# CHAPTER 3

## Bird abundance in the Thale Noi non-hunting area

### 3.1 Studies completed

Graphical and statistical methods were applied for incidence rates of resident birds on three studies. The first study examined distribution of 49 resident birds by using mosaic plots and bubble charts. The manuscript has been accepted for publication in the *Journal of International Society for Southeast Asian Agricultural Science* volume 17 No.2: 95-103, 2011 under title “Distribution of Resident Birds in a Protected Tropical Habitat in South Thailand”.

The second study aimed to identify groups of resident birds characterizing behaviours of the birds that reflected habitats and food by using factor analysis (Lattin *et al*., 2003). The manuscript has been accepted for publication in the *Journal of Sustainability Science and Management* volume 7 No.1: 42-48, 2012 under title “Bird Assemblages in the Thale Noi Non-Hunting Area, Southern Thailand”.

The third study investigated methods for identifying daily incidence rates for bird species. The manuscript has been developed for further publication.

## 3.2 Published paper on the first study

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# DISTRIBUTION OF RESIDENT BIRDS IN A PROTECTED TROPICAL HABITAT IN SOUTH THAILAND

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## ABSTRACT

We investigated the distribution of birds in the Thale Noi protected area of southern Thailand. The data comprised the numbers of particular species of birds sighted monthly at seven locations of the Thale Noi non-hunting area during 2004-2007, and site characteristics also were collected by field survey, focus group, and land-use data in 2000. Graphical methods were used to analyse the distributional pattern of incidence rate with species, site and season as determinant factors. The results showed that site and season were associated with incidence of resident birds. In particular, the continuously flooded grassland was mostly related to incidence of resident species. Furthermore, the flooding season led to the high abundance of resident species. The six species with high abundance in the January-March season were *Dendrocygna javanica* (Lesser Whistling-Duck), *Himantopus himantopus* (Black-winged Stilt), *Bubulcus ibis* (Cattle Egret), *Nettapus coromandelianus* (Cotton Pygmy-Goose), *Porphyrio porphyrio* (Purple Swamphen) and *Phalacrocorax niger* (Little Cormorant).They preferred seasonally inundated wetland habitats such as *Melaleuca* swamp forest, rice field and grassland.

**Key words**: Thale Noi, non-hunting area, wetland, graphical method, mosaic plot, bubble plot

## INTRODUCTION

Knowledge of the species distribution on protected areas helps officials to understand how to effectively manage these areas. It is especially important to know how species guild distributions are affected by factors such as location and season, and by specific environmental characteristics including land use by human communities. Bird distributions are particularly important because they are commonly used as indicators of ecological conditions (see, for example, O'Connell et al., 2000, Davidar et al., 2001, Schrag et al., 2009). Graphical methods are powerful tools to show how site and season are associated with abundance of resident species. These methods can make bird distribution data presentation more effective and attractive.

The Thale Noi non-hunting area is an important breeding site for birds, covering 457 $km^2$ in southern Thailand, part of which was declared as a Ramsar site, the first in Thailand, in 1998. The area has a high diversity of wetland habitat comprising a freshwater lake, marshes, seasonally flooded grassland and rice fields, swamp forest, plantation, local communities and other human uses. This area was previously studied on two occasions, first by Kaewdee et al. (2002) who investigated waterbird abundance based on monthly sightings from April 1998 to March 1999 of five common resident species at the Ramsar site. The second study was undertaken by Chumrieng and Kongthong (2005), who observed abundance and behaviour patterns of all birds seen at five different sites from February 2005 to September 2006, finding 105 different species and estimating an average resident population of 36,595 per square km.

Beginning in 2004, officials monitoring the Thale Noi non-hunting area have routinely reported numbers of all birds seen on a day around the middle of each month at seven fixed locations. In our study we converted these data to daily incidence rates for the 49 common resident species among the 117 species observed, and thus investigated distribution of resident birds to understand the associations between these species-specific incidence rates and the site and (quarterly) season using graphical methods.

## MATERIALS AND METHODS

### Bird data and study area

The bird sightings were provided for the Thale Noi non-hunting area from the responsible agency, the National Park, Wildlife and Plant Conservation Department, Ministry of Natural Resources and Environment, Thailand. Data were collected monthly by officers in seven stations for the four years (2004-2007). The surveys were designed to be conducted on the same day each month, simultaneously at each site, from 8 am to noon and from 1 pm to 4 pm, along the routes designed for counting birds. Species were identified using binoculars and field guides (Lekagul and Round, 2005).

The seven sites over the wetland preservation area studied (Fig. 1) comprise Khuan Kreng (1), Khuan Nang Whean (2), Khuan Thale Mong (3), Klong Yuan (4), Khuan Khi Sian (5), Ban Pran (6) and Laem Din (7). Subsequently site characteristics were recorded by field survey and focus group. Based on remote-sensed data from the Department of Lands collected in 2000, land use types for each site within a 6-kilometer radius were also recorded.

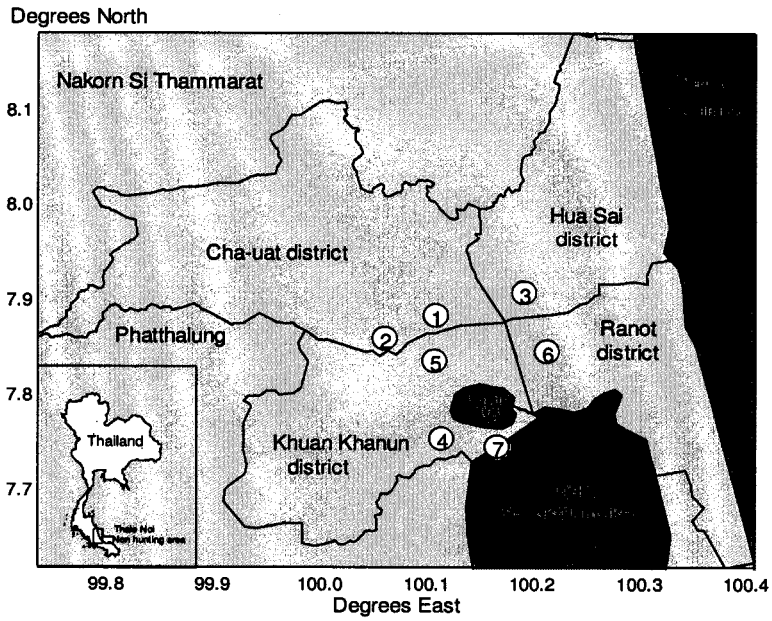


**Fig. 1.** Study sites in the Thale Noi non-hunting area, southern Thailand : Khuan Kreng (1), Khuan Nang Whean (2), Khuan Thale Mong (3), Klong Yuan (4), Khuan Khi Sian (5), Ban Pran (6) and Laem Din (7)

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**Data Management**

The 'resident' categories for bird species were defined using two criteria: (a) resident species status was categorized according to Lekagul and Round (2005), and (b) the species was seen in the Thale Noi non-hunting area in each year of the data collection period. The latter criterion was added to ensure that the resident birds belonged to the specified area. These criteria were satisfied by 49 species. Both scientific names and common names followed Gill and Donsker (2010). In addition, the Lekagul and Round (2005) criterion was used for five species with names different to Gill and Donsker (2010), namely House Swift, Cattle Egret, Common Flameback, Olive-backed Sunbird and Little Cormorant. In addition, daily (7-hour) incidence rates for all 49 resident species were calculated by site and season. Site characteristics collected by the Department of Lands were arranged as land use types for each site within a 6-kilometer radius.

The study periods were defined as January-March, April-June, July-September, and October-December. Periods of three months were chosen to correspond to the natural seasonal cycle in the area and because choosing shorter periods gave rise to excessive numbers of zero incidence rates, thus complicating analysis (Martin, et al., 2005).

**Graphical Method**

Mosaic plots (Hofmann, 2003) were used to display the associations between overall incidence rates and the site and season factors. These graphics represent values such as counts or incidence rates in a contingency table by rectangular tiles with areas proportional to the values. Since mosaic plots become difficult to decipher when one of the factors in the contingency table has a large number of levels, we used bubble charts to depict the associations between the species-specific incidence rates and the site and seasonal factors. Bubble charts are structurally identical to mosaic plots, but use circles rather than rectangles.

Computation and graph creation were performed using the R program (R Core Development Team, 2009).

## RESULTS AND DISCUSSION

Daily incidence rates of 49 resident species are listed in Table 1 and graphed in Figure 2. The highest incidence rate was for the Lesser Whistling-Duck which had around 30 per cent of all birds seen, with 448 occurrences per day on average. It was the dominant species in the area.

**Table 1** Daily incidence rates (individuals/day) of resident species in Thale Noi: 2004-2007

| Scientific Name | Common Name | Rates | *IOC | *Lekagul |
|---|---|---|---|---|
| *Acridotheres fuscus* | Jungle Myna | 16.44 | I | L |
| *Acridotheres tristis* | Common Myna | 21.62 | I | L |
| *Aegithina tiphia* | Common Iora | 1.48 | I | L |
| *Amaurornis phoenicurus* | White-breasted Waterhen | 4.32 | I | L |
| *Apus affinis* | House Swift | 15.69 | | L |
| *Ardea purpurea* | Purple Heron | 11.98 | I | L |
| *Ardeola bacchus* | Chinese Pond-Heron | 43.26 | I | L |
| *Ardeola speciosa* | Javan Pond-Heron | 2.15 | I | L |
| *Bubulcus ibis* | Cattle Egret | 142.55 | | L |
| *Caprimulgus macrurus* | Large-tailed Nightjar | 0.18 | I | L |

| Scientific Name | Common Name | Rates | *IOC | *Lekagul |
|---|---|---|---|---|
| *Centropus bengalensis* | Lesser Coucal | 0.49 | I | L |
| *Centropus sinensis* | Greater Coucal | 3.46 | I | L |
| *Copsychus saularis* | Oriental Magpie Robin | 4.61 | I | L |
| *Coracias benghalensis* | Indian Roller | 0.38 | I | L |
| *Corvus macrorhynchos* | Large-billed Crow | 21.48 | I | L |
| *Dendrocygna javanica* | Lesser Whistling-Duck | 448.07 | I | L |
| *Dicrurus macrocercus* | Black Drongo | 9.93 | I | L |
| *Dicrurus paradiseus* | Greater Racket-tailed Drongo | 0.24 | I | L |
| *Dinopium javanense* | Common Flameback | 0.29 | | L |
| *Egretta garzetta* | Little Egret | 44.64 | I | L |
| *Egretta intermedia* | Intermediate Egret | 73.28 | I | L |
| *Gallinula chloropus* | Common Moorhen | 3.11 | I | L |
| *Halcyon capensis* | Stork-billed Kingfisher | 0.41 | I | L |
| *Halcyon smyrnensis* | White-throated Kingfisher | 3.90 | I | L |
| *Haliastur indus* | Brahminy Kite | 6.24 | I | L |
| *Himantopus himantopus* | Black-winged Stilt | 153.30 | I | L |
| *Hirundo rustica* | Barn Swallow | 52.86 | I | L |
| *Ixobrychus cinnamomeus* | Cinnamon Bittern | 2.45 | I | L |
| *Ixobrychus sinensis* | Yellow Bittern | 1.14 | I | L |
| *Lonchura striata* | White-rumped Munia | 1.09 | I | L |
| *Megalaima lineata* | Lineated Barbet | 0.34 | I | L |
| *Metopidius indicus* | Bronze-winged Jacana | 2.20 | I | L |
| *Nectarinia jugularis* | Olive-backed Sunbird | 3.63 | | L |
| *Nettapus coromandelianus* | Cotton Pygmy-Goose | 52.44 | I | L |
| *Orthotomus sutorius* | Common Tailorbird | 4.07 | I | L |
| *Passer montanus* | Eurasian Tree Sparrow | 9.94 | I | L |
| *Phaenicophaeus tristis* | Green-billed Malkoha | 0.43 | I | L |
| *Phalacrocorax niger* | Little Cormorant | 56.89 | | L |
| *Ploceus philipinus* | Baya Weaver | 3.79 | I | L |
| *Porphyrio porphyrio* | Purple Swamphen | 95.33 | I | L |
| *Porzana cinerea* | White-browed Crake | 1.38 | I | L |
| *Pycnonotus blanfordi* | Streak-eared Bulbul | 0.71 | I | L |
| *Pycnonotus finlaysoni* | Stripe-throated Bulbul | 0.12 | I | L |
| *Pycnonotus goiavier* | Yellow-vented Bulbul | 7.59 | I | L |
| *Rhipidura javanica* | Pied Fantail | 1.64 | I | L |
| *Streptopelia chinensis* | Spotted Dove | 11.03 | I | L |
| *Treron curvirostra* | Thick-billed Pigeon | 5.08 | I | L |
| *Turnix suscitator* | Barred Buttonquail | 0.14 | I | L |
| *Vanellus indicus* | Red-wattled Lapwing | 10.73 | I | L |

*IOC and *Lekagul: references for citing English names of birds

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Corresponding incidence rates by site and season are listed in Table 2 and graphed in Fig. 2. The highest incidence rate occurred at Laem Din, which had 9,540 occurrences per day in January-March. Most birds were seen in the January-March and April-June seasons, although this effect was confined to the Laem Din site: the seasonal patterns at the other sites showed less variation. In the Thale Noi region the rainy season begins in November and continues until January, with the result that all areas are flooded until February.

**Table 2.** Incidence rates (per 7-hour day) for all 49 resident species by site and season: 2004-2007.

| | Season | | | |
|---|---|---|---|---|
| **Site** | **Jan-Mar** | **Apr-Jun** | **Jul-Sep** | **Oct-Dec** |
| 1. Khuan Kreng | 466 | 344 | 146 | 306 |
| 2. Khuan Nang Whean | 194 | 225 | 223 | 235 |
| 3. Khuan Thale Mong | 923 | 834 | 990 | 1155 |
| 4. Klong Yuan | 735 | 474 | 293 | 367 |
| 5. Khuan Khi Sian | 940 | 654 | 434 | 851 |
| 6. Ban Pran | 1567 | 1399 | 983 | 1185 |
| 7. Laem Din | 9540 | 6850 | 2179 | 2999 |

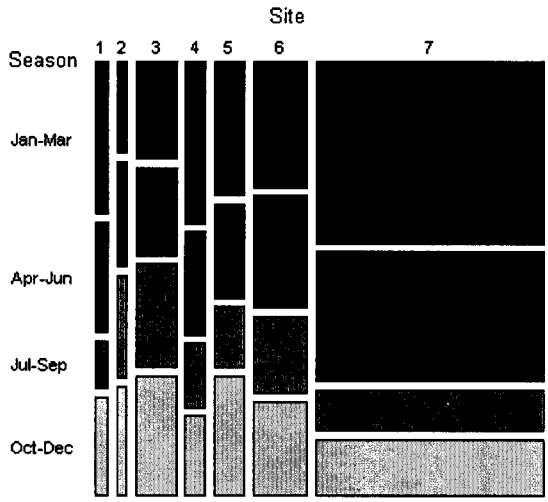


**Fig. 2.** Mosaic plot showing distribution of overall incidence rates of resident species by site and season: 2004-2007, areas of rectangular tiles indicate bird abundance.

The investigation by Angkapreechases (1985) suggested that January to April is the period of high bird population but from July to October the population is low. The results of the present study are consistent with these findings, with the exception of Khuan Nang Whean and Khuan Thale Mong, which showed the highest bird population in the period from October to December. The fact that these two sites are located on higher land may explain our result. In the Thale Noi region the rainy season begins in October to December (Jintanugool and Round, 2011). Most birds moved to puddles on land to forage during periods of heavy rainfall (Liangphonphan, 1999).

The results based on the land-use data for 2000 show that the two major land uses in the Thale Noi non-hunting area were wetland habitat and agricultural practices (Table 3). Wetland habitat

included swamp forest and freshwater lake, whereas agricultural practices consisted of paddy field, rubber plantation and mixed orchard. In addition, site characteristics collected by field survey and focus group are mostly similar to the land use data except for the increasing agricultural areas. Most had changed to oil palm and rubber plantation especially in sites 1, 2 and 3.

**Table 3.** Land use ($km^2$) in each site within a 6-km radius.

| | Site (see Table 2) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Land Use ($km^2$)** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **Total** |
| Swamp forest | 78 | 31 | 64 | 21 | 51 | 30 | 21 | 296 |
| Wetland | 25 | 11 | - | 5.0 | 24 | 23 | 15 | 103 |
| Lake | - | - | - | 16 | 8.0 | - | 78 | 102 |
| Paddy field | 12 | 71 | 10 | 56 | 29 | 60 | - | 238 |
| Para rubber | 2.0 | 3.0 | 1.0 | 8.0 | 3.0 | - | - | 17 |
| Mixed orchard | 1.3 | 5.2 | 3.0 | 2.0 | 0.3 | 4.0 | - | 16 |
| Lowland village | 1.0 | 0.7 | 1.8 | 3.0 | 0.5 | 0.3 | 0.3 | 8.0 |

The incidence of the 49 resident species by site and season is shown informatively by bubble charts (Fig. 3). This graph illustrates the distribution of species by season (right panel), which indicates that of the six species with high density in January-March, four of them were still high in April to June. In addition, these high density species, with the exception of the Cattle Egret, occurred at Laem Din. These species were *Dendrocygna javanica* (Lesser Whistling-Duck), *Himantopus himantopus* (Black-winged Stilt), *Bubulcus ibis* (Cattle Egret), *Nettapus coromandelianus* (Cotton Pygmy-Goose), *Porphyrio porphyrio* (Purple Swamphen) and *Phalacrocorax niger* (Little Cormorant). They preferred seasonally inundated wetland habitats which occurred in the January-March season. Additionally, site 7 where the birds were seen in high abundance is not only seasonally flooded for longer periods but also contains wetlands including *Melaleuca* forest and grassland. Studies have shown that these habitats are very important as feeding and breeding sites for bird species (Czech et al., 2002; Kaewdee et al., 2002; Fasola et al., 1996; Hamer et al., 2006; Nguyen et al., 2009). Furthermore, in flooded conditions the wetland birds are prevalent both during and after the flooding, especially ducks (Shimada et al., 2000). This type of habitat provides an ideal foraging zone for a large number of waterfowls (Nguyen et al., 2009).

This study indicates that the Thale Noi non-hunting area is an important habitat for supporting waterbirds in wetlands, whereas the protected areas have been partly converted to agricultural areas such as oil palm and rubber plantations, particularly in sites 1, 2 and 3. Bird richness was then reduced by more than 60 % (Aratrakorn et al., 2006). Schrag et al. (2009) suggested that continued conversion of native ecosystems to annual crops may lead to a decrease in the overall richness of avifauna, because species richness is negatively correlated with agricultural expansion. In addition, forested habitats with dense native vegetation cover are effective for conservation of forest and endemic avifauna (Lee et al., 2007). Furthermore, Nguyen et al. (2009) found that the hydrological condition in the Tram Chim national park exerted a strong influence, sometimes positive and sometimes negative, upon wetland grassland structures including vegetation communities and the fauna, which could support birds by providing roosting, foraging and breeding areas.

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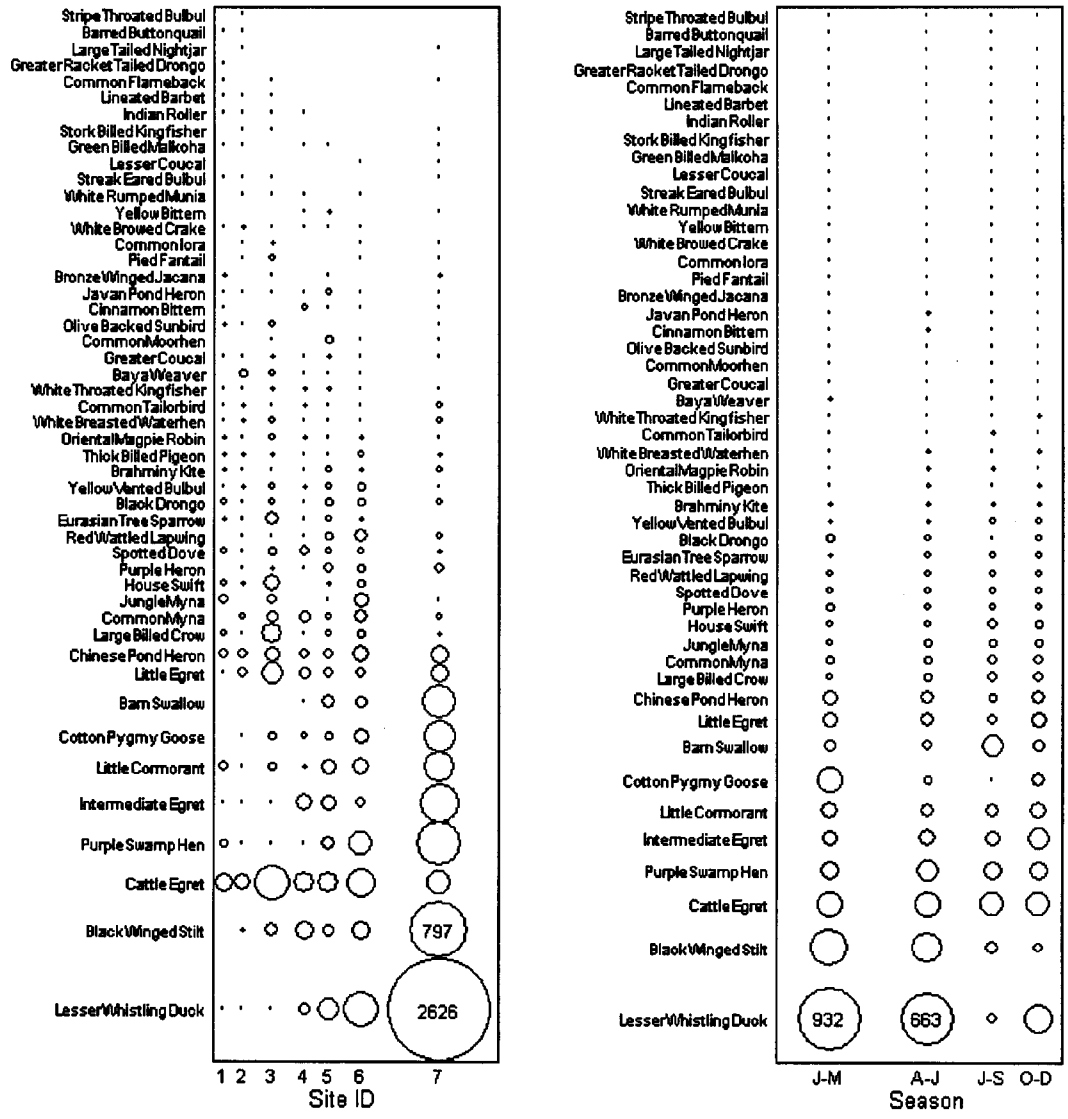


**Fig. 3.** Bubble charts showing distribution of incidence rates of 49 resident species by site (left panel) and by season (right panel), circles indicate bird abundance; numbers are given for incidence rates greater than 500 per day.

## CONCLUSION

The Thale Noi non-hunting area is mostly wetland ranging from freshwater lakes, marshes and swamp forest to seasonally flooded areas. Graphical methods highlight how resident bird species abundance is distributed with respect to location and season. The largest numbers of bird species occurred in habitats predominantly providing continuous flood and grassland in the January-March season and at Laem Din. High water bird biodiversity requires natural flooding and drying disturbance on lowland rivers (Kingsford et al., 2004) and diversity of habitats establishes wider bird distribution. The Thale Noi non-hunting area has been utilized both wildlife and human communities. Effective

management of this area is required to protect habitats of bird species. For example, human activities that interfere with bird habitats should be avoided.

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## 3.3 Published paper on the second study

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*Volume 7 Number 1*, June 2012: 42-48

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# BIRD ASSEMBLAGES IN THE THALE NOI NON-HUNTING AREA, SOUTHERN THAILAND

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**Abstract:** Bird assemblages in the Thale Noi protected area of southern Thailand were investigated using data concerning 23 common resident species routinely reported every month from January 2004 to December 2007 at seven wetland locations. These common resident species were selected using three requirements: (1) they are defined in Lekagul and Round (2005), (2) they were seen in each of the four years, and (3) they had median incidence rate per day greater than zero. The aim of this study was to classify groups of species with respect to incidence rates by season and location. Using factor analysis to find groups of species with common incidence patterns, we isolated five groups of birds that correlated with respect to their habitats and availability of food. The first group (seven species) was found in habitats predominantly providing continuous flooding and aquatic plants. The second group (six species) was found in terrestrial habitats containing various food supplies, especially grain and insects. The third group (six species) was found in habitats connecting from shallow fresh water to suburban environments and typically providing insect food sources both in water and on land. The fourth group (two species) was found in similar habitats to that of the second group, but related to fruit trees. The fifth group (two species) was found in lowland habitats with dense undergrowth providing different food types including insects, seeds and fruit, particularly figs. The classification reflects bird behaviours rather than bird taxonomies.

KEYWORDS: resident birds, Thale Noi non-hunting area, wetland, factor analysis

### Introduction

Understanding species assemblages in habitat areas gives ecologists insight on how to effectively manage threatened areas. Bird assemblages are particularly important because they are commonly used as indicators of ecological conditions (O'Connell *et al.*, 2000; Davidar *et al.*, 2001; Schrag *et al.*, 2009).

The Thale Noi non-hunting area is an important site for birds, covering 457 km$^2$ in southern Thailand, part of which was declared as a Ramsar site, the first in Thailand, in 1998. The area has been used by numerous migratory and resident birds as breeding sites and feeding grounds (Chumrieng & Kongthong, 2005; Kaewdee *et al.*, 2002). In addition, the area has a high diversity of wetland habitat comprising a freshwater lake, marshes, seasonally-flooded grassland and rice fields, swamp forest, and plantations.

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Bird assemblage is related to habitat characteristics and also has been used as an indicator of ecological health (O'Connell *et al.*, 2000; Graham & Blake, 2001, Bryce *et al.*, 2002; Mason & Macdonald, 2005). Several statistical methods have been used to investigate relationships between habitat attributes and bird assemblages, including generalised additive models (Kangas *et al.*, 2010) and principal components analysis (Murkin *et al.*, 1997), as well as the Bird Community Index (O'Connell *et al.*, 2007). Major differences between these methods are based on data scale and study purposes. Data quality is a key issue affecting the reliability of methods. For example, Kangas *et al.* (2010) studied the relative importance of recreation as well as environmental variables on bird communities in protected areas in Finland using generalised additive models. Data containing bird counts and habitat variables were used for analysis. Murkin *et al.* (1997) used

monthly aerial photographs and Geographic Information System (GIS) techniques to characterise habitats, and weekly avian censuses for determining the response of blackbirds, waterfowl, and American Coots to changes in habitat structure using principal components analysis. O'Connell *et al.* (2007) used data from the North American Breeding Bird Survey (BBS) to assess ecological conditions.

The Thale Noi non-hunting area has not been previously studied with respect to relationships between bird assemblages and habitat features. The aim was to identify groups of resident birds characterising behaviours of the birds that reflected habitats and food by using factor analysis (Lattin *et al.*, 2003). Understanding the habitat characteristics associated with bird assemblages is an essential approach towards sustainable management of protected areas for the benefit of wildlife.

## Materials and Methods

### *Bird data*

The bird data were provided by the responsible agency of the Thale Noi non-hunting area, from the National Park, Wildlife and Plant Conservation Department, Ministry of Natural Resources and Environment, Thailand. Data were monthly counts collected by the officials in seven stations over the four years 2004-2007, using a framework developed by academics working in the agency. Numbers of resident species were counted on a specified day in each month by taking observations within circles of 100-meter radius around each point, along transect lines, using a point count method with binoculars. The observation periods began simultaneously at each site, from 8 am to noon and from 1 pm to 4 pm.

### *Study area*

The Thale Noi non-hunting area covers parts of Phatthalung, Nakhon Si Thamarat and Songkhla provinces of southern Thailand. Seven locations (Figure 1) were selected for collecting the bird counts, comprising Khuan Kreng (1), Khuan Nang Whean (2), Khuan Thale Mong (3), Klong Yuan (4), Khuan Khi Sian (5), Ban Pran (6), and Laem Din (7). The two major habitats in the Thale Noi non-hunting area are wetlands and agricultural plots. Wetland habitat includes swamp forest and a freshwater lake, whereas agricultural practices consist of paddy fields, rubber plantations and mixed orchards.

### *Data management*

The 'resident' categories for bird species were defined using three criteria: (a) resident species status as categorised according to Lekagul and Round (2005), (b) the species was seen in the Thale Noi non-hunting area in each year of the data collection period, and (c) they had median incidence rate per day greater than zero. Using these criteria, the bird species used thus contained 23 common resident birds among the 117 species observed. The study periods were defined as January-March, April-June, July-September, and October-December, giving 16 quarterly periods over four years, called 'seasons' for this study. Numbers of birds sighted in a day (7 hours) were converted to daily incidence rates. The incidence rates were thus classified by 4 seasons, 7 sites, and 4 years, giving an outcome data array with 23 columns corresponding to the bird species and $4 \times 4 \times 7 = 112$ rows corresponding to occasions observed.

The incidence rates have very skewed distributions with large proportions of zero values. Since outcomes with skewed distribution complicate statistical analysis, the daily incidence rates were transformed by adding 1 before taking natural logarithms. This method is a common practice since these transformed rates are finite and remain zero when the incidence rate is zero (Clarke & Warwick, 1994).

### *Statistical analysis*

In preliminary analysis, box plots were used to display incidence rates of each species. These graphs indicate the degree of dispersion and skewness in the data, and identify outliers (Tukey, 1977). The common names of the species are presented on the vertical axis. The horizontal axis shows incidence rates (Figure 2).

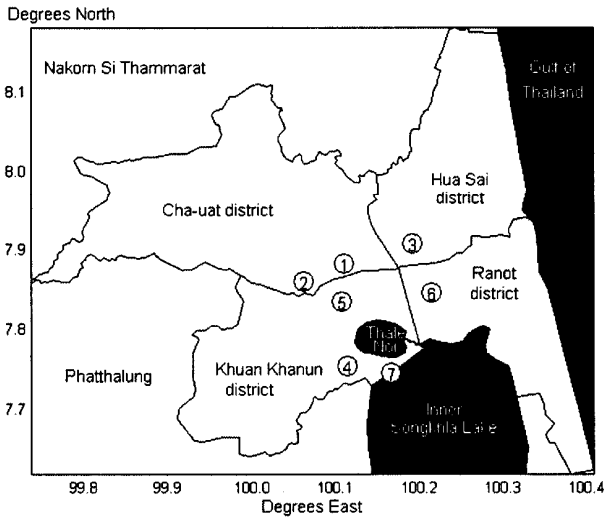


Figure 1: The Thale Noi Non-hunting area with study areas and sampling sites: 1- 7. Thale Noi is the single lake in the study area and is surrounded by the 7 sampling sites: 1-3 are located in Nakhon Si Thammarat,: 4-5, and 7 are located in Phatthalung and 6 is located in Songkhla, southern Thailand. Sites 1, 3, and 5 are mainly swamp forest. Site 2, 4, and 6 are mainly rice fields. Site 7 is mostly seasonally-flooded grassland.

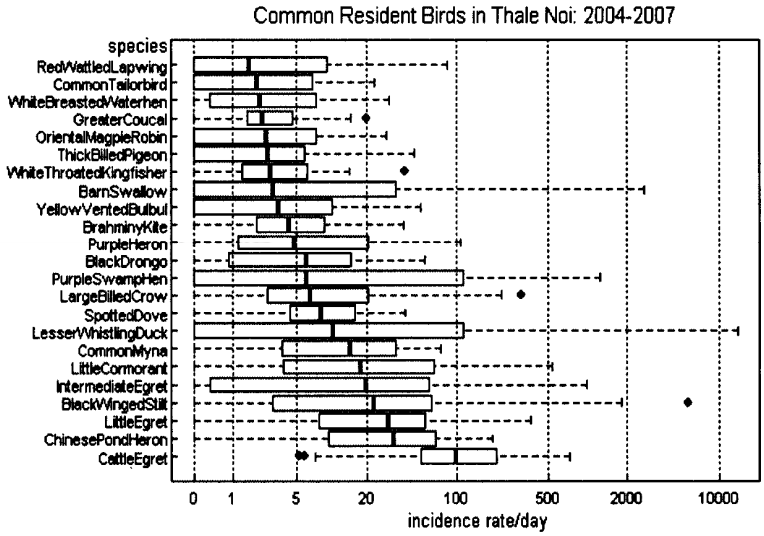


Figure 2: Box plots showing distributions of incidence rates of the 23 resident bird species, ordered by median incidence rates. Horizontal bars cover 50% of each distribution between the lower and upper quartiles. Black vertical stripes show median incidence rates. Black dots show outliers.

The factor analysis (Lattin *et al.*, 2003) used is essentially the same as that conventionally used in ecological studies (Sampantarak *et al.*, 2011). Sampantarak used factor analysis on nine environmental variables (òrganic carbon, total nitrogen, sediment pH, water depth, water pH, salinity, etc.) to form three factors. The three factors were then used as predictor variables in a multivariate multiple-regression model. The aim of the factor analysis in the study was to allocate the 23 bird species into a smaller number of interpretable groups that tended to appear on

the same occasions. The incidence rates of the 23 species thus comprise the variables of interest. Each variable has 112 observations corresponding to combinations of season, year and site. The initial step is the determination of the matrix of correlation coefficients between these 23 variables. The second step is the estimation of factors (groups of species) from the correlation matrix. Ideally each factor (which must contain at least two species to contribute to the factor analysis) contains species that have large correlations with each other and small correlations with species in other groups. To achieve this, species that are not correlated with any other species are said to have high "uniquenesses" and are conventionally omitted from the factor analysis. The factors comprise weighted linear combinations of the species and may be rotated to maximise the weights within each group and minimise the weights outside each group. The resulting weights are called "loadings". Species are assigned to factors based on their loadings. "Promax" rotation was used in preference to "varimax", which requires the rotations to be orthogonal (Browne, 2001).

**Results and Discussion**

Box plots (Figure 2) showed that the Cattle Egret was seen at every location in every season. The rapid expansion of the Cattle Egret's range is due to its relationship with humans and their domesticated animals. It was typically found in fields and dry grassy habitats, reflecting its dietary reliance on terrestrial insects rather than aquatic prey (McKilligan, 1984). The Lesser Whistling-Duck was seen with the highest numbers, with maximum above 10,000 individuals per day, but this species and eight others were not seen on at least 25% of the quarterly periods. These results are consistent with findings of Chumrieng and Kongthong (2005). Flooded conditions provide ideal foraging zones for a large number of waterfowls (Nguyen *et al.*, 2009). This condition resulted in a number of wetland birds increasing their numbers both during and after the flood, especially ducks (Shimada *et al.*, 2000). The majority of the study areas were inundated, particularly in January-March. Birds were seen in large numbers during that season.

The factor analysis gave five groups of species comprising 7, 6, 6, 2 and 2 species, respectively (Table 1). Component species of the first group were the Purple Swamphen (*Porphyrio porphyrio*), Little Cormorant (*Phalacrocorax niger*), Lesser Whistling-Duck (*Dendrocygna javanica*), Intermediate Egret (*Egretta intermedia*), Red-wattled Lapwing (*Vanellus indicus*), Brahminy Kite (*Haliastur indus*), and Chinese Pond-Heron (*Ardeola bacchus*). They prefer mainly wetland habitat including fresh water, marsh and shallow water providing aquatic plants to feed and hide, particularly the Purple Swamphen and Lesser Whistling-Duck. The diet of these two species consists predominantly of plant matter including shoots, leaves, roots, stems, flowers and seeds. Others feed mainly on small fish. The first group thus identified a habitat with attributes predominantly providing continuous flood and aquatic plants.

Components of the second group were the Spotted Dove (*Streptopelia chinensis*), Greater Coucal (*Centropus sinensis*), Cattle Egret (*Bubulcus ibis*), White-throated Kingfisher (*Halcyon smyrnensis*), Large-billed Crow (*Corvus macrorhynchos*), and Black Drongo (*Dicrurus macrocercus*). These species are mostly land birds preferring terrestrial habitat and feeding on a variety of food on the ground. The Greater Coucal and Spotted Dove are usually found walking on the ground while foraging. The Cattle Egret forages on the land, especially with cattle. The diet of the Black Drongo in agriculture land includes a variety of insects (Asokan *et al.*, 2010). Vegetation is an important factor in relation to Black Drongo density (Asokan, Ali & R. Manikannan, 2009). The second group was thus identified with terrestrial habitat containing various food supplies, especially grain and insects.

Component species of the third group were the Common Myna (*Acridotheres tristis*), Little Egret (*Egretta garzetta*), Black-winged Stilt (*Himantopus himantopus*), Common Tailorbird (*Orthotomus sutorius*), Barn Swallow (*Hirundo*

Table 1: Results of the factor analysis listing the rotated factor-loading matrix for the five-factor solution.

| Common Name | F1 | F2 | F3 | F4 | F5 | Uniquenesses |
|---|---|---|---|---|---|---|
| Purple Swamphen | **1.10** | -0.15 | -0.21 | | | 0.076 |
| Little Cormorant | **0.88** | 0.18 | -0.13 | -0.12 | | 0.131 |
| Lesser Whistling-Duck | **0.70** | -0.19 | 0.31 | | | 0.273 |
| Brahminy Kite | **0.64** | 0.38 | -0.16 | -0.11 | -0.26 | 0.402 |
| Red-wattled Lapwing | **0.63** | -0.11 | 0.29 | 0.36 | | 0.307 |
| Intermediate Egret | **0.61** | | 0.40 | -0.15 | -0.44 | 0.063 |
| Chinese Pond-Heron | **0.34** | 0.16 | | | 0.25 | 0.685 |
| Spotted Dove | -0.14 | **0.83** | 0.23 | | -0.32 | 0.324 |
| White-throated | -0.29 | **0.76** | 0.10 | | -0.38 | 0.456 |
| Greater Coucal | 0.15 | **0.68** | | -0.13 | | 0.443 |
| Large-billed Crow | | **0.66** | | 0.11 | 0.31 | 0.311 |
| Cattle Egret | | **0.64** | 0.15 | | 0.18 | 0.431 |
| Black Drongo | 0.32 | **0.39** | -0.15 | 0.13 | | 0.635 |
| Common Myna | -0.43 | 0.13 | **0.88** | 0.24 | 0.22 | 0.264 |
| Little Egret | -0.12 | 0.27 | **0.73** | -0.23 | 0.28 | 0.355 |
| Black-winged Stilt | 0.16 | | **0.60** | | 0.23 | 0.472 |
| Common Tailorbird | | -0.11 | **0.51** | 0.12 | -0.16 | 0.713 |
| Purple Heron | 0.48 | | **0.51** | 0.17 | | 0.220 |
| Barn Swallow | 0.28 | 0.10 | **0.42** | | | 0.588 |
| Yellow-vented Bulbul | | | 0.15 | **0.92** | | 0.192 |
| Oriental Magpie Robin | | 0.25 | | **0.62** | | 0.529 |
| White-breasted | -0.15 | -0.11 | 0.30 | -0.23 | **0.63** | 0.615 |
| Thick-billed Green | | | | 0.18 | **0.47** | 0.685 |

Note: The 5 common factors are F1, F2, F3, F4 and F5. Loadings less than 0.1 in magnitude are not shown in the results. Highlighted values correspond to the maximum factor loading for each species.

Uniquenesses for each species are values close to 1, providing evidence that they cannot be associated with any other species. For this analysis, no uniqueness exceeded 0.75 so all species were included in the factor model.

*rustica*) and Purple Heron (*Ardea purpurea*). These birds prefer a wide range of habitats from saltwater to freshwater, and woodland to human habitats. The Common Myna thrives in urban and suburban environments. The Little Egret and Black-winged Stilt feed on aquatic insects whereas the Common Tailorbird and Barn Swallow actively forage on insects, with the latter preferring Diptera including flies and mosquitoes (Møller, 2001). Connecting habitat from shallow fresh water to suburban environment providing food sources, mainly insects both in water and land habitat, thus identified the third group.

The fourth group contained the Yellow-vented Bulbul (*Pycnonotus goiavier*) and the Oriental Magpie-Robin (*Copsychus saularis*). These species are found from open woodland to human habitat and are fond of fruits. The birds in both the second and fourth factors are all land birds, but differ in their diets and foraging behaviours. So the fourth group was thus identified with fruit trees.

The White-breasted Waterhen (*Amaurornis phoenicurus*) and Thick-billed Pigeon (*Treron curvirostra*) comprised the fifth group. The White-breasted Waterhen is found in freshwater

marshes and dense undergrowth and forages on the ground. It feeds mainly on seeds, insects and small fish. The habitat of the Thick-billed Pigeon in Peninsular Malaysia is lowland forest, and pigeons of the genus *Treron* are fig-eating specialists (Lambert, 1989). So the fifth group was thus identified with lowland habitat with dense undergrowth providing different food types including insects, seeds and fruit, particularly figs.

Applying exploratory factor analysis to bird data provided groups of bird species. The birds in the same group had similar behaviours, and these behaviours were related to habitats and food sources. Many studies have found that vegetation variables and habitats correlate with bird species richness and diversity (Thinh, 2006, Waltert *et al.*, 2005). Furthermore, food-supply can affect bird diversity, abundance, breeding ecology and flocking behaviour (Sodhi, 2002). Bird species using similar proportions of microhabitats forage in different proportions of vertical strata. This niche segregation enables these species to coexist in the same habitat (Kwok, 2009). For example, The White-breasted Waterhen and Thick-billed Pigeon were allocated to the same group, and they coexist with vertical strata.

The Thale Noi non-hunting area is mostly wetland ranging from a freshwater lake, marshes and swamp forest to seasonally-flooded areas. The important determinants of bird assemblages are thus habitats predominantly providing continuous flood and aquatic plants. These habitats contain niches of wetland birds. High water-bird biodiversity requires natural flooding and drying disturbance on lowland rivers (Kingsford *et al.*, 2004) and diversity of habitat establishes wider bird distribution. Therefore, sustainability of wetland management is an essential approach to provide alternative habitats for water birds. It is also helpful to retain the entire wetland ecosystem. The Thale Noi non-hunting area should do likewise to protect wetland habitat for bird species.

In conclusion, factor analysis can be effectively applied to ecological data in order to classify groups of birds that reflect their behaviours rather than their taxonomies. For this study, it revealed habitat attributes and food types associated with the occurrence of groups of resident birds.

**Acknowledgements**

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### 3.4 Results on the third study

Box plots (Figure 3.1) showed that the Cattle Egret was seen at every location in every season. Greater Coucal was seen with the lowest average, 3 individuals per day, whereas Lesser Whistling-Duck was seen with the highest average, 448 individuals per day. The eight others labeled with asterisks (*) were not seen in at least 25 % of the quarterly periods. Mean was higher than median in every species indicating skewed distribution. Therefore mean are directly not informative itself for summarizing the data. The negative binomial GLM and additive log-linear model are thus considered for further analysis of these data.

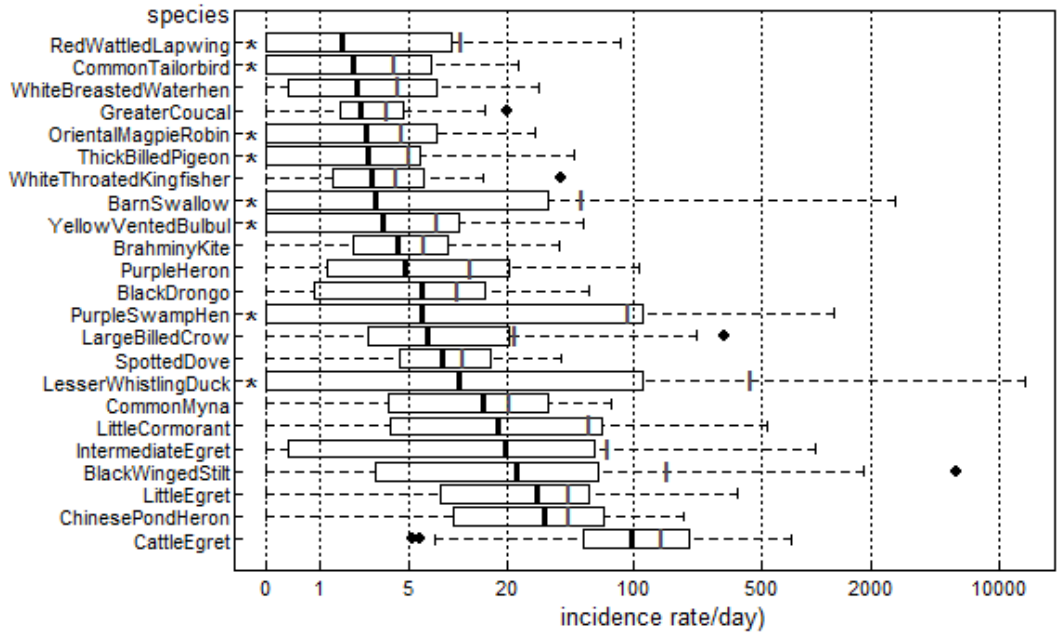


Figure 3.1 Box plots showing distributions of incidence rates of the 23 resident bird species, black and grey vertical stripes show median and mean incidence rates, respectively, black dots show outliers, The labeled species(*) show they have zero numbers for at least 25 % incidence rate calculated.

The incidence rates are classified by 4 seasons, 7 sites, and 4 years, giving samples of size 112 for each of the 23 resident bird species. We consider a model with three factors (species, site and season)

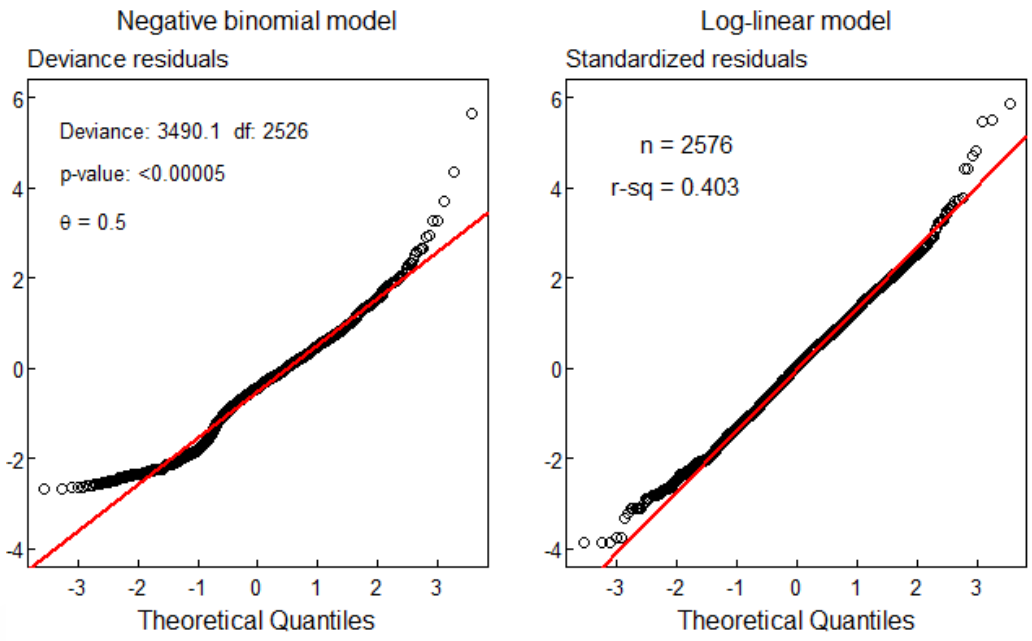


Figure 3.2 Residual plots for negative binomial and log-linear models

Figure 3.2 shows residuals plots for negative binomial and log-linear models. The negative binomial model (left panel) is not satisfactory even with a very small estimate for θ. In addition, residual deviance (3490.1) is still more than its degrees of freedom (2526). It leads to consider an alternative additive linear model similar to that for analysis of pneumonia incidence rates (Kongchouy et al., 2010). We fit a linear model with transformed outcome and three additive factors. This model (right panel) gives a better fit. The normality assumption is reasonable apart from a few high outliers.

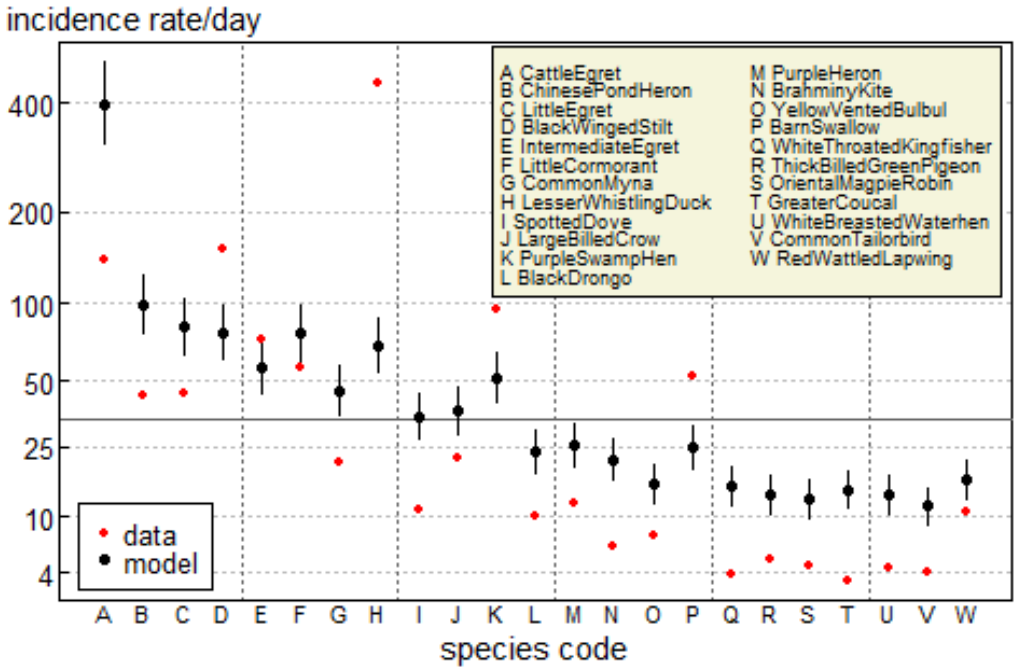


Figure 3.3 Daily incidence rates for each bird species adjusted for season and site factors

This graph shows confidence intervals for adjusted incidence rates based on log-linear model. The horizontal line shows overall mean incidence rate from model (33.76 individuals per day). The confidence intervals also classified resident birds as above mean, below mean, or not evidently different from mean, for each species studied. The means of the data indicated average of each species separately on its own as if there appeared only one species at that time, whereas the means from model indicated average of each species which appeared naturally with others. Therefore the means from the model indicated incidence rates for each bird species adjusted for season and site factors. With comparing means of data to that from the model, most of them from model were higher than those from data. However, there are four species for which means of data were higher than those of model.

The nine species with the high incidence rates comprised Cattle Egret (*Bubulcus ibis*), Chinese Pond-Heron (*Ardeola bacchus*), Little Egret (*Egretta garzetta*), Black-winged Stilt (*Himantopus himantopus*) Intermediate Egret (*Egretta intermedia*), Little Cormorant (*Phalacrocorax niger*), Common Myna ( *Acridotheres tristis*) Lesser Whistling-Duck (*Dendrocygna javanica*), and Purple Swamphen (*Porphyrio porphyrio*). However the incidence rates of two species based on data showed very obvious differences from those obtained using the model. These species were Cattle Egret and Lesser Whistling-Duck.

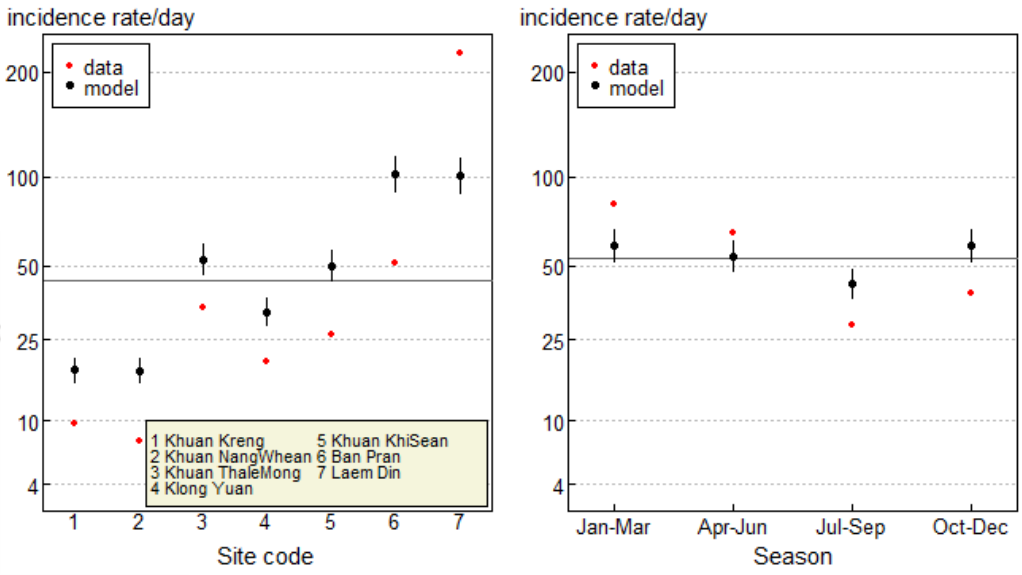


Figure 3.4 Adjusted incidence rates by site (left panel) and season (right panel)

These plots show that the incidence rates vary with location. With comparing means of data to that from the model, most of them from model were higher than those from data except Leam Din. The resident birds were seen with lower numbers in Khuan Kreng and Khuan Nang Whean, and with higher numbers in Ban Pran and Leam Din.

The seasonal effect is relatively small. The lowest numbers of resident birds were seen during July-September.

**3.5 Discussion on the third study**

With these data, the negative binomial model provided poor fit, whereas a simple linear regression model gives a quite satisfactory fit, with taking logarithms of the incidence rates after replacing the zeros by appropriate constant. The negative binomial model might fail to cover the range of overdispersion situations that probably occur in ecological study, particularly for abundance data. In this case, the data used show that occurrence of bird species are not independent. Groups of birds related to their habitats and availability of food (Rittiboon and Karntanut 2011). It is possible to see more than one species at the same time. The data also contained a large number of species, particularly Lesser Whistling-Duck instead of many zeros.

The log-linear regression modelling based on aggregated data by species, site, season, and year were well fitted by this simple model of 2576 cells, 528 (20.50 %) zero counts. To modify data in this model, we added a constant 1 to all counts before taking logarithms. This method was usually applied to ecological data and these transformed rates were also finite and remain zero when the incidence rate was zero (Clark and Warwick 1994). Based on ecological data, there are many zero (often 50-80 per cent of all values) and zero-inflated count distribution in abundance data. Warton (2005) considered zero-inflated models to model such data. However Warton (2005) revealed a finding that a Gaussian model based on transformed abundance fitted data surprisingly well. Kongchouy et al. (2010) also suggested a similar finding

that a simple linear regression model with normal errors gave a quite satisfactory fit, even though the proportion of zero counts was substantial.

According to Figure 3.3, the incidence rates of species from the model are mostly higher than those from data. This is the result of each species being adjusted for other factors affecting bird occurrence. The mean from model indicated average of each species which occurred together under adjusted other factors. Cattle Egret and Lesser Whistling-Duck were very obvious differences between mean from model and mean of data. This result revealed that the Cattle Egret was found at the Thale-Noi non-hunting area with the highest incidence rates (394 individuals per day). The such differences mean between from model and data of two species might be their measurements within different pattern of occurrence especially, the Lesser Whistling-Duck. It is remarkable for its occurrence as flocks. Furthermore the species with high incidence rates were found in the Thale-Noi non hunting area with diversity of wetland habitats, particularly seasonally flooded, aquatic plants, *melaleuca* forest and grassland. (Kaewdee et al. 2002, Chumrieng and Kongthong 2005, Rittiboon and Karntanut 2011, Rittiboon et al. 2012).

Similarly, the mean from the model are mostly higher than those from data except for site 7 Laem Din shown as Figure 3.4 (left panel). A large number of Lesser Whistling-Duck was seen at site 7. The mean from model indicated average of each site which responded to analysing all sites together, whereas the means of the data indicated average of each site which seemed separate analysis from other sites. The resident birds were seen with higher numbers in Ban Pran and Laem Din, whereas they were seen with lower numbers in Khuan Kreng and Khuan Nang Whean. Studies

have shown that wetland habitats including rice field, *Melaleuca* forest, grassland and inundated areas are very important as feeding and breeding sites for bird species (Fasola and Ruiz 1996, Czech and Parsons 2002, Kaewdee 2002, Hamer et al. 2006, Nguyen et al. 2009). Similarly, the majority of Ban Pran and Laem Din comprise such wetland habitats. It probably influence high abundance of bird species. In contrast, Khuan Kreng and Khuan Nang Whean partly converted to agricultural areas, leading to a decrease in the overall richness of avifauna (Aratrakorn et al. 2006, Schrag et al. 2009).

However, the seasonal effect little relates to occurrence of these birds as Figure 3.4 (right panel). It shows incidence rates are mostly average occurrence rates. This due to resident bird is a species which is present throughout the year and presumed to breed (Lekagul and Round 2005).