Survival and Foraging Area of the Released Fledglings Barn Owl (*Tyto alba*) in Oil Palm Plantation from Different Training Techniques

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ชื่อวิทยานิพนธ์ ความอยู่รอดและอาณาเขตหากินของลูกนกแสกจากการปล่อยด้วยวิธีต่างกัน

ผู้เขียน นายสุเนตร การพันธ์

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บทคัดย่อ

การศึกษาความอยู่รอดและอาณาเขตการหากินของลูกนกแสกจากการฝึกด้วยวิธีต่างกัน มีวัตถุประสงค์เพื่อเปรียบเทียบความอยู่รอดและขนาดอาณาเขตระหว่างลูกนกแสกที่มีการเตรียมความพร้อมให้สามารถล่าเหยื่อได้ก่อนปล่อย และลูกนกแสกที่ไม่ได้ผ่านการเตรียมความพร้อม เพื่อใช้ในการพัฒนาการวิธีการนำนกแสกใช้ในกำจัดหนูที่เป็นสัตว์ศัตรูพืชในพื้นที่เกษตรกรรม โดยติดเครื่องส่งสัญญาณวิทยุที่ตัวลูกนกที่ฝึกให้ล่าก่อนปล่อย 5 ตัว และลูกนกที่ไม่ได้ฝึกให้ล่า 6 ตัว ผลการศึกษาจากการติดตามสัญญาณวิทยุพบว่า ในเดือนแรกหลังจากที่ปล่อย ลูกนกที่ฝึกให้ล่าก่อนปล่อย รอด 3 ตัว (60%) ส่วนลูกนกที่ไม่ได้ฝึกให้ล่า รอด 2 ตัว (33 %) ลูกนกที่ฝึกให้ล่า 2 ตัว มีชีวิตอยู่จนถึงฤดูสืบพันธุ์ถัดมาและอีก 1 ตัวตายหลังจากนั้นอีก 1 เดือน ส่วนลูกนกที่ไม่ได้ฝึกให้ล่าก่อนปล่อย มี 1 ตัวที่อยู่รอดจนถึงฤดูสืบพันธุ์ถัดไป อาณาเขตที่ลูกนกแสกใช้โดยเฉลี่ยในหนึ่งสัปดาห์ทั้งที่ฝึกให้ล่าและไม่ได้ฝึกให้ล่า คือ 1.41 และ 0.93 ตร.กม. ซึ่งไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติในทั้งสองเพศ ระยะทางจากจุดปล่อยเฉลี่ยใน 5 สัปดาห์ ระหว่างลูกนกแสกที่รอด ลูกนกแสกที่หายไปและลูกนกแสกที่ตายไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติ ลูกนกแสกมีอัตราการตายสูงในช่วงเดือนแรกที่ปล่อย แต่ก็มีลูกนกแสกบางส่วนสามารถตั้งถิ่นฐานและสืบพันธุ์ได้ ดังนั้นหากเริ่มต้นด้วยการปล่อยลูกนกแสกเป็นจำนวนที่มากพอ จะทำให้อัตราการเพิ่มจำนวนนกแสกในสวนปาล์มน้ำมันเร็วยิ่งขึ้น

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ABSTRACT

Barn owl has been used successfully as a biological control agent for rats in oil palm plantations in Malaysia. However, the suitable technique for a reintroduction of this bird species in new plantations is unknown. The objective of this study was to compare the survival and home range size of the released barn owl fledglings between those trained to hunt live rats and the untrained fledglings. Fledglings in the wild were caught at the age of 7 weeks and they were transferred to the large wire cage for acclimatization in a new plantation. They were divided into two groups: fledglings that were trained to hunt live rats and untrained fledglings. The transmitters were attached to all fledglings before releasing. Tracked birds were monitored 3 times a day and their foraging range were determined. 5 fledglings were trained to hunt and 6 were untrained. A month after release, three trained birds (60%) and two untrained birds (33%) survived. Two trained fledglings were alive to the following breeding season, one died after a month. One untrained fledgling~~s~~ was alive to the following breeding season. The average weekly home range sizes of the trained and untrained fledglings were 1.41 and 0.93 km^2 respectively. The average home ranges of the trained and untrained fledglings (both sex) were not significantly different. The average dispersal distance, survival, disappearance and death fledglings in 5 weeks were not significantly different. Generally, the mortality rate was high in the first few weeks after release. Although more resources for bird training were needed, the survival of the trained fledglings was much higher than the untrained fledglings. Since food was plentiful, these survived birds could settle rapidly in the plantations.

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Sunate Karapan

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CHAPTER 1

Introduction

Barn owl populations are declining in many parts of the world due to changes in agricultural practices and climate (Bunn *et al*, 1982). The owl is known for its close association with man and agriculture because it is often observed roosting or nesting on farmsteads. The rapid loss of natural habitat and residues from rodenticide in farms, and hunting from a negative belief in Southeast Asia that the barn owl brings bad luck to man. The devastating effects of agricultural chemicals on non-target wildlife have featured prominently in the decline of many predatory birds which occupy a position at the top of the food chain (Newton, 1979).

In Thailand, oil palm plantations cover the area of 480,000 ha most of which are in the South. Rats are indicated to be a major cause of revenue loss in oil palm plantation (Duckett, 1984). Some farmers exercised rat control by chemical substance. When barn owls take contaminated rodent prey and get killed thus its population is declining due to the rodenticide. Barn owl population is suggested to establish naturally in some oil palm estates in Peninsular Malaysia (Duckett, 1984). Indeed, the rapid spread of this bird has been attributed to the increasing area planted to oil palm and the large numbers of rodents that are always associated with palm planting if no effective rodent control is conducted (Wood and Liau, 1984). Lenton (1980) showed that the diet of the owls was highly specific to rats indicating the high potential of owls as agents for biological control. In Malaysia barn owl is commonly used for controlling rat population in oil palm plantation. Setting nest boxes can induce population establishment of barn owl. Since this bird cannot build nest by itself, an estate can extend its range geographically and increase population density where basic breeding stocks are present (Duckett, 1984). An effort to increase barn owl population for biological control is highly successful. Earlier attempts to use natural barn owls as a control agent of rats in the oil palm plantation in Thailand gain a little success. Sangsawan Oil Palm Plantation, Suratthani province is the first plantation that applied this technique in constructing 7 nest boxes in 1992. Two years after, there was still no barn owls using nest boxes. They reintroduced a couple of barn owls into the plantations. Then, after the fourth year, the barn owls were found to occupy the nest boxes and the numbers of barn owls increased from one pair in 1996 to at least 105 pairs in 2004. Rodenticide was not applied in this plantation since 1996, and rat control has relied on barn owls since 1996.

In order to encourage farmers to use barn owl as a biological agent to control rat population in the oil palm plantation, the population size of barn owls need to be increased. If the famers want to use barn owls instead of rodenticide, they have to stop using all chemical substances because the barn owls will receive them accumulatively in their preys. The rat population will increase after the application of rodenticide is stopped. Although there are some barn owls in these oil palm plantations, their numbers are probably not enough to control the rats. In order to foster a rapid increase of barn owl population, apart from building boxes, we should find the way to increase the barn owl population to a level that can potentially reduce the destruction of the oil palms by rats.

Translocating barn owl is one of the techniques for a rapid increase of the population. Nevertheless, it is hard to catch free-living adult birds. Fledgings are more suitable for translocation because they are easy to catch from the nest boxes. Naturally, fledglings slowly dwindled as young individuals dispersed, rarely to reappear around the nest site again (Lenton, 1980). So the young fledglings that cannot fly yet are more suitable for taking to a new area. However, the survival and area use of fledglings after capture and releasing is still unknown. The objective of this research is to find out the strategy to translocate the barn owls into a new area.

The questions of this research are as follows: (1) Do fledgings trained with live preys before release have greater survival rate than the untrained counterpart? (2) Can the released birds settle in a new area? It is hypothesized that the trained fledglings fed with live preys have greater survival rate than the untrained fledglings and the fledglings from both treatments can settle in the new area.

CHAPTER 2

Literature review

Classification of Barn Owls

There are about 133 different species of owls in the world, all are classified in the Order Strigiformes. This order is divided into two Families, Tytonidae and Strigidae. Each of these two families is divided into two sub-families, Tytonidae which contains the Tytoninae, with the single genus, *Tyto* (Barn and grass owls) and the Phodilinae with a single genus, *Phodilus* (Bay owls). The Tytonidae, unlike the Srigidae, has a distinctive heart-shaped face with the tail often ending in the shallow V, the inner and middle toes are of equal length with the claw or talon of the middle toe possessing a comb-like serrated edge. The wishbone and breast-bone, unlike those of the Strigidae, are fused together and the bone dividing the two eye sockets is thick. The eyes are dark, the relatively small ear openings are elongated and covered by a larger skin flap. The rounded wings are large with the eighth, ninth and tenth primary feathers of similar length. The legs are long and slender and the mesoptile plumage of the young is downy and quite unfeather-like (Shawyer, 1998).

Tytonidae owls are cavity nesters which mean they prefer to nest in dark places like tree cavities, caves, pipes or barns. In many parts of the world they have chosen to nest in barns and silos, hide in a dark corner where humans wouldn't see them. This is why they are called "barn owls". The reason they do this is because most of their natural nest sites have been destroyed, and barns are usually located near grassy fields where their prey can be found (Trapp, 2003).

Barn owl

Barn owls (*Tyto alba*) comprise 36 subspecies with a worldwide distribution (Taylor, 1994). The subspecies of barn owls in Thailand are not clear. Robson (2002) indicated that there were two subspecies of barn owls in Thailand: *Tylo alba stertens* and *T. a. javanica*.

Barn owl is medium sized, with relatively long legs, and heart shaped facial disk. It is very variable in colouration depending on race, from pale birds with white under-parts and pale buff upper-parts; to some island races which have rufous buff under-parts and dark gray upper-parts. A variable gray veiling on the upper-parts seems to be characteristic of the species. Females tend to be generally darker and more heavily marked than males.

Distribution

Following Taylor (1994), there is only *Tyto a. javanica* that is found in Thailand, *T. a. stertens* was reported to distribute from India, Pakistan to Myanmar. From the Owl World Trust (2005), *T. a. stertens* distributed from Indian sub-continent, Southern China, Vietnam and Southern Thailand while *T. a. javanica* distributed in Malay peninsula and Greater Sunda land.

The barn owl can be found in every continent. Barn owl is considered the most widely distributed land bird in the world occurring in most of Europe, most of Africa, India, Pakistan, south-east Asia and Australia through the Pacific Island and to North, Central and South America and even the Falkland Islands. It is therefore found in widely differing zones ranging from the extremes of tropical rainforest to desert climates although these two extremes are usually avoided (Voous, 1960).

However, the barn owl does not breed in China, Mongolia, Korea, Japan, Taiwan, Borneo, Philippine, Iran, Afghanistan, west of Russia and Kazakhstan. It is also absent from Greenland, Iceland and almost the southern fringes of Canada, in southern hemisphere, Antarctica and New Zealand (Voous, 1988). Nevertheless, it was known to breed on the Folkland Island, sub-Antarctica (Mccafferty and Lurcock, 2002). The different races vary in size from the tiny Barn Owl of the eastern Canary Isles (*T.a. gracilirosstris*), measuring only 28 cm to the much larger race (*T.a. furcata*), in Cuba which measures 43 cm (Voous, 1988).

Habitat

Barn Owl is mainly a bird of open habitats such as grassland, wetland, semi-arid areas and savanna but is also able to exploit grassy margins in some of the most intensively farmed and afforested regions of the world as well as the inside mature plantations of oil palm, date, coconut and pomegranate orchards and vineyards, where trees are well spaced and flight is unhindered (Shawyer, 1998). Generally, the owls avoid forests except some island races. They can live up to 4000m above sea level (World Owl Trust, 2005).

Foraging area

There were many studies about the foraging area of barn owls which used the radio tracking method. Radio telemetry utilizing miniature transmitters was used by Lenton (1980) on 4 individuals of barn owls (1 male in breeding season, 1 male in non-breeding season and 2 females in non-breeding season) at Carey Island, Selangor, Malaysia. Lenton (1980) showed that in non-breeding period, females hunted over an area of 78 ha, although only a portion (8.4 -25.3 ha) was covered on any one night. Over three nights, the breeding males encompassed a total of 142 ha of which 12.8 to 33.3 ha were covered on any one night. By contrast, during non-breeding period, the males encompassed a much smaller home range than the female (20.2 – 238.9 ha), again only fractions of the total areas were covered on any one night (range, male: 0.6 – 10.5; female: 10.7 - 73.7 ha).

In central Utah, U.S.A., where a colony of barn owls in a disused steel mill, Smith *et al*. (1972) found that home ranges overlapping between individuals could reach 100%, but the most common degree of overlapping were 55-77 %. The sign of territoriality was only observed during the nesting cycle and then only within a radius of 5-10 meters around the nest site. Shawyer (1998) studied in Lincolnshire, England showed that in the breeding season, barn owls usually concentrated most of their hunting within 1.0-2.0 km of the nest but would range up to 4 km or more occasionally. Foraging takes place over only part of the home range and in those places where small mammal prey is most prolific.

Food and feeding

The barn owl is primarily a predator of small mammals, although varying proportions of other preys, particularly birds and occasionally amphibians, reptiles and arthropods, have been found in oral pellet content analysis. Lenton (1980) analysed the contents of 2,839 pellets from sites mainly in Selangor and Johore in Malaysia and found that 98% of the prey items were rats. Similarly, Salvati *et al.* (2002) found out the food of barn owls in oil palm including rats *(Rattus* sp.) 99.15 %, others mammals 1.29 %, arthropods 0.50 %, birds 0.38 %, amphibians 0.21 % respectively. Some populations may specialise on a particular prey species (e.g. palm rats in Malaysian palm plantations). The barn owl is the selective predator that can be used for an integrated rat control system (Brown, 1972; Lekunze *et al.*, 2001).

Breeding

Barn owls have an almost passerine-like reproductive strategy (short but highly productive) that is quite unlike that of most other raptors. It does seem to fit many correlates of *r*-selection proposed by Pianka (1970). At least near the northern extreme of their ranges, they: (1) exist under variable and uncertain climate conditions, (2) face catastrophic mortality from adverse weather,(3) exhibit early reproduction, (4) are essentially semelparous, and (5) have a short life. Additionally, juveniles often disperse widely from their natal sites, allowing them to use new or ephemeral resources (Stewart 1980, Lenton 1985).

The barn owls have enormous capacity to raise large and multiple broods where food supplies are rich and climates are mid highlighting an important aspect of the bird’s breeding biology which is unmatched by any other birds of prey. Their early maturation, large clutch size, multiple clutches, and low survival rates are characteristic of species that have evolved in harsh environments. Barn owls reproduce quickly and intensely to maximize its fitness (Marti, 1997).

Barn owl often breeds in the first year at between 10 and 11 months of age although males sometimes do not breed until their second year (Shawyer, 1998). The barn owl is usually monogamous, only selecting another mate when one of the pair has died. Polygyny was detected by Martinez and Lopez (1999). They found that the male hunted in the vicinity of two nests and delivered prey to both of them (40 m apart), and by the two hens feeding their broods simultaneously. Both clutches were considered as first, and five fledglings were successfully raised in both nests. In Thailand, serious courtship usually begins in September and breeding season is between August to May (Khobkhet, 1999).

They begin their screeching display flights in and around the main roosting sites, one of which will eventually be chosen for breeding, usually the nest site from pervious season. At this stage, the males also begin patrolling their favoured hunting area, momentarily stopping to hover as if in an attempt to make their presence known. The site that the male selects is a prey-rich habitat in order to encourage a mate (Shawyer, 1998).

Females incubate their eggs while males forage (Khobkhet, 1999). The female becomes less active as egg-laying approaches when she is fed almost entirely by the male. Copulation itself which takes about 15-20 seconds, is normally preceded by the male presenting the female with prey from the food cache which has often become quite substantial at the stage. The food item is often held by the hen throughout the act of copulation which occurs repeatedly each evening for weeks prior to, during, and even after egg laying (Shawyer, 1998).

Eggs and incubating

The barn owl has an enormous breeding potential. It commonly lays clutches 4 to 7 eggs (Taylor, 1994). The range of clutch size is from 2 to18 eggs. In the wild, however, even in the best feeding conditions, the numbers which are laid and eventually hatch will ultimately be dictated by how many females are capable of covering during incubation. The average of laying interval was 2.4 days. Hence, the fledglings in the same clutch are different in ages. Total incubation periods varied from 40-52 days measured from the first egg laid to the last chick hatched (Durant *et al,* 2004). Most chicks fledged around the age of 60 days (range 55-65 days) (Lenton, 1980).

Double clutches

Barn Owl is known to be able to lay replacement clutches, second and third clutch (Taylor, 1994; Lenton, 1980). Occasionally, females began a second clutch while fledglings of the previous brood were still not independent (Martinez and Lopez, 1999). In captive, barn owl can produce six clutches of eggs over a period of 22 months in Maryland, USA (Maestrelli, 1973).

Clutch size did not vary significantly between years or between females, and was fairly constant throughout the season and did not vary between females; laying dates of females that laid one clutch did not differ from those of females that laid second clutches; pairs laid up to three clutches per year (Martinez and Lopez, 1999).

Hatching (Shawyer, 1998)

After the chicks hatch out, they develops rapidly. The eggs hatch at staggered intervals depending on the laying interval, usually about every 48 hours. They can vary enormously with the youngest and oldest in a brood sometimes being separated by up to 30 days or even more.

On hatching, the young are pink – skinned with large pot bellies, measure about 50 mm long and weigh about 12 g. The closed eyes form protruding lumps on the side of the large head and the bill which is a pink colour possesses a tiny cream coloured egg tooth on the top of the beak near the tip.

For the first week, the hen does not feed any rough but just the soft part. The male continues to copulate when he arrives with food. In confined spaces, this takes place while the hen is crouching above the eggs of small young.

Throughout the first week, the fledgling begins to hold its head up, the legs also become noticeably stronger which results in more movement around the nest. During the second week, the first owlet to hatch becomes noticeably stronger than its nest mates and begins to use its wing stumps to move more rapidly around the nest. The eyes open for short periods. At the start of the third week, at this stage in its development the primary quill tips are just visible at the edge of the wings. With wings raised and tail wagging it is now able to move backwards. In the fourth week, the amount of prey being brought in to the brood is close to its maximum. The fledgling can now stand up, the claws begin to lengthen and the eyes begin to turn brown. In the beginning of the fifth week weight gain begins to drop and the amount of prey being delivered to the nest also begins to fall off. The fledgling very active at this age, snoring loudly when hungry, flapping its wings and wandering beyond the nest. In sixth week, fledgling has usually achieved maximum weight of about 380-400 g. At the seventh week, the facial disk has form although the white stiff feathers which eventually cover the cere up to the forehead have not fully grown at the mid-line to cover the skin. By the start of the eighth week the tail feathers extend beyond the primaries although down is still present on tops of the legs. By the middle of the eighth week the first attempts at short flight hops are usually made although the primary feathers are still growing quite rapidly.

By the beginning of the ninth week the owlets have usually trimmed down to about 340 g and look very adult in appearance. By now it can only be distinguished from its parents by its more excitable behaviour and exaggerated head movements. The oldest owlets now leave the nest frequently. The hen on arriving with food will usually only present it to one of the youngsters if it follows her back into the actual nest site and this behaviour persists until all of them are capable of flying well. The male on the other hand simply arrives at the empty nest to leave the food he has caught and continues to have little to do with the young.

By the start of the tenth week the growth of the wing feathers is complete and training of the youngsters to find and catch prey commences. The hen will initially arrive near the nest backing away from the brood to entice the oldest members out of the site. As the days go on she will then begin circling above the nest with food in her feet snoring loudly to draw the youngsters out into the open where they will either flop into the grass or fly beneath calling in anticipation. The first successful prey capture by a young owl is not normally made until the end of the tenth week at which time it will utter its first pure screech. At the time the adults which are by now often roosting together again at a traditional site sometimes at some distance from the nest, are rarely seen. The young remain more conspicuous and continue to be tolerated within the home range of the adults, although they usually driven out of the parental roost should one of them attempt to enter. At this stage in their development the owlets are highly vulnerable to the elements and it is not unusual to see them sitting out and commonly die of starvation. This would appear to be the most significant cause of natural mortality in juvenile birds.

Biological control by barn owl

Oil palm

Oil palm estates provide a variety of habitat in that the palm grows rapidly producing a continuity of open ground to closed canopy woodland. The raising of the canopy provides progressively increased access space until an eventual maximum of around 10 meters is reached. The economic life of a palm may be 30 years. Each field of palm is set in rows and barn owls fly under and along these rows in search of prey.

The development of rat control in oil palm plantation.

It is well-known that rats are widespread in the tropics where they are serious agricultural pests. Rats are classified in the family Muridae. Muirds as a group have a broad diet. They scavenge, eat fruits and vegetables, and prey on small animals, particularly insects, slugs and similar forms. They are capable of adapting to and surviving on a wide range of foods (Wood and Liau, 1978).

The rat species responsible for damage in oil palms is the Wood Rat (*Rattus tiomanicus*) which lives on the ground nesting in the piles of old fronds cut from palms, or in the crowns. It feeds on developing fruit bunches and detached fruit that fall to the ground when ripe. Field studies show populations without control to be in the order of 200-600 individual per ha. From this, times consumption in captivity, losses in the region of 5% or more of the oil product is indicated (Wahid *et al*. 1996).

Systematic rat control was developed in oil palm plantations in the 1960s and 1970s by comparing bait mixtures and application techniques mainly for anticoagulant poisons, in trials with related ecological studies. *Rattus tiomanicus* populations of 100–600/ha were estimated in plantings of a range of ages and localities, and numbers fluctuated slowly within these limits in a single plot without control, monitored over 20 years. Optimum control was with maize based wax-bound baits applied one per palm (generally 114–138/ha) with “replacement rounds” of those taken, at 4-day intervals until acceptance declined below 20% (usually about 5 or 6 rounds), doing large areas at 6-month intervals to minimise intermediate build up. Potential losses are estimated at 5–10% of the palm oil product, worth, within the wide price limits of recent years, from $(US)48 to 288/ha. Baiting cost is around $15/ha. (Wood and Fee, 2003).

In an effort to reduce the use of chemicals for rat control, the potential of biological control of rats with barn owls has been investigated. Lenton (1980) showed that the diet of the owls was highly specific to rats indicating the high potential of owls as agents for biological control.

Biological control

The barn owl builds up significant populations in oil palm plantation if nesting boxes are provided. Many oil palm plantations have done this, eschewing other forms of control. Visible rat damage seems to be less (Duckett and Karuppiah,1990), but evidence on the effect on rat population size is presently inconclusive (Chia and Lim, 1995).

The effect of rat control by barn owls was realized two to three years after the establishment of nest boxes at a density of 1 per 7.5 ha of 1 per 10 ha (Wahid *et al*, 1996).

The barn owl is a highly developed and effective predator of rats on oil palm plantations where these pests constitute almost 100 % of its diets. It never achieved a density of population there in that was capable of total rat control, but, could be considered a useful tool within an integrated control system utilizing baits (Duckett, 1982).

Reintroduction

Definition of IUCN

Re-introduction is an attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated or become extinct. Re-establishment is a synonym, but implies that the re-introduction has been successful.

IUCN 1997

Translocation is the movement of living organisms from one area with free release in another. The three main classes of translocation distinguished in this document are defined as follows:

Introduction of an organism is the intentional or accidental dispersal by human agency of a living organism outside its historically known native range.

Reintroduction of an organism is the intentional movement of an organism into a part of its native range from which it has disappeared or become extirpated in historic times as a result of human activities of natural catastrophe.

Re-stocking is the movement of numbers of plants or animals of a species with the intention of building up the number of individuals of that species in an original habitat.

Translocations are powerful tools for the management of the natural and man made environment which, properly used, can bring great benefits to natural biological systems and to man, but like other powerful tools they have the potential to cause enormous damage if misused. This IUCN statement describes the advantageous uses of translocations and the work and precautions needed to avoid the disastrous consequences of poorly planned translocations.

Potential benefits of reintroduction programs include (1) increasing the number of animals in a small population, (2) increasing genetic diversity in a small population, (3) reducing inbreeding depression in small populations, and (4) establishing new populations (Scott and Carpenter, 1987) and they urge those who are rearing birds for release or conducting translocation programs of egg, nestlings, juveniles, or adults to (1) band or mark, released birds to distinguish them from wild counterparts; (2) ensure that captive-produced birds, reared by hand, parents, puppets, or young; (3) document the conditions under which birds are prepared for different types of release programs, including capture techniques, handling methods, holding cages, and transportation procedures; (4) record the conditions of the release, document the condition of the release habitat and the environmental conditions at the time; (6) monitor, as much as possible, the movement and activities of released birds at least through first breeding; (7) determine the survival and breeding success by age and sex of birds reared and released under different conditions; (8) document the use of medications administered to birds before or during release (Scott and Carpenter, 1987).

Reintroduction of barn owls

Meek *et al.* (2003) studied the released barn owls in lowland southern England between 1979 and 2000 and found no significant difference in the overall survival period (the number of days between ringing as fledgling and recovery of the dead bird) between (1) fledged young of released adults which did not disperse away from their release site and so fed their own young (38 recoveries); (2) fledged young of adults which deserted their release site and which were therefore fed by placing food in the breeding box, in the absence of parents (11 recoveries); (3) fledged young put into a release site without parents and therefore completely fed by placing food in the breeding box (3 recoveries); and (4) fledged young of independent/wild owls (52 recoveries). There was not any significant difference in survival when only the first 30 days (X^2=0.89, p=0.64) or 100 days (X^2=0.042, p=0.98) were applied.

Farjardo *et al*. (2000) studied patterns of dispersal, survival and mortality in rehabilitated barn owls (*Tyto alba*) in Spain, including both wild birds and captive birds released individuals based on the recovery of death birds. They found that the two most often reported causes of death for rehabilitated birds were road traffic accidents and starvation (51.2 and 26.8%). Among the rehabilitated birds that were reported as having starved, 90% of cases occurred within 4 weeks after release. After this critical period, these birds follow natural mortality and dispersal patterns. Barn owls released after live prey training had more chances of survival than owls rehabilitated without this kind of training ($\bar{x}$= 115.3 days, n=26, S.E. ±35.9; $\bar{x}$= 13.1 days, n=15, S.E. ± 5.28) respectively.

Fundamentals of radio tracking

Radio tracking, as a technique to locate studied animals in the field and to transmit information about their physiological condition, is becoming increasingly popular in the study of wildlife (Kenward, 1987). In simple terms, one detects the direction from which the strongest signal pulses are coming emitted from animal tagged with a radio transmitter and detected with some system of antenna and receiver. Signals could be detected at distance up to 1000 meter. Depend on the position of the bird with in the oil palm.

Transmitter

Weight

The weight of a transmitter is proportional to the power of signal emitted and the battery life required. One must establish the weight go transmitter the can safely be carried by the study bird. It is suggested that weight of the transmitter should not exceed 5 % of the bird's body weight.

Barn owls weigh approximately 500 gram and transmitter (holohill, manufactured by ltd., U.S.A.) weighing total 12 gram. The transmitters were attached to the bird by harness of rubber tube (5 mm diameter) around the base of wings, therefore the package in the middle of the back and over the rump and along the tail feathers (figure). It is an accepted rule of thumb that if the total package weight of a transmitter is not to affect the normal flight and body movements of a bird it must weight less than 5 % of the bird's body weight (Lenton, 1980).

Battery life

Within the weight limitations, one can select either a lithium battery of solar-powered model of transmitter. The lithium battery provides a constant signal and their life vary from 4-6 months to 1 year. The longer life battery is bigger in size and weight than the shorter life battery. Battery life that will be used in this study is about 12 months.

Frequency

To avoid interference with or disturbance from other radio-wave users, should consult with the authority in one's country for radio communication. The different frequencies depends on how many birds are going to be tagged at one time but it is preferred to make the difference at least 20 KHz to avoid interference.

Figure 1. The transmitters were attached to the bird by harness of rubber tube

CHAPTER 3
Methodology

Duration

The study was conducted between September 2006 to August 2007.

Study sites

There were 2 study sites: Saeng Sawan Oil Palm Plantation (1800 ha), Prasaeng district, Suratthani province (8° 38’ N, 98° 59’ E) (Figure 2) and Chumphon Industry Oil Palm Plantation (1920 ha), Pratiew district, Chumphon province (10° 57’ N, 99° 24’ E) (Figure 3).

Nest boxes in Saeng Sawan Oil Palm Plantation were built 10 years ago. At present, the barn owls distribute throughout the area. The fledglings from this plantation distribute to the other surrounding areas. This plantation is the source of fledgling in this study.

Chumphon Industry Oil Palm Plantation is the main area for this study. This plantation has an area as large as the Saeng Sawan Oil Palm Plantation. This area has been prepared to stop using rodenticide. The nest boxes have just been built for settlement of the barn owls. in the area. This plantation is therefore suitable for the experiment.

Figure 2. Saeng Sawan Oil Palm Plantation, Prasaeng district, Suratthani province

Figure 3. Chumphon Industry Oil Palm Plantation, Pratiew district, Chumphon province

Saeng Sawan Oil Palm Plantation was divided into 3 zones: the western zone, the central zones and the eastern zone. The ages of oil palm are different in each zone. The ages of oil palm in the western zone, the central zone and the eastern zone are 15-20, 20-25 and 10-15 years respectively.

In 1992, 7 nest boxes were built in the western zone of this oil palm plantation. No birds used these nest boxes for 2 years. So the introduced barn owls were released. In the third year (1995), it was found that the barn owls used the nest boxes for breeding, laying eggs and feeding their chicks. After that, the population of barn owls in this zone increased and distributed to the central and the eastern zones.

The present study was undertaken at Chumphon Industry Oil Palm Plantation, Chumphon province. The oil palms are about 10-25 years old. The area covers about 1600 ha and is surrounded by other oil palms and rubber plantations.

In 2004, the nest boxes were set in Chumphon Industry Oil Palm Plantation. Before the nest boxes were set there were a few natural habitats for them. Then, the nest boxes were used to induce the wild barn owls and the introduction of the trained barn owls to live in the plantation. The release of fledglings began in 2005. During the first year, no nest boxes were used by the barn owls. In 2006, 20 introduced barn owls were released and it was later found that 10 nest boxes were used. The numbers of the nest boxes used by the barn owls increased to 40 in 2007. At present, about 200 nest boxes are distributed randomly over the estate. Generally, where boxes are set-up and there is no intensive baiting control, there seems to be good establishment of owls.

At the time of this study, there were small farmers living around this estate and there was no evidence of the practice of using pesticides. It is suggested that the main cause of fatality of the barn owls is not the pesticide.

Monitoring Methods

Source of fledglings

163 nest boxes in Saeng Sawan Oil Palm Plantation was checked every two weeks in the breeding season in the area covering 5x4 km^2,. All of the nestlings were banded when they were at least 4 weeks old. This population was used as a source population for the reintroduction into a new plantation.

Tracking scheme

Treatments

Tagging

There were 2 treatments which comprised

(1) 5 fledging trained to hunt rats. (live-trained fledglings)

(2) 6 untrained fledgings.

Information:

Pre-experiment preparation

Before taking the fledgings from their nests, it was assumed that they acquired sufficient killing skill and knew how to eat preys. The fledgings at the age of 7 weeks were selected because at this age the feather cover was comparable to adult, their parents did not stay with them and they could not fly. The fledgings were taken from the nests (one owl per nest) and were fed together with dead rats. These birds were allowed to acclimate the released site for 10 days. Then every fledging was checked for its health. The nests were already prepared in these aviators. In this period, they were fed with rats (dead/live) until they were ready to be released.

(1) Fledgings trained to hunt

The birds were fed with the dead rats. When they were 8 weeks old or older, they were fed with live rats. The rats were released into the cage for every bird. Trained until they can hunt by themselves, indicated by disappearing of rats. Then they were taken to the new aviator where they prepared to release.

(2) Untrained fledging

For untrained fledging, they were fed with only dead rats until released.

Radio tracking and home range analysis

The radio tracking techniques was used to follow individual birds on foot using a hand held, 3 element Yagi antenna. Birds were tracked between 8.00 - 10.00 p.m., 0.00-2.00 a.m. and in day time roost.

Tracked birds were monitored at least once a week at their roost site and also periodically tracked at night while foraging, depending on the accessibility of their locations. Fledging were located as frequently as possible during the early period after reintroduction, facilitated by two telemetry stations. Topographical maps and GPS were used in the field to plot the locations.

For every radio tracking, the position for each bird were plotted on the field map. The locations of bird were plotted by using Arcview geographic information system (GIS) software. The home range in defined as the area in which an animal spends most of its time. Determination of range size was based on the minimum convex polygon.

CHAPTER 4

Results

Radio tagging on fledglings

Survivals

There were 2 treatments which consisted of 5 fledglings that were trained to hunt and 6 untrained fledglings. A month after release, three trained birds (66%) and two untrained (33%) survived. Two trained fledglings were alive to the following breeding season, one died after a month. One untrained fledgling was-alive to the following breeding season (Table 1).

Table 1. Survival status in a period of time from each release of fledgling barn owls in a new oil palm plantation.

	ID	**sex**	**Age (week)**	**Survival**					**(until 1 month)**	**(until breeding season)**
				week 1	week 2	week 3	week 4	week 5		
T	A3	M	12	A	A	A	A	A	S	S
	D1	M	13	A	A	A	A	D	S	D
	B15-2	F	13	L					L	L
	B7	F	12	A	A	A	A	A	S	S
	A8	F	13	A	A	L			L	L
UT	B12	M	12	A	A	D			D	D
	B15	M	13	A	A	D			D	D
	D6	M	14	A	L				L	L
	B3	F	13	A	A	A	L		S	L
	B5	F	12	A	A	A	A	A	S	S
	D1-2	M	12	L					L	L

Note : T=trained, UT=untrained, M=male, F=female, S=survived, D=death, L=Lost A=Alive

A survival rate was estimated by the Kaplan-Meier method. Based on this method, the confirmed dead fledglings were used in the calculation as non-censored data while the other, lost and alive, were referred to as censored observation. The status of fledglings from the last day of observation was used in the calculation. The survival rate of 5 trained fledglings during the 35 day period was 0.750 (95% CI 0.426-1.000, Table 2). One fledgling was confirmed dead (Table 1). For 6 untrained fledglings, the survival rates during the 20 days and 34 days were 0.750 and 0.500 respectively (95% CI 0.426-1.000 and 0.188-1.000, Table 2).

The difference between the survival rates of both releasing techniques were tested by Mantel-Haenszel test (the log-rank method). There was no significant difference (P=0.262) between the two techniques.

Table 2. Kaplan-Meier estimates of survival of the trained and untrained fledglings

Fledglings	**Occasion**	**Time (days)**	**Kaplan-Meier survival estimate ± SE**	**95% Confidence Interval**
trained	1	35	0.750 ± 0.217	0.426 - 1.000
untrained	1	20	0.750 ± 0.217	0.426 - 1.000
	2	34	0.500 ± 0.250	0.188 - 1.000

Home Range

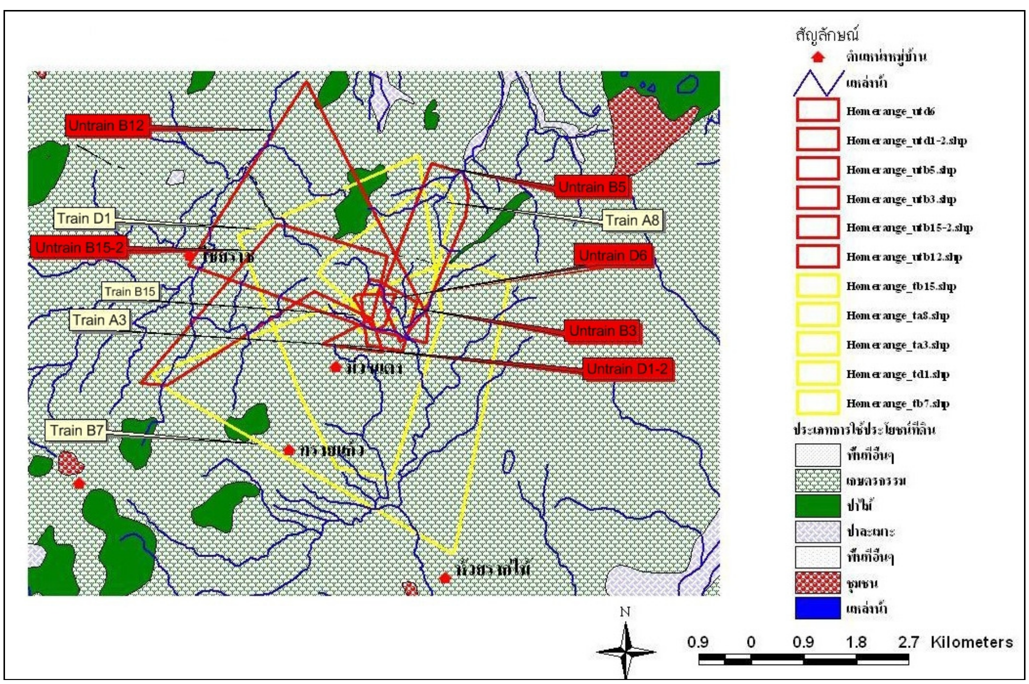
The average weekly home range of all released fledglings for 5 weeks was 1.15 km^2. The average weekly home ranges of 1^{st} - 5^{th} week were 1.13, 1.52, 0.43, 2.54 and 0.50 km^2 respectively. The home range of each individual is shown in Table 3 and Figure 4.

Table 3. Home range of barn owl fledglings in a new oil palm plantation

	no.	sex	status	Number of location	Home range (km^2) week 1	week 2	week 3	week 4	week 5	Average weekly home range ±SD (km^2)
T	A3	M	S	83	0.17	0.51	0.18	0.58	0.30	0.35±0.19
	D1	M	D	66	4.13	1.19	0.76	6.20	0.26	2.51±2.55
	Average HR (Male)				2.15	0.85	0.47	3.39	0.28	1.43±1.32
	B15-2	FM	L.	13	0.32					0.32
	B7	FM	S	89	1.93	0.84	1.71	1.71	3.06	1.85±0.80
	A8	FM	L.	36	1.06	0.40	0.37			0.61±0.39
	Average HR (Female)				1.10	0.62	1.04	1.71	3.06	1.51±0.95
	Total average HR				1.52	0.74	0.76	2.83	1.21	1.41±0.86
UT	B12	M	D	18	0.44	8.94				4.69±6.01
	B15	M	D	42	3.11	1.17	0.69			1.66±1.28
	D6	M	L	28	0.33	0.29				0.31±0.03
	D1-2	M	L	3	0.60					0.60
	Average (Male)				1.12	3.47	0.69			1.76±1.5
	B3	FM	L	84	0.47	0.36	0.51	0.16		0.38±0.16
	B5	FM	S	69	0.48	1.74	0.96	0.57	0.15	0.78±0.61
	Average HR (Female)				0.48	1.05	0.74	0.37	0.15	0.56±0.35
	Total average HR				0.91	2.50	0.72	0.37	0.15	0.93±0.93

Note : T=trained, UT=untrained, M=male, FM=female, S=survived, D=death, L=lost

Figure 4. Home range of the trained and untrained fledglings



Home range of the trained fledglings for hunting

The average weekly home range of trained fledglings was 1.41±0.86 km^2. The average weekly home ranges of the trained fledglings of the 1^{st} - 5^{th} were 1.52, 0.74, 0.76, 2.83, and 1.21 km^2 respectively. The average weekly home range of the male trained fledglings was 1.43±1.32 per km^2. The average weekly home ranges of male trained fledglings of 1^{st} - 5^{th} week were 2.15, 0.85, 0.47, 3.39 and 0.28 km^2 respectively.

The total weekly average of the female trained fledglings was 1.51±0.95 per km^2.The average weekly home ranges of female trained fledglings of the 1^{st} - 5^{th} week were 1.10, 0.62, 1.04, 1.71, and 3.06 km^2 respectively.

Home range of the untrained fledglings

The average weekly home range of all untrained fledglings was 0.93±0.93 km^2. The average weekly home ranges of all untrained fledglings of 1^{st} - 5^{th} week were 0.91, 2.50, 0.72, 0.37, and 0.15 km^2 respectively. The average weekly home range of male untrained fledglings was 1.76±1.50 per km^2. The average weekly home ranges of male trained fledglings of the 1^{st} - 3^{rd} week were 1.12, 3.47 and 0.69 km^2 respectively. The weekly average of female untrained fledglings was 0.56±0.35 per km^2. The average weekly home ranges of female trained fledglings of the 1^{st} - 5^{th} week were 0.48, 1.05, 0.74, 0.37 and 0.15 km^2 respectively.

The difference of average home ranges between sexes in each technique was tested by Mann-Whitney U test. There was no significant difference between sexes in both groups (p=0.288, 0.290). The average home range of the female untrained fledglings was obviously low. The difference of average home ranges between the trained and untrained fledglings (both sexes) were not also significantly different (P=0.526).

Home ranges of surviving, disappearing and dead fledglings

The average weekly home range of 3 surviving fledglings was 0.99 km^2. The average weekly home ranges of the 1^{st} - 5^{th} week were 0.86, 1.03, 0.95, 0.95, and 1.17 km^2 respectively. The average weekly home range of 5 lost fledglings was 0.32 km^2. The average weekly home ranges of 1^{st} – 3^{rd} week were 0.56, 0.35 and 0.44 km^2 respectively. The average weekly home range of 3 death fledglings was 2.69 km^2. The average weekly home ranges of the 1^{st} - 5^{th} week were 2.56, 3.76, 0.73, 6.2, and 0.26 km^2 respectively.

The average home range sizes of surviving, disappearing and dead fledglings in 5 weeks were tested by Kruskal-Wallis test. There was no significant difference among surviving, disappearing and dead fledglings home range size (P=0.64).

Table 4. Home range of surviving, disappearing and dead fledglings

Fledglings	**n**	**Number of location**	**Home range (km^2)**					**Home range (average) (km^2)**
			week 1	week 2	week 3	week 4	week 5	
S	3	241	0.86	1.03	0.95	0.95	1.17	0.99
L	5	164	0.56	1.05	0.88			0.32
D	3	126	2.56	3.76	0.72	6.20	0.26	2.70

Note : S=survival, L= lost, D=death

Dispersal

The average weekly dispersal distance of all released fledglings of 5 weeks was 1.07 km. The maximum distance of fledglings traveled from the release site for 5 weeks was 5.20 km.

The average weekly dispersal distances of the 1st - 5th week were 1.07, 1.45, 1.44, 1.28 and 1.96 km respectively.

Table 5. Dispersal distance from the released site of radio-tagged barn owl fledglings

	no.	sex	status	Number of location	Average dispersal range (km)					Dispersal range (average) (km^2)	Longest distance
					week 1	week 2	week 3	week 4	week 5		
T	A3	M	S	83	0.46	0.80	0.70	0.77	0.84	0.71	1.18
	D1	M	D	66	1.88	1.96	2.08	1.69	1.76	1.87	3.44
	Average DR (Male)				1.17	1.38	1.39	1.23	1.30	1.29	3.44
	B15-2	FM	L.	13	1.03					1.03	1.03
	B7	FM	S	89	1.08	0.74	0.94	1.20	3.79	1.55	4.95
	A8	FM	L	36	1.39	1.83	1.59			1.60	2.17
	Average DR (Female)				1.17	1.29	1.27	1.20	3.79	1.74	4.95
	Total average DR				1.17	1.33	1.33	1.22	2.13	1.44	4.95
UT	B12	M	D	18	0.37	2.51	0.71			1.20	4.46
	B15	M	D	42	2.50	2.50	2.67			2.56	5.20
	D6	M	L	28	0.80	0.77				0.79	1.53
	D1-2	M	L	3	1.28					1.28	1.87
	Average (Male)				1.65	1.92	1.69			1.75	5.20
	B3	FM	L	84	0.57	0.74	0.77	0.84		0.73	1.18
	B5	FM	S	69	0.46	1.17	2.09	1.92	1.46	1.42	2.53
	Average DR (Female)				0.52	0.96	1.43	1.38	1.46	1.15	2.53
	Total average DR				1.00	1.53	1.56	1.38	1.46	1.39	5.20

Note : T=trained, UT=untrained, M=male, FM=female, S=survived, D=death, L=lost

Dispersal of trained fledglings

The average weekly dispersal distance of trained fledglings was 1.44 km. The average weekly dispersals of th 1^{st} - 5^{th} week were 1.17, 1.33, 1.33, 1.22 and 2.13 km respectively. The longest dispersal distance of the trained fledglings was 4.95 km.

The average weekly of dispersal distance of the male fledglings was 1.29 km. The average weekly dispersal distances of the male trained fledglings of the 1st-5th were 1.17, 1.38, 1.39, 1.23, and 1.30 km respectively. The longest dispersal distance of the male trained fledglings was 3.44 km. The total weekly average of dispersal distance of the female fledglings was 1.74 km. The average weekly dispersal distances of the female trained fledglings in 1^{st}-5^{th} were 1.17, 1.29, 1.27, 1.20, and 3.79 km respectively. The longest dispersal distance of the female trained fledglings was 4.95 km.

Dispersal of untrained fledglings

The average weekly dispersal distance of the untrained fledglings was 1.39 km. The average weekly dispersals in the 1^{st} - 5^{th} week were 1.00, 1.53, 1.56, 1.38 and 1.46 km respectively. The longest dispersal distance of the untrained fledglings was 5.20 km.

The average weekly dispersal distance of the male untrained fledglings was 1.75 km. The average weekly dispersal distances of the male untrained fledglings in the 1^{st}-3^{rd} were 1.65, 1.92 and 1.69 km respectively. The longest dispersal distance of the untrained male fledglings was 5.20 km. The average weekly dispersal distance of the female untrained fledglings was 1.15 km. The average weekly dispersal distances of the female untrained fledglings of the 1^{st}-5^{th} were 0.52, 0.96, 1.43, 1.38, and 1.46 km respectively. The longest dispersal distance of he untrained female fledglings was 2.53 km.

The difference of dispersal distances between sexes in each technique was tested by Mann-Whitney U test. There was no significantly different between sexes in both group (p=0.744, 0.331). The average dispersal distance of the female untrained fledglings was obviously low. The difference in dispersal distances between the trained and untrained fledglings (both sexes) were not significantly different (P=0.715).

Dispersal distance (separated by surviving status after release)

The average weekly dispersal distance of the surviving fledglings was 1.23 km. The average weekly dispersal distances of the 1^{st} - 5^{th} week were 0.67, 0.90, 1.24, 1.30, and 2.03 respectively. The average cumulative dispersal distance of the surviving fledglings was 4.95 km.

The average weekly dispersal distance of the lost fledglings was 1.18 km. The average weekly dispersal distances of the 1^{st} – 4^{th} week were 1.01, 1.68, 1.18 and 0.84 km respectively. The average cumulative dispersal distance of the lost fledglings was 2.17 km. The average weekly dispersal distance of the dead fledglings was 1.83 km. The average weekly dispersal distances of the 1st - 5th week were 1.58, 2.32, 1.82, 1.69 and 1.76 km^2 respectively. The average cumulative dispersal distance of the dead fledglings was 5.20 km (Table 6).

The average dispersal distances between surviving, disappearing and dead fledglings in 5 weeks were tested by Kruskal-Wallis test. There was no significant~~ly~~ difference among surviving, disappearing and dead fledglings (P=0.06).

Table 6. Dispersal distances of surviving, disappearing and dead barn owls fledglings

Fledglings	**n**	**Number of location**	**Average dispersal range (km)**					**Dispersal range (average) (km^2)**	**Longest dispersal distance**
			week 1	week 2	week 3	week 4	week 5		
S	3	241	0.67	0.90	1.24	1.30	2.03	1.23	4.95
L	5	164	1.01	1.68	1.18	0.84		1.18	2.17
D	3	126	1.58	2.32	1.82	1.69	1.76	1.83	5.20

Note : S=survived, D=death, L=lost

Behaviour of the fledglings before release

Before release, the fledglings were kept in the cage which had enough space for hunting. The nest box was built inside the cage as a shelter for fledglings during the day time. During that period, the fledglings could not fly yet, and the keeper avoided being seen by the fledglings as much as possible because the fledglings might be disturbed. When the fledglings could fly, they were fed with the live rats. The rats in the cage usually hid near the corner of the cage or on the grass. On the first few days, the fledglings did not hunt. After the 3rd-5th days, the fledglings could hunt. From this study, the fledglings could-live for 3-5 days without eating.

The fledglings hunt by flying to the prey, using one of their talons to catch the prey and using the other talons to plunge the head of the prey. If there were more than one rat in the cage, the fledglings would hunt for every rat in the cage. The fledglings that could hunt more than one rat had eaten some parts of the body of their prey. This was different from the way they ate when they could not hunt yet. At that time, they separated the head and the body and then swallowed all part of the prey. At the age of 11-12 weeks, the fledglings frequently flew from one side of the cage to the other side. It came to our notice that some fledglings that did not fly much in the cage could fly very well when they were released. After release, most of the fledglings were still in the oil palm plantations. Sometimes, the fledglings were found shortly in the nearby rubber plantation then they returned to the oil palm plantations. During the day time, the fledglings frequently perched on the oil palm leave. In the large oil palm plantation area, there were some small streams or the reservoir in the plantation. The fledglings were usually found near the water.

CHAPTER 5
Discussion

Monitoring of the released fledglings

In this study, six out of eleven (54.54 %) released fledglings died or lost in the first month. Although it is not known whether the birds lost or moved to a new area, it is most likely that they died somewhere. This result was similar to the study of Farjado *et al*. (2000) that the mortality rate of the reintroduced fledglings was high in the first month. In their study, the major cause of death is due to starvation. Starvation is also an important cause of post-release mortality in barn owls in the UK (The Barn Owl Trust, 1898). From the observation in this study, other causes for the death of the released fledglings were injury caused by the oil palm thorns which resulted in inflamed feet or talons and the fledglings were unable to catch prey.

From this study, the survival rate and the mortality rate of the released fledglings trained under two conditions are not significantly different. Although the trained and untrained fledglings had high mortality rate in the first month, the trained fledglings had higher survival rate than the untrained fledglings. The mortality of the untrained fledglings in the oil palm plantation may result from foraging inexperience even though food (*Rattus* sp.) is relatively abundant in the oil palm plantation. Farjado *et al*. (2000) and Meek *et al* (2003) monitored the trained, untrained fledglings and the fledglings in nature in Spain and England and found that the survival rates of the trained and the wild barn owls were not significantly different. After surviving the critical period in the first mouth, the released fledglings followed natural mortality (Farjado *et al*., 2000). In this study, though there were only few released fledglings it is believed that the release of barn owl fledglings into the oil palm plantation to control the numbers of rats is still an eligible technique. Releasing high number of fledglings could compensate for their mortality rate. Barn owl is different from other birds of prey by being mature in a short period of time and by its capability of producing large clutch size. There was one female untrained fledgling that could breed and reproduce four chicks (released in April 2007, bred in November

2007). In the Chumphon Industry Oil Palm Plantation, 20 fledglings were released in 2004. In the following year, 8 nest boxes were occupied by adult females for laying eggs and another 20 fledglings were released. In 2006, 40 nest boxes were occupied and another 20 fledglings were released. In 2007, 102 occupied nest boxes were occupied.

The average weekly home range size of the trained fledglings in the first month was 1.41 km^2. The average weekly home range of the untrained fledglings was 0.93 km^2. These home ranges were small when compared to the studies of the released barn owls in the temperate zone. In England, the average home range of the trained and untrained fledglings were 24 ± 8 km^2 (n=32) and 33 ± 9 km^2 (n=3) respectively (Meek *et al.*, 2000). In the temperate zone, the density of preys (e.g. rats) of small mammals is low while the density of prey in the tropics is high. In the oil palm plantation, there are plenty of oil palm fruits which contain high energy nutrient. The number of rats in the oil palm plantation is large because of the abundance of food. *Rattus tiomanicus* populations in an area of 100–600/ha were estimated in the oil palm plantation (Wood and Fee, 2003). Barn owls in the tropical zone may not need to use a large home range to forage as that of the temperate zone. It is more beneficial to the barn owls to select a home range rich supply of food. The habitats that offer large numbers of prey close to the nest allow the barn owls to breed early and produce large and sometimes second broods (Shawyer, 1997).

When the home range of surviving, disappearing and dead fledglings were considered, the dead fledglings had the largest average weekly home range. The experience of the fledglings might affect their survival rate. The birds that were not successful in catching rats may have to fly farther and might be starving. The rats in the area which may experience barn owl predation could have higher ability to hide from the predator than those from the non-barn owl area.

In this study, the home ranges of fledglings overlapped between individuals. This finding is similar to the study of barn owls nesting in a disused steel mill, central Utah, USA (Smith *et al.*, 1972). They found that the home range of a barn owl colony overlapped between individuals. The sign of territoriality in a radius of 5-100 meters around the nest site was observed during the breeding period (Shawyer, 1997). Thus, a small area could support a high number of barn owls if the food were abundant.

The average cumulative dispersal distance of all released fledglings of 5 weeks was 2.91 km. Four fledglings dispersed more than 3 km from the release site and disappeared from the area. The longest distance from a release point of the trained fledglings was 4.95 km. The longest distance from the release point of the untrained fledglings was 5.20 km. The average dispersal distance from the release point of both the trained and the untrained was not much different. These are similar to the study of Balmer *et al*. (2000) that 81 % of juvenile barn owls were found within 0-10 km of the release site, which is similar to wild birds in their first year of life. The maximum distance recorded in that study was 262 km. The present result is also similar to the study of Bunn *et al*. (1982); that 37 % of barn owls moved more than 3 km from their nest site within two weeks of fledglings. Thus the released barn owls appear to be acting similarly to wild birds (Farjado *et al*., 2000; Meek *et a.,* 2003).

When the survival of fledglings was considered, the dispersal distance of surviving, dead and disappearing fledglings were 1.23, 1.18 and 1.83 respectively which were not much different. Apart from inexperience, the further dispersion of young barn owls from the release area may be caused by the possibility that juveniles were excluded from the area by established adults (Gannon *et al.*, 1993). Stress, risk of predation and mortality may reduce chances of survival in barn owls dispersing over greater distances (Martinez and Lopez, 1995).

Application of the research: Reintroduction of barn owl into oil palm plantation in Thailand

In order to successfully release barn owls into the oil palm plantation, we have to pay attention to the availability of barn owl stock, time for release, nest box availability and suitability of habitats.

1) The availability of barn owl stock

Although trained fledglings have more survival rate than the untrained fledglings, there is a limit to this practice. The farmers who want to release barn owls into any area must spend more time and money to take care of fledglings. Furthermore, in this study, it was difficult to trap live rats for for the trained fledglings. Live rats must be captured by cage, but its success was low. So releasing the untrained fledglings is a more practical method in the oil palm plantation. To compromise with a higher death rate, farmers have to release more fledglings.

If the number of barn owls introduced into the area was low, barn owl population might face inbreeding depression. In 1994, one pair of barn owls was introduced into the Saensawan Oil Palm Plantation, Suratthani Province. Ten years later, there were more than 150 pairs in the area in the breeding season. Physical disability was found in some fledglings (blind, had one leg or one wing). Such disability may result from inbreeding depression.

In this study, 33% of the released barn owls survive and settled in the area when 30 barn owls were released in the first year and the equal survival rate were resulted.

The area of oil palm plantation in Amphoe Patiew, Chumphon and Amphoe Bang Sapan Noi, Prachuap Khiri Khan is about 1920 ha (12,000 rai). In 2006, 300 nest boxes were built in this area. 30 untrained barn owls were released in the first year (2006). In 2010, the population of the barn owls in this area amounted to about 900 individuals. The percentage of oil palm eaten by rats decreased from 10-20% to 7%.

3) Time for the release of barn owls

The breeding season of barn owls is during the rainy season in southern Thailand (August-November). In the rainy season, the food is abundant for barn owls and their chicks. In this study, female fledglings that had been released in April 2007, bred in November 2007, laid 6 eggs and hatched 4 chicks. Fledglings should be released before the breeding season because they will have time to adapt themselves to a new area. So the suitable time for releasing barn owls in Thailand is between April – September which is the rainy season and early breeding season of barn owls.

4) Nest box availability

Naturally, limiting factor of the barn owls is the nesting site. In nature, barn owls do not make the nest by themselves. During breeding, they can nest in many places like caves, tree cavities and the fronds of palm trees. They also accept nest boxes in many parts of the world. Nest boxes were set to attract the birds to live and raise their chicks in oil palm plantation.

Nest box is a necessary factor for barn owls in the oil palm plantation because oil palm trees in the plantation do not safe space for barn owls. Oil palm fruits are collected every 20 days and oil palm collection may accidentally attack fledglings in the nests. When they find the suitable nest, they will use the same nest in the next breeding season.

These nest boxes are a long-term investment for the plantation. The maintenance of the nest boxes depends on the quality of the materials. If one barn owl can hunt the rats about 350-700 individuals per year, this amount of rats can destroy the products of oil palm about 1.1-2.5 tons per year per rai. Currently, the cost of pesticide is about 625 baht/ha/year (100 baht/rai/year). Therefore, the cost of nest boxes will be much lower compared to losses from crop damage.

The optimum number of nest boxes in the oil palm plantation is 1 nest box per 20 hectares (Lenton, 1980). The number of the nest boxes depends on the amount of rats. The density of nest boxes in the area should be higher than 1 nest box per 20 hectares in the area which has high density of rats. In 1600 ha of Saeng Sawan oil palm plantation, 200 nest boxes were occupied by barn owls (1 nest per 8 ha). This is similar to the oil palm plantation in Malaysia where the suitable nest boxes density was 1 nest per 7.5 ha or 1 nest per 10 ha (Wahid et al, 1996). The position of nest boxes should be far from human activities. If the nests were disturbed, the birds might fail to lay their eggs and leave their nests.

5) Suitability of habitats

A suitable area for the release of barn owls should be large enough for barn owl activities. Most of the oil palm plantations in Thailand are small area (< 100 ha) which are surrounded by other plantations such as rubber plantation, fruit orchards and farmlands. The sum of these areas is large. That leads to the possibility of using barn owls for biological control. The suitable size of the area should be at least 8 ha (50 rai). The area adjacent to other oil palm plantations or other agricultural areas is recommended. In the case of the plantation that oil palms are still young, the nest boxes should be set on the trees near the plantation because the barn owls do not use the nest boxes in the open area.

Though the release of barn owls could not be the best solution to control rats in oil palm plantation, they represent one of many tools to reduce the destruction of palm fruits. Using rodenticide in the oil palm plantation must be stopped when the farmers decide to use barn owls as a biotic agent to control the number of rats in the plantation. The effect of rodenticide to other animals will decrease and the biodiversity in the plantation may re-establish. The cost of using biological control is high at the beginning but the results are environmentally worthy in the long term.

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