat, requires species or animal to show particular lifestyle responses in order to persist. For species that managed to adapt well within the urban surroundings, they often find themselves – relatively - having abundance of food, a lot of dwelling places, less competition, less predators (Galef & Clark, 1971; Lines *et al.*, 1994) and also characterized by unsteadiness in time and space (Pocock *et al*., 2004).

Commensal mammals live in habitats that appear to provide benefits and costs compared with natural and semi-natural (non-commensal) habitats (Pocock *et al*., 2004). Naturally, in native conditions, rodents depend upon wild environment for their existence; their cover and food source are provided by natural means of living (Jackson, 1972; Gilman, 1978). However, in the urban areas, these rodents find cover and food in human settlement areas and in an indirect way, ‘shared’ these basic factors with humans. Therefore, urbanization led to obvious landscape-level

changes and habitat fragmentation that significantly altered the structure and functions of affected natural environment (Niemelä, 1999).

The increase in the number of commensal mammals towards the urban centre reflects a number of human causes (McKinney, 2002). One of the factors is that higher human population densities located close to urban centre produce increasing importation of commensal mammals. Another factor is the increase in anthropogenic area towards the urban centre provides opportunities for commensal mammals to exploit the new resources (Adams, 1994; Marzluff, 2001). Human city dwellers or commonly known as Norway rat or its scientific name is *Rattus norvegicus* have been reported to exploit most urban environment around the world successfully (Traweger & Slotta-Bachmayr, 2005). The distribution of the Norway rat is widely spread in the urban areas showing that this species managed to live 'in harmony' with humans. In urban areas, this commensal rats are more common to be spotted in commercials sections, especially in markets, restaurants, and grocery stores than in residential areas (Godin, 1977).

In this study, the emphasis is given to *Rattus norvegicus*. This is because this species has a close relationship with human and is believed to be the highest number of species that can be found in human settlements (urban areas). The presence of these pests in the urban areas also has brought about a negative impact from the economical and health aspects (Raj *et al.,* 2009; Patergnani *et al.,* 2010). Higher population of commensal rats in human dwellings may expose us to the outbreak of diseases, for example Leptospirosis. This happens via food and water that is contaminated with urine and faeces of rats. In our country, few death cases have

been reported from people infected with Leptospirosis. In terms of economic lost, businessmen will suffer loss due to their stocks been damaged or contaminated by rat faeces, or electrical equipments been bitten by rats.

Georgetown, Penang, although there has never been a death reported due to these rodents (Kaur, 2010), yet preventive measures to hamper the growth of the rat's population need to be taken. The presence of a high population of rats in the city will eventually bring negative impacts to the tourism aspects, especially that now the city is known as the Penang Heritage City.

The radio-telemetry method is frequently used in doing research on home range and movements of small mammals (Nass, 1977; Zwicker, 1989; Buckle *et al*., 1997; Whisson *et al.,* 2007, Gómez Villafañe *et al.,* 2008, Eiris & Barreto, 2009). In Malaysia, the study of home range of small mammals is often related to rodent pest control in the agriculture industry. In the Penang island, study of home range and movements of *Rattus norvegicus* and *Bandicota benglensis* was conducted in several market situated in the island (Faizul Nizam, 2008; Radzlina, 2008).

A stable rat population in the city exists in distinctive colonies and they do not mingle with other colonies (Patergnani *et al.,* 2010). Normally, home range and movement of city rats are smaller than in their natural habitat. The suitable habitat conditions in the city – where the rats can get all the resources needed – made the rats do not linger far from the source. Modification in the urban landscape also prohibits the rats from travelling to different places (Dickman & Doncaster, 1987).

Knowledge regarding the home range of this commensally rat in the urban area is necessary, as it enhance our expertise in controlling the population.

In modern rat control and management, various methods were applied to suppress the population of rat in urban areas. One of the methods is by integrating the application of Geographical Information System (GIS). The application of GIS was widely use in modern rat management to facilitate in the assessment program in order to determine the degree of rat infestation in an urban area (Traweger & Slotta-Bachmayr, 2005).

In this study, the aim of using GIS is to gain information concerning the potential distribution of *R. norvegicus* within the city area. In addition, GIS will help to ease the researcher's effort in searching, analyzing and presenting the data map. Map users often ask questions and these questions usually require extensive research and analysis of maps and related data. Thus, GIS provides powerful automated tools to answer these questions. In this study, several questions have been developed regarding the population and potential habitat of *R. norvegicus* in the town of Penang. In the same time, this will help other researches that are also related to the distribution of any other kind of animals to analyze and make use of the data.

Besides that, the distribution map of *R. norvegicus* can be established using the system integrated in the GIS. The distribution map of rats using GIS can predict areas with a high potential for rat infestation. Since the usage of GIS on the rat population is still new in our country, perhaps this newly introduced application can promote a better understanding about the ecology of this animal in an urban

environment. Furthermore, the knowledge on the spatial distribution of the population is imperative in planning and implementing an efficient rats' control mechanism (Frant & Davis, 1991).

1.2 Research rationale

Rattus norvegicus is a species possessing a highly adaptive potential and can be found in almost all habitats worldwide**.** This rat is also known as a commensal animal and generally has a close relationship with human. An overpopulation of these rats can cause several problems like damage through gnawing, pollution of faeces and urine, and further transmission of pathogens through excrements. However, in Malaysia (especially Penang Island), there is a gap to the report made by the public concerning on the nuisance caused by this rat.

Thus, the rationale of the study is to enhance the knowledge regarding the species' adaptation and behaviour, and to get ready for this species' pest management control in the future. From the study, pattern of the distribution and abundance of this pest in the city of Georgetown can be determined. This is important for the local authorities, especially the Penang Municipal Council, to have a picture of the areas that have been infested by this pest from the information given. Also, from the study, problematic areas with regard to this matter could be determined. Problematic areas mean that the areas have a large population of rats support and serve as an important habitat for this species. It is essential to know the problematic areas so that a solution or control method could be specifically designed for each situation.

Furthermore, by using the GIS, the location of the problematic areas can be determined and this system can also help for further assessment in controlling the rat population. By implementing this system, a more efficient and inexpensive strategy can be implemented in the city of Georgetown to curb the problem.

In addition, the study can identify other factors that increase rat population beside the habitat variable used in the study; one of them is whether the attitude of the public is in support of the rat population. This assumption could be used by the local authorities in their campaign to increase the public awareness and educate them on the impact of the rodent in the urban areas. This is because the matter needs to be controlled jointly by the public and the local authorities. A shift from a short-term method of using rodenticides in controlling rat population to an integrated pest management system can be applied by the local authorities as a long-term control of these *R. norvegicus* when better information are obtained.

Furthermore, the usage of habitat suitability in this study could show that the most important factor that contributes to the outbreak of the rat population in the Georgetown city. The population of rat might vary within the trapping location, thus identifying the factors that caused higher population of rat in certain locations could help lessen the time and energy needed to implement a specific method in those area.

1.3 Research objectives

To better comprehend on the ecology of the commensal rat *R. norvegicus* in the city, a number of research objectives have been outlined. Research on the pests has been conducted in the Georgetown city area that consists of three kinds of human residence, namely the inner city areas, commercial areas and mix-settlement areas (refer Figure 1.1).

The objectives of this study are:

1) To determine the distribution and abundance of *Rattus norvegicus* throughout the study sites and at the same time to determine the potential suitable habitat for *R. norvegicus.*

2) To determine the movement and the home range size of *Rattus norvegicus* in the market and human settlement areas. The home range study was done in the inner city area; in the Campbell market and in police quarters. Detection of the radio-collared rat is able to provide various details such as the rats' active period, nest position, movement distance and patterns.

3) To establish a GIS distribution map of *Rattus norvegicus* in relation to the different habitat features and to develop an integrated habitat suitability mapping using the GIS (Geographical Information System) and Multi criteria Decision Analysis (MCDA) for the control and management of *Rattus norvegicus* for local authorities.

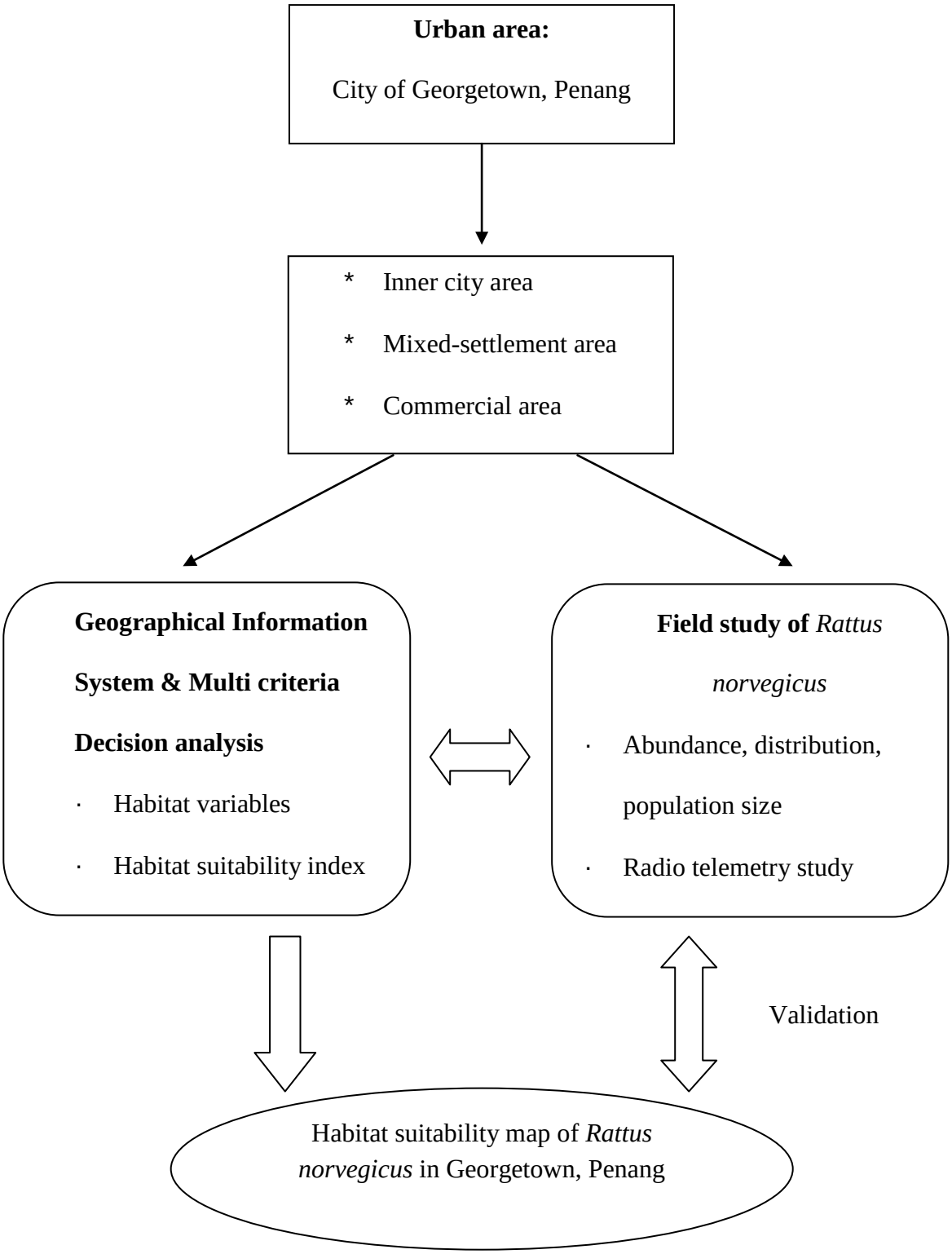

Figure 1.1: A model chart that describes the study objectives.

CHAPTER TWO

Literature review

2.1 Introduction to Rodentia

The Rodentia make up almost 40% of mammal species and represent the largest order of mammals, comprising 1063 species in 228 living genera. Rodentia order also has successfully reached higher number of mammalian which include 28 families (Meehan & Cole, 1974; Macdonald & Fenn, 1994; Aplin *et al*., 2003; Singleton *et al*., 2003). Class into order Rodentia, thus *Rattus norvegicus* belong to the family Muridae and sub family Murinae (Old world rats and mice) (Nowak *et al*., 1983). The genus *Rattus*, has about 56 species (Feldhamer *et al*., 2004).

The name of the order is derived from the Latin *rodere* meaning gnawing. The rodent's incisors are remarkable in their length and in their structure. As for rat, the incisor teeth grow at a rate of about 5 inches per year (Randall, 1999). "Rodents keep their teeth worn-down by continuously working them against each other and by gnawing on hard surface" (Randall, 1999). The incisors teeth in rodents important in cutting all the food into pieces inside the mouth that make it suitable for the check teeth to grind the food afterward. A part from that, the incisor help to remove any hard thing such as roots and also to gnaw access hole in building. The incisors teeth are also essential in collecting material to build a nest, carrying the food, for grooming and defense against predator (Greaves, 1982).

Between the incisors and the check teeth is called diastema. Rodents were classed into the three suborders, based on the working of the bone-muscle pulley systems of their jaws (Macdonald & Fenn, 1994). Rodent play a major role in the ecology of almost all tropical habitats, as seed predators and scatter-hoarding seed dispersal agents, as consumers of invertebrate, small vertebrates and their eggs and as prey for carnivorous snakes, mammals and birds. A study of British owls in the 1980s showed that yellow-necked mice and wood mice formed about 12 percent by weight of the diet of the tawny owl, 14 percent of the long-eared owl's diet and 10 percent of the barn owls. A part from that, 5% from the total 40% of rodentia has become pest, and the rest has become a 'biological agent' in the environment as mention before.

The rodent fauna of Malaysia amounts to about one-third of the total naturally occurring wild mammals in the country. Fifty-five species of rodents have been recorded in Peninsular Malaysia (Medway, 1978) and 62 species in Sabah and Sarawak (Medway, 1977) and common in cities and suburban areas throughout Malaysia (Medway, 1983).

2.1.1 Rat as a pest

Commensal rodent, genus *Rattus* has commonly known as a major pest in the agricultural based country (Faizul, 2008). The main economic effect of rodent pests is to cause loss of agricultural production. Rodents pest are also the reservoirs of a large number of infectious organisms that responsible for transmitting diseases to human and livestock (Traweger *et al.,* 2006). Members of all rodent families have

been implicated as pests of agricultural. Squirells (Family *Sciuridae*), bamboo rat (Family *Rhizomyidae*), rats and mice (Family *Muridae*) and porcupines (Family Hystricidae) are known as rodent pest in agricultural plantation. As in urban area, rodent pest cause considerable damage to manufactured goods and damage on building (Yong, 1992). High adaptability to changing environment and high in reproduction allowed rodent pest to advance side by side with man (Gerozisis & Hadlington, 2005).

In Malaysia, rodent pest represent 10% of mammalian species. In Peninsular Malaysia rats have been recognized as important pests in agricultural (Lam, 1992) for example oil palms for several decades (Wood, 2006). In the case of oil palm plantation, the damage causes by these rats are toward immature and mature palms. They eat the inflorescences and fruits of immature palm. Rats also cause damage to leaves by tearing strips from them to use as nesting materials (Ng & Khoo, 1992) Studies have been made to determine the species involved, to assess the losses, create and imperative pest control and to accumulate biological and ecological information in relation to their status as pests (Wood, 2006).

Rodents pest cause a significant problem for agriculture in Vietnam with rodents damage 20-30% of the annual pre-harvest rice crop. The ricefield rat, *Rattus argentiventer* is recognized as the main pest in the lowland irrigated rice-growing areas of Vietnam (Brown *et al.*, 2005). Similar situation occurs in Dongting Lake region which is one of the most important regions for agricultural production in the Yangtze Valley of China (Zhang *et al*., 2006).

Commensal rodent also has become pests in urban environment. “An explosion in urban development will favour commensal rodent” (Meyer, 2003). The development of urban environments suits their ecological requirement and they are very good at exploiting the urban opportunity. These commensal rodents can tolerate many habitats and can adapt very well especially habitat association with man for instant in human settlement.

Commonly, the commensal rodents usually found in urban areas are *Rattus norvegicus* (Norway rat), *Rattus rattus* (House rat) and *Mus musculus* (House mouse). Norway rat is more terrestrial than house rat, even though not as agile as house rat. Commensal rat could cause some degree of economic damage to country, company and individual. They eat and contaminate large amounts of feed, damage structures by gnawing and burrowing and may spread diseases that affect livestock and people. It can also cause traumatic and emotional problem to certain people (Zahner *et al.*, 1985; Razlina, 2008).

In Pulau Pinang, rat has been reported to be the fourth major pest after, cockroach, mosquitoes and ant. There are reports from the public to Penang Municipal Council regarding the nuisance cause by the rats (Nurul Liyana, 2008). The species known as pest in Penang are Norway rat (*Rattus norvegicus*), House rat (*Rattus rattus*), House mouse (*Mus musculus*) and Bandicoot rat (*Bandicota bengalensis*) (Nurul Liyana, 2008).

2.1.2 *Rattus norvegicus*

2.1.2.1 Origin and distribution in urban areas

The Norway rat *Rattus norvegicus*, also called the brown rat is commonly known as commensal rat (Jackson, 1972; Nowak *et al*., 1983; Traweger & Slotta-Bachmayr, 2005). This rat is also called with many other names; some are brown rat, barn rat, sewer rat or whart rat (Timn *et al*., 1994). Commensal means the rat came to live in habitat associated with human in a human-dependent relationship. In biological sense, the term 'commensal' refers to animal that live as tenants of human and share their food (Greaves, 1982). According to Maria (2002) Norway rats are origin to central Asia. This species is not origin from Norway, but entered Europe in the mid 1500s on ships from Norway. The species spread more to densely populated areas of western Russia in the first decade of the 18th century (Lund, 1994). Based on current distribution, they are spread all over the world, where they can be found most in temperate regions, invaded many island but restricted in Antartica.

R. norvegicus has been distributed throughout the world by water transpotation or by stowing away (Lund, 1994). It also believed that this rat was also spread by trains and automobile. They are also excellent swimmers and may invade new regions. The famous German/Russian naturalist Pallas claimed that seeing on a certain day on 1727, huge number of Norway rats swim over the Volga River close to the town of Astrachan (Lund, 1994).

R. norvegicus live in particularly close association with people and can be found in almost all cities in the world. Study in the city of Salzburg shows that this

rat was patchily distributed around the city. This rat prefers the proximity of water source, which means the place often wet and moist for example sewer, ponds and river (Traweger & Slotta-Bachmayr, 2005). However, it can also be found in dry areas and usually being the primary species around garbage cans, fishing areas and shorelines, shopping malls, restaurant, market and warehouses (Maria, 2002; Nurul Liyana, 2008).

Distribution of *R. norvegicus* in the city of Moncalieri, Italy shows that the distribution of this species are irregularly scattered over the city. It can be found most in water bodies and building without proper maintenance. In area with a stable population or colonies, rats show strong site-fidelity (Sacchi *et al.,* 2008). Rat in an urban area are correlated with derelict buildings and disposal anthropogenic waste (Traweger *et al.,* 2006). High level of habitat disintegration characteristic of urban area in Baltimore, Maryland, causing the *R. norvegicus* to limit their movement within the city areas. The distribution of this rat is concentrate in high food resources area. Most individual were assigned to their area of capture and this shows strong site fidelity (Gardner Santana *et al.,* 2009).

"These rats are rarely found in areas remote from human habitation or arable land" (Greaves, 1982). Today, human settlements are now the ecological niche of this rat: the city, farm, sewer and others (Nurul Liyana, 2008). The reason for the obvious success of these rats because it high adaptation or lack of specificity (Lund, 1994). In Malaysia *R. norvegicus* can be found restricted to coastal towns, including Kuala Lumpur, Kuah Langkawi, Georgetown Penang, Johor and other state as well (Medway, 1983).

2.1.2.2 Behaviour of *Rattus norvegicus*

"*R. norvegicus* with its opportunistic behaviour has been the prerequisite to make this animal that live in close proximity to human" (Traweger *et al.*, 2006). The behaviour perform by this rat give this rat an advantages to adapt in habitat associate with human. *R. norvegicus* is the most efficient ground dwelling rodent compared to house mouse (*Mus musculus*) and house rat (*Rattus rattus*) (Greaves, 1982).

In urban areas, *R. norvegicus* may burrow into the ground in building for example under basement level, cellar, and lowers floor (Nowak *et al.*, 1983). For food storage and nest, the underground will have a long tunnel, as well as a chamber. *R. norvegicus* is a clever animal, the chamber also act as a nest for them, and they will have two types of nest; outdoors and indoors. The outdoor burrows will have two or more opening so that this rat has a choice when escaping (Greaves, 1982). As for indoors, the nest will be inside walls, underneath equipment and in crawl spaces.

Whenever food, water and shelter are present there is always a basis for the establishment of rat population (Lund, 1994). These rats nearly eat any type of food (biological matter), but they prefer high-quality foods such as meat and fresh grain. Therefore, *R. norvegicus* can be categorized as an omnivorous animal (Nowak *et al*., 1983; Maria, 2002; Baizura, 2006). Sometimes these rats will eat human garbage when favourite foods are not available.

The adaptability as far as food preference are concerned, is seen well in *R. norvegicus* because they can thrive on the variety of waste food in drains. To a

certain extent they can live on human faeces, but they will prefer waste from the restaurant and food industries that flow to the drain (Lund, 1994; Channon *et al.*, 2006). For adult rat, they eat about a third of their weight in one day and as for the young, they will learn how to feed from the mother.

Activity pattern show by vertebrate is influence by changing of weather (Briese & Smith, 1974). Terrestrial animal shows higher activity during day time and increase its activity in the night (Bider, 1968). *R. norvegicus* is a nocturnal animal and active for foraging after dusk. According to a research done in the laboratory, at 7.30 pm is the peak hour of rat activity, and the activity will rise again at 2.30 am, but the activity will decrease toward daytime. If the population is large, they can be seen during daytime (Gerozisis & Hadlington, 2005; Nurul Liyana, 2008). *R. norvegicus* homerange is about 50-100 meters and they will find food around this range. They seldom go beyond 100 meters from the nest to find food or water (Timn *et al*., 1994). When foods available are plenty, they do not travel from the nest but concentrate on that particular area.

R. norvegicus tend to form colonies which ranging from 15-220 individuals (Gerosis & Hadlington, 2005; Maria, 2002). Male *R. norvegicus* are organized into a dominance hierarchy, in which age is a better predictor of high status than is body weight (Macdonald & Fenn, 1994). The more dominance males, usually the larger and well established individuals, command the most favoured nesting sites (Greaves, 1989). The group territory of rats, often associated with one male and one to several females with their offspring, is usually very small (Macdonald & Fenn, 1994). Since these rats are aggressive, social conflicts are most common at feeding sites.

Food and shelter are the two factors that contribute the increasing number in rat population. Litters of 6 to 12 young are born 21-23 days after conception. Newborns rats are hairless and their eyes and ears are closed, but they grow rapidly (Greaves, 1989; Timn *et al*., 1994). They become completely independent at about 3-4 weeks and reach reproductively maturity at 3 months age. Females are usually capable of *postpartum estrus* and may come into heat every 4 or 5 days, and they may mate within a day or two after the litter has born (Greaves, 1989; Macdonald & Fenn, 1994).

R. norvegicus have keen taste, hearing, sense of smell and touch but have poor sight. They are neophobic, wary of new things in their environment, which affects how trapping and other method of pest management activities are carried out (Gerozisis & Hadlington, 2005). They used the whiskers in judging the shape of object and potential pathway (Greaves, 1989). Rats can develop 'bait shyness' when they become wary of food that does not 'taste right' or when they ingest sublethal doses of bait. So it is often prudent to pre-bait with non-toxic baits or foods (Timn *et al*., 1994). They also an excellent swimmer and can obtain water from toilet, sinks, rain puddles, ponds or condensation from utility pipes. Its ability to travel sewers and drains and enter buildings through these passageways makes it a citywide problem.

2.1.2.3 Morphology of *Rattus norvegicus*

Mature rats are range between 150-400g and about 163-265 mm long. The body of *R. norvegicus* is heavy-set (Gerozisis & Hadlington, 2005). The fur is brown or reddish gray above and typically whitish gray on the belly (Tweedie, 1978; Medway, 1983; Timn *et al*., 1994). They have small eyes and ears and the nose is blunt. The scaly tail is short then the head and body. The tail is dark on the upperside, unpigmented on the underneath. The length of the tail is around 170 - 230 mm (Figure 2.1).

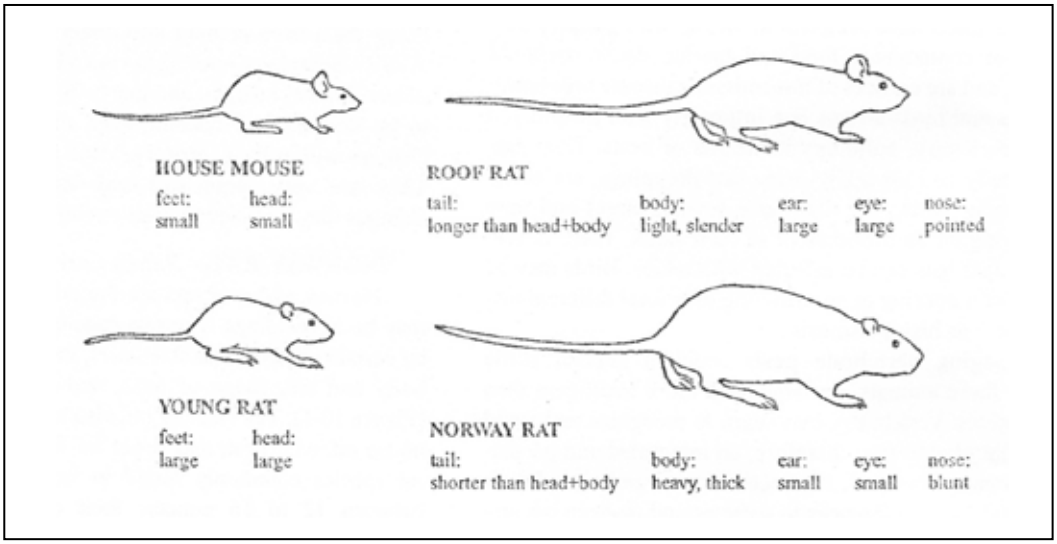

Figure 2.1: The Norway rat and House rat can be identified by certain physical characteristics. (Source: Vertebrate Pest-Chapter 10: Pest Management Principles)

2.1.3 Impact of *Rattus norvegicus* in urban areas

The urban environment is particularly vulnerable to be colonized by synanthropic animals (invasive species) (Parlange, 1998). Urban environment has been an ideal place that supports the *R. norvegicus* population. Ideal conditions for the development of rat population are provided by the increasing availability of food and water sources and also harborage within which the rat can live.

Overwhelming population of rat in urban areas can lead to various kinds of problems. One of these is they pose a threat to public health by serving as reservoirs for pathogens that can be transmitted to human and animal (Gratz, 1994; Easterbrook, 2007) since this rat live in close proximity (Easterbrook, 2007). If transmitted to human, may cause outbreaks of diseases often with high morbidity and some mortality (Gratz, 1994). Utensils or food sourced during preparation in the cafes or restaurant can be contaminated by rodent-borne infectious agents through urine and faeces. This happened when poor sanitation is practiced and no measures are taken to exclude rat entry into the restaurants. Contamination might also occur by direct contact with urine or feaces where bacteria enter the skin through small scratches for example, Weil's diseases (Gerozisis & Hadlington, 2005).

A large number of rodent species are hosts to the virus and viraenia may persist for several months in them; the virus is found in the saliva, urine and feaces of infected rats and the infection is probably transferred by human contact with contaminated through the food stuff. Norway rats have been vectors for bubonic plague, leptospirosis, thypus, spotted fever, tuleramia, salmonellosis food poisoning

(*Salmonella* bacteria), infectious jaundice and other serious diseases (Gratz, 1994; Easterbrook, 2007; Zuo *et al.*, 2008).

In addition, they also cause structural damage to building by burrowing and gnawing (Timn *et al*., 1994). They damage structure further by gnawing openings through doors walls ceiling and floors. *R. norvegicus* also gnaw on electrical wires or water pipes, either in structure or below ground. The gnawing of wire and cables has caused short-circuiting, which result in equipment breakdown or very costly fires. Considerable damage to insulated structures can occur as a result of rat burrowing and nesting in walls (Meehan, 1984).

2.1.4 Rat management in municipal area in Malaysia (Penang Island)

In Pulau Pinang, rat control has been carried out by the Penang Municipal Council (MPPP), Department of Public Health under the Vector and Transmitted Diseases Control Unit. The department has been established in 1976. The aim of the department is to, investigate all the complaint of disturbance by infestation of crows, mosquitoes, rodents and other pest. Control and prevent infestation of rats based on source control method, trapping by live wire cage and rodenticides in market, food stalls and public place and other. Pest control action under MPPP comprises the whole of Penang areas.

Actions taken for rat control by the Penang Municipal Council were based on the information provided to them by the public. The complaint from the public was transfer to Public Relation Department and complaints were compiled. Action was

taken by the Department of Public Health. Basic routine has been carried out in the areas reported to have problems with rat populations and sometimes depend on the degree of infestation (3 times a week). The team was put on with a special uniform (Personal Protective Equipment (PPE) before carry out the task. This is important to prevent injury to a person while handling the rodenticides.

The Department of Public Health has developed several control of rat management, but the plan was toward the usage of rodenticides. They used Talon to poison the rat and it is effective compared using warfarin (first generation anticoagulant). In the areas with high infestation, zinc phosphate will replace the Talon, because they only use single dose rodenticide. Acute rodenticide example zinc phosphate may give good result, but no very effective. Even though the onset of toxicosis is rapid, but later give rise to bait-shyness. The cost using Zinc phosphate is about RM400 per bin. Average allocation for pest control in Penang island is equal to RM 200000 per year.

Besides that, Municipal council also collaborate with Health Department (government hospital) by cleaning the hospital areas and conduct awareness campaign for public at the same time. Public awareness about pest in urban areas are still low, therefore they tend to blame MPPP for the unpleasant environment. Hawker and restaurants may be liable to a heavy fine by Department of Licenses (MPPP) if found responsible for rat infestation.

In order to have a good rat management, it is essential to define the characteristics within the habitat that favor the infestation (Murphy & Marshall, 2003). The administrator should have a precise method on how to control the rat in the city of Penang. The approach of using rodenticides could only constituent for short period. A long term program should be implemented in the future for example toward using Integrated Pest Management. Using various methods in controlling the rat could help in decreasing the rat population in the city.

2.1.5 Integrated pest management (IPM)

Integrated Pest Management (IPM) is a decision-making process designed to identify the conditions causing a particular pest problem to occur. IPM devises ways to change those conditions to discourage recurrence of the problem and also select the least-toxic strategies and tactics to directly suppress the pest population with minimum impact on human health, the environment and non target animals.

In IPM program, the treatment is not to eradicate the pest, but to suppress pest populations below the level at which they cause unacceptable damage. An immediate pest problem may often require fast results, usually best achieved by a lethal chemical or rodenticides (Smith, 1994). But using rodenticides might not be the best solution, since it only can support a short-term pest control (Traweger *et al*., 2006). A combination using non-chemical control and chemical control are the essential method to form the integrated approach in resolving rodent problems.

2.2 Home range of rat using the radio telemetry

The method using the radio-telemetry studies to gain information on target species is not very popular among scientist in our country. But currently the method is widely used, especially in agriculture area. Through radio-telemetry the home range and core area of the target species can be determined. The information gain can be further analyzed to establish an appropriate pest control method.

A study regarding home range of *Rattus tiomanicus* has been conducted in an oil palm plantation in Johore, Malaysia (Buckle *et al*., 1997). The study determines the ranging behaviour and habitat utilization of the *R. tiomanicus*. The researcher used the radio-tracking as a measure of efficiency in field trials of rodenticides applications for rat control in oil palm. In the experiment the radio-tracking of rats in untreated control plot provided an opportunity to observe about the ranging behaviour and habitat utility of *R. tiomanicus*.

Besides that, a lot of study also has been carried by other country using the transmitter's radio. For example the study of beach vole, *Microtus breweri* in determines the home range and the spatial distribution of that species (Zwicker, 1989). Other study using the radio-tracng is to find the relationship of home range with breeding activity in *Apodemus argenteus* and *Apodemus speciosus* in order to reveal their mating systems (Oka, 1992).

Apart from that, home range pattern and seize of *R. norvegicus* in urban areas was determine by availability of food. From the study, food has been the main factor

followed by social interaction and shelter. Male *R. norvegicus* will go out first to ensure the surrounding is safe for female and litter to move out afterward. Through observation, male *R. norvegicus* return to the nest early from female and litters. These rats usually move at regular basic toward place where the food availability is high. Using detection process shows point of location that always assures food availability. Besides using direct observation, signaling from the radio-telemetry help the researcher to determine the main food source from the detection process. The home range study was conducted in Chowrasta market in inner city of Georgetown (Faizul Nizam, 2008).

Relatively the movement of male and female rat is different. The movement of female rat is influence by food source and nesting site, as for male rat the movement depend on food source and oestrus female. Other factor influence sizes of movement are sex, age, feeding habit, reproduction pattern, population density, habitat and productivity. Home range areas show negative correlation with the population density of animal (Perry & Garland, 2002). When the population is high in certain area, the home range of an individual species will be smaller. According to Faizul Nizam, (2008) home range areas of female and male of *R. norvegicus* shows no obvious differences, it is because high availability of food and human activity.