Declaration

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

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AVIAN DIVERSITY OF RICE FIELDS IN SOUTHEAST ASIA

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ABSTRACT

The thesis investigated avian diversity within rice fields at three locations in the Philippines. From February 2012 until April 2014, avian community structure was recorded to determine the effect that different farming techniques have upon frequency and abundance within the habitat. Investigations were conducted to challenge the common misconception that all birds are a threat to crop yield, with detailed research into the life-cycle and diet of the Eurasian tree sparrow (*Passer montanus*).

Twenty-seven continuous months of bird surveys were conducted to record annual, and temporal, changes in frequency and diversity. A total of 130 species were recorded, and explanations for abundance patterns discussed. Species biological richness scores indicated that time of year and field stage are important factors affecting diversity within rice fields.

To investigate the effect different farming techniques have upon avian diversity, two large-scale crop manipulations were investigated; fields under a water management technique (Alternate Wetting and Drying) and areas of accelerated rice production. Both investigations indicated that avian frequency and abundance were higher within manipulated fields when compared to control sites. Differences in community structure are discussed identifying a change under manipulated conditions.

Artificial nest boxes were used to record breeding season and productivity, with biometric measurements, for the Eurasian tree sparrow sub-species '*saturatus*', which produced more eggs but successfully fledged fewer young, over a longer breeding period. A significant difference in wing formulae between sexes indicates a difference in life-style strategies. To determine diet, stable isotopic analysis of claws measured ratios of $\delta^{15}N$. Differences in $\delta^{15}N$ were compared to a control group fed on a 'pure' diet. Results indicated a mixed diet when given free choice, but could not be identified within the current data set.

Management strategies to reduce potential yield loss to birds, along with considerations for future work, are discussed.

“All birds eat rice”

-Filipino rice farmer

“What gets us into trouble is not what we don’t know.

It’s what we know for sure that just ain’t so.”

- Mark Twain

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IRRI
INTERNATIONAL RICE RESEARCH INSTITUTE

CGIAR | Global Rice Science Partnership

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ABBREVIATIONS AND DEFINITIONS

ABBREVIATIONS:

AWD – Alternate Wetting and Drying

CIS – Community Irrigated System

GRiSP – Global Rice Science Partnership

IRRI – International Rice Research Institute

IUCN – International Union for Conservation of Nature

NIA – National Irrigation Association

PAGASA - Philippine Atmospheric, Geophysical and Astronomical Services Administration

PhilRice – The Philippine Rice Research Institute

PSA – Philippine Statistics Authority

WBCP – Wild Bird Club of the Philippines

Definitions:

Barangay	- Filipino term for a small collective, such as a district, village or small number of farms.
Bunds	- The risen embankment, or path, which surrounds a rice field. Often used as boundaries and for access.
Lodging	- The rice plants are forced over onto the ground before full maturity, making harvest difficult. There are multiple reasons why this occurs.
Puddling	- Where water collects in small puddles, often footprints in the soil, within a rice field. There is no standing surface water within the field and these puddles are the only exposed water.

Ratooning - Where a harvested field is left and the remaining stubble continues to grow, allowing for a second harvest. Sometimes referred to as Regrowth, where plants continue to grow but not intended to be harvested a second time.

Tillers - A rice tiller is a grain-bearing branch of a rice plant, opposed to other leaves of the plant.

Dry season crop - For this thesis, the dry season crop is between November and April.

Monsoon crop - For this thesis, the monsoon crop is between May and October.

4-2 - Four rice crops over two calendar years

5-2 - Five rice crops over two calendar years

A list of bird names and the taxonomic classifications of common species often referred to throughout the thesis can be found in Appendix 1.

General Introduction

1.1 Birds of rice fields

Globally, rice fields support a wide diversity of species: mammalian, amphibian, invertebrate and avian. The unique method of farming this crop, keeping fields continually flooded (Tabbal *et al.,* 2002; Bouman *et al.,* 2006), potentially provides a wetland habitat which is maintained throughout the year, often during times when natural wetlands would be dry (Donald, 2004; Taylor & Schultz, 2010). Conversion to agricultural land is one of the major factors in changing land use of Southeast Asia (Sodhi *et al.,* 2009). Rice fields become important supplementary artificial wetlands for birds as natural wetlands reduce in size and dry up (Donald, 2004; Taylor & Schultz, 2010; Sizemore & Main, 2012). The challenge to ecologists and conservationists is to balance economic productivity and ecosystem processes in such human-modified habitat (Martin *et al.,* 2012).

Birds provide a great opportunity to assess the health of an ecosystem or habitat as they are relatively easy to recognise and count (Kushlan, 1993; Larsen *et al.,* 2012). When determining potential environmental impacts using birds as indicators, reliable and extensive baseline figures must be established and continually assessed (Gregory *et al.,* 2003). Though different methods can be applied, each possesses varying strengths and weaknesses (Gregory *et al.,* 2003). Rice fields potentially have an important role with regards to the species found within them. Twenty-five percent of the Italian population of Eurasian bittern (*Botaurus stellaris*) have been shown to time their breeding to when the rice crop is > 35 cm, delaying for up to two weeks compared to those nesting in natural wetlands (Longoni *et al*., 2007). Within Korea and Japan, 22% of globally threatened bird species occur in rice fields (Fujioka *et al.,* 2010) with 54% of Asian endangered species found in Chinese rice fields (Wood *et al.,* 2010).

Rice fields potentially influence and support the local avian diversity but may play a larger more important role for migratory species (Wood *et al.,* 2010). During migration, species spend considerable time feeding during stopovers. Dunlins (*Calidris alpina*) were tracked on their Northern migration through the Eastern part of the Pacific Flyway, preferring short bursts of flight and longer periods of foraging in wetlands (Warnock *et al*., 2004). The use of stop-over sites, in a "stepping stones" fashion, has been well documented (Acosta *et al*., 2010; King *et al*., 2010; Longoni, 2010; Wood *et al.,* 2010; Wymenga & Zwarts, 2010). Wetland habitats found along migration paths have the potential to support a great number of bird species. The Philippines could be vital for stop-over sites as birds travel either North or South on migration. Being the last land mass to the East of Asia, between Taiwan and Indonesia, it may provide opportunities for migrating species to feed. Currently, the importance of rice fields for migratory species within South-East Asia is generally unknown. With natural wetlands decreasing, will species move further into rice fields to feed during migration? Do farming methods influence the success of these species? More importantly, how can this be recorded?

Information currently available is primarily limited to basic distribution information and independent studies of selected species. In 2010, the Waterbird Society produced a special publication entitled '*Ecology and Conservation of Birds in Rice Fields: A Global Review'* (Elphick *et al.,* 2010a). This publication presented papers on three main elements of birds in rice fields; regional papers on species presence, rice cultivation impacts upon avian diversity, and the interactions between human and bird activities in rice fields. The need to concentrate within countries that produce the most rice is recognised within this special publication. The references of birds in rice fields were compared from these regional papers and categorised on their geographic cover, general bird guild and the main purpose of the study (Table 1.1). A total of 303 references were checked; 179 are reported in Table 1.1, 46 were not relevant (not birds and/or rice fields), 27 were non-English journals with no access, 25 were not accessible, 16 could not be found and 10 were bird books, field guides or country check lists. Countries within Asia produce 89% of the global market of rice (Elphick, 2015), the largest quantity in the world (Table 1.2) and although considerable work has been conducted within the area, the majority focus on bird presence within the investigated country (not shown) or with regards to a specific species and their ecology, concentrating on birds associated with water, such as waterfowl, long-legged wading birds, shorebirds and gruiformes (Table 1.3), which is not surprising given the society's primary focus on waterbirds.

In 2015, a review on migratory songbirds of the East Asian-Australasian Flyway was published (Yong *et al.,* 2015), focusing on 32 families of passerines (170 long-distant and 80 short-distant migrants) which occurred within the flyway within all habitats. Reviewing ecology, breeding and current populations highlighted a lack of knowledge on several species and their movements throughout the region, as many species had a relatively small breeding range. The importance of tropical forests as over-wintering habitats are addressed with agricultural management of rice fields mentioned as an important factor, with land-clearance and conversion of wetland to rice fields being a primary threat to some species.

Rice fields are commonly sampled for migrants within other parts of Asia, although not currently within the Philippines, which supports a number of wintering populations (Bamford *et al.,* 2008). Monitoring such birds within the rice fields may provide further information on species population numbers and ecology.

Table 1.1 Supporting literature within Waterbirds 33, Special Publication 1 (Elphick *et al.,* 2010a) on birds in rice fields. References are split between all birds, waterbirds & shorebirds (see Table 1.3). 'Other birds' depicts studies on specific non-waterbird families, groups or singular species. 'USA & Americas' includes Canada, USA, Mexico and all South American Countries. Migration, landscape preference and studies on birds as bio-indicators are classified as 'Ecology of species', often concentrating on a single species. Rice field fallow management is classified as 'Farm management'. Prey abundance within rice fields and changes in land use is classified as 'Rice as a habitat'. Full reference list in Appendix 2.

Geographic Location	Avian Group	Reason for Study	No. of References
Global	All	Descriptive	1
Global	All	Farm Management	1
Global	All	Rice as a habitat	1
Global	Waterbirds	Rice as a habitat	3
Global	Waterbirds	Descriptive	1
Global	Waterbirds	Ecology of species	1
Global	Waterbirds	Conservation	1
Global		**Total**	**9**
USA & Americas	All	Rice as a habitat	5
USA & Americas	All	Ecology of species	1
USA & Americas	All	Farm management	1
USA & Americas	Waterbirds	Ecology of species	12
USA & Americas	Waterbirds	Rice as a habitat	4
USA & Americas	Waterbirds	Farm Management	4
USA & Americas	Waterbirds	As a benefit	3
USA & Americas	Waterbirds	As a pest	3
USA & Americas	Waterbirds	Descriptive	2
USA & Americas	Other birds	Ecology of species	1
USA & Americas	Other birds	As a benefit	1
USA & Americas	Other birds	As a pest	3
USA & Americas		**Total**	**40**
Europe	Waterbirds	Ecology of Species	21
Europe	Waterbirds	Rice as a habitat	15
Europe	Waterbirds	Conservation	4
Europe	Waterbirds	As a pest	2
Europe	Other birds	Ecology of Species	3
Europe		**Total**	**45**
Africa	Waterbirds	Ecology of species	1
Africa	Other birds	As a pest	1
Africa		**Total**	**2**

Table 1.1 (continued)

Geographic Location	Avian Group	Reason for Study	No. of References
Middle-East	Waterbirds	Descriptive	1
Middle-East		**Total**	**1**
Africa	Waterbirds	Ecology of species	2
Africa		**Total**	**2**
Asia	All	Descriptive	8
Asia	All	Rice as a habitat	7
Asia	All	Ecology of species	4
Asia	All	Conservation	1
Asia	Waterbirds	Ecology of species	28
Asia	Waterbirds	Rice as a habitat	5
Asia	Waterbirds	Farm Management	4
Asia	Waterbirds	As a pest	3
Asia	Waterbirds	As a benefit	2
Asia	Waterbirds	Conservation	1
Asia	Other birds	As a pest	5
Asia	Other birds	Ecology of species	3
Asia	Other birds	As a benefit	1
Asia		**Total**	**74**
Australia	All	Rice as a habitat	1
Australia	All	Descriptive	1
Australia	Waterbirds	Rice as a habitat	2
Australia	Waterbirds	Ecology of species	1
Australia	Waterbirds	As a benefit	1
Australia		**Total**	**6**

Table 1.2 Top ten rice producing countries in 2013, ranked by mean annual production (2006 – 2010). Amounts listed per million tonnes. Mean annual data from GRiSP (Global Rice Science Partnership, 2013); 2013 data from FAOSTAT (2014a).

Country	Mean annual production from 2006 - 2010 (million tonnes)	Annual production in 2013 (million tonnes)
China	197.21	203.61
India	143.96	159.20
Indonesia	66.46	71.28
Bangladesh	50.06	51.50
Vietnam	39.98	44.04
Myanmar	33.20	28.77
Thailand	31.59	36.07
Philippines	15.77	18.44
Brazil	11.23	11.78
Japan	10.60	10.76

The understanding of bird communities and their effects within rice fields are disproportionately represented by studies from the United States of America (USA) and Europe (Elphick *et al*., 2010b; Ibáñez *et al*., 2010; Elphick, 2015). The majority of studies reported from within Asia are restricted to single species (Table 1.1). Although studies which concentrate upon a single species provide an insight into research trends on avian communities within rice fields throughout the world, it is not a "*one rule fits all*" but describes some of the mechanisms at work within Asian rice fields. Asia produces over 90% of the global market of rice and has the highest number of globally threatened bird species that occur regularly within its region in any continent (Crosby & Chen, 2006). This presents a significant opportunity for investigation into the knowledge of avian use of rice fields (Elphick *et al*., 2010b). Within lowland tropical and sub-tropical habitats in Asia, rice is grown at an accelerated rate when compared to both the USA and Europe and there are generally two or more crops per year compared to temperate climates. Therefore in tropical and sub-tropical climates a great deal of data can be collected and trends explored each year. Further broad and detailed studies are required to strengthen the understanding of the role that rice plays in avian conservation (Elphick *et al*., 2010b, 2010c; Wood *et al.,* 2010) and to determine the benefits of different farming methods on wildlife whilst minimising detrimental impacts upon crop yield. With the exception of migratory species, avian diversity is restricted to geographical location, meaning each country needs to be investigated individually with local biodiversity taken into account. This thesis will concentrate on the rice growing regions of the Philippines.

1.2 Birds of the Philippines

1.2.1. General Trends

The Philippines is listed as one of the highest ranked countries for avian diversity and endemism in the world (Peterson *et al.,* 2000) and has been identified as a biodiversity hotspot of conservation importance (Balmford & Long, 1994; Myers *et al.,* 2000). Consisting of over 7000 islands, currently the country has 672 known avian species, 235 of which are endemic (Wild Bird Club of the Philippines (WBCP), 2013). Of these, 52 are listed as Vulnerable, 14 as Endangered and 15 as Critically Endangered by the International Union for Conservation of Nature (IUCN; WBCP, 2013). The occurrence and distribution of avian species varies dramatically between islands (Peterson, 2006) and needs to be accounted for during interpretation of research findings.

Table 1.3 Full list of bird Families found within the Philippines. Category column lists the separate categories into which the birds have been classified (for this thesis).

Family	Common, English Name	Category
Megapodiidae	Megapodes	Other
Phasianidae	Pheasants and allies	Other
Anatidae	Ducks, Geese and Swans	Waterbirds
Procellariidae	Petrels and Shearwaters	Shorebirds
Hydrobatidae	Storm Petrels	Shorebirds
Podicipedidae	Grebes	Waterbirds
Phaethontidae	Tropicbirds	Waterbirds
Ciconiidae	Storks	Waterbirds
Threskiornithidae	Ibises and Spoonbills	Waterbirds
Ardeidae	Bitterns, Egrets and Herons	Waterbirds
Pelecanidae	Pelicans	Shorebirds
Fregatidae	Frigatebirds	Shorebirds
Sulidae	Boobies	Shorebirds
Phalacrocoracidae	Cormorants	Shorebirds
Anhingidae	Darters	Waterbirds
Pandionidae	Ospreys	Other
Accipitridae	Kites, Hawks and Eagles	Other
Falconidae	Falconets and Falcons	Other
Rallidae	Crakes, Rails and Coots	Waterbirds
Gruidae	Cranes	Waterbirds
Turnicidae	Buttonquails	Other
Burhinidae	Stone-curlews, Thick-knees	Shorebirds
Recurvirostridae	Stilts and Avocets	Waterbirds
Rostratulidae	Painted-snipes	Waterbirds
Jacanidae	Jacanas	Waterbirds
Scolopacidae	Sandpipers, Plovers and Snipes	Waterbirds
Glareolidae	Pratincoles	Waterbirds
Laridae	Gulls and Terns	Shorebirds
Stercorariidae	Skuas	Shorebirds
Columbidae	Pigeons and Doves	Other
Cacatuidae	Cockatoos	Other
Psittacidae	Parrots	Other
Cuculidae	Cuckoos	Other
Tytonidae	Barn Owls	Other
Strigidae	Owls	Other
Podargidae	Frogmouths	Other
Caprimulgidae	Nightjars	Other
Hemiprocnidae	Treeswifts	Other
Apodidae	Swifts	Other
Trogonidae	Trogons	Other
Coraciidae	Rollers	Other
Alcedinidae	Kingfishers	Waterbirds
Meropidae	Bee-eaters	Other
Upupidae	Hoopoes	Other
Bucerotidae	Hornbills	Other

Table 1.3 (continued).

Family	Common, English Name	Category
Megalaimidae	Asian Barbets	Other
Picidae	Woodpeckers	Other
Eurylaimidae	Broadbills	Other
Pittidae	Pittas	Other
Acanthizidae	Australasian Warblers	Other
Artamidae	Woodswallows	Other
Aegithinidae	Ioras	Other
Campephagidae	Cuckooshrikes	Other
Pachycephalidae	Whistlers	Other
Laniidae	Shrikes	Other
Oriolidae	Orioles	Other
Dicruridae	Drongos	Other
Rhipiduridae	Fantails	Other
Monarchidae	Monarchs	Other
Corvidae	Crows	Other
Bombycillidae	Waxwings	Other
Stenostiridae	Fairy Flycatchers	Other
Paridae	Tits	Other
Alaudidae	Larks	Other
Pycnonotidae	Bulbuls	Other
Hirundinidae	Swallows and Martins	Other
Cettiidae	Cettia Bush Warblers and allies	Other
Phylloscopidae	Leaf Warblers and allies	Other
Acrocephalidae	Reed Warblers and allies	Other
Locustellidae	Grassbirds and allies	Other
Cisticolidae	Cisticolas and allies	Other
Timaliidae	Babblers	Other
Pellorneidae	Ground Babblers	Other
Zosteropidae	White-eyes	Other
Irenidae	Fairy-bluebirds	Other
Sittidae	Nuthatches	Other
Sturnidae	Starlings and Rhabdornis	Other
Turdidae	Thrushes	Other
Muscicapidae	Chats and Old World Flycatchers	Other
Chloropseidae	Leafbirds	Other
Dicaeidae	Flowerpeckers	Other
Nectariniidae	Sunbirds	Other
Passeridae	Old World Sparrows	Pest
Estrildidae	Waxbills, Munias and allies	Pest
Motacillidae	Wagtails and Pipits	Waterbirds and Other
Fringillidae	Finches	Other
Emberizidae	Buntings	Other

The avian fauna of the Philippines faces a number of threats. One of these is habitat loss caused by mining and logging activities (Haribon, 2014) and by land use conversion to infrastructure or agriculture. In fact, land use conversion is considered to have caused the greatest loss of natural forest within Southeast Asia (Sodhi *et al.,* 2004). Moreover, redirection of waterways or conversion of wetlands for rice fields decreases available water resources. Hunting pressure for food, trade or sport further increases the risks to avian abundance and diversity (Haribon, 2014). The loss of avian diversity due to deforestation has been explored in the literature (Haribon, 2014), but few have investigated the differences before and after conversion from natural wetlands to agricultural land (Sodhi *et al.,* 2004). There is a clear need to expand current knowledge about the avian community that uses rice fields and their adaptions to the changing habitat (Elphick *et al*., 2010c; Ibáñez *et al*., 2010).

1.2.2. Conflicts with rice production

Conflicts between birds and agriculture are recognised globally (Lemy *et al.,* 2000; Wilson *et al.,* 2010). Within rice fields damage can occur either directly, by eating grains (De Grazio & Besser, 1970; Elliott, 1979; Subramanya, 1994; Cummings *et al.,* 2005), or indirectly, through trampling by larger birds such as flamingos or cranes (Tourenq *et al.,* 2001; Gopi Sundar, 2009), or grazing within flooded fields causing damage to young plants (Lane *et al.,* 1998; Amano *et al.,* 2004, 2007; Merkens *et al.,* 2012). Within Africa, farmers mention that direct bird damage is the second highest loss of rice yield after weeds (de Mey *et al*., 2012; de Mey & Demont, 2013).

The majority of Philippine rice farmers believe that "*all birds eat rice*" (*pers. obs*.). Their primary concern is their crop and the yield they can harvest. Birds are more visually obvious within rice fields than any other taxa and are blamed for any loss in yield, regardless of species (*pers. obs*.). If birds are perceived to have a negative impact upon crop yield then they are considered a pest (Elphick, 2010) and this inter-generational attitude will require sustained education to overcome it. There is no scientific literature on the full community of birds that occur within the rice fields of the Philippines, therefore it is difficult to prove that not all birds are feeding on rice. It is assumed that the small number of granivorous birds which occur throughout the agricultural landscape will feed on rice, but their ecology and population numbers are unknown. There are large wading birds that may cause visible damage by trampling rice plants during the early stages of growth, though the effect of this and any potential yield implications have not been explored.

Challenging the "*all birds eat rice*" attitude and explaining to farmers which species occur and why, will hopefully influence their management practices to better support avian diversity. Baseline figures of current bird communities may highlight trends in association with certain management techniques. Once this deeply entrenched stigma on all birds has been removed, requiring sustained education to overcome it, there will be a higher likelihood that rural communities will be interested in protecting and attracting those species which provide an ecosystem service. Understanding the complete avian community present in rice crops might also assist in the identification of methods aimed at reducing damage to crops.

1.2.3. Benefits to rice production

The effects of birds upon the rice crop may not all be detrimental. There are various examples of how natural bird behaviour can benefit the rice crop, thereby increasing their economic value to farmers. For example, species which graze in flooded fields may manage unwanted vegetation through preferential foraging of weed seeds, reducing the potential need for herbicides (Hohman *et al.,* 1996) as well as hunting young golden apple snails (*Pomacea canaliculata*), acting as a control agent of this rice pest (Teo, 2001; Sawangproh *et al.,* 2012).

Investigations in other agricultural ecosystems demonstrate the regulation and preventative effect that birds can have upon invertebrate pests (Perfecto *et al.,* 2004). Birds have the greatest impact on managing low to moderate invertebrate populations (Sekercioglu, 2006). From shade grown coffee to oil palm plantations, different species of birds responded to pest outbreaks (Whelan *et al.,* 2008; Horgan *et al.,* 2014) as well as dampening the overall damage (Perfecto *et al.,* 2004). Perfecto *et al.* (2004) reviewed ecosystem services provided by birds in shade-grown coffee plantations but work within other agricultural landscapes such as rice fields is still needed. Avian ecosystem services could play an important role in the tropics through providing year-round management of invertebrates and limiting the need for farmers to constantly rely on insecticides, only using them during severe outbreak events (Way & Heong, 1994; Sekercioglu, 2006).

A number of granivorous and omnivorous species have shown gut plasticity during breeding and/or ontogeny (Feare, 1984; Brzęk *et al.,* 2009), this involves physical changes on their digestive system, allowing them to change their diet to increase protein intake, usually by increasing the amount of invertebrates within their diet whilst decreasing the total amount of grain consumed. If this is happening with granivorous species resident in rice fields in the Philippines, then avian species considered to be pests might, at certain times throughout the year, instead be considered beneficial to rice farmers by limiting invertebrate pests.

Barn owls (*Tyto alba*) have been shown to take rats in cocoa plantations, yet are inconsistent as an ecological control mechanism in palm oil plantations (Wood & Fee, 2003). In rice fields there is little to no literature available on the use of birds of prey to manage rat populations. However, in palm oil plantations the number of owls is shown to increase within an area with the addition of artificial nest boxes. These are examples of how birds could potentially benefit farmers within the Philippines. However, with no reliable baseline figures to compare past and current avian trends, this opportunity is being overlooked.

Research on the full economic benefits of birds within agricultural landscapes is still site-specific and within its infancy, with little work being undertaken to scale up these methods throughout the entire rice market. It is important to have a full understanding on the global impact that birds might have upon the market as well as the environment (Elphick, 2010). It is in gaining this information and highlighting the potential economic benefit that birds might provide ecosystem services and the reduced cost of bird deterrents which will be of benefit to many that grow rice. By identifying beneficial bird species to rice farming as well as understanding the avian community present and the interactions therein, best management practices can be established that would encourage avian ecosystem service providers to use agricultural land. One challenge is to implement a method of ecosystem management as opposed to previous avian pest management approaches that have species-specific goals (Pimentel *et al.,* 1992a; Tscharntke *et al.,* 2005; Princé *et al.,* 2012). An ideal outcome would be to simultaneously reduce yield losses in the fields and provide a safe artificial wetland habitat for avian diversity.

However, the effects of perturbations caused by agricultural practices, either positive or negative, cannot be understood fully unless there are quantified baseline data on avian diversity in rice fields in Asia, along with their annual trends. Only through detailed studies under typical conditions can deviations caused by environmental or land management changes be understood. Investigations conducted throughout this study have focused on surveying birds within individual fields in the wider agricultural landscape in an attempt to quantify the responses of avian species to changes in land management practices.

1.3 Agricultural Production

Throughout this thesis the rice field stages will be mentioned. Table 1.4 summarises the three basic growth phases of a rice crop, with a brief description within each phase, along with those during the non-growing periods. Research within this thesis will look at field stages during both the crop growth phases and the fallow periods.

Table 1.4 Six phases of a rice field, with the 10 distinct crop stages. Duration of phase in parenthesis displayed as Days After Sowing (DAS).

Phase	Stages
Land Preparation	A tilled and levelled field, often flooded
Vegetative (0 – 55 DAS)	Germination to emergence Seedling Tillering Stem elongation
Reproductive (55 – 90 DAS)	Booting Heading Flowering
Ripening (90 – 120 DAS)	Milky grain Doughy grain Mature grain
Fallow - Stubble	After harvest, with some remaining stalks still present
Fallow - Regrowth	Field is left with some secondary growth from rice and weeds. Often left dry but sometimes flooded (management is site-specific).

The different growth stages of the rice crop are separated into three phases (Vegetative, Reproductive and Ripening) which are recorded during all investigations in this thesis. This is different from the majority of literature which only differentiates whether there is a crop growing or if fields are fallow, not distinguishing between the different growth stages. Research reported in this thesis will outline changes in avian diversity as the crop develops and if this change is significant. However, agricultural systems as managed landscapes do not necessarily coincide with biological processes. Times of optimal crop stages therefore may be out of phase with seasons, months for example, which are strong drivers of biological activities such as breeding. Different crop management, at either; a field, barangay or regional scale provides a challenge during analysis and makes interpretation difficult. Resulting in a number of small models being conducted, opposed to an ideal singular statistical model, with all factors included, to determine significant interactions within a lowland irrigated rice habitat.

1.4 Research aims and outcomes

Within Asia there is still a great deal of work to be conducted in comparison with other parts of the world where there is a better understanding of the trends of avian species and communities present in rice fields (Warnock *et al*., 2004; Blanco *et al.,* 2006; Bos *et al.,* 2006; Acosta *et al.,* 2010; Elphick *et al.,* 2010a; Longoni, 2010; Taylor & Schultz, 2010; Wymenga & Zwarts, 2010; Yong *et al.,* 2015). Consequently, it is necessary that research within Asia needs, at the outset, to be "broad" in nature, focusing on identifying general trends and relationships, before further species-specific investigations can be initiated. The current study examines the relationship between birds in rice lowland agro-ecosystems in the Philippines; an ecosystem where rice is important socially, economically and nutritionally. My focus will primarily be on studying bird communities in individual fields, before scaling up to the catchment level.

My specific research aims are as follows:

- To identify the avian diversity that occurs within rice fields in the Philippines.
- To investigate if annual abundance patterns can be identified within rice fields.
- Determine whether farming methods, such as water management, have an effect on common avian species within rice fields at a catchment level and what population level effect this might have.
- Determine if intensification of rice production on a large scale has an effect upon species diversity, abundance and temporal distribution within rice fields.
- Investigate the life cycle of an assumed pest species, the Eurasian tree sparrow (*Passer montanus*), to determine their pest status, how breeding and moult patterns effect their presence within rice fields and potential management implications.

From these aims, a number of hypotheses are proposed (Table 1.5).

Table 1.5 Hypotheses, predictions and tests along with the relevant chapter it was tested in.

Hypotheses	Prediction	Test	Chapter
The use of chemicals on rice fields will affect both the abundance and diversity of birds found within them.	A decrease in prey availability will result in bird abundance being significantly lower in rice plots that have had insecticide applied when compared to sites which were left non-sprayed	Comparing paired plots, half of which have been treated with an insecticide. Differences in bird numbers should be due to the effects of the chemical application.	3
Rice fields in the Philippines will support a large and diverse community of avian species.	Due to the management of the habitat, rice field avian diversity will be dominated by waterbirds. However a large number of other avian guilds will be recorded using these sites.	Surveying of rice fields to record the total number of individuals and diversity present throughout the year.	4
Avian abundance and diversity recorded within rice fields will be dependent upon the separate ecology of each species.	Migration and breeding strategies of the avian diversity will be factors affecting their occurrence within rice fields.	Surveying of rice fields to record the total number of individuals and diversity present throughout the year and comparing this to specific species ecology.	4
Alternative Wetting and Drying (AWD) will change the dynamics of the avian community found within rice fields of the Philippines.	There will be a decrease in the number of waterbird species recorded within sites adopting AWD, due to the reduction in standing water.	Surveying of paired plots, half of which have adopted the AWD management system. Differences in bird numbers should be due to the effects of the water management.	5
Irrigated fields which have historically not suffered from water scarcity would support a greater community of species associated with rice fields.	Fields located near the source of irrigation will support a greater community of species, irrespective of whether they employ AWD. Birds would be attracted to these sites before AWD enforcement and continued to show site preference.	Surveying of paired plots at different distances from the irrigation source. By comparing survey results, any differences would be detected. Avian preference would result in an increase in abundance at either sites.	5

Table 1.5 (continued).

Hypotheses	Prediction	Test	Chapter
The '5 in 2' crop will progress through field stages at an accelerated rate, but there will be a decrease in the amount of time spent at each stage.	This rapid change in stages will attract more individual birds to these fields, as any preferred field stages will occur more frequently than in the '4 in 2' sites.	Surveying paired plots throughout the year will record changing numbers of birds, during different field stages and times of the year.	6
The '5 in 2' crop will display an overall reduction in biological richness compared to the '4 in 2' crops.	A reduction in the total amount of time spent within any "preferential" field stages results in the '4 in 2' crops recording higher diversity overall.	Surveying paired plots throughout the year will record changing numbers of birds, during different field stages and times of the year.	6
The field stages which require more water will support migrating waterbirds, regardless of management.	Field stages such as land preparation or the vegetative phase, will support a greater number of waterbirds during February and March, or September and August before and after migration, regardless of the intensified management of that site.	Bird preference will be displayed as a peak in abundance during specific field conditions, in this case wet at specific times of the year.	6
The Eurasian tree sparrow (*Passer montanus*), will change its diet through the year similarly, to other sub-species of this bird, to provide the extra nutrients required.	Tree sparrow diet composition will reduce in grain and increase in invertebrates during their breeding season.	Comparisons of stable isotope ratios at different times of the year will detect changes in diet over time.	7
Stable isotope ratios of ^{15}N will provide data on diet changes in Eurasian tree sparrows.	^{15}N readings will be able to identify different trophic levels of the bird's diet.	Stable isotope analysis of $\delta^{15}N$, from claw samples compared to a control group fed on a controlled diet.	7

General Methodology

To enable comparisons to be made between investigations within this thesis, survey protocol was kept similar throughout. As an agricultural system, lowland irrigated rice fields are susceptible to seasonal and management changes, providing a challenge in ecological surveys and interpretation of results. As a result, survey data were collected along with habitat information (weather, field disturbance etc.) to eliminate unfavorable conditions. This chapter provides a full description of the sites surveyed and methods used to collect data.

2.1 Study sites

The Philippines is an archipelago in Southeast Asia, in the Western Pacific Ocean, lying between 4° and 21° North latitudes, 116° and 127° East longitudes (GRISP, 2013) and consists of over 7'000 islands. The Philippines produces a large amount of rice, similar to most countries in Asia, although not enough to supply demand. The country still imports around 2 million tonnes of rice a year (GRISP, 2013) with pressure to reduce the shortfall.

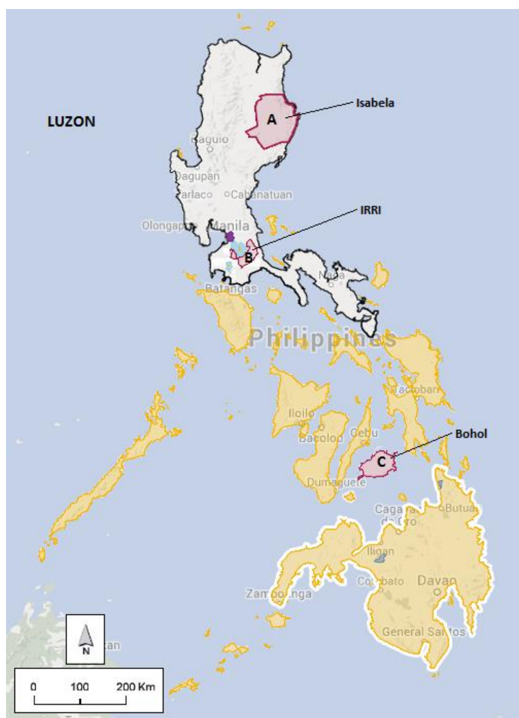

Figure 2.1 A map of the Philippines archipelago identifying the provinces of the three study sites. Luzon Island (highlighted in white) is the location of two of the study sites, Isabela (A; see 2.1.1.), and Laguna (B; see 2.1.2.); and the third study site is Bohol (C; see 2.1.3.), an island to the south of Luzon island. Map produced using Google Maps (2015).

2.1.1. Isabela (Location of Study Site A)

The province of Isabela is located approximately 280 km northeast of Manila (17° 7'N; 121° 37'E; Figure 2.2).

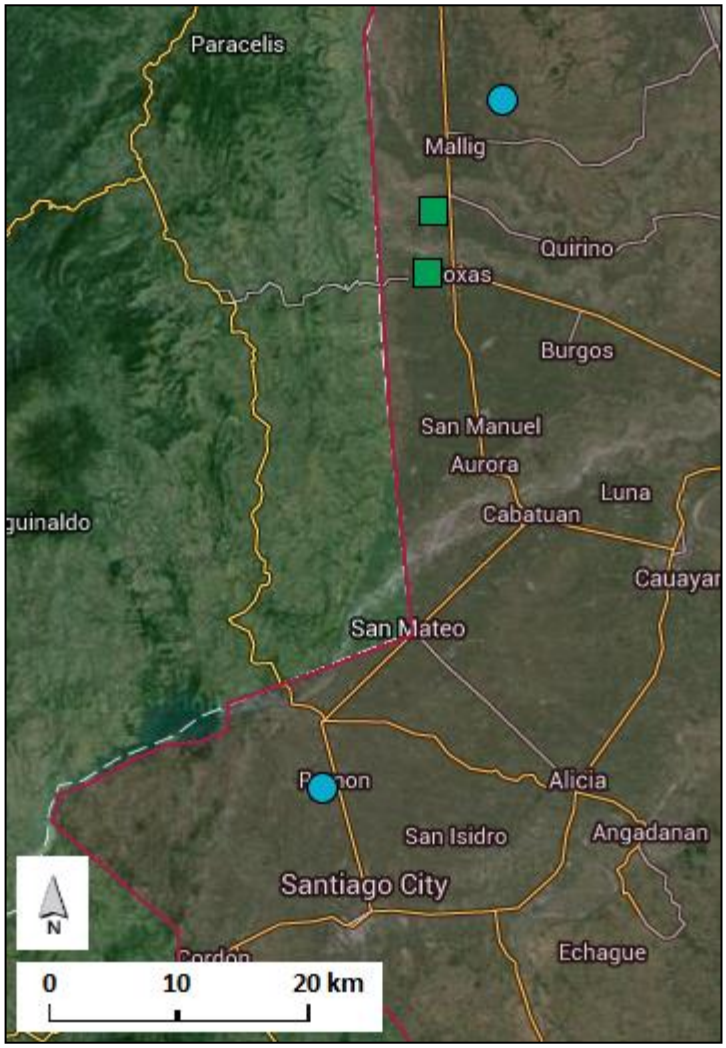

Figure 2.2 Site locations within the west of the Province of Isabela (shaded red). Blue circles represent traditional cropping system; green squares are those with an intensified cropping system.

In 2014, Isabela produced 1,277,623 tonnes of lowland irrigated rice (PSA, 2015) making it the country's second largest rice producing province. Located between the Sierra Madre Mountains to the east and the Mountain Province to the west, the province experiences few water supply issues.

2.1.2. IRRI Experimental Station (Location of Study Site B)

The experimental station (ES) of the International Rice Research Institute (IRRI) is located approximately 55 km southeast of Manila, in Los Baños, Laguna (14° 10'N; 121° 15'E; Figure 2.3). The farm has 209 ha of rice fields where research is conducted under varying management techniques. The station is divided into two methods of farming; the lowland irrigated fields and the simulated upland area, where the crops are mainly rainfed.

Figure 2.3 Map of the IRRI headquarters, showing the locations of the experimental fields. Fields used regularly in this research are highlighted in orange. Boundary between IRRI and UPLB rice fields, represented as a yellow line. Map produced using Google Maps (2015).

Unlike other areas of the Philippines, IRRI rarely suffers from limited water supply as it is located on the foothills of Mount Makiling. The experimental farm has access to natural springs, and water is collected and stored in reservoirs throughout the farm and used when necessary.

Fields used by the University of the Philippines, (Los Baños, UPLB) are adjacent to the experimental farm, creating the large agricultural habitat displayed in Figure 2.3. A fence was erected in 2014 through the fields (yellow line in Figure 2.3) and around the perimeter, separating the northern IRRI fields and the southern UPLB fields.

The experimental station enforces a strict no hunting or fishing policy. With a local population living on the edges of the fields, this was difficult to enforce. The erection of the fence should keep restricted hunting and fishing activities to a minimum, potentially enhancing the habitat for bird life. However, the fence is unlikely to affect the presence or abundance of avian species found within either group of fields.

2.1.3. Bohol (Location of Study Site C)

On the Island of Bohol, Visayas (9° 59'N; 121° 37'E), sites were located approximately 635 km south of Manila (Figure 2.4). A large area of agricultural land is located in the northeast of the island.

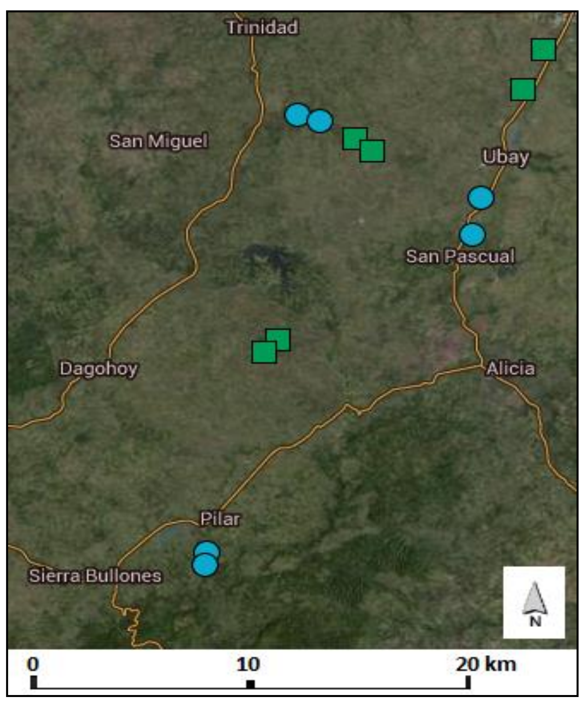

Figure 2.4 Site locations within the Northeast of Bohol. Blue circles represent sites using traditional irrigation; green squares are those adopting Alternate Wetting and Drying (AWD). Map produced using Google Maps (2015).

Between 1997 and 2007, two dams were built to irrigate 10,260 ha of rice fields in the municipalities of Pilar and San Miguel, though rainfed and water diverted rice fields are found outside of this area. Water is released to the command area of the dam on a weekly schedule, controlled by the National Irrigation Association (NIA). Alternative Wetting and Drying (AWD) is enforced in areas generally located close to the dams (see Chapter 5).

Avian species composition is known to vary dramatically between islands in the Philippine archipelago (Peterson, 2006). Bohol is located over 600 km south of the Island of Luzon and, as a result, a different community of bird species are present compared to the other two study sites (Birdlife International, 2001; Haribon Foundation, 2014).

2.2 Climate

The experiment station is located within a Type I climate region, based on the Modified Corona's Classification by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), with two pronounced seasons: dry from November until April and then wet during the rest of the year. Bohol and Isabela are within a Type IV region, with rainfall throughout the year (Table 2.1). Two crops of rice are grown each year in the Philippines where there is access to irrigation, with planting occurring at different times depending upon location within climatic regions.

Table 2.1 Mean temperature (a) and rainfall (b) of study sites in 2014, from The Weather Channel (2015a). Standard Deviation displayed in parenthesis.

(a) **Temperature (°C)**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Isabela	23	25	25	27	30	30	29	28	28	27	26	25	25.7 (±0.7)
IRRI	26	27	28	30	32	29	28	28	28	28	28	27	27.0 (±0.4)
Bohol	26	27	28	28	30	30	28	29	28	28	28	27	26.8 (±0.3)

(b) Rainfall (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Isabela	42.6	31.6	179	52.1	34.4	46.3	136.3	171	159.5	304.4	327	300	138.2 (±32.4)
IRRI	0	1.5	6.1	0	42.9	337.6	315.5	145.6	256.1	187.7	29.47	66.05	107.7 (±37.1)
Bohol	124.7	23.1	45.5	95.3	0	145.8	251.1	102.4	198.1	145.3	55.37	298.2	115.1 (±26.2)

2.3 Survey Techniques

Many methods of bird surveying were considered, each with individual strengths and weaknesses. Bibby *et al.* (2000) provides a full review of the different census techniques available. A common methodology was implemented within all investigations for consistency with minor changes in the rationale where appropriate. Information with regards to survey method chosen during these investigations (spot counts), expanding into survey technique (duration, recording method), the choice of locations within each site, and specific details on field methods which addressed assumptions within the framework, described by Bibby *et al.* (2000) are described below.

2.3.1. Spot counts

Twenty-minute spot counts were adopted in preference to transect counts because moving through rice fields would damage crops and farmers would not grant access to the bunds between fields without supervision. The choice of methodology was contingent on causing minimal disturbance to the fields and enabling surveys to be conducted without farmer supervision.

2.3.1.1. Site selection and location

Sites were systematically selected due to their location, method of management that was being investigated and whether permission was granted by the land owner/manager. All sites selected were located next to roads or public paths so that an observer could stand/sit without needing access to the fields themselves. If the survey point was on a road, observations were made from a vehicle.

Field location next to roads and frequently used footpaths are likely to affect the occurrence of birds within these sites (Forman *et al.*, 2002; McClure *et al.,* 2013). However, bunds between rice fields are often used by locals, or animals (e.g. dogs), as a method of access to other locations and are infrequently used. Therefore it is assumed that no fields are isolated from these disturbances. The count data presented within this thesis are likely to under record the total abundance of species compared with rice fields which do not border roads or paths, though it is likely to have a minimum effect.

Fields selected were surrounded by other rice fields of similar management to eliminate edge effect as a potential factor in analyses. Care was taken to ensure there were large distances (> 1 km) to other habitats in the area, such as rain-forest or urban areas, again to reduce edge effect.

2.3.1.2. Recording methods of surveys

Surveys were conducted between dawn and midday and were initiated as soon as there was adequate light to enable accurate identification and counting. Between three and eight surveys were conducted sequentially each day (varying in number, different in each investigation within the thesis) with the order of the sites surveyed rotated on successive days. On occasion, surveys were delayed for logistical reasons (e.g. traffic congestion), but this was thought to have minimal impact on the data collected.

Verner and Ritter (1986) mention that time of day is important for recording occurrence and that some species are more likely to be recorded at certain times within the day. Twenty minute spot counts are likely to record a representative ‘snapshot’ of both number of individuals and diversity of species using rice fields (see below), taking into account the restrictions of available time and a single surveyor.

The presence of species was established using both sight, aided by the use of binoculars (Bushnell H_2O, 8x42), and sound in an attempt to increase the probability of recording most of the species within the rice field. Birds were recorded moving into the site (either on the ground or through flight) or out of the site, with the exception of individuals where the observer did not lose sight of the bird and it left shortly after entering to reduce 'double counting'. Birds that left the site but immediately returned (for example to move location within the field or during display flights) were recorded once as a '*left and re-entered*'.

Sound is essential in the recording of some species, such as the white-browed crake (*Porzana cinerea*) which, during the latter stages of rice development, can travel through the fields unseen. Using sound to survey 'booming' bitterns is common practice elsewhere (Frommolt & Tauchert, 2014); no bitterns were heard at any time within rice fields although two species, cinnamon and yellow bitterns, were regularly recorded visually (*pers. comms*.). Sound can lead to over-estimation of species, such as the white-browed crake, because sound travels through the rice fields from outside of the surveyed site, but does contribute to recording the presence of species such as the common kingfisher (*Alcedo atthis*) and wood sandpiper (*Tringa glareola*) that are often heard calling when flying.

2.3.1.3. Duration of counts

Duration of counts was dependent upon a number of factors, primarily the habitat being surveyed. Bibby *et al.* (2000) mention that in most temperate situations, a 5 minute observation period would reduce the risk of 'double counting' (a risk that would be expected to increase with time). A literature review of previous surveys of avian diversity of rice fields from temperate regions (Europe and USA) provided a useful insight into the likely bird communities expected within the rice fields of the Philippines. The most common bird category expected to occur were waterbirds, species which are expected to walk short distances between sites, rather than fly, increasing the possibility of being under-represented in surveys. They were more likely to 'go to ground' when disturbed than fly off, resulting in a likely under-recording of these species.

During the latter stages of rice development (particularly during the reproductive and ripening phases), it became increasingly more difficult to observe birds on the ground, with certain species, particularly waterbirds, less likely to take flight and therefore recorded rarely. By increasing the duration of counts to 20 minutes, there is a likelihood of identifying the majority of species visible within a lowland irrigated habitat (Fuller & Langslow, 1984).

2.3.1.4. Size of surveyed sites

All surveys during these investigations were conducted within a set area where species that traverse, forage or depart are recorded. This approach is similar to fixed radius counts (Bibby *et al.,* 2000). Recording only those birds within a defined area was thought to increase accuracy as the observer could concentrate on that specific area. An area approximately 10 m x 50 m was surveyed at each site. This area was chosen within either bounded bunds, for smaller fields, or using visual markers (such as irrigation structures) in larger sites, allowing for consistent recording at each site. During site establishment, there was a preference for sites with a bund or levee in the middle to provide a 'cut through' in the field allowing for better visibility of bird species that travel through the fields on foot.

2.3.1.5. Reducing the impact of observer presence on bird activity

To allow species to acclimatize to the observer's presence, a 5 minute 'grace-period' was used between the observer arriving and the survey starting. If surveys were conducted from a vehicle, this 'grace-period' was reduced to 1 minute as birds are disturbed less by the presence of a vehicle than the presence of a human observer (Bye *et al.,* 2001; Manning & Kaler, 2011).

Bibby *et al.* (2000) claim that birds are unlikely to occur within 10 - 20 m of an observer due to their aversion to a human presence. However, within rice fields, birds can only be recorded close to the observer because long-distance identification is difficult due to reduced visibility at the later stages of rice development. This can lead to the quiet, sulky species being under-represented, whereas the loud, territorial and more-aggressive species can be over-recorded.

2.3.1.6. Bird movement during detection; a question of independence

Bird movement through a habitat can be difficult to observe and record, as mentioned above. Using sound can aid in identification though sometimes the number of calling individuals is difficult to determine. If two calls are recorded, separated by a short time and coming from different areas of the surveyed field, it is not known if this is a single individual who has moved or two individuals calling to one another. The question of independence might similarly affect visual recordings, though to a lesser degree. To compensate for this, only birds seen using the sites were recorded and all calls were treated as independent. For the purpose of these investigations, birds seen 'using the site' are defined as individuals which enter into the observed area as part of their natural behaviour, under regular circumstances of their own free will. These include behaviours such as hunting or seeking shelter.

For example, brown shrikes (*Lanius cristatus*) were often recorded flying into the crop to hunt. The number of times the individual flew into the crop was recorded as opposed to the individual being recorded once as a 'perched' bird. This method records the number of biodiversity events rather than the total number of individuals and will lead to over-recording of individuals. It can then be assumed that fields which provide more hunting opportunities for the birds will have a higher number of individuals because they have been recorded within them more frequently. Any farming techniques which affect the entire food web, not just avian diversity, might be identified by the number of hunting events recorded within them.

For completeness during the surveys, all activities were recorded per individual. This provides a large data set to test a number of hypotheses, whilst also allowing for future work and interactions to be explored during analysis. Similarly, certain behaviours and activities which were not required were removed from the analysis (see below).

2.3.1.7. Interactions between habitat and environment

A number of environmental factors were recorded and adjusted for during the surveys. The interaction between habitat and species can be strong (Bibby *et al.,* 2000) and it is these influences that are recorded within the survey results. Site location, survey time and 'bird category' have been discussed. To reduce errors and compensate for any potential differences a number of other factors were recorded during surveys to be eliminated, or tested, during analysis.

Weather conditions were recorded during all surveys. Some birds were observed to shelter from rain and reduce their activity within the fields during a downpour. Survey data were excluded from analysis if affected by moderate (consistent but small rain droplets) to heavy (consistent, oppressive, large heavy droplets) rain.

Human and animal activity within the target and immediately adjacent fields was recorded on a five-point scale (Table 2.2). All records with a score of 5 were subsequently removed from analyses as the level of disturbance was deemed to be too high.

Table 2.2 Five-point scale to record activity in surveyed and neighbouring fields

Score	Activity levels
1	Only the observer and vehicle in close vicinity
2	Human presence upon road limited to 1 or 2 individuals or other vehicles.
3	Human presence upon road moderate and/or low activity in non-neighbouring fields.
4	Human activity in neighbouring fields and/or cattle within observed field.
5	Human activity within the observed field and/or dogs within observed field.

On occasion, bird scaring devices were erected within surveyed rice fields. The devices used differed between the sites but generally fell into two categories; either flags and tape or a 'diversion bird' made from a coconut shell with 'wings' made of vegetation. To reduce impact of the study on the farmers, observations were made with no influence upon management, including the implementation of any bird deterrents. If a deterrent was erected within the study site, or on the adjoining bund, this was noted and accounted for within the statistical analysis.

Unlike most previous studies on birds in rice fields, field stage was recorded during surveys. The difference in crop composition between fields in their early vegetative stage (wet, low vegetation, sparsely separated) and the later stages (drier, approximately 0.8 m in height and dense within the field) will have an effect upon the birds present within the field and how species utilize the fields and should therefore be a critical factor recorded in studies of biological diversity in rice fields. Crop height was categorised and recorded as either; 0, 0-15 cm, 15-30 cm or ≥ 30 cm.

Irrigation was recorded during each survey as follows: wet, puddling, moist or dry. Elphick and Oring (1998) determined how water level was a factor affecting avian diversity within rice fields, as birds with longer tarsus measurements were recorded more frequently within deeper water levels. Similarly, birds with small tarsus lengths were recorded within fields with shallower surface water. In the present study, if a field was flooded water depth was calculated taking measurements with a clear ruler, at three different locations along the edge of the field. It was assumed that the calculated mean was representative of the field as a whole.

2.3.1.8. Bird identification

The observer's bird identification skills are assumed to be accurate throughout the period of data collection. A single misidentified bird will have little effect on the overall results. However, a single species consistently misrepresented will have ramifications for the results of any statistical analysis. For example, the crested myna (*Acridotheres cristatellus*) is a mid-sized black passerine, with a white patch on its wing, in the starling family (*Sturnidae*), and is regularly seen within rice fields. Similar in appearance, a small- to mid-sized, black bird with a white eye-brow is the white-browed shama (*Copsychus luzoniensis*), a forest endemic. If these species were confused and recorded once it might be ignored. However, if this error was repeated throughout it could suggest that a forest endemic is likely to occur within rice fields, leading to the assumption that agricultural habitat is important in supporting forest species.

Occasionally large flocks (approximately > 100 individuals) were recorded within the fields, the majority of which were of a single species. However, sometimes other species of the same family were seen within the flock. During these occasions, the total number of individuals were counted and identified to family only. The current study focuses on what fields provide for avian diversity and which management practices may have a detrimental effect on their life cycles, meaning identification to family was deemed adequate. Within larger flocks an error may occur with regards to exact numbers of species, but this is unlikely to have an overall effect on the total data set.

If an unknown species was observed within the survey area, key identification features and behaviour where checked against those found in Kennedy *et al.* (2000), "*A Guide to the birds of the Philippines*", to a minimum accuracy of family level. A local enthusiast (Paul Bourdin), with years of experience in the rice fields of the Philippines, was asked to confirm the likelihood of any unique and unusual records to increase the accuracy of the record.

Accurate recording of sex and age might provide further information about the movements of species throughout the Philippines. However obtaining this information is difficult when collecting observational and auditory data within a limited timeframe. Many avian species found within the rice fields of the Philippines are not sexually dimorphic, meaning sexing them through sight or sound in the field is not always possible. Similarly, some bird species develop their plumage before fledging;

meaning accurate aging of birds is difficult. Where possible, differences were recorded during all of the counts, but due to limited numbers, these were removed during analysis. Future in-depth surveys of rice management on avian diversity at a single site might attempt separating species records by sex or age to determine if their usage of rice fields differs during different life stages.

2.3.1.9. Bird territories

A bird's territory size will have an effect upon how likely it is to be recorded within the field surveys. By restricting counts to a smaller defined survey area within the habitat, the community of birds present is unlikely to be representative of the entire community of species, as those with a large home range have a lower chance of being recorded. This makes direct comparisons between sites difficult. It is a question of scale; biodiversity needs to be recorded as an entire ecosystem and will consist of multiple spatial scales or species groups (Tews *et al.,* 2004). For example, larger bird species will have a larger home range when compared to a smaller passerine. Thus, you are more likely to record a zitting cisticola (*Cisticola juncidis*) in their breeding territory with a mean size of 250 m in diameter (Motai, 1970: cited in Yamagishi & Ueda, 1986), than a grey heron (*Ardea cinerea*) with a foraging territory of many hectares (Marion, 1989). The presence of a bird of prey might have an effect upon how visible other smaller species might be. Hunting pied harriers (*Circus melanoleucos*) close to surveyed sites seemed to reduce the visibility of other species during surveys, resulting in lower counts. Repetition of surveys will reduce the chance of this error having major effects upon results.

2.3.2. Use of Mist Nets

Mist netting is a well-established method of bird censusing, though it presents its own challenges. Bibby *et al.* (2000) mentions that, regardless of trapping effort, mist-netting may only capture around 40% of the total species present within a forest habitat. Forests are ideal for mist-netting as the nets are less visible to birds than in open areas, increasing their success in catching birds. Mist netting within rice fields, however, means placing the nets above the crop, increasing their visibility. A small number of trials using smaller mist-nets (single-shelved) were conducted within maturing crops, though yielded few captures. Mist-nets in rice fields were often exposed to wind allowing the shelves to billow and stretch. Mist netting was used in the study reported in Chapter 7 in an attempt to map post-fledging movements of Eurasian tree sparrows (*Passer montanus*) around the IRRI experimental station but few re-captures were recorded and overall capture rates were approximately 1 bird every

45 minutes of net erection. Making this method of recording population movements ineffective at this small scale.

Driving birds from rice fields into nets, by setting up nets at one end of a field and then walking through the crop towards the net, might yield better results but increases effort, the number of individuals needed to conduct data collection and damage to the crop. This method would presumably capture more species which are not able to avoid nets on the wing as they escape or those which do not 'go-to-ground' when disturbed. Other methods of netting, including nocturnal mist netting, might provide more captures of species such as the wood sandpiper (*Tringa glareola*) during times when the species moves in large flocks on migration. This should be considered for future work.

2.3.3. No recordings and data removal (*Post hoc*)

To avoid collinearity and problems during analysis, some survey factors were removed during analysis. These are outlined below.

2.3.3.1. Weather

The start of surveys was postponed to allow for showers to stop. A maximum time limit of 30 minutes was allowed before the survey was cancelled and the observer proceeded to the next survey. As sites were generally separated by a minimum of 1 km, rain at one site did not necessarily indicate rain at the next site, allowing further data collection. The long time period of data collection and the repeated surveys of the methodology compensates for the occasional loss of survey data due to rain.

Counts during moderate to heavy rains indicated differences between species which could still hunt in the wet and those which sheltered (*pers. obs*.). Swallows (*Hirundo sp.*) were recorded during most rains, only being absent during heavy rain events. Many other species were not observed or heard during times of moderate to heavy rains. If rain was intermittent or described as 'spitting', these data were included in the analyses as there was no visible decrease in avian abundance or frequency.

2.3.3.2. Time of day

Surveys were conducted at dawn and then continued until completion and no later than midday. Bibby *et al.* (2000) mentions that dusk counts provide a better opportunity for recording a greater number of species, but within the Philippines, avian abundance within rice fields was visibly reduced within the afternoon/evening (*pers. obs*.). A number of insects have shown extreme temperature avoidance behaviour and will be reduced in numbers during midday (Holm & Edney, 1973; Fellers, 1989). As insects avoid the heat, this reduces the amount of food available for hunting birds during the hottest periods within the day. European starlings (*Sturnus vulgaris*) foraged more under shade than in direct sunlight and made less journeys to their nests once temperatures were > 31.5 °C (Clark, 1987). Other bird species may forage in the shadow of rice crops making them more difficult to see and less likely to be recorded during a survey conducted during the hotter times of day. Previous literature shows a high number of invertebrates are active, or emerge, under dark conditions, such as dusk, dawn, at night or during cloudy weather (Kisimoto, 1968; Caveney *et al.,* 1995; Huhta *et al.,* 2000; Wilson & Lucchi, 2007). Many avian species will not be able to hunt during the night due to limited visibility. Therefore surveying in the morning is more likely to record a larger number of species than in the evening, due to the bird species hunting any invertebrates remaining after their night time activities.

Within the Philippines, there is only a difference of an hour in daylight hours between the longest and shortest days of the year. Surveys were conducted at similar times throughout the year with surveys starting once light conditions were adequate to observe the entire site. A small number of different technologies have been trialled to determine if avian species could be identified during morning twilight. Boonstra *et al.* (1995) used a thermal imager to survey a number of different habitats that they deemed as adequate to survey birds in areas of low to no vegetation. Agricultural land was trialled but only during a 'land preparation' phase, meaning visibility was clearer than a growing field. An NEC Thermal Tracer was borrowed from a different environmental group and taken on a small number of evening and morning trials to establish if this was a viable method of data collection. Fields were scanned using the built-in monitor and any 'hot spots' were investigated using a torch to determine species. During the evening surveys however, little could be identified from the background heat (land, rice and water which had been heated throughout the day) and no birds were seen or recorded. The thermal imager worked slightly better during early morning surveys, being able to identify some birds perching in the rice canopy and some within a levelled rice field. However, the picture quality was poor and the distance between observer and the 'hot spots' needed to be smaller, risking scaring away most of what could be seen before identification was possible. Heat spots of creatures which did not move were often amphibians although it was not possible to distinguish between birds and amphibians at distance, meaning the thermal imager could not be used for long-distance surveying.

A first generation image intensifier, a Yukon Spartan NVMT-2 3x42, was trialled providing a different response. The intensifier's magnification, and built in infra-red light beam, was able to help the observer distinguish between birds and amphibians at a longer distance than the thermal imager, though species identification was still a challenge. Often birds would be scared away by the observer before the species had been determined. Birds flying over were difficult to track or identify with the image intensifier and the observer was unsure if all birds had been seen within their vicinity.

Both technologies are thought to provide a benefit when used on larger animals over a longer distance (Croon *et al.,* 1968; Graves *et al.,* 1972; Sidle *et al.,* 1993; Boonstra *et al.,* 1995) but, for surveying birds in rice fields, were not adopted for night-time surveys. They were both trialled during the land preparation phase, when fields are flat and flooded, allowing for better distance viewing and it is thought that once the crop is established within the rice fields, it would be difficult, to identify a bird from the background using either machine. However, as technology progresses and develops, future surveys may be able to investigate the utility of new devices.

Preliminary Study: Pesticide application

Bird surveys were conducted on active rice farms at three provinces in the Philippines, opposed to relying upon experimental stations. Although it is thought that this would be better representative of the 'real world', there is some loss in the ability to control all potentially important factors. Environmental factors such as site location in relation to other habitats can be managed during the process of site selection. Other potential factors can be eliminated using specific methodology during data collection (see above). However, to reduce the impact of the study upon the active rice farms, the field management conducted by the farmers was not restricted and no preferences were made. This left the farmers free to continue the method of farming they deemed fit. Therefore, farmers were given questionnaires each year to establish if there were any major differences in farming practices which might have an effect upon the avian diversity present. One factor which differed between all farms was the chemical input into fields.

Farmers spread a wide variety of different chemicals onto their fields, but they generally fell into five categories; fertiliser, herbicide, insecticide, molluscicide and rodenticide. Within these categories there was a wide variety of brands with different active ingredients requiring different application rates. Chosen inputs were generally based upon brand availability and cost; because of this, no two sites surveyed used the exact same chemical inputs. To determine therefore if chemical input generally was a significant factor affecting avian diversity and abundance a preliminary test of the effects of insecticide application was conducted during the dry season (February – May 2012), on three rice field plots at the IRRI Experimental Farm. These plots were part of an ongoing investigation into the effects of insecticides on insect abundance and rice yield. Of the five categories, insecticides were thought to have the biggest impact on bird abundance by reducing food availability within the fields.

3.1 Introduction

Pesticide use has one of the greatest negative impacts on the number of species and individuals in agricultural systems (Pimentel *et al*., 1992b) by upsetting the natural balance between the land and the species present (Harvey *et al.,* 2008). Repetitive or intensive pesticide usage will decrease invertebrate resources for birds (Fasola & Ruiz, 1996; Tourenq *et al.,* 2003). Organically grown rice has a greater abundance of invertebrates within fields (Taylor & Schultz, 2010). Mesléard *et al.* (2005) identified that within a rice growing region of France, organic fields offered four times greater biomass of prey compared to conventional fields for foraging herons. Chemical inputs on rice agriculture change the invertebrate community structure within the fields, potentially having a negative impact upon avian diversity found within the habitat by reducing the availability of prey. Modelling studies within the US determined the use of pesticides as a better correlate to declining grassland bird populations than agricultural intensification (Mineau & Whiteside, 2013).

Bioaccumulation of dichlorodiphenyltrichloroethane (DDT) can manifest as the thinning of egg shells, or by direct poisoning, in birds (Stickel *et al.,* 1984; Boncompagni *et al.,* 2003; Parsons *et al.,* 2010). DDT is now banned in a number of countries although traces can still be found within the environment (Wilson *et al.,* 2009). Many other active ingredients within pesticides are still available for farmers to use and systemic insecticides are listed as low-risk to fish and birds (Lahm *et al.,* 2009). However, recent studies have shown that even a minor intake of treated seed can cause impaired reproductive success and mortality in small bird species (Gibbons *et al.,* 2015). The use of neonicotinoids has been shown to reduce male reproductive success in Quails in Japan (Tokumoto *et al.,* 2013), although they are deemed to be of low toxicity to vertebrates. Either directly or indirectly, the use of insecticides will affect bird numbers but the key question for this study is whether chemical application changes wild bird frequency or abundance during surveys in rice fields of the Philippines. If insecticide application were significant, then farm and site management (no. of applications, active ingredient etc.) would need to be accounted for in any statistical analyses, but this would raise serious problems due to the collinearity of these factors.

This preliminary study tested the hypothesis that, due to a decrease in prey availability, bird abundance was significantly lower in rice plots that have had insecticide applied when compared to sites which were left non-sprayed. In particular, the measurable difference in avian abundance will be more apparent immediately after the spray application but will decrease as the insecticide effect decreases. The objectives are to monitor three paired sites of rice fields, recording total bird abundance and diversity over a single cropping season, to test whether a significant difference can be detected between fields which have been sprayed with insecticides and those that have not.

3.2 Methods

Three rice fields at the IRRI experimental station, separated by >1 km, were equally divided into two lengthwise plots, separated by a plastic barrier >1 m high. In one plot, an insecticide was applied (here after "sprayed") whilst the other was left (here after "unsprayed"). Bird surveys were conducted every three days unless there was bad weather or if any of the chemicals (herbicide, insecticide etc.) were being applied to the field, then they were postponed until the following day. Twenty minutes of continuous scan sampling was conducted at dawn, after a 5 minute grace period once the observer had arrived, rotating the order which sites were surveyed to reduce a time of day effect. All birds seen or heard within the defined area; 10 m (width of field) by 50 m (half of the field length) were recorded. Each record consisted of; species, number of individuals and their activity (on the bund, displaying behaviour, disturbed flight out of field, moving in, moving in and then immediately out, foraging/hunting, moving out and then immediately back in, over, perched, and territory disputes) were recorded. Observations were aided by the use of binoculars (Bushnell H_2O, 8x42). Surveys were conducted from the transplanting phase in February until harvest in May, when the crop was harvested. All plots received three applications of fertiliser (N-P-K fertiliser [100-40-20 kg/ha]); on the day of planting, once during tillering and once at panicle initiation.

Sprayed plots were given an enhanced systemic insecticide; Virtako (chlorantraniliprole 20% + thiamethoxam 20%). Its active ingredients are chlorantraniliprole (a selective insecticide for caterpillars and other plant eating creatures with a low toxicity to birds) and thiamethoxam (a broad spectrum insecticide of all insects classed as a neonicotinoid which is low to moderately toxic to birds). To simulate farmer practices, plots had insecticide applied throughout the growing period at 30 day intervals, beginning 15 days-after-transplanting. Maximum care was given to avoid pesticide drift between fields whilst unsprayed plots were sprayed with water.

A backward stepwise Generalized Linear Mixed Model (GLMM) ANOVA with a Poisson's Log distribution was conducted, in IBM SPSS Statistics (version 21), including all main and 2-way interactions. Factors included within the model were; site (Site A, Site B, Site C), management (sprayed, unsprayed), crop (land preparation, vegetative, reproductive, ripening, fallow), species category (waterbird, grainivorous, other), activity (on the bund, flew in, flew out, in then out, foraging/hunting, out then in, over, perched, territorial dispute, and spray hunting, where birds are attracted into the field by farm workers disturbing the invertebrates as they move through the crop spraying chemicals) and month (February, March, April, May). Data was checked to ensure they conformed to the underlying assumptions of the test. Non-significant interaction and main terms were removed sequentially using a backwards stepwise elimination procedure.

Figure 3.1 One of the surveyed fields showing the divider (middle, back) and the separated plots in the foreground, part of an ongoing experiment. Nets located at the back were erected for an exclusion trial. Picture courtesy of Dr. F. Horgan.

3.3 Results

Unless otherwise stated, all means are displayed as means per survey to eliminate any differences in survey effort between months or field stage.

Table 3.1 All factors and significant interactions from a backward stepwise GLMM ANOVA, with Poisson log distribution. '*crop*' is the field stage, '*species_category*' is the species category (Waterbird, Granivorous or Other) and '*activity*' is what the bird was recorded doing.

Factor / Interaction	Wald Chi-Square	Df	P - Value
site	6.279	2	0.043
management	0.026	1	0.872
crop	6.122	2	0.047
species_category	9.262	2	0.01
activity	20.689	10	0.023
month	7.358	3	0.061
site * management	7.358	2	0.025
site * month	29.883	6	<0.001
site * crop	20.911	4	<0.001
site * species_category	13.823	3	<0.001
site * activity	74.391	11	<0.001
month * species_category	11.217	4	0.024
month * activity	46.422	14	<0.001
species_category * activity	26.263	6	<0.001

Avian abundance was significantly affected by; site, crop stage, species category and their activities during surveys (Table 3.1) but not by month or if they were sprayed or unsprayed.

Specifically, the absence of insecticide spraying did not significantly affect abundance as a term in its own right but as part of a significant interaction with site (Figure 3.2).

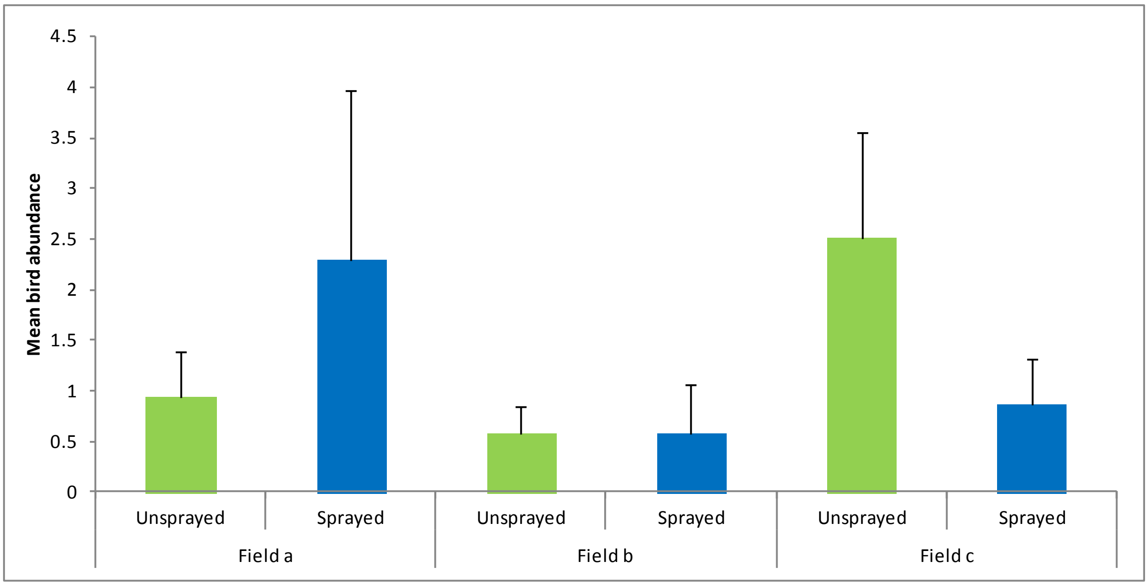

Figure 3.2 Mean bird abundance per management (sprayed or unsprayed) between the three sites. Mean (± standard error) from a backward stepwise GLMM ANOVA, with Poisson log distribution.

Spraying insecticide only had a significant effect upon avian abundance at a site level, producing varied results. Overall patterns of change in avian abundance on sprayed and unsprayed sites were very similar (Figure 3.3).

There was no significant difference between the plots sprayed with insecticide and those that were not (Table 3.1). When displayed as total recorded bird abundance over time (Figure 3.3), both treatments exhibit the same trends, increasing and decreasing at similar intervals.

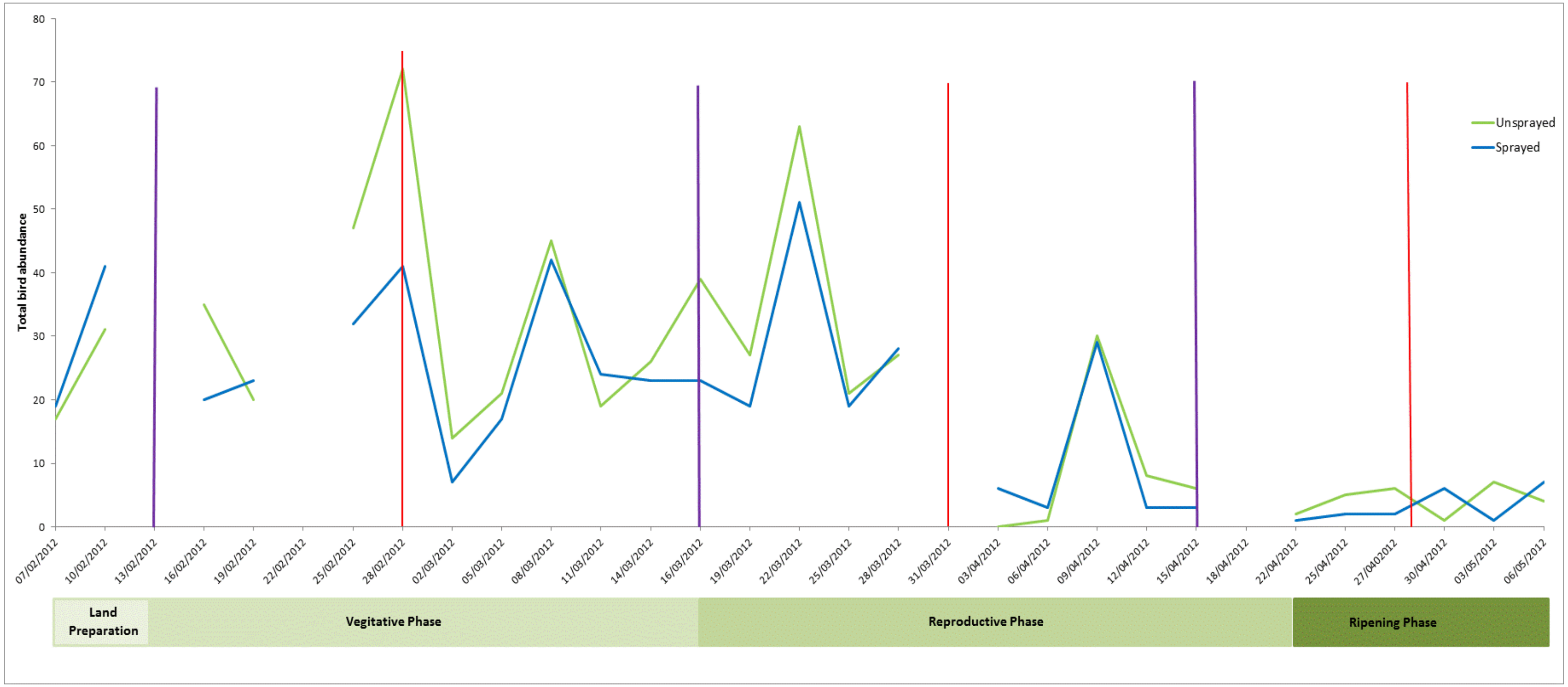

Figure 3.3 Total bird abundance on sprayed versus unsprayed sites during the dry season of 2012, with relevant field stage displayed below. Gaps in data are from no-survey days (spray application, management or poor weather). Vertical lines represent; Fertiliser application (Purple), Pesticide Application (Red). Crop was harvested after final survey. Figure shows mean birds recorded per survey. Surveys were not conducted within 48 hours of pesticide application. On dates where spraying and surveys cross over, the surveys were conducted first.

The different sites surveyed had a significant effect upon avian abundance both as a term in its own right (Figure 3.4) and as part of a significant interaction with; month, crop stage, category and activity (Figure 3.5 – 3.8).

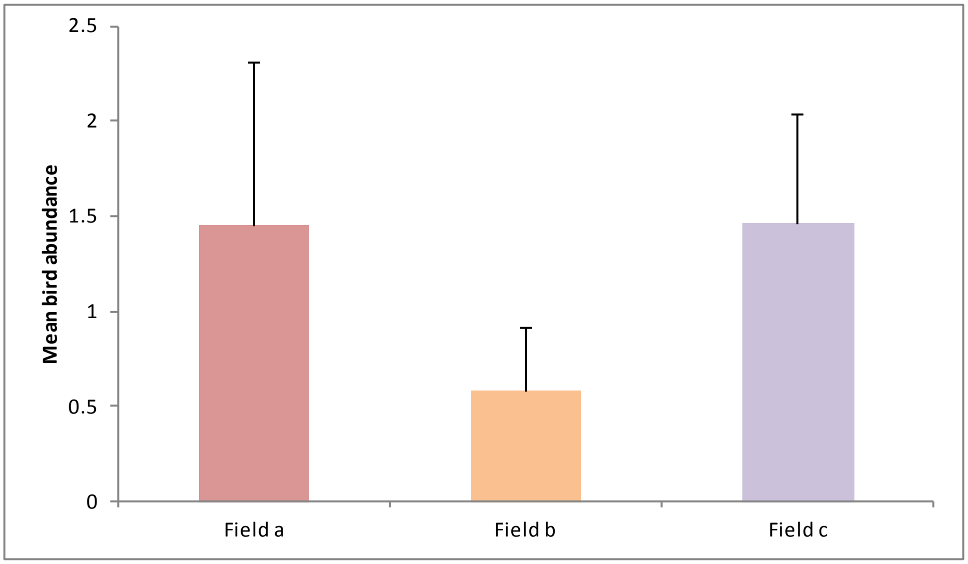

Figure 3.4 Mean (± standard error) bird abundance (regardless of management) at each site per survey.

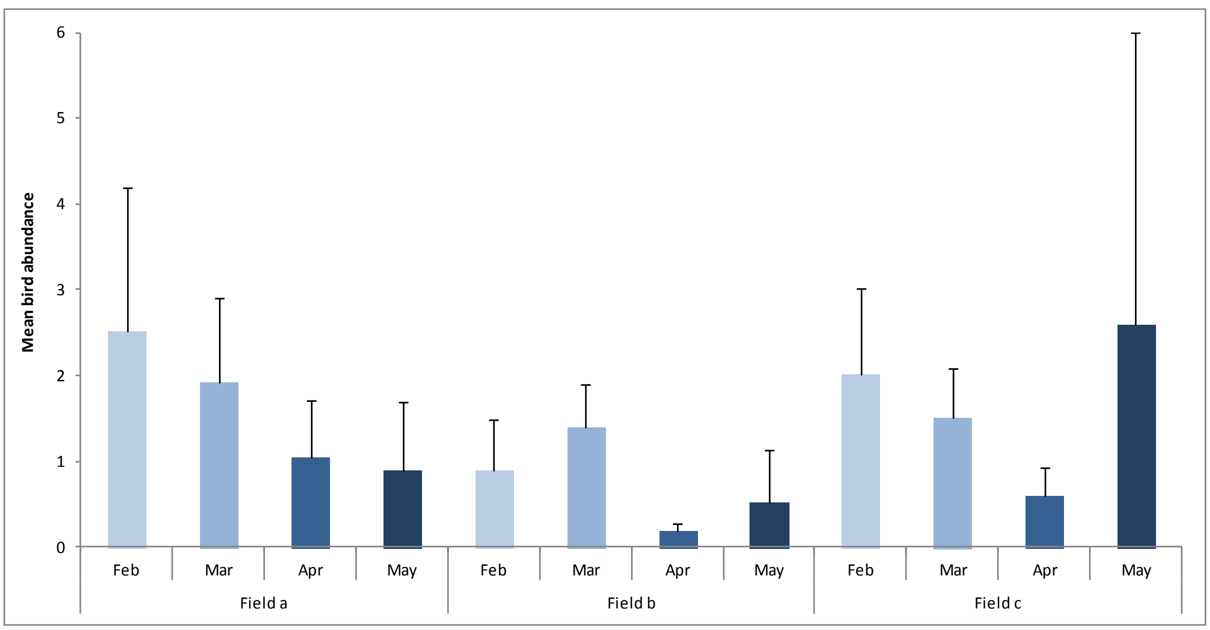

Figure 3.5 Mean (± standard error) bird abundance (regardless of management) at each site, per month. Definitions of month are; Feb is February, Mar is March, Apr is April and May.

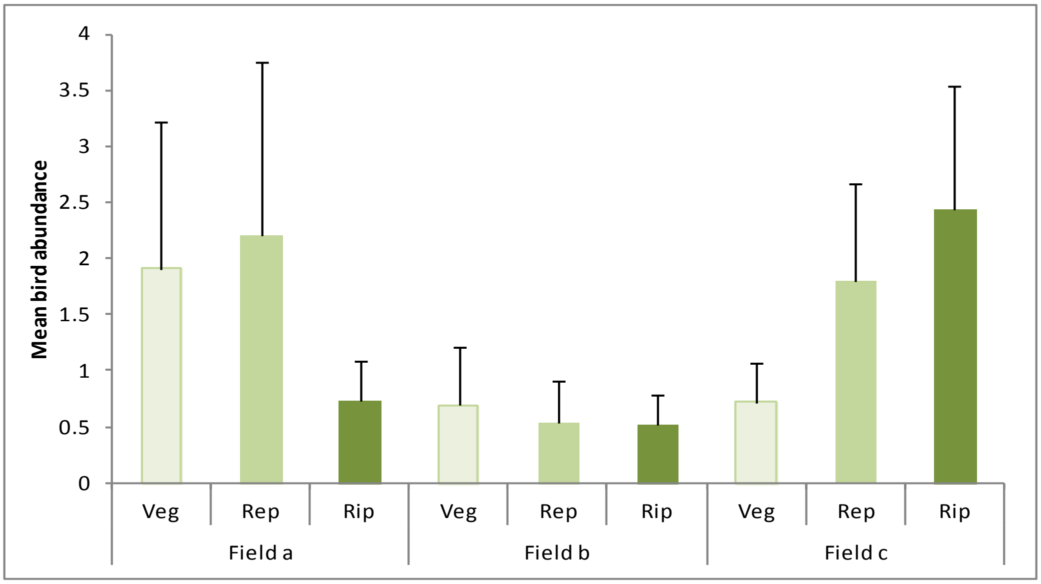

Figure 3.6 Mean (± standard error) bird abundance (regardless of management) at each site per field stage. Definitions of Field stage are; Veg is vegetative, Rep is reproductive and Rip is Ripening phase.

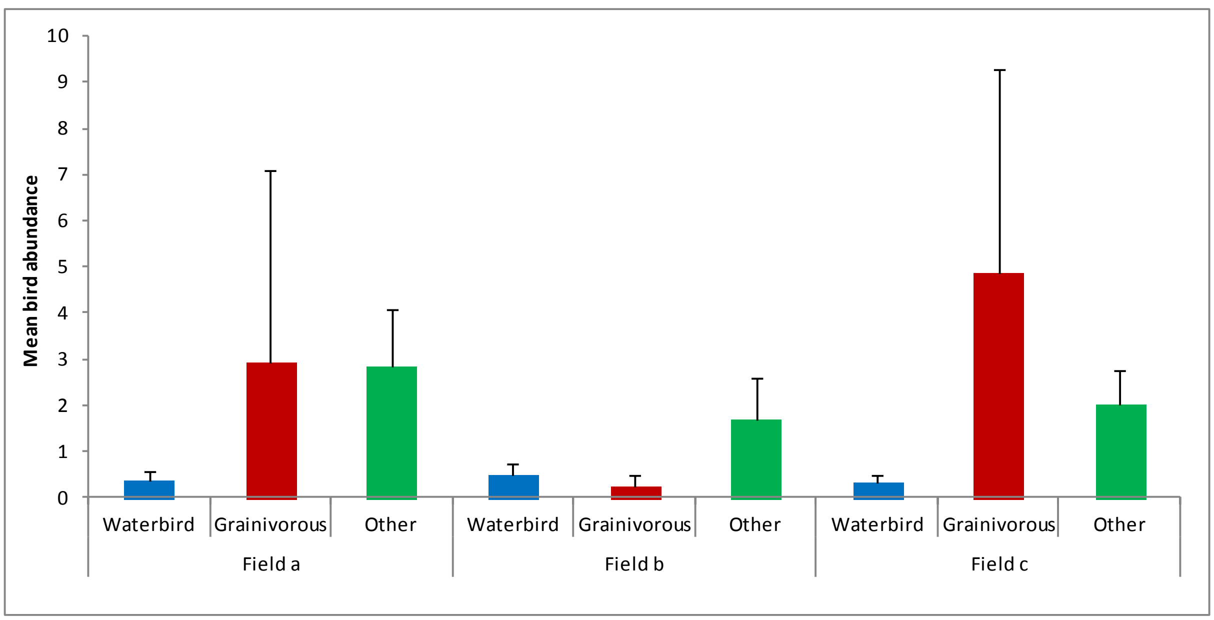

Figure 3.7 Mean (± standard error) bird abundance (regardless of management) at each site per bird category.

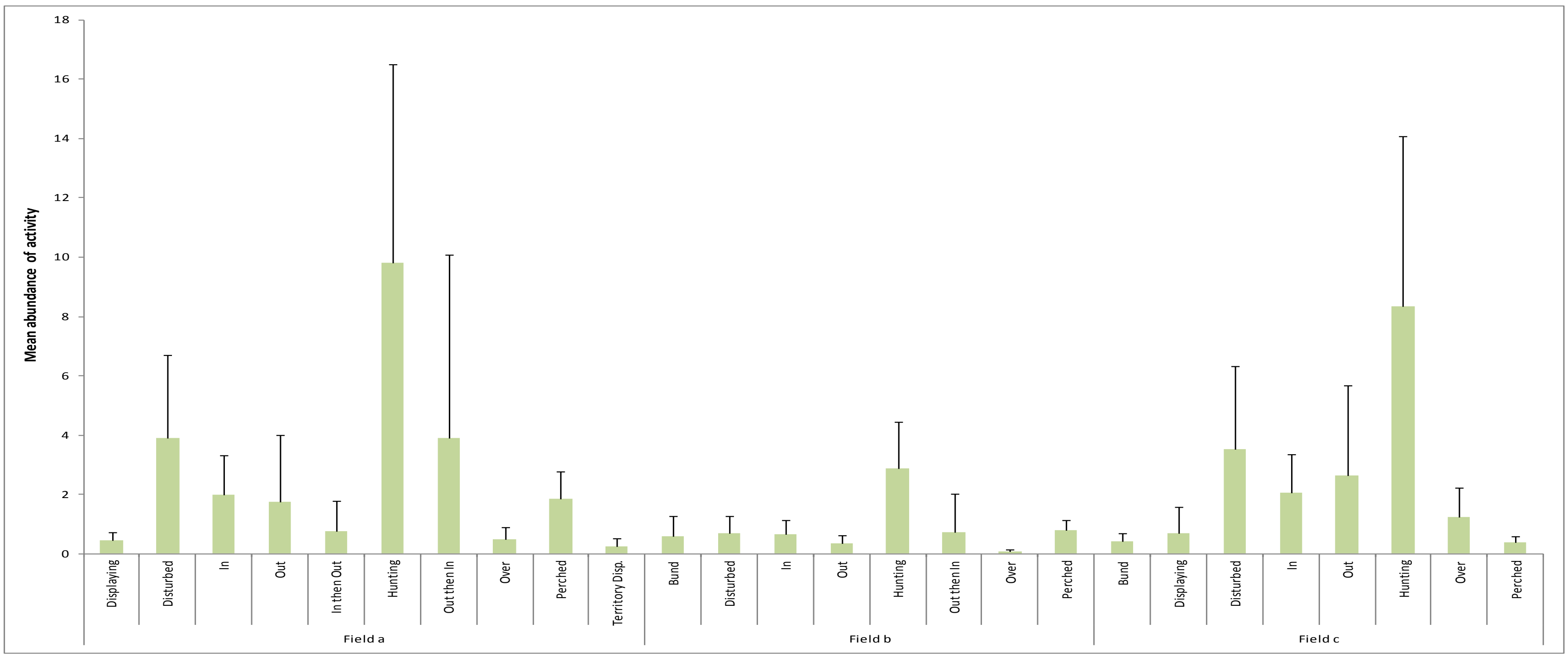

Figure 3.8 Mean (± standard error) abundance of activity (regardless of management) at each site. Definitions of activities are; '*Bund*' observed bird is seen using the bund hunting, perching etc. '*Displaying*' are those conducting behaviour believed to be for mating such as singing, song-flights etc. '*In*' is the bird enters the site, on foot or by flight. '*Out*' is the bird leaves the site, either on foot or by flight. '*In then Out*' the bird enters but immediately leaves either through disturbance or being erratic. '*Foraging/Hunting*' is the bird searching for food on the ground or seen hunting from a perch, includes species hunting on the wing; low flight over the fields, sometimes with sharp directional changes to catch prey. '*Out then In*' is the bird moving within the site using flight. '*Over*' is the bird flying over but not a species which hunts on the wing. '*Perched*' is the bird standing on bamboo sticks, net, fence or on top of the crop but not seen feeding. '*Territory Disp.*' is territorial behaviour such as attacking other individuals of the same species.

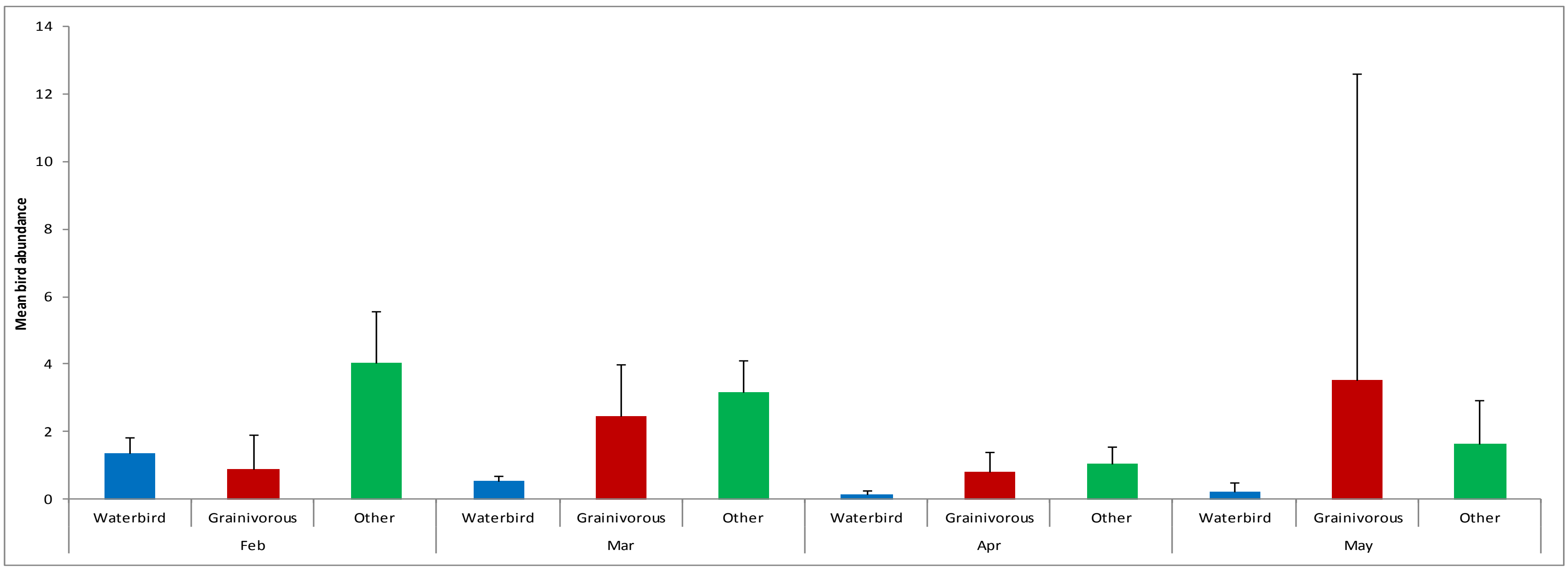

Figure 3.9 Mean (± standard error) bird abundance (regardless of management) per bird category, each month. Definitions of month are; Feb is February, Mar is March, Apr is April and May.

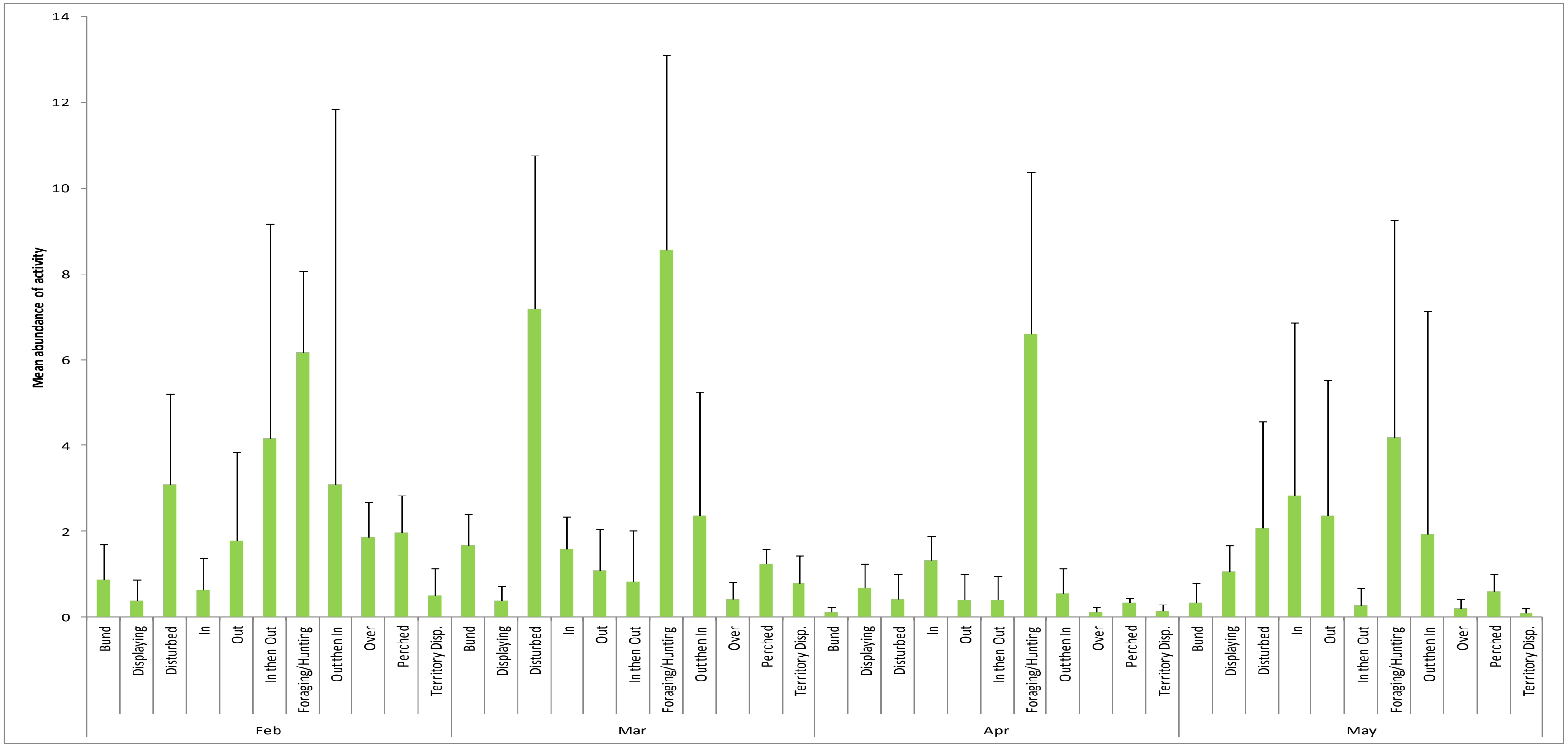

Figure 3.10 Mean (± standard error) abundance of activity (regardless of management) per month. Definitions of activities are; '*Bund*' observed bird is seen using the bund hunting, perching etc. '*Displaying*' are those conducting behaviour believed to be for mating such as singing, song-flights etc. '*In*' is the bird enters the site, on foot or by flight. '*Out*' is the bird leaves the site, either on foot or by flight. '*In then Out*' the bird enters but immediately leaves either through disturbance or being erratic. '*Foraging/Hunting*' is the bird searching for food on the ground or seen hunting from a perch, includes species hunting on the wing; low flight over the fields, sometimes with sharp directional changes to catch prey. '*Out then In*' is the bird moving within the site using flight. '*Over*' is the bird flying over but not a species which hunts on the wing. '*Perched*' is the bird standing on bamboo sticks, net, fence or on top of the crop but not seen feeding. '*Territory Disp.*' is territorial behaviour such as attacking other individuals of the same species. Definitions of month are; Feb is February, Mar is March, Apr is April and May.

Similar to management technique, differences between months had no significant effect on abundance but it was part of a significant interaction with category (Figure 3.9) and activity (Figure 3.10).

Both activity and species category displayed significant differences in the bird abundance recorded within these rice fields in their own right, also when as part of an interaction (Figure 3.11 – Figure 3.13).

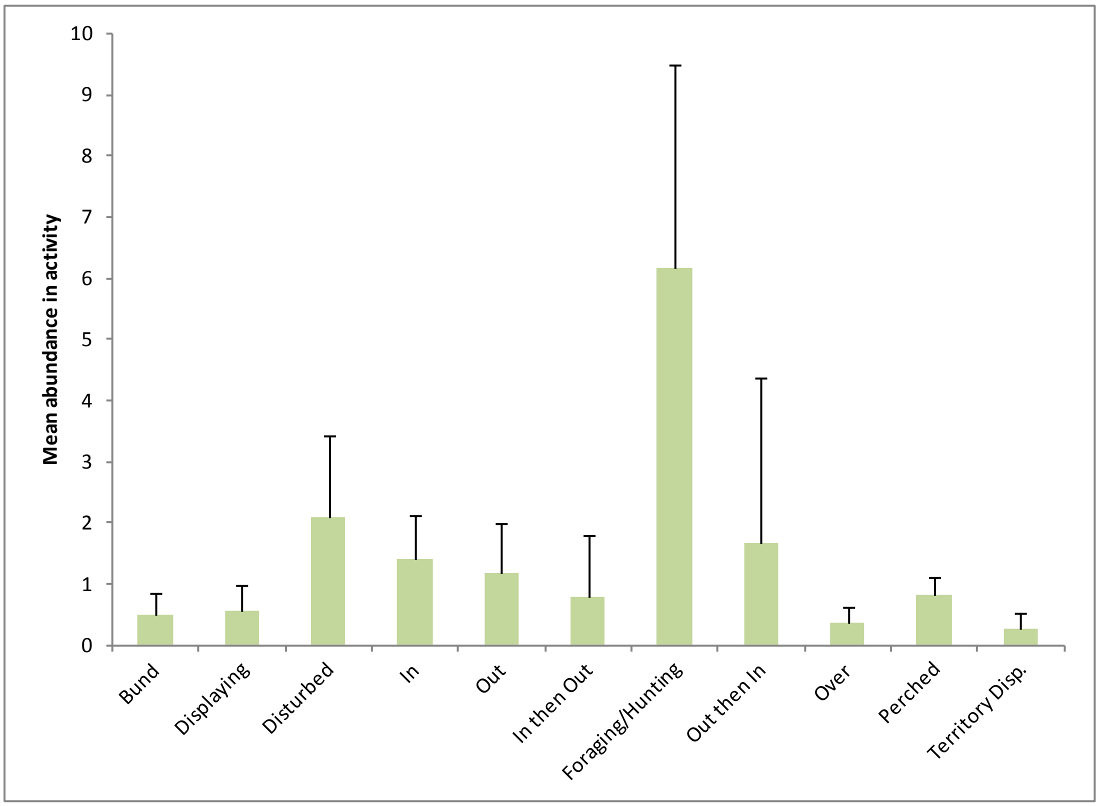

Figure 3.11 Mean (± standard error) bird activity within rice fields. Definitions of activities are; '*Bund*' observed bird is seen using the bund hunting, perching etc. '*Displaying*' are those conducting behaviour believed to be for mating such as singing, song-flights etc. '*In*' is the bird enters the site, on foot or by flight. '*Out*' is the bird leaves the site, either on foot or by flight. '*In then Out*' the bird enters but immediately leaves either through disturbance or being erratic. '*Foraging/Hunting*' is the bird searching for food on the ground or seen hunting from a perch, includes species hunting on the wing; low flight over the fields, sometimes with sharp directional changes to catch prey. '*Out then In*' is the bird moving within the site using flight. '*Over*' is the bird flying over but not a species which hunts on the wing. '*Perched*' is the bird standing on bamboo sticks, net, fence or on top of the crop but not seen feeding. '*Territory Disp.*' is territorial behaviour such as attacking other individuals of the same species.

Bird abundance and visibility are linked to bird activities within the field. Behaviours which require movement or a change in location are more visible to the observer and therefore more likely to be recorded. Activities such as; hunting, flying (In, Out or Over) or being disturbed represent the highest number of activities recorded.

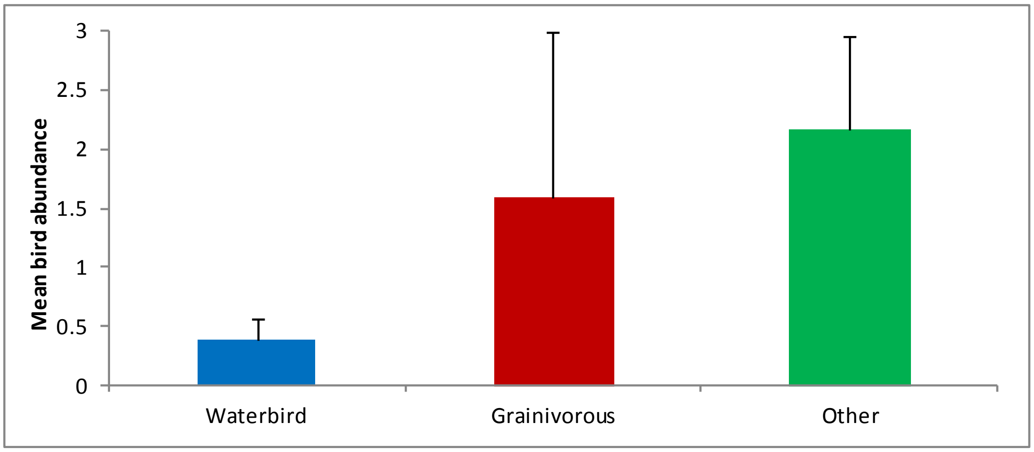

Figure 3.12 Mean (± standard error) bird abundance (regardless of management) per bird category.

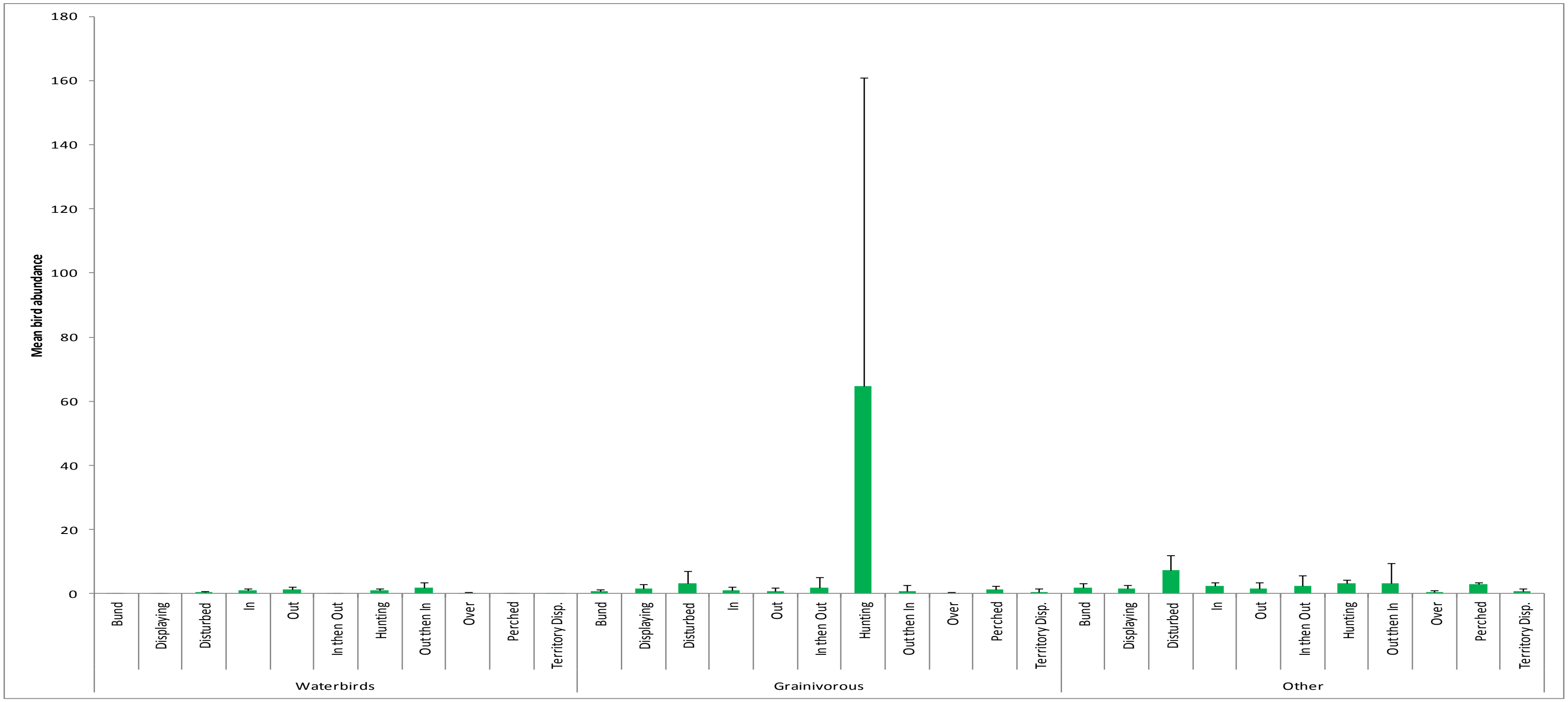

Figure 3.13 Mean (± standard error) abundance of activity (regardless of management) per bird category. Definitions of activities are; '*Bund*' observed bird is seen using the bund hunting, perching etc. '*Displaying*' are those conducting behaviour believed to be for mating such as singing, song-flights etc. '*In*' is the bird enters the site, on foot or by flight. '*Out*' is the bird leaves the site, either on foot or by flight. '*In then Out*' the bird enters but immediately leaves either through disturbance or being erratic. '*Foraging/Hunting*' is the bird searching for food on the ground or seen hunting from a perch, includes species hunting on the wing; low flight over the fields, sometimes with sharp directional changes to catch prey. '*Out then In*' is the bird moving within the site using flight. '*Over*' is the bird flying over but not a species which hunts on the wing. '*Perched*' is the bird standing on bamboo sticks, net, fence or on top of the crop but not seen feeding. '*Territory Disp.*' is territorial behaviour such as attacking other individuals of the same species.

Finally, the field stage during bird surveys displayed significant differences within mean bird abundance as a term in its own right (figure 3.14) but only once within an interaction with site (Figure 3.6).

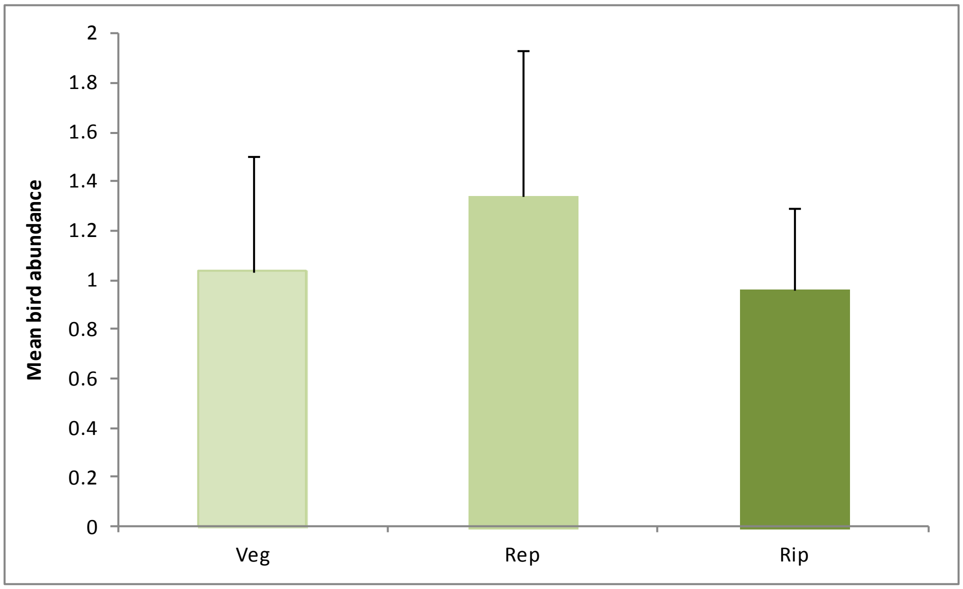

Figure 3.14 Mean (± standard error) bird abundance (regardless of management) per field stage. Definitions of Field stage are; Veg is vegetative, Rep is reproductive and Rip is Ripening phase.

The entire data set was pooled and a mean bird count, per survey, was calculated. There was no significant difference in mean bird abundance between sites which applied insecticides compared to neighbouring sites which did not.

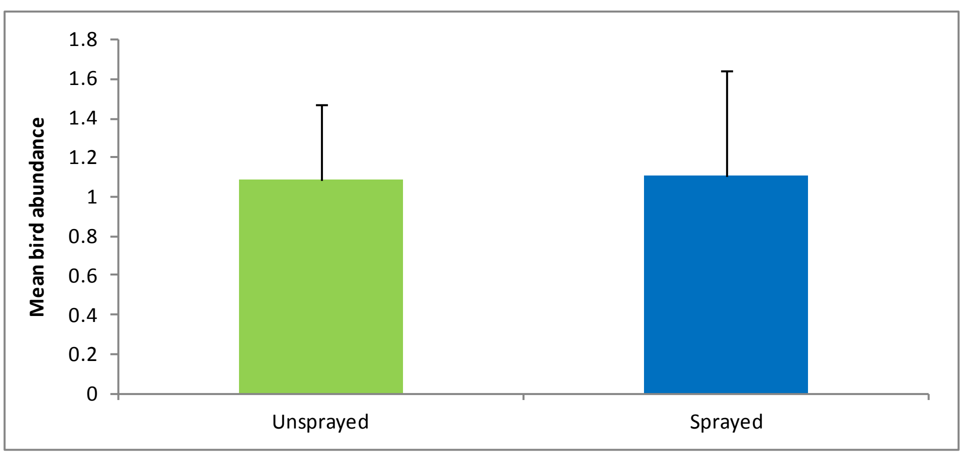

Figure 3.15 Mean (± standard error) effect of insecticide application on bird abundance.

3.4 Discussion

Overall there was no significant difference between fields sprayed with insecticides (chlorantraniliprole 20% + thiamethoxam 20%) and the paired control fields (Figure 3.15). With restrictions upon time and resources, only one insecticide was tested during this preliminary study. Ideally, all different active ingredients should be tested in an attempt to quantify how different insecticides affect avian abundance. Though farmer surveys were conducted during all investigations, the application of chemicals along with brand and active ingredients will not be included in future investigations, to reduce statistical complexity.

Avian abundance has been used to display changes between sprayed and unsprayed fields as there was no significant difference in diversity, measured through species categories (Table 3.1). Overall there was a significant difference between the categories, as granivorous and other birds were recorded more frequently than waterbirds (Figure 3.12), however this did not change when placed in an interaction with management. Therefore it may be suggested that applying insecticides to rice fields effects the entire community, regardless of dietary requirements, although this work needs expanding upon before this can be recognised as fact.

Caution should be taken when interpreting these results. Insecticide application was conducted upon an experimental station and management of the plots were conducted under strict conditions, some of which are not representative of the 'real world' where other limiting factors might be relevant. Application of the insecticide was conducted throughout the growing period, representative of farmer practices. However, some farmers might apply more if they feel it is required and therefore additional applications might have an impact on avian diversity which was not recorded here. Further work should be conducted on the relationship between chemical input and avian diversity.

Regardless of management and whether the fields had been sprayed or not, avian diversity showed similar trends (Figure 3.3). Both active ingredients within the insecticide used act by paralysing the invertebrates; chlorantraniliprole by causing the release of stored calcium, which initiates muscle paralysis, and thiamethoxam, which blocks the nerves, resulting in paralysis. Both would result in a number of invertebrates still being present within the rice fields, but unable to move. This might explain the increase in bird numbers around 10 days after insecticide application, either as birds hunt the paralysed or dead invertebrates or as new invertebrates move into the habitat because the previous invertebrates have died. Unfortunately, for health reasons, surveys could not be conducted at sites within the first 48 hours after chemical application, although this information would help determine the initial effects of the spray application. Comparative studies on bird abundance and invertebrate management may determine if the birds are hunting the dead individuals or those moving into the area.

This methodology does not account for the possibility that birds become ill after exposure to insecticide, either through direct ingestion or eating affected insects. If birds were to become ill due to the application of chemicals, they might develop an aversion to the area, an aversion which might apply to a larger area than just the treated plots.

Differences in bird abundance were more likely due to a site difference than the management (Figure 3.4), as different sites peaked in abundance during different management techniques (sprayed or unsprayed). Combined with the difference in mean bird abundance at site 'C' this explains the significant difference from the GLMM. These differences are probably due to a combination of unmeasured factors which have an effect upon the occurrence and frequency of birds.

3.5 Conclusions from Preliminary Study

The use of insecticide had no significant effect upon the abundance or diversity of avian species within the rice fields of the Philippines, when compared to a non-sprayed field, and therefore we can reject the hypothesis that sites with insecticide application will have reduced bird abundance. The preliminary study did raise a number of other factors to be considered in the following investigations. These include:

- *Site location* – surrounding areas, immediately adjacent fields, distance between both treatments and repeats.
- *Field conditions* – crop stage, irrigation level, crop height.
- *Bird categories* – keep as above.
- *Bird Activity* – target specific activities that are relevant to each study.

Bird Communities in a tropical lowland rice cropping system

4.1 Introduction

In 2013, 4.7 million ha of rice was harvested within the Philippines (FAOSTAT, 2014a), which accounts for 48.5 % of agricultural land and approximately 15.6 % of the total land area of the country (Moog, 2006). This makes the Philippines the eighth largest producer of rice in the world (GRiSP, 2013; Table 1.2).

Large areas of land are being used for the production of rice but these are often overlooked by ornithologists, both internationally and domestically, so that information on the avian diversity associated with rice-based cropping systems is poor. Those people who do spend time in the fields tend to be farmers and farm labourers who characteristically assume that most bird species present are pests, an attitude which is passed down through the generations. Within Asia, in particular, there has been little descriptive work on the diversity of bird species present in rice fields, with most work focusing instead on the ecology of a single species or the movement of waterbirds. However, it is only through the quantification of avian diversity within the rice agroecosystem that changes in population sizes and community structure can be monitored and appropriate actions taken if required (Elphick, 2010). The almost continuous production of rice in irrigated lowlands of the Philippines, in comparison with temperate regions in which rice is grown for four to six months per year, offers an invaluable opportunity to investigate the interaction between this form of food production and avian diversity.

Agricultural land can be managed to support avian diversity. Within the United Kingdom (UK), birds associated with an agricultural habitat have shown a decrease in numbers since changes in farming methods were established in the 1940s (Robinson & Sutherland, 2002). These changes in avian populations, however, were only identified as a result of long-term (> 50 years) monitoring, such as the work undertaken by Baillie *et al.* (2014). Through detailed investigations a number of wildlife-friendly techniques have been suggested to support current populations in an attempt to stabilise and improve these numbers. Wildlife-friendly techniques include; the use of hedges (Hinsley & Bellamy, 2000; Robinson & Sutherland, 2002; Batáry *et al.,* 2010), set-aside margins (Fuller, 2000; Henderson *et al.,* 2000; Robinson & Sutherland, 2002; Vickery *et al.,* 2002; Newton, 2004) and 'organic' management of crops (Robinson & Sutherland, 2002; Batáry *et al.,* 2010).

An initial requirement for improving our knowledge of rice-associated avian diversity is to identify those species present and their frequency and abundance. However, it is necessary that observations across multiple seasons and years are recorded to help understand how changes in food availability and cover, provided by the rice fields, may affect the behaviour of species and life cycles at specific times of the year. For example, particular stages of rice production may provide migratory species with valuable foraging opportunities whilst on passage to their final destinations, whereas some resident species may elect to nest within the fields themselves whilst others breed in other habitats but use rice fields for foraging. In particular, it is only through understanding the role which rice fields play in supporting both resident and over-wintering bird populations that agricultural management practices can be identified to support threatened avian species and contribute to their conservation (Elphick & Oring, 1998; Elphick, 2004; 2010b).

Given the paucity of information on basic patterns of use of rice habitats by birds, the objectives of this chapter are to quantify temporal patterns of avian diversity and abundance within rice fields in the Philippines as a baseline for future studies. This investigation will concentrate on irrigated rice fields which, in 2010, accounted for 71% of the total rice production area of the Philippines (GRiSP, 2013). For comparison, species were categorised into seven divisions based upon their diet and / or ecology: omnivores; insectivores; granivores; birds of prey; waterbirds and water associated species; species that hunt on the wing; and transient species. These categories are not mutually exclusive, and birds were primarily categorised depending upon diet, then by hunting method to reduce complications in displaying data. It is hoped that this information will then be used to determine changes in avian abundance over time and in relation to different crop management schemes, as well as document the annual changes which occur, effecting those species recorded within the rice fields and when.

4.2 Materials and Methods

Records of birds within rice fields were collated from a combination of surveys conducted as part of the whole PhD study outlined in this thesis. Data on the abundance of species and community structure within rice fields were recorded from surveys conducted as part of the experimental studies outlined in Chapters 4-6; only those data from control sites are presented here, as these were associated with the typical pattern of rice management present in the Philippines. Twenty minute spot counts were conducted at each site, between 5 am and noon, with a set time between data collection days spanning 3 days to 4 weeks depending on location. Results were recorded by merging data collected at different times from three study sites and then averaged per survey to provide a mean per month to account for differences in survey effort. Overall, the dataset spanned a period of 27 months from February 2012 – April 2014 inclusively.

4.2.1. Study Sites

Study sites were located in: Bohol (San Miguel, Pilar and Ubay), the IRRI Experimental station (Luzon) and Isabela (Luzon).

4.2.1.1. San Miguel, Pilar and Ubay (Bohol)

The data for Chapter 5 were recorded from six paired locations (individual fields) within three sites in the north-east of Bohol during the dry seasons of 2013 and 2014. That chapter investigates whether there is a difference in bird abundance between rice fields using different water management regimes. The data used here are from the six control sites adopting a traditional method of irrigation where fields had a standing layer of water; ranging between puddled fields and a mean depth of 52 mm.

Two fields were studied at each of the three locations of the irrigation network (upper: San Miguel; middle: Pilar; bottom: Ubay). Data were collected during February and April 2013 and March and May 2014. These surveys coincided with the same crop stage each year; one during the vegetative phase and one during the reproductive phase, but were different months due to a change in the local planting calendar. All sites were a minimum of 1 km apart to ensure independence of counts.

4.2.1.2. IRRI Experimental Station (Laguna, Luzon)

The IRRI experimental station is located 50 km south of Metro Manila, on the lower slopes of Mount Makiling. The station contains a number of rice fields covering approximately 209 ha under different management regimes, creating a mosaic of habitats. These are bordered by urban areas, rainforest and other agricultural land. The station has a small coconut grove, a number of water reservoirs which provide water from a natural subterranean source and two natural waterways which pass through the farm. Two-thirds of the farm is managed as irrigated lowland rice fields whilst the remaining third uses a drier ‘upland’ method of rice cultivation. Unlike many other agricultural areas, hunting is prohibited at IRRI and security is present to deter any unauthorized poaching. In theory, this means that birds are protected, potentially elevating the number of species using these rice fields compared to other locations, though hunting does still occur. Data were collected monthly from February 2012 until May 2013 at three locations separated by a minimum distance of 1 km.

4.2.1.3. Mallig and Ramon (Isabela, Luzon)

Isabela in the north of Luzon is one of the largest provinces in the Philippines. It has a large area of agriculture dedicated to the production of rice. The survey data used here were taken from four field sites located within the barangays (village or district; see *Abbreviations and Definitions*) of Mallig and Ramon; these were the control sites for the intensification study outlined in Chapter 6 and were managed using the traditional method of irrigation (four crops over two years). Data were collected monthly from September 2012 until April 2014, with two fields surveyed at each location, and sites separated by a minimum distance of 1 km to ensure independence of counts.

4.2.2. Survey Method

4.2.2.1. Spot Counts

Twenty-minute spot counts were conducted at all sites as described by Bibby *et al.* (2000), although the frequency of surveying varied in order to meet the specific objectives of the respective studies. All spot counts were conducted by the author. Counts were conducted from the same position, located adjacent to fields in pre-selected sites which fit specific characteristics; > 1 km from other surveyed sites and not adjacent to other types of management. An area of 10 m x 50 m using bunds or other permanent physical features of the rice fields, such as irrigation structures, to define the edges of the surveyed area.

4.2.2.2. Species Identification

Every effort was made to identify all individuals seen to species level. However, at times it was only possible to identify birds to the family level. Field notes were taken during surveys and attempts to identify unknown species were made subsequently using Kennedy *et al.* (2000); identification to family level reduced the amount of time spent identifying "problem" species, thereby allowing the greatest amount of time for observing the range of species present within the restricted survey timeframe. Species such as the pacific swallow (*Hirundo tahitica*) and barn swallow (*Hirundo rustica*) were recorded as '*swallow*', especially where a large number of individuals were observed hunting over a field simultaneously. Similarly, the three species of munia (family *Lonchura*) were sometimes observed in mixed flocks; and were recorded as '*munia*'.

4.2.3. Intra-annual and Inter-annual Differences

Patterns of variation within and between years were compared using mean monthly abundance estimates calculated for each species by averaging count data across all survey locations within and between study sites. Intra-annual differences were derived by merging data from multiple years; inter-annual differences were derived by considering data collected in different years separately. Inter-annual differences in abundance were confined to those species where peaks in abundance were recorded and are considered in the context of temporal changes associated with the management of the rice crop. Four stages of rice crop development are recognised, with two crops harvested each year; land preparation (LP: Apr-Jul & Oct-Dec), vegetative phase (Veg: Jul/Aug & Jan), reproductive phase (Rep: Aug/Sep & Feb) and ripening phase (Rip: Sep/Oct & Mar/Apr).

Intra-annual differences in abundance are presented in seven categories for 71 species for which sufficient data were available from spot count surveys: granivorous species (3 species); commonest waterbirds (6 species); waterbirds which are partial migrants (5 species); migratory waterbirds (3 species); resident waterbirds (6 species); waterbirds of conservation importance (2 species); species which hunt on the wing (5 species); birds of prey (4 species); the most abundant resident species (including 2 insectivorous species) and breeding species (6 species).

For ease of use and unless otherwise stated, only species with a total count higher than 50, over the entire data collection period (February 2012 - April 2014), were graphically represented. By limiting records, comparisons between species can be identified more clearly.

4.2.4. Species Richness Indices

Two indices of species richness were calculated to examine how changes in rice field habitats affected the diversity of birds present at different times of the year and within different stages of the rice crop: Margalef's diversity index (Clifford & Stephenson, 1975) and Simpson's index (Simpson, 1949).

Margalef's diversity index (D_{mg}) provides a simple measure of richness from abundance data and is calculated as:

$$D_{mg} = \frac{(S-1)}{\ln N}$$

where *S* is the number of species and *N* is the number of individuals. This index attempts to estimate species richness independently of sample size, with higher values indicating higher richness.

Simpson's index provides a simple inverse measure of diversity and is calculated as:

$$D_{sim} = \sum \left(\frac{n_i[n_i-1]}{N[N-1]} \right)$$

where n_i is the number of individuals of the *i*th species and *N* is the total number of individuals. This index reflects the probability that two randomly selected individuals belong to the same species. Consequently, as diversity decreases, values of D_{sim} increase. Simpson's index is less sensitive to species richness, focusing on the more abundant species and not, for example, on individual sightings of rare species. In addition, unlike other indices such as the Shannon-Weiner index, Simpson's index can be used on relatively small (< 1000) data sets (Magurran, 2004).

Diversity indices were calculated for each month and for five stages of crop development: land preparation, vegetative, reproductive, ripening; and fallow. The fallow phase was further divided into stubble (dry field, short cut stalks) and regrowth (wet field, mid-tall re-growing tillers).

4.3 Results

4.3.1. Bird species recorded

Based upon spot counts and information collated from one historical site, a total of 130 species were recorded (Tables 4.1a – 4.1g). Of these, 90% were recorded by the author during 2012 to 2014. Only 54% were recorded during the 20-minute spot counts (4 granivorous species; 28 waterbirds; 9 insectivores; 8 aerial hunting species; 6 birds of prey; 8 omnivorous species; 8 transient species).

Table 4.1 List of species recorded within rice fields in the Philippines from all control data (thus representing a 'typical' management technique) from chapters 2 – 7 of this thesis. Species are divided according to their diet and / or ecological characteristics: (a) granivorous species; (b) waterbirds and water associated species; (c) insectivorous species; (d) birds which hunt on the wing; (e) birds of prey; (f) omnivorous species; and (g) transient species. '*Records*' indicates the number of times the species was recorded during surveys. '*Aggregated Count*' indicates the total number of individuals recorded during surveys. '*IUCN*' is the species' conservation status as listed on the IUCN Red List. '*Status*' is the migratory status of the species; A = accidental, R = resident; M = migratory; R, M = a migratory species for which a resident population is also known to occur within the Philippines, '?' = unknown (data taken from the Wild Bird Club of the Philippines (WBCP) annual checklist 2016). '*Breeding*' indicates species which were known, or assumed, to have bred in or close to rice fields. '*Typical Habitat*' is where the species is likely to occur naturally. Species which display no records or aggregated counts are from *ad hoc* and historical records of the IRRI experimental station (2009 – 2014: Paul Bourdin Unpublished data).

(a) Granivorous species

Name	Scientific Name	Records	Aggregated Count	IUCN	Status	Breeding
Tree sparrow	*Passer montanus*	483	1908	LC	R	Y
Scaly-breasted munia	*Lonchura punctulata*	16	32	LC	R	Y
White-bellied munia	*Lonchura leucogastra*	10	16	LC	R	
Chestnut munia	*Lonchura atricapilla*	253	805	LC	R	Y
Java sparrow	*Lonchura oryzivora*			VU	R	

(b) Waterbirds and water associated species

Name	Scientific Name	Records	Aggregated Count	IUCN	Status	Breeding
Grey heron	*Ardea cinerea*			LC	M	
Purple heron	*Ardea purpurea*	7	7	LC	R	
Great egret	*Ardea alba*	1	1	LC	R, M	
Intermediate egret	*Egretta intermedia*	4	4	LC	M	
Little egret	*Egretta garzetta*	19	22	LC	R, M	
Black-crowned night heron	*Nycticorax nycticorax*	1	1	LC	R	
Javan pond heron	*Ardeola speciosa*	1	1	LC	R	
Eastern cattle egret	*Bubulcus coromandus*	173	401	LC	R, M	

(b) Waterbirds and water associated species (cont.)

Name	Scientific Name	Records	Aggregated Count	IUCN	Status	Breeding
Yellow bittern	*Ixobrychus sinensis*	75	95	LC	R	
Von schrenck's bittern	*Ixobrychus eurhythmus*			LC	M	
Cinnamon bittern	*Ixobrychus cinnamomeus*	50	54	LC	R	
Black bittern	*Dupetor flavicollis*	1	1	LC	R	
Black-faced spoonbill	*Platalea minor*			EN	A	
Wandering whistling duck	*Dendrocygna arcuata*	4	8	LC	R	
Barred rail	*Gallirallus torquatus*	3	4	LC	R	
Buff-banded rail	*Gallirallus philippensis*	8	9	LC	R	
Slaty-breasted rail	*Gallirallus striatus*			LC	R	
Plain bush-hen	*Amaurornis olivacea*			LC	E	
White-breasted waterhen	*Amaurornis phoenicurus*	18	19	LC	R	
Ruddy-breasted crake	*Porzana fusca*	1	1	LC	R	
White-browed crake	*Porzana cinerea*	69	85	LC	R	Y
Watercock	*Gallicrex cinerea*	1	1	LC	R	
Common moorhen	*Gallinula chloropus*	67	78	LC	R, M	Y
Greater painted snipe	*Rostratula benghalensis*	8	15	LC	R	Y
Pacific golden plover	*Pluvialis fulva*			LC	M	
Little ringed plover	*Charadrius dubius*	10	20	LC	R, M	
Kentish plover	*Charadrius alexandrinus*			LC	M	
Oriental plover	*Charadrius veredus*			LC	A	
Marsh sandpiper	*Tringa stagnatilis*			LC	M	

(b) Waterbirds and water associated species (cont.)

Name	Scientific Name	Records	Aggregated Count	IUCN	Status	Breeding
Common greenshank	*Tringa nebularia*			LC	M	
Green sandpiper	*Tringa ochropus*			LC	M	
Wood sandpiper	*Tringa glareola*	124	327	LC	M	
Common redshank	*Tringa totanus*			LC	M	
Common sandpiper	*Actitis hypoleucos*	12	13	LC	M	
Pin-tailed /Swinhoe's snipe	*Gallinago stenura/megala*	14	16	LC	M	
Red-necked stint	*Calidris ruficollis*			LC	M	
Temmick's stint	*Calidris temminckii*			LC	M	
Long-toed stint	*Calidris subminuta*	1	1	LC	M	
Sharp-tailed sandpiper	*Calidris acuminata*			LC	M	
Ruff	*Philomachus pugnax*			LC	M	
Black-winged stilt	*Himantopus himantopus*			LC	R?, M	
Red-necked phalarope	*Phalaropus lobatus*			LC	M	
Whiskered tern	*Chlidonias hybrida*	38	84	LC	M	
White-winged tern	*Chlidonias leucopterus*			LC	M	
Common kingfisher	*Alcedo atthis*	36	53	LC	M	
White-throated kingfisher	*Halcyon smyrnensis*	1	1	LC	R	
Collared kingfisher	*Todiramphus chloris*	16	18	LC	R	
Pectoral sandpiper†	*Calidris melanotos*			LC	A	

† Country first (Paul Bourdin)

(c) Insectivorous species

Name	Scientific Name	Records	Aggregated Count	IUCN	Status	Breeding
Barred buttonquail	*Turnix suscitator*	2	2	LC	R	
King quail	*Excalfactoria chinensis*			LC	R	
Lesser coucal	*Centropus bengalensis*	30	32	LC	R	
Great eared nightjar	*Lyncornis macrotis*			LC	R	
Philippine nightjar	*Caprimulgus manillensis*			LC	E	
Pied bush chat	*Saxicola caprata*	30	41	LC	R	Y
Oriental reed-warbler	*Acrocephalus orientalis*			LC	M	
Clamorous reed warbler	*Acrocephalus stentoreus*			LC	R	
Striated grassbird	*Megalurus palustris*	182	214	LC	R	
Tawny grassbird	*Megalurus timoriensis*			LC	R	
Zitting cisticola	*Cisticola juncidis*	172	219	LC	R	Y
Golden-headed cisticola	*Cisticola exilis*	6	6	LC	R	
Eastern yellow wagtail	*Motacilla tschutschensis*	52	77	LC	M	
Grey wagtail	*Motacilla cinerea*	66	119	LC	M	
White wagtail	*Motacilla alba*			LC	M	
Paddyfield pipit	*Anthus rufulus*	9	14	LC	R	
Pechora pipit	*Anthus gustavi*			LC	M	
Black drongo	*Dicrurus macrocercus*			LC	A	

(d) Species that hunt on the wing

Name	Scientific Name	Records	Aggregated Count	IUCN	Status	Breeding
Oriental pratincole	*Glareola maldivarum*	27	87	LC	R, M	
Glossy swiftlet	*Collocalia esculenta*	1	1	LC	R	
Ameline swiftlet	*Aerodramus amelis*	2	2	LC	E	
Purple needletail	*Hirundapus celebensis*			LC	R	
Asian palm swift	*Cypsiurus balasiensis*			LC	R	
House swift	*Apus nipalensis*			LC	R	
Blue-tailed bee-eater	*Merops philippinus*	93	158	LC	R	
Barn swallow	*Hirundo rustica*	21	37	LC	M	
Pacific swallow	*Hirundo tahitica*	101	305	LC	R	
Striated swallow	*Cecropis striolata*	3	3	LC	R	
White-breasted woodswallow	*Artamus leucorynchus*	32	68	LC	R	

(e) Birds of prey

Name	Scientific Name	Records	Aggregated Count	IUCN	Status	Breeding
Brahminy kite	*Haliastur indus*	4	4	LC	R	
Pied harrier	*Circus melanoleucos*	16	17	LC	R, M	Y
Common kestrel	*Falco tinnunculus*			LC	M	
Peregrine falcon	*Falco peregrinus*	2	2	LC	R, M	
Eastern grass owl	*Tyto longimembris*	1	1	LC	R	Y
Brown shrike	*Lanius cristatus*	176	204	LC	M	
Long-tailed shrike	*Lanius schach*	36	41	LC	R	

(f) Omnivorous species

Name	Scientific Name	Records	Aggregated Count	IUCN	Status	Breeding
Rock Dove	*Columba livia*	4	11		R	
Red Turtle Dove	*Streptopelia tranquebarica*	16	28	LC	R	
Spotted Dove	*Spilopelia chinensis*	29	40	LC	R	
Zebra Dove	*Geopelia striata*	59	77	LC	R	
Horsfield's Bush Lark	*Mirafra javanica*			LC	R	
Oriental skylark	*Alauda gulgula*	30	32	LC	R	
Large-billed crow	*Corvus macrorhynchos*	16	22	LC	R	
Asian glossy starling	*Aplonis panayensis*	46	169	LC	R	
Crested myna	*Acridotheres cristatellus*	11	20	LC	R	
Common starling‡	*Sturnus vulgaris*	1	1	LC	A	

‡ Country's fourth record (Richard Smedley)

(g) Transient species

Name	Scientific Name	Records	Aggregated Count	Typical Habitat
Little grebe	*Tachybaptus ruficollis*			Terrestrial; Freshwater; Marine
Western osprey	*Pandion haliaetus*			Terrestrial; Freshwater; Marine
Chinese sparrowhawk	*Accipiter soloensis*			Terrestrial; Freshwater
Philippine serpent eagle	*Spilornis holospilus*			Terrestrial; Freshwater

(g) Transient species (cont.)

Name	Scientific Name	Records	Aggregated Count	Typical Habitat
Grey-faced buzzard	*Butastur indicus*			Terrestrial; Freshwater
Spotted buttonquail	*Turnix ocellatus*			Terrestrial; Freshwater
Common emerald dove	*Chalcophaps indica*	1	1	Terrestrial
Philippine hanging parrot	*Loriculus philippensis*	2	2	Terrestrial
Plaintive cuckoo	*Cacomantis merulinus*			Terrestrial
Oriental cuckoo	*Cuculus optatus*			Terrestrial: Forest
Rough-crested malkoha	*Dasylophus superciliosus*			Terrestrial: Forest
Scale-feathered malkoha	*Dasylophus cumingi*			Terrestrial: Forest
Philippine coucal	*Centropus viridis*			Terrestrial: Forest
Philippine scops owl	*Otus megalotis*			Terrestrial: Forest
Luzon hawk-owl	*Ninox philippensis*			Terrestrial: Forest
Indigo-banded kingfisher	*Ceyx cyanopectus*			Terrestrial; Freshwater
Coppersmith barbet	*Megalaima haemacephalus*			Terrestrial
Golden-bellied gerygone	*Gerygone sulphurea*			Terrestrial

4.3.2. Intra-annual Differences in Abundance

The abundance of granivorous species peaked during fallow and land preparation (Figure 4.1). Interestingly, the peak in abundance of granivorous species between April and August coincided with a decreased abundance of brown shrikes (*Lanius cristatus*).

Peaks in the abundance of several resident waterbird species were evident in July and September (Figure 4.2), for migratory waterbird species in the early and latter parts of the year (Figure 4.3) and for a range of partially migratory species at different times of the year (Figure 4.4). However, peaks for individual species were not consistently concomitant with the different phases of the rice crop associated with the two harvests produced each year (i.e. a species may have shown a peak with one period of land preparation but not both).

Little ringed plovers (*Charadrius dubius*) displayed peaks in abundance in Aug-Sep and Dec, while common sandpipers (*Actitis hypoleucos*) were recorded throughout July - May (Figure 4.5).

The highest abundances of species which hunt on the wing were recorded primarily from Oct-Feb, although the blue-tailed bee-eater (*Merops philippinus*) was most commonly recorded in August (Figure 4.6).

Birds of prey were rarely observed within rice fields. However, a species considered to be an 'honorary bird of prey', which was frequently recorded during surveys was the brown shrike (*Lanius cristatus*). Although as noted above, there were no sightings of this species in May - June (Figure 4.7).

The abundance of six species (common moorhen, greater painted snipe, pied bushchat, pied harrier, white-browed crake and zitting cisticola) which were recorded demonstrating clear signs of breeding (such as nest establishment, carrying nest material, or the presence of recently fledged young) during the spot counts in this study are presented in Figure 4.8. A steep decline in the abundance of all six species was recorded during the month of August, at a time when the crop was in the late Vegetative phase.

A similar August decline was observed for the five most frequently recorded resident species (chestnut munia, munia [mixed flocks], striated grassbird, tree sparrow and zitting cisticola; Figure 4.9). Breeding birds and the most frequently recorded resident birds are likely to be affected by a common factor causing their reduced recorded abundance, independent of their dietary requirements, as both granivorous and insectivorous species are affected. However, the common factor does not seem to affect cinnamon bitterns and collared kingfishers (Figure 4.2), common sandpipers (Figure 4.3), little ringed plovers (Figure 4.4), and blue-tailed bee-eaters (Figure 4.6) all of which increased in recorded abundance during August.

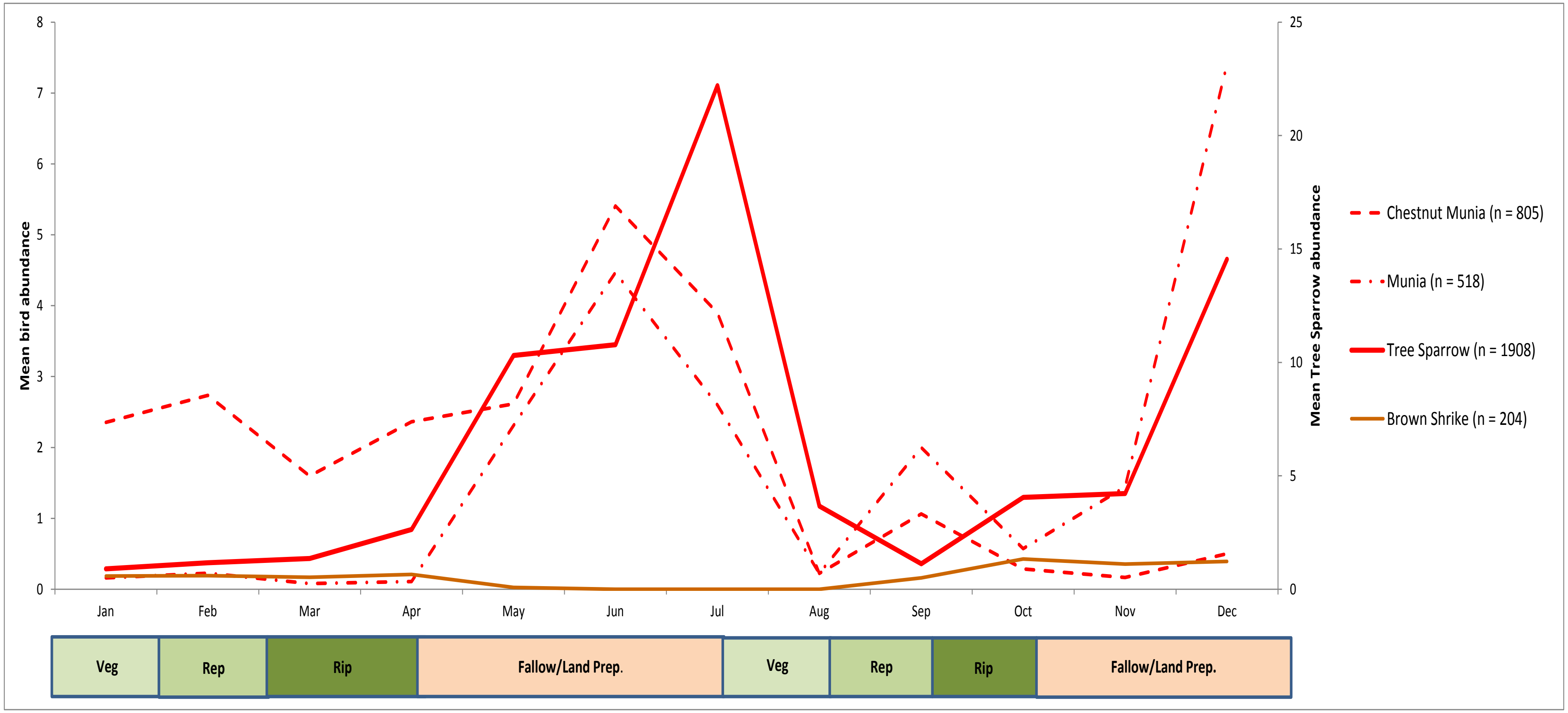

Figure 4.1 Monthly means of granivorous species and brown shrikes, throughout the year in rice fields of the Philippines. Mean abundance for tree sparrows is plotted on the Y-axis to the right; values for all other species are plotted on the Y-axis to the left. The rice crop stage is presented along the X-axis; Veg = vegetative phase; Rep = reproductive phase; Rip = ripening phase; and Land Prep. = land preparation phase, when fields are levelled and flooded.

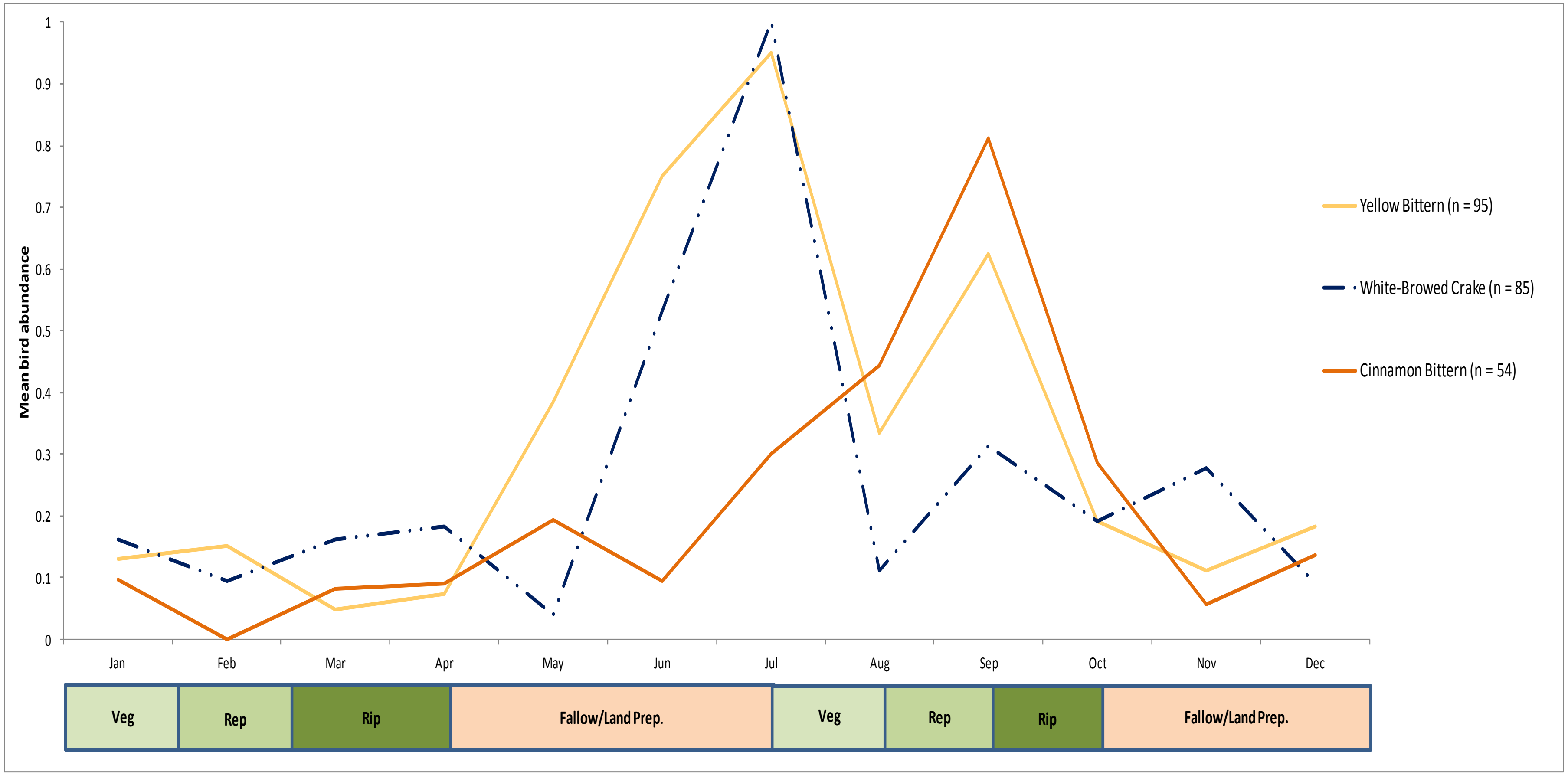

Figure 4.2 Mean monthly abundance of resident waterbirds in rice fields of the Philippines. The rice crop stage is presented along the X-axis; Veg = vegetative phase; Rep = reproductive phase; Rip = ripening phase; and Land Prep. = land preparation phase, when fields are levelled and flooded.

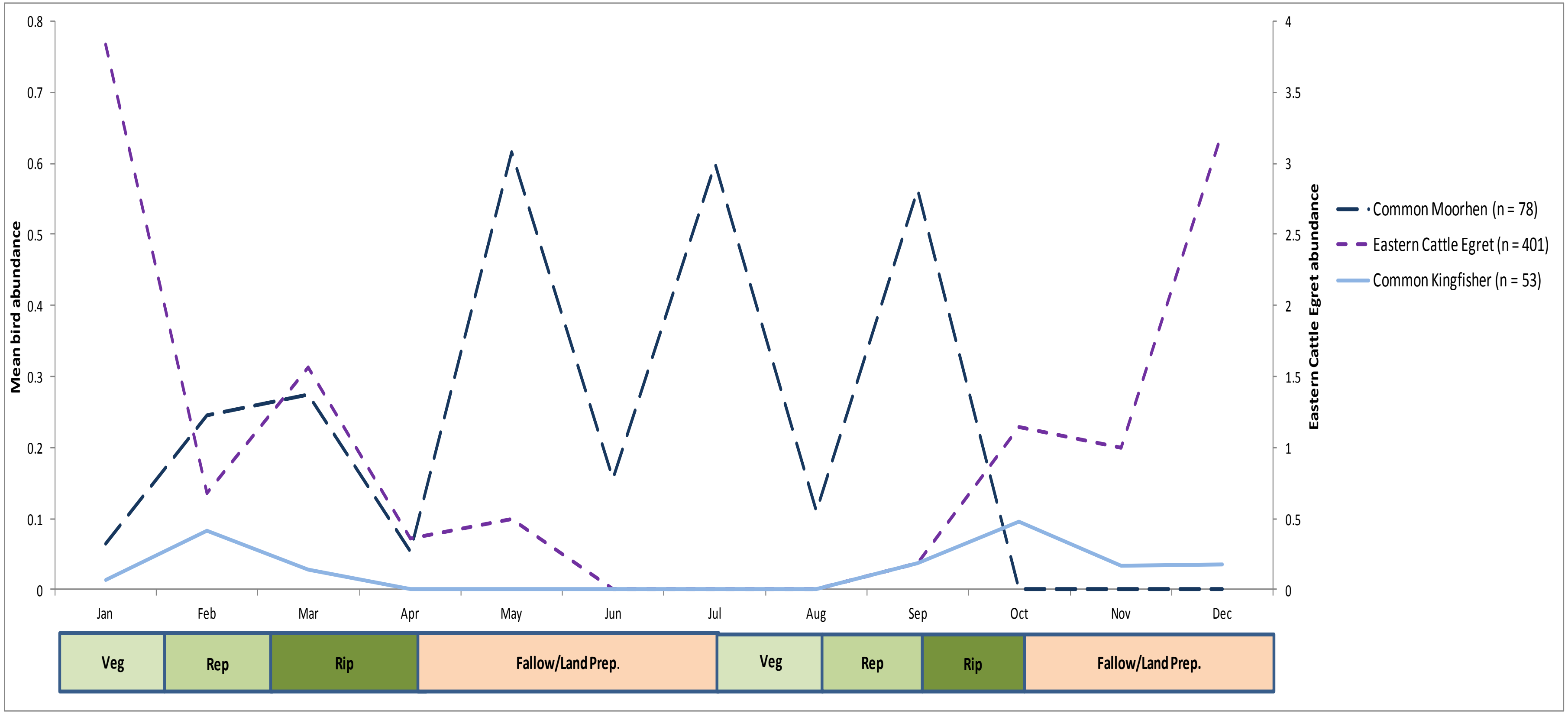

Figure 4.3 Mean monthly abundance of both migrant (common kingfisher) and partial migratory waterbird species in rice fields of the Philippines. Mean abundance for eastern cattle egret is plotted on the Y-axis to the right; values for all other species are plotted on the Y-axis to the left. The rice crop stage is presented along the X-axis; Veg = vegetative phase; Rep = reproductive phase; Rip = ripening phase; and Land Prep. = land preparation phase, when fields are levelled and flooded.

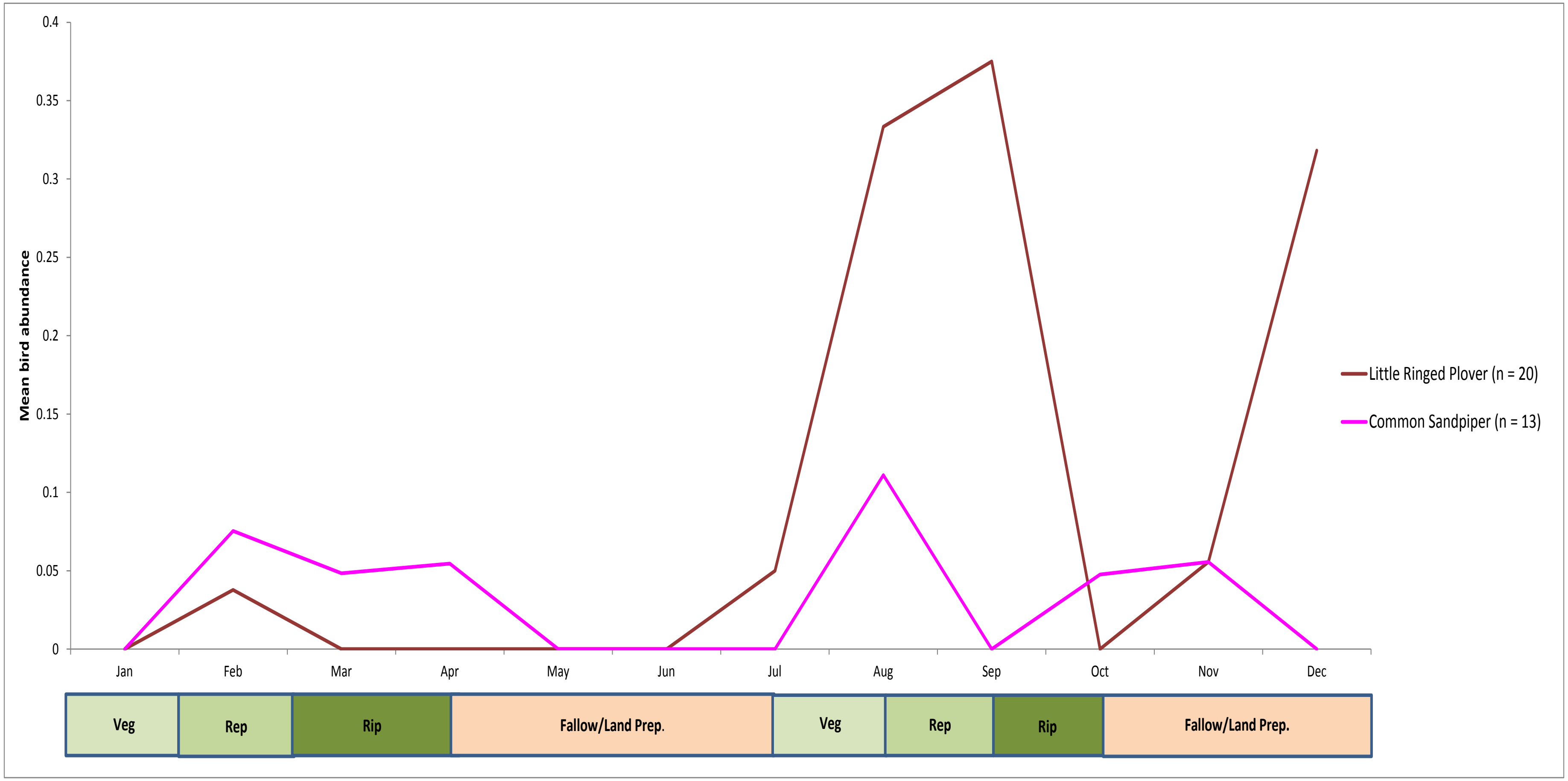

Figure 4.4 Mean monthly abundance of two waterbird species of conservation interest in rice fields of the Philippines. The rice crop stage is presented along the X-axis; Veg = vegetative phase; Rep = reproductive phase; Rip = ripening phase; and Land Prep. = land preparation phase, when fields are levelled and flooded.

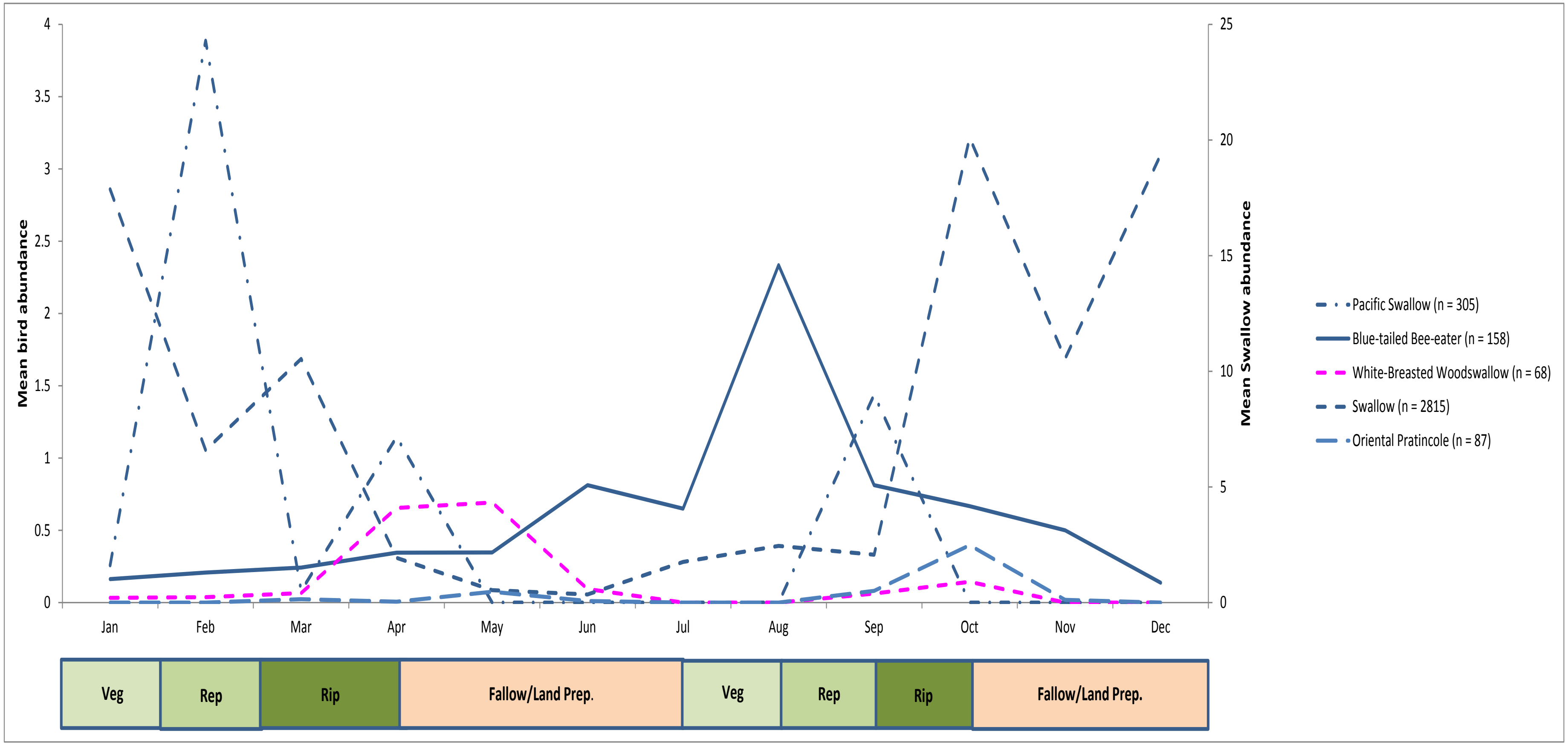

Figure 4.5 Mean monthly abundance of bird species which hunt on the wing in rice fields of the Philippines. Mean abundance for swallows is plotted on the Y-axis to the right, and for other species on the Y-axis to the left. The rice crop stage is presented along the X-axis; Veg = vegetative phase; Rep = reproductive phase; Rip = ripening phase; and Land Prep. = land preparation phase, when fields are levelled and flooded.

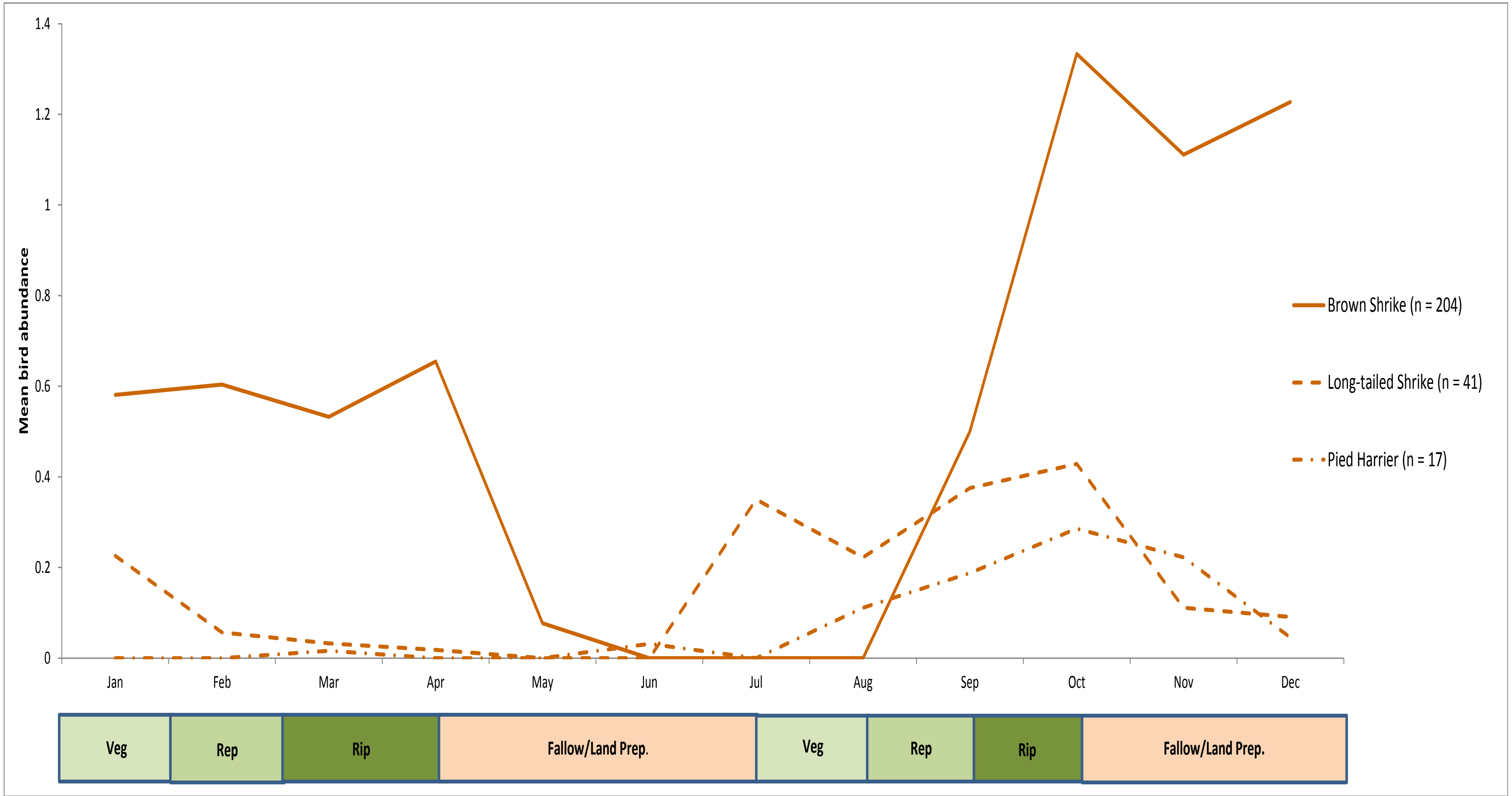

Figure 4.6 Mean monthly abundance of birds of prey in rice fields of the Philippines. The rice crop stage is presented along the X-axis; Veg = vegetative phase; Rep = reproductive phase; Rip = ripening phase; and Land Prep. = land preparation phase, when fields are levelled and flooded.

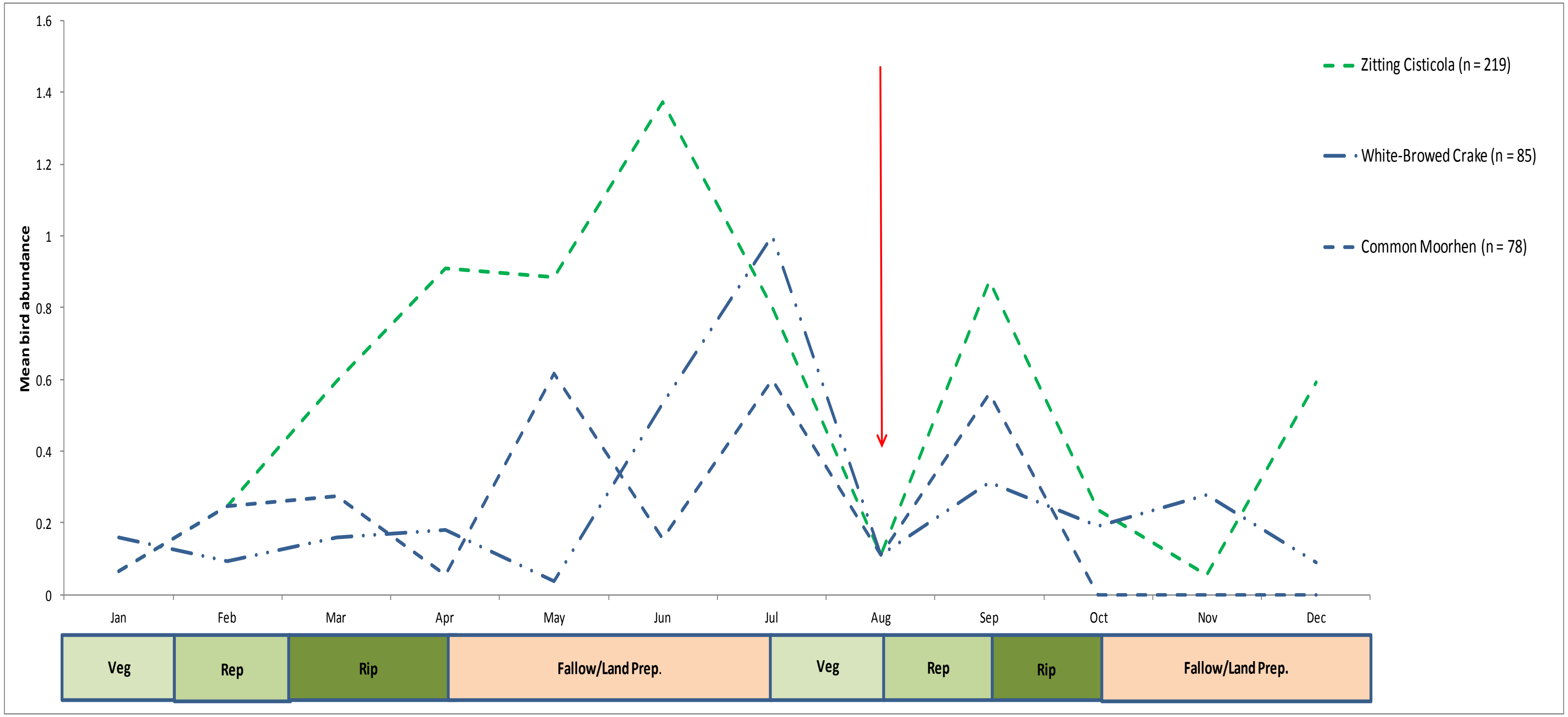

Figure 4.7 Mean monthly abundance of species which demonstrated breeding within, or in close proximity to, rice fields in the Philippines. The rice crop stage is presented along the X-axis; Veg = vegetative phase; Rep = reproductive phase; Rip = ripening phase; and Land Prep. = land preparation phase, when fields are levelled and flooded. The red arrow highlights the steep reduction of mean bird abundance during August.

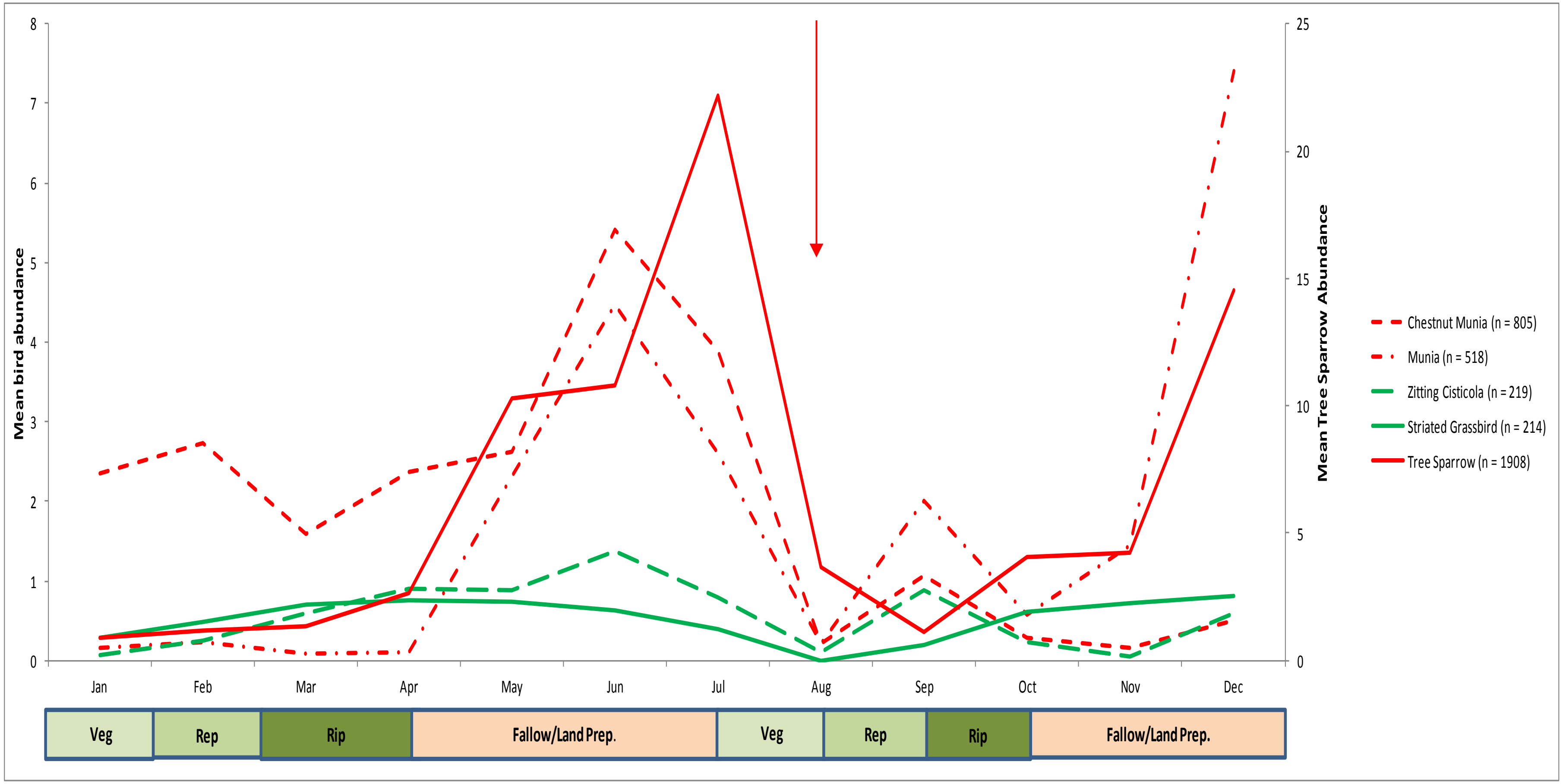

Figure 4.8 Mean monthly abundance of the five most frequently recorded resident species in rice fields of the Philippines. Granivorous species are presented in red whilst insectivorous species are presented in green. Mean abundance for tree sparrows is plotted on the Y-axis to the right, and for other species on the Y-axis to the left. The rice crop stage is presented along the X-axis; Veg = vegetative phase; Rep = reproductive phase; Rip = ripening phase; and Land Prep. = land preparation phase, when fields are levelled and flooded. The red arrow highlights the steep reduction of mean bird abundance during August.

4.3.3. Inter-annual Differences in Abundance

Two species were found to dominate the spot counts: tree sparrows and swallows. Peak numbers of swallows were recorded between August and March in 2012-2013, and between October and January in 2013-2014 (Figure 4.9). Peak numbers of tree sparrows were recorded in June and July 2012, between April and July, 2013, and between October and December, 2013 (Figure 4.9 – 4.10). The peak in abundance of tree sparrows might be a response to an increase in invertebrates, as a result of rainfall which peaks between January and February 2013 (Figure 4.11).

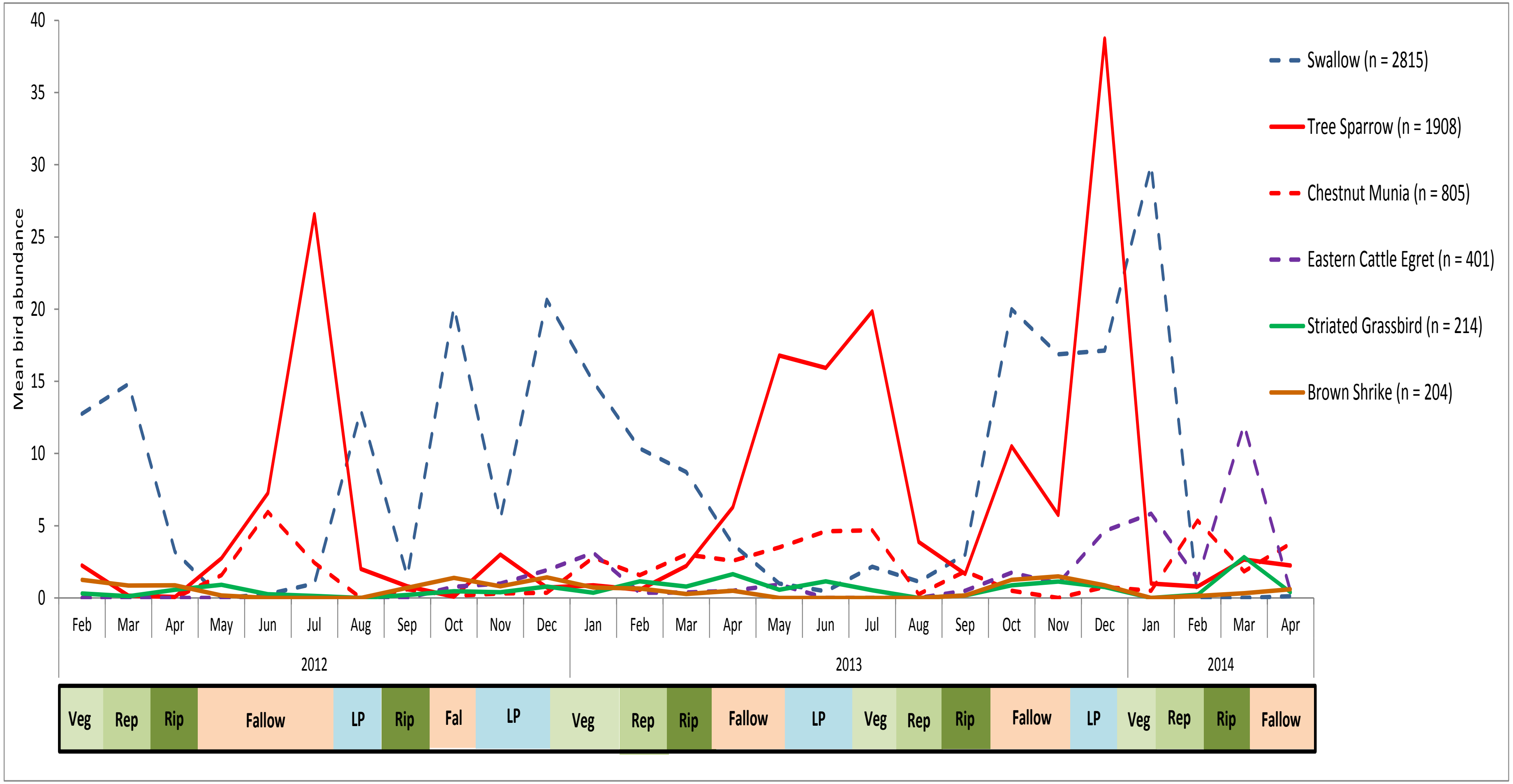

Figure 4.9 Mean monthly abundance of the six most recorded bird species in rice fields of the Philippines throughout the entire data collection period. The rice crop stage is presented along the X axis; Veg = Vegetative Phase, Rep = Reproductive Phase, Rip = Ripening Phase, and Land Prep. = Land Preparation, when fields are levelled and flooded.

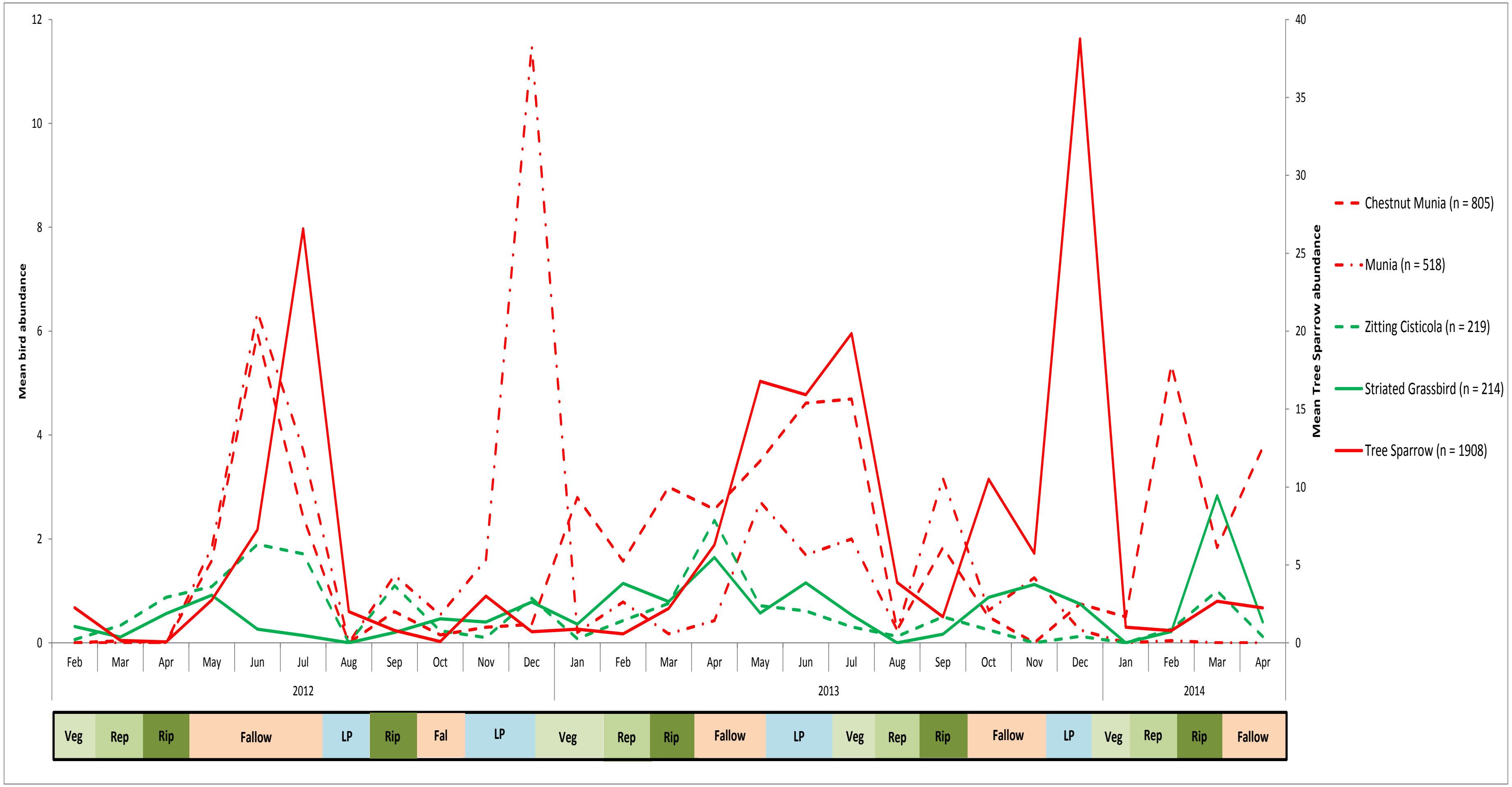

Figure 4.10 Mean monthly abundance of resident species in rice fields of the Philippines throughout the entire data collection period. Mean abundance for tree sparrow is displayed on the Y-axis to the right, and for other species are displayed on the Y-axis to the left. The rice crop stage is presented along the X axis; Veg = Vegetative Phase, Rep = Reproductive Phase, Rip = Ripening Phase, and Land Prep. = Land Preparation, when fields are levelled and flooded.

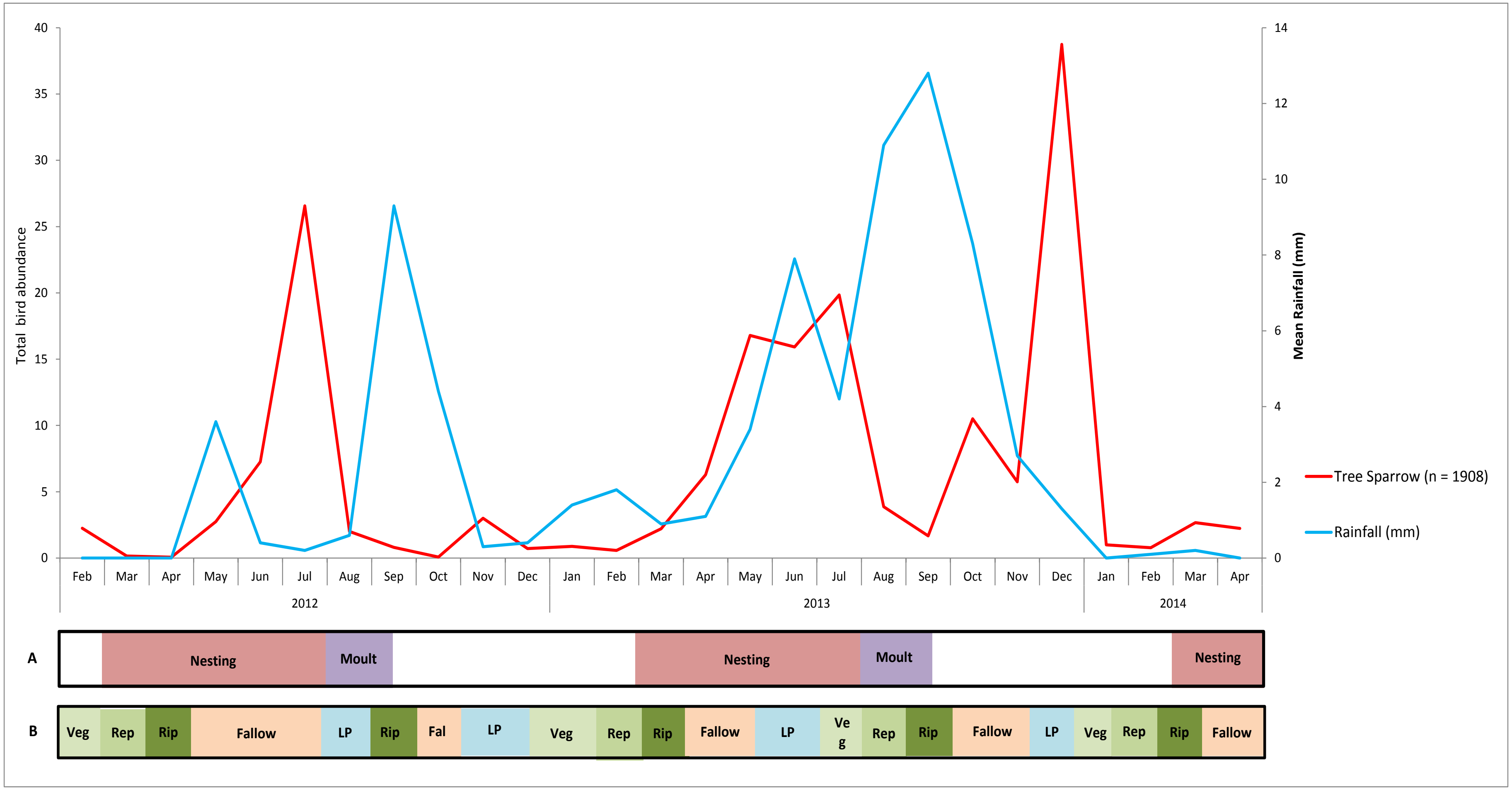

Figure 4.11 Mean monthly abundance of tree sparrows in relation to mean volume of rainfall (www.wunderground.com), life cycle (A) and field stage (B). Information on nesting and moult patterns are taken from Summers-Smith (1995) and data from Chapter 6. Mean rainfall is displayed on the Y-axis to the right, and tree sparrow abundance is displayed on the Y-axis to the left. Tree sparrow life cycles are presented along the X axis (A); Nesting = Breeding (from laying of the first brood until final fledglings have gone), and Moult = the time period taken to moult. The rice crop stage is presented along the X axis; Veg = Vegetative Phase, Rep = Reproductive Phase, Rip = Ripening Phase, and Land Prep. = Land Preparation, when fields are levelled and flooded.

4.3.4. Species Richness Indices

Species abundance, based on Margalef's diversity index, was highest in February, whereas species diversity (Simpson's index) was greatest in May (Table 4.2).

Table 4.2 Indices of monthly avian diversity in rice fields in the Philippines. Increasing values for Margalef's diversity index and decreasing values for Simpson's index are indicative of increasing biodiversity richness.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Margalef's Diversity Index D_{mg}	65.19	**125.5**	71.74	74.86	41.29	39.14	40.88	16.96	37.83	55.47	21.28	48.09
Simpson's Index D_{sim}	0.54	0.48	0.30	0.17	**0.11**	0.20	0.15	0.39	0.12	0.20	0.18	0.51

In the context of the stage of rice development, species richness was highest when fields were fallow and particularly when stubble was present. Species diversity was high during the reproductive phase and through the fallow, stubble and regrowth stages of the rice crop (Table 4.3).

Table 4.3 Indices of avian diversity in rice fields in the Philippines in relation to the stage of rice crop development. Increasing values for Margalef's diversity index and decreasing values for Simpson's index are indicative of increasing biodiversity richness. Figures for fallow fields have also been calculated separately for "stubble" and "regrowth" phases.

	Stage of lowland rice crop						
	Land Prep.	**Vegetative**	**Reproduction**	**Ripening**	**Fallow**	**Stubble**	**Regrowth**
Margalef's Diversity Index D_{mg}	71.91	136.37	52.32	148.15	**207.00**	**183.63**	25.62
Simpson's Index D_{sim}	0.21	0.25	**0.14**	0.23	**0.14**	0.15	**0.13**

4.4 Discussion

4.4.1. Intra-annual Differences in Abundance

A little more than half (54%) of total avian diversity was recorded during 20-minute spot counts throughout the morning, with the remaining species noted during *ad hoc* counts of the rice fields. Though changes in time of day, and year, are likely to affect results (discussed below) it is unlikely to have such a large effect, emphasizing the need for the methodology of bird surveying within rice fields to be improved, increasing the likelihood of recording the full community of birds present during future investigations.

Only 22 species (of 71) provided > 50 records during data collection to allow meaningful intra-annual comparisons. A total of 130 species were recorded (Tables 4.1a – 4.1g), demonstrating the high diversity of bird species that utilise the rice crop habitat and highlights the limitations of survey data alone for the assessment of avian abundance and diversity.

4.4.1.1. Monthly abundance of granivorous birds and brown shrikes

Four of the five species of granivorous birds recorded historically at the IRRI Experimental Station were also recorded during spot counts conducted during the present study; the only species not observed was the Java sparrow, a species listed as Vulnerable by the IUCN. Two species dominated spot counts: the tree sparrow and chestnut munia.

Peaks in the abundance of granivorous birds tended to relate to field stage, more specifically the mature and fallow stages of the crop, the latter probably due to spilled grain left after harvesting. For example, Htwe & Singleton (2014) reported a mean loss of 400 kg ha^{-1} of spilt grain at rice field sites located 5 km from the IRRI farm. In the current study, tree sparrows were observed foraging for dropped grain in dry fields more often than flooded fields explaining the drop in their frequency during the vegetative and reproductive phases. Overall, granivorous species appear to prefer to feed on dropped grain more than grain still growing on the plants (Ripening phase). Horgan *et al*. (2016) noted that during bird surveys of rice fields in the Philippines, tree sparrows were not recorded feeding directly from rice panicles and munias fed on weed seeds more than on rice. During the fallow months of May - July, chestnut munias increased in number, feeding in harvested fields or on those crops still maturing. Unlike other granivorous species, however, the abundance of chestnut munia did not peak again in December, during the second fallow period. This might be due to foraging opportunities elsewhere or due to their moult strategy e.g. leaving to a different location or habitat to moult. Additional studies are needed to document their movements within the landscape around this time.

During the later stages of the first rice crop (April - August), brown shrikes decreased in abundance as they left for their breeding grounds on mainland Asia. Simultaneously, three granivorous species (tree sparrow, chestnut munia and, munia) increased in abundance. This could be due to an abundance of food, a response to the departure of a major predatory species, or possibly both. However, these granivorous species also increased in abundance in the second phase of fallow crop / land preparation (in November and December) when brown shrikes were also present. Given that the two peaks were broadly similar in magnitude, there is little evidence to suggest that the presence / absence of shrikes had a major impact on the numbers of these granivorous species.

4.4.1.2. Monthly abundance of resident waterbird species

The majority of resident waterbird species increased in mean abundance during the fallow and land preparation phase (Figure 4.2). This might be because of either:

1. Reduced shelter. The majority of waterbird species will forage in established and tall crops. Once harvested, the shelter is no longer available and the birds are driven into the remaining unharvested fields. The birds move more often between fields, and are therefore recorded more frequently in response to their increased visibility. Territorial disputes also increased during the harvesting period, as the number of suitable fields decreased (*pers. obs.*).
2. Breeding. Birds are more visible during breeding either through an increase in display behaviour, having to forage further and more frequently to provide for their mate or offspring or an increased number of individuals because of fledged young. The effect of breeding is discussed further below (see 4.4.2.2).

A second peak in waterbird abundance occurred during the monsoon crop (May - October), between the reproductive and ripening phase of growth. This increase in abundance might be because the crop has reached a height where the birds can take refuge within the fields. The fields will have a supply of water during this time which keeps the ground soft, ideal for species attracted by aquatic invertebrates.

Another explanation for this increase in abundance during the second crop is the reduced area of land under management coinciding with the end of the breeding season. As individuals are no longer breeding, or restricted to nesting sites, many will be more mobile and therefore the likelihood of being recorded increases.

The collared kingfisher peaked in abundance during March and August, approximately halfway through the cropping season. This species was observed hunting for invertebrates and golden apple snails (*Pomacea canaliculata*) throughout the entire year and was one of the few species observed hunting the invasive pest within the rice fields. High numbers of golden apple snails occur during the land preparation phase (Stuart *et al.,* 2014), when they are mobile under flooded conditions and more visible to bird predators due to lack of vegetative cover. The collared kingfisher hunts from a perched position, and during the land preparation phase, there are few structures within rice fields available to perch upon. This species should be considered as an ecosystem service provider, with future work focusing on the introduction of perches across the rice crop habitat throughout the entire year, to assess the potential of this species to manage golden apple snails.

4.4.1.3. Monthly abundance of waterbird species that are either migratory (common kingfisher) or partially migratory

Counts of common kingfisher (*Alcedo atthis*), the only migratory species recorded more than 50 times, varied during the course of the season in a similar way to a typical migratory species; with a peak in abundance prior to departure, a relatively short period when they are absent, and then a peak when they return (Figure 4.3). The common kingfisher over-winters in the Philippines before migrating north to its breeding grounds in mainland Asia (Birdlife International, 2012). It was often recorded at the same location throughout the monsoon seasons, indicating over-wintering site preference. However, presumed winter-ranges were not consistent between years. This species was often heard before seen, as it gave a high-pitched call when flying over the top of the crops.

A number of waterbird species in the Philippines are known to be both resident and migratory (WBCP, 2016). These include eastern cattle egrets, which were frequently seen in rice fields, but are known to breed in other habitats. Most waterbird species have abundance patterns that are consistent with migrating species. The exception is common moorhens (*Gallinula chloropus*), which were recorded in good numbers throughout the year.

Common moorhen were frequently observed in the rice field habitat. It is a highly visible species that is observed feeding in open habitat and is frequently involved in territorial disputes. Peaks in the abundance of this species occurred in May, July and September, with a less pronounced peak in February and March (Figure 4.4). The occurrence of small numbers of moorhen chicks throughout the year suggests that their breeding was not restricted to any particular season. It is possible that the peaks in abundance that occurred between February and September could be a reflection of the breeding success of this species.

In the UK, moorhens incubate eggs for 19 - 21 days, taking another 6 - 7 weeks before the young fledge (Ferguson-Lees *et al.,* 2011). The observed peaks in abundance, separated by approximately 60 days, could reflect a temporary increase in the population as birds fledge and then disperse.

These species were mainly recorded when a rice crop was present and reduced in abundance during fallow stages. Currently the two-crop annual rice production system of the Philippines coincides with a migratory pattern of the waterbirds, with actively growing crops available prior to departure and on return from migration. If the time frame for the rice production system were to change, there is a concern that optimal habitat would not be available at critical times during their migratory movements. This issue will be investigated further in Chapter 6.

4.4.1.4. Monthly abundance of birds which hunt on the wing

Birds which hunt on the wing are likely to use rice fields across an extensive area as a source of aerial invertebrates. In contrast, most other avian species will use the rice fields as a localised two or three dimensional habitat that provides a safe environment and food resource.

Many species of bird which hunt on the wing have selected their habitat across a wide area, though limited in choice by changes in wind direction and availability, and a peak in numbers is likely to reflect the overall area, rather than the crop stage in the specific study site (Figure 4.6). The blue-tailed bee-eater and barn swallows were not present throughout the entire year, migrating to breed, before returning and peaking in numbers during the monsoon crop.

All bird species appeared to decrease in abundance during the fallow and land preparation stages of the rice crop, possibly reflecting a reduction in the number of invertebrates present. These avian species are likely to be ecosystem service providers, contributing to the management of flying invertebrates within rice fields. However, further detailed work on their dietary habits is needed to determine what they are hunting over rice fields, and whether they are having any impact on the number of any invertebrate species.

The most recorded and abundant group of birds found in rice fields belonged to the family *Hirundo*. Barn Swallows (*Hirundo rustica*) and pacific swallows (*Hirundo tahitica*) have similar life cycles, with the exception that the barn swallow migrates. Both species are insectivorous and use the rice fields in a similar way. The uniform height and large areas of agricultural land, along with the supply of invertebrates, makes the rice field habitat ideal for these species. Both swallow species were often recorded perched together on appropriate structures, such as bamboo sticks used as markers within a rice field, or on rat barrier fencing. It can be assumed that these species will hunt and stay relatively close to areas with ample perching opportunity. Due to their hunting strategy of fast and conspicuous flight over the rice, it is difficult to avoid multiple counting of individuals, and it can be difficult to identify them to the species level. During surveys, they were often recorded as '*Swallows*'.

4.4.1.5. Monthly abundance of birds of prey

The survey methods deployed in this research were not designed for species with large home ranges and as a consequence, birds of prey were rarely recorded during surveys (see Chapter 2). For example, a peregrine falcon (*Falco peregrinus*) was only recorded twice in all of the studies, despite two survey sites having an over-wintering peregrine during the winter months of 2012 and 2013. Similarly, common kestrels (*Falco tinnunculus*), which are the raptors mostly likely to use agricultural landscapes for hunting (Kennedy *et. al.,* 2000) were not recorded during surveys. Other examples of species seen within rice fields but not recorded during studies include grey faced-buzzards (*Butastur indicus*) and Philippine serpent eagles (*Spilornis cheela*).

To monitor raptors, vantage point surveys are recommended (Hardey *et al.,* 2009). Previous knowledge in raptor movements in the area helps monitor and map territories. Birds of prey offer an important opportunity for pest management through ecosystem engineering. In other agricultural crops, such as the introduction of barn owls (*Tyto alba*) in oil-palm plantations, owls can manage pest outbreaks and reduce the overall damage (Sekercioglu, 2006), though this is contentious (Puan *et al.* 2011). Encouragement into areas can be as basic as the introduction of perches and nest boxes (Brown *et al.,* 1988: Askham, 1990: Kay *et al.,* 1994) and a reduction in persecution. However, barn owls do not occur naturally within the Philippines; the closest species is the grass owl (*Tyto longimembris*) which nests on the ground and therefore would not respond to artificial nest boxes.

The brown shrike (*Lanius cristatus*) is a small, carnivorous, bird which over-winters within the Philippines (WBCP, 2013). Obvious within rice fields and often recorded perching on structures within the fields, it often hunts from a perched position and will defend a small winter territory, which has been recorded as c. 0.25 ha in Taiwan (Lefranc, 1997). With a varied diet, these birds will hunt smaller passerine birds. Within the rice fields, it was common to observe shrikes flying at flocks of granivorous birds. No successful hunting of small passerines was recorded, although it was noted that smaller birds appeared to avoid the immediate vicinity of brown shrikes. Encouragement of this species, perhaps by the erection of hunting perches alongside rice crops, might provide a method for reducing the number of small granivorous birds within the rice crop.

4.4.1.6. Monthly abundance of top resident species

The presence of insectivorous species was steady throughout the year, displaying only minor peaks in abundance. The amount of invertebrates present within crops is related to the management of the fields, such as pesticide application (Way & Heong, 1994; Stafford *et al.,* 2010). Differences in the frequency of insectivorous species were expected between management techniques, but no differences were actually recorded.

Rice panicles are only available for a short period of time within the fields, promoting a peak in avian abundance during these times (Figure 4.9). The breeding cycle of zitting cisticolas (*Cisticola juncidis*) may explain the slight peak in June. It is one of a few species which nest within the rice crop, creating a small bowl in the stalks of the plant and binding them together with materials, such as spider web. However, harvesting reduces the amount of time available for nesting. Their peak in June might be due to increased visibility, because as the crops are harvested it forces them into a smaller area of habitat, with increased movement between sites and increasing territorial displays. The peak in abundance could also be a result of successful pairs fledging young before harvest. The decrease in abundance after June likely represents the time when the species moults (Baker, 1997).

4.4.1.7. Monthly abundance of breeding species

Currently there are few data about bird species which nest within, or in close proximity to, rice fields in the Philippines. Species in this chapter (Figure 4.8) were pooled from a collection of records of breeding behaviours (displaying or mating), young fledged birds or nest remains found within rice fields but it may not represent the full list of breeding species present. The zitting cisticola forms nests between stems of the rice plant, and a couple of these nests were discovered during surveys.

Common moorhens and the greater painted snipe were observed in rice fields in a family unit with very small young. The white-browed crake, pied bushchat and pied harrier were all recorded in, or around, rice fields with juvenile birds and, with the exception of the harrier, adults were observed providing food for the young. All of these species develop adult plumage after moult making identification of young easier, with the exception of the zitting cisticola. The common moorhen was the only species which showed the potential evidence of multiple broods within the same season.

Breeding species increased in abundance as the year progressed followed by a sharp drop in August (red arrow on Figure 4.8). This decrease might be due to the beginning of the monsoon season, a natural dispersal of individuals due to changing crop stage or related to their life cycles, such as a post-breeding moult reducing their occurrence within rice fields (e.g. Summers-Smith, 1995).

Data on the breeding dynamics of avian species within rice fields of Asia are severely lacking. Finding natural nest sites within rice fields is difficult especially when trying to minimise disturbance and damage to both the birds and the crop. If a nest is easy to find, the majority of the time eggs will be taken by human poachers (*pers. obs.*).

4.4.1.8. Species of Conservation Concern and other species to note

In a publication by Bamford *et al.* (2008) on population estimations and important wetland sites for Wetland International, the countries in the East Asian – Australasian flyway were assessed. The Philippines was mentioned as important within the flyway, due to the number of shorebirds it supported during migration and the population of over-wintering waterbirds it sustains (Bamford *et al.,* 2008). Forty-three species were recorded during visits to coastal or near-coastal sites of the Philippines but no surveys were conducted inland. Six species were listed as abundant within the Philippines during non-breeding periods (Bamford *et al.,* 2008); of those, 4 were recorded within rice fields (Table 4.2), two during the present study (little ringed plover (*Charadrius dubius*) and common sandpiper (*Actitis hypoleucos*); Figure 4.6).

The distance species need to travel might account for the difference in numbers recorded during surveys. The common sandpiper (*Actitis hypoleucos*) must travel north to Japan and beyond, to breed, whereas the little ringed plover (*Charadrius dubius*) breeds within China (Birdlife International, 2016), which is much closer to the Philippines. The difference in numbers, as well as the peak in abundance for the little ringed plover in August and September, might therefore be the return of the breeding population to their wintering grounds. With some staying within the

Philippines and others using sites as a stop-over to feed before continuing their migration. This might account for the numbers in the beginning of the year, because flocks move through the Philippines on their way to their breeding grounds, leaving in small flocks and returning in larger numbers.

The common sandpiper was recorded either solitarily or in a pair, and is quiet and smaller than the commonly recorded wood sandpiper (*Tringa glareola*). The common sandpiper was difficult to record when not in flight, as it was often observed walking through rice fields and it is therefore likely that they were under-recorded during surveys.

On their return from migration, numbers of little ringed plovers (*Charadrius dubius*) peaked in September, with a high proportion in juvenile plumage. These are presumably fledged birds that have left the nest site and returned with adult birds. This would suggest that chronological timing associated with events such as reproduction can be a major factor underlying species presence / absence in rice fields.

The current study supports the theory that lowland irrigated rice fields support at least some of the population, though how many utilise rice fields is unknown. There is limited natural coastal habitat remaining as most of it has been subject to major urban development, fisheries and agriculture. Thus, birds surveyed in natural coastal wetlands are likely to have been forced into small areas. As these species are frequently recorded in rice fields, a habitat that is very extensive in the Philippines, large numbers of these birds may go unrecorded due to lack of surveying in rice fields. These findings suggest that the importance of the Philippines as a migratory stop-over, or wintering ground, for these species is under-estimated. Therefore, there is an increased importance in understanding how these species might respond to changes in agricultural practices.

A number of important species recorded in Table 4.1 merit further discussion, either for reasons of conservation or to highlight issues relevant to the survey methodology, as this will form the basis for data collection protocols used in subsequent chapters.

- **Black-faced spoonbill (*Platalea minor*)**

  In January 2014, three black-faced spoonbills were identified north of Manila in Candaba Marsh, an area of wetland which had, until recently, been a protected 'Important Birding Area' (IBA) due to breeding flocks of Philippine duck (*Anas luzonica*). The area has slowly reduced in size because of encroaching agriculture. This is the southern-most record of black-faced spoonbill in the Philippines, with a small number of birds seen each year further to the north of Luzon. It is listed as Endangered on the IUCN Red-List (available online). If black-faced Spoonbill is regularly using rice field habitats in Candaba, then adopting wildlife friendly practices has the potential to help stabilise and support populations of this species. Farmers who adopt wildlife friendly practices could benefit by marketing their rice as wildlife friendly, charging a premium for their crop (Syroechkovskiy, Jr., 2006).

- **Black-capped night heron (*Nycticorax nycticorax)***

  This species was most likely under-recorded, but was regularly seen and heard during dawn and dusk, because it forages and hunts at night. It is a relatively large species that roosts during the day in forests and hunts during the night in rice fields, often noticed as it moves between the two habitats. An alternative method of surveying needs to be developed for this species to more clearly understand their use of rice fields.

- **Javan pond heron (*Ardeola speciosa*) and Chinese pond heron (*Ardeola bacchus*)**

  The Javan pond heron is common throughout Mindanao and the Visayas (recorded once during surveys within Bohol), and although a few isolated individuals have been recorded further north, they are not common in Luzon. However, the movement of this species through the entire country is generally under-recorded. It is believed that the species is slowly spreading north but, with few observers in rice fields, such movement will likely go unnoticed.

  Similarly, the Chinese Pond Heron (*Ardeola bacchus*) is a rare migrant to the north of Luzon and may be slowly expanding its range further south into the Philippines. Similar in appearance to the Javan Pond Heron, and with occasional records on birding websites to the north, the overlap of these species is currently unknown (*pers. comm*. P. Bourdin, 2012). Further surveys, particularly in agricultural habitats, are required to clarify this.

- **Pied harrier (*Circus melanoleucos*)**

  Although rarely recorded as more than single individuals, the differences between males and females were noted at sites in Isabela, although they were pooled together for this investigation. As previously mentioned, their abundance within a rice field habitat is under-recorded as the surveyed fields made up a small proportion of their large home ranges. An adult male and female were often seen during data collection in the vicinity of the surveyed fields, but they were only noted a few times within the site survey (Table 4.5). Pied harriers were recorded 'near-by' at other sites in Isabela and Bohol, but never over the surveyed fields.

In Isabela, both an adult male and female were seen landing in a rice field close to the study site. After harvest, in 2012, an immature male and immature female were seen in the area. Due to the species post-natal dispersal behaviour, these immature birds are likely offspring of the adult pair seen previously in the area. There were no further signs of breeding the following year, although the adults and juveniles were still present. If this species were to breed in rice fields, they might contribute towards the management of mammalian rice pests.

- **Ruddy breasted crake (*Porzana fusca*)**

  A species rarely seen in rice fields, the ruddy breasted crake was recorded in one of the 365 surveys conducted. It is an extremely shy species and will hide amongst the crops when disturbed. Because of this, it is unknown if the number of records is an accurate representation of its abundance within the Philippines. Another individual was caught and released from a rat trap during field trials of a different investigation during 2012 (*pers. comm*. C. Jones. 2012).

- **Pintail / Swinhoe's snipe (*Galinago stenura/megala*)**

  Snipe were often recorded to family only, due to the complexities of identification during field surveys. A key identification feature is that the outer tail feathers of the pintail Snipe are pin-like in appearance, whereas these feathers are fully formed in the swinhoe's Snipe. This feature is difficult to observe at a distance during spot counts.

- **Red-necked phalarope (*Phalaropus lobatus*)**

  This species was not observed during data collection, but was occasionally seen during *ad hoc* surveys of the IRRI rice fields. Classified as a sea bird, it was often recorded in flooded fields with other waterbirds. It is unknown if these had moved inland because of adverse weather conditions out at sea or whether they followed the flock moving inland, which they were identified with.

- **Eastern grass owl (*Tyto longimembris*)**

  In October 2012, ecologists working in a rice field located close to the IRRI experimental station, recorded a "*Large, white bird which was not an egret*" within their fields (*pers. comm*. C. Jones. 2012). After a short search, an Eastern grass owl nest was found, with a pair of adult birds in the vicinity. This nest was observed weekly and a number of dead rats were found within the nest. At its peak, 4 eggs had been laid. However, during November, a tropical depression passed over the site, lodging (flattening) the rice and destroying the nest: no adults were seen in the area afterwards. It is believed that this is the first record of Eastern grass owls nesting within a rice field.

Owl pellets (*n = 3*) were collected from the nest and dissected. The remains were identified as mainly vertebrates (most likely the rat species *Rattus tanezumi* or *R. exulans*) and also the remains of crustaceans; as a small number of Carapaces (*n = 2*) were found. In African grass owls (*Tyto capensis*), a closely related species, the diet consists mainly of rodents during the breeding season (Riegert *et al.,* 2007). If this is the case for the Eastern grass owl, this species would be beneficial to rice farmers and by encouraging these birds to nest within rice field habitat, e.g. by providing set-aside land, these birds could contribute to the management of rodent pests.

- **Java sparrow (*Lonchura oryzivora*)**

  This species divides opinion on conservation and species management. The Java sparrow is a granivorous bird often associated with rice fields in its native breeding range of Indonesia. However, due to trapping for the pet trade and persecution within rice fields, it is listed as Vulnerable on the IUCN Red List (available online). As an introduced species to the Philippines, and pleasing to the eye, these birds are often caught and traded. Feral populations have been seen in rice fields, but in small numbers. However, the species is potentially an invasive pest which, if left, might cause conflict with rice farmers in the future. With numbers currently low, the key question is whether steps should be taken to eradicate this potential pest or should they be protected within the Philippines. Considerable work needs to be conducted on this species in the future.

- **Philippine cockatoo (*Cacatua haematuropygia*)**

  Though not included in the data presented here, as it occurs only on the island of Palawan, this species is mentioned due to its conservation importance. Similar to the Java sparrow, this species has been seen feeding on rice from maturing plants. But unlike the Java sparrow, this species is endemic to the Philippines and is currently listed as Critically Endangered (IUCN). Farmers wish to manage these birds as they take panicles, decreasing yield. If these birds were removed, the species may become extinct (*pers. comm*. Cockatoo Foundation). Work needs to be conducted on whether this species makes a significant impact upon crop yields and what processes can be adopted, by farmers, to minimise loss whilst promoting the conservation of this species.

4.4.2. Inter-annual Differences

Only the top 10 species provided enough data for inter-annual differences to be considered.

4.4.2.1. Mean abundance of most recorded species over 27 months

Two species were dominant; tree sparrows and swallows. Tree sparrows peaked between June and July, during the Fallow and Land preparation phases of the crop. Factors responsible for the changes in abundance are considered further in section 4.4.2.3. Chestnut munias were also found to increase in abundance during the fallow stages of the crop, but not to the same extent as that seen in tree sparrows.

Swallows tended to return from migration in large numbers and then slowly reduce in abundance before leaving the following year. There was a strong pattern relating mean abundance of swallows with field stage; higher abundances tended to occur during the presence of a rice crop, although a specific crop stage did not seem to have an effect.

The brown shrike, cattle egret and striated grassbird (*Megalurus palustris*) all displayed their highest peaks in abundance between November 2013 and March 2014. The cattle egret had previously peaked during this time in 2012 but not to the extent of 2013/14 (Figure 4.9). A possible explanation for this elevated abundance might be due to a large typhoon which passed through the Philippines during November 2013, disturbing the populations of these species and resulting in them travelling into new areas to avoid areas affected by the typhoon, such as the sites surveyed in this investigation (see below).

Of the six most recorded bird species in the rice field habitat (Figure 4.10), only one was a waterbird species, although the majority of literature on birds in rice fields concentrates on waterbirds (Warnock *et al*., 2004; Longoni *et al*., 2007; Elphick *et al.,* 2010a; Wood *et al.,* 2010). This demonstrates how rice fields can contribute to the entire food web, which should be considered when predicting management impacts on conservation and ecology. Three of the six species are insectivorous indicating that the majority of birds attracted to the rice fields are there for animal prey and not the rice. From 130 species identified in rice fields, only five are granivores (Table 4.1) and feed directly from the plants. A small number of other species (*n = 4*) may forage dropped grain opportunistically; however, it is unlikely that they will remove grains directly from the stem, or may do so only during specific times of their life cycle e.g. when rearing young for example (*pers. comm*. S. Serrano)

4.4.2.2. Mean abundance of resident species over 27 months

The abundance of granivorous species peaked through the Fallow and Land preparation phase of the rice crop, and then declines once the crop is present and/or the fields are flooded. During the long fallow period of 2012, abundance peaks occurred for chestnut munias, tree sparrows and mixed flocks of munias. The shorter peak in April 2013, displayed by tree sparrows, also indicated lower mean abundance. If fallow periods were directly related to the number of these species observed, a shorter fallow period with flooding might reduce abundance and decrease the numbers found. This does not explain the large peak in munia abundance that occurred during December 2012. This peak did not reoccur in December 2013 and may be linked to differences in annual weather conditions.

One explanation for the increase in granivorous birds during the fallow period might be due to the absence of 'bird boys', locals employed to stay in the crop all day to scare away any birds during the later growth stages of the crop. It is not common practice in the Philippines but '*bird boys*' are employed by IRRI at the Experimental Station. These '*bird boys*' are not employed during the fallow periods, leaving the harvested fields unguarded. Wherever possible, sites were chosen where no '*bird boys*' were present, although on some occasions they would be close to the study sites and would move birds away from their fields and others nearby. It is worth noting that '*bird boys*' are unlikely to remove the risk of yield loss to birds, but will instead move the risk to other fields in the area. If disturbance was too high during bird surveys, these data were not included in the analysis. Further work is required to determine the practical effect of '*bird boys*' and other bird deterrents on bird abundance and crop damage.

In August of each year there were sharp drops in mean abundance of all species (Figure 4.10). Each year had a different crop stage during this month and there was no difference in weather conditions, in contrast to July and September, to identify any environmental reason for this drop. Two theories are put forward to explain these declines:

1. Assuming all of the birds are under the same reproductive pressures and are restricted to one breeding season, it is possible that the low mean abundance in August might result from parental birds moving their fledgling birds into safer neighbouring habitats. This assumes

there is post-fledgling parental care (Summers-Smith, 1995; Svensson & Nilsen, 1997; Tarwater & Brawn, 2010). Alternatively, adult birds might be moving fledglings out of their territory.

2. The drop in abundance occurs weeks after the monsoon season has started. The rains bring the end of the dry season. Until then, it can be assumed the only areas with a water supply are those in rice fields being kept artificially flooded whilst other areas dry out. The observed August drop in abundance might occur after other habitats become water-logged, making surrounding refugia habitats highly productive. Such habitats would develop lush weedy vegetation together with increased invertebrate populations and with concomitant high seed and invertebrate banks, which themselves attract the birds (*pers. coms*. P. Bourdin, 2014). This decline might be birds moving from rice fields into other productive areas which were once dry and dusty with no value for the birds.

The tree sparrow has been studied extensively in other parts of its range (Summers-Smith, 1988) and a small number of differences in lifestyle traits have been observed between sub-species. The tree sparrow present in Luzon, both at the sites in Isabela and at IRRI, is the sub-species *Passer montanus saturatus*; while at Bohol it is the sub-species *P. m. malaccensis* (Summers-Smith, 1995). Assuming the species as a whole are similar in their life cycles, the drop in recorded abundance in August is most likely influenced by moult patterns than other factors. Adults are post-nuptial moulters, waiting until the final brood have fledged before starting their moult, though a little cross-over may occur (Ginn & Melville, 1983). The adult moult lasts 4 - 6 weeks (Ginn & Melville, 1983; Summers-Smith, 1995). The breeding season starts earlier the closer to the equator the sub-species is located (Summers-Smith, 1995), with first broods laid in late February (unpublished data; see Chapter 7). Studies from Singapore and Malaysia identify a longer breeding and moulting period lasting 7-8 months (Ward & Poh, 1968; Medway & Wells, 1976). If breeding lasts from February until the end of July, followed by a 6 week moult, in which the adults do not return to their breeding territories (Summers-Smith, 1995), this would account for the reduced number of individuals recorded during this time. In Figure 4.13, the abundance of tree sparrows decreased from July to August and then increased again from September onwards. This is consistent with a time frame of 6 weeks for the birds to complete their moult.

The influence of moult might account for the reduced abundance of tree sparrows recorded in August, but this may not be the case for all species that were found to have a reduced abundance during August. Further research on breeding and moult patterns are required for each species for this to be identified as a general rule.

4.4.2.3. Tree sparrow abundance in relation to rainfall over 27 months

There appears to be a weak relationship between tree sparrow abundance and rainfall. Tree sparrows were not seen regularly during wet periods and seemed to prefer drier fields for foraging. Assuming their window for breeding and moult runs between late February and mid-September (as discussed above), their moult would coincide with the increase in monthly rainfall during the monsoon season. This strategy would result in individuals breeding and then moving away from the rice fields as rainfall increases. As the moulting process hinders the bird's capability to fly, moulting during heavy rains of the monsoon period might be the optimal strategy, because foraging opportunities are severely limited at this time.

The largest peak recorded in tree sparrow abundance was during December 2013. Outside of the breeding season and not during the fallow period of the crop, this peak does not fit with the current theories behind this species' pattern of abundance. Typhoon Haiyan (local name: *Yolanda*) is likely to have caused this peak. After making landfall in Leyte it headed west, during the first week of November 2013, at a sustained speed of 195 mph (The Weather Channel, 2015b). Areas which sustained damage were approximately 200 km south of IRRI; the eye of the storm did not pass directly over the surveyed sites. Migrating songbirds (Streby *et al.,* 2015) and waterbirds (Niles *et al.* 2010) have been shown to avoid strong weather systems, but tree sparrows are resident and small scale movement might be expected (*pers. comms*. J.C.T. Gonzalez, 2014). Summers-Smith (1995) stated that tree sparrows are "unlikely" to migrate and that, when they did, it was rare for them to travel more than 500 km. The large peak in abundance of tree sparrows seen in November and December might be birds that had been displaced by Typhoon Haiyan. It is possible that this distance may not have been travelled by individual birds; but movements of birds heading north further than normal to avoid the typhoon, in a 'leap-frog' movement (Boulet & Norris, 2006). This would explain the time difference between the typhoon striking in November and the recorded peak in December.

Landscape modelling of rat outbreaks in Myanmar shows an increase in rodent populations 15 months after a major climatic event, because of an increase in availability of food and shelter, which lengthens the breeding season (Htwe *et al.,* 2013). With only 5 months abundance data after typhoon Haiyan, any long-term effects because of a similar food bounty sustaining an increased population of tree sparrows, was not possible to determine. In the short-term, the birds are more mobile and likely to immediately move away from the affected area (Streby *et al.,* 2015). Surveys conducted within damaged areas of the Philippines, after a severe weather event, would provide evidence of bird movements and how fast they are likely to return to areas, to take advantage of this dropped grain.

Typhoon Haiyan might account for the peaks in abundance that occurred in the succeeding months for swallows, chestnut munia and cattle egrets (Figure 4.10). Another granivorous bird, the chestnut munia was likely to benefit from the increase in dropped grain after the typhoon. As some of the swallows would have been migratory, the peak in numbers that occurred after the typhoon might be the birds returning from areas which the typhoon had moved through. Individual birds might not return to wintering grounds further south if these areas had been extensively damaged. It is possible that the displaced birds would remain in their new northerly habitats, although in insectivorous species this is thought to be less likely. Invertebrates are likely to benefit from typhoon damage, with increased shelter and food provided by the damaged areas. Without tracking data, or ringing recoveries, these suggestions cannot be validated and this highlights the need for greater long-term monitoring effort within the Philippines.

4.4.3. Species Richness Indices

The indices scores presented in Table 4.2 and 4.3 provide a useful indication of the optimal conditions in the rice fields of the Philippines for avian diversity, both in terms of time of year and in terms of the field stage of the rice plants.

4.4.3.1. Time of year

Habitats that are recognised as important for bird populations usually only attract large numbers of birds at particular times of the year. To assess the value of a particular habitat for any species or group of species, it is important therefore to identify the times of year when the bird species use that particular habitat.

Rice fields supported the highest abundance of birds in February (D_{mg} = 125.5), at the time when the weather is improving. Migratory birds are preparing to leave and resident birds are preparing to breed. The highest avian diversity was in May (D_{sim} = 0.11), at the time when species are passing through on migration and are able to utilise the mosaic of habitats that are available in the rice crop habitat. Some fields are being harvested while others are in fallow (both dry stubble fields with short cut stalks, and wet fields regrowing tillers), with a few fields being prepared for planting.

Where there is a concern that changes in rice production management practices could have a detrimental effect on bird species, the effect would most likely be seen at the time of year when there are peaks in bird activity. To this end, it would be sensible for future bird surveys to predominantly be conducted in February (when there is a peak in bird abundance) and in May (when there is a peak in bird diversity).

4.4.3.2. Field Stage

When considering the different stages of the crop cycle, the fallow phase, which occurs immediately after harvest and is available for 5.5 months of the year, had the highest recorded bird abundance (D_{mg} = 207). It also had a high diversity (D_{sim} = 0.14), comparable only with the reproductive phase of the crop.

During the reproductive phase, crops provide shelter and fields are kept flooded allowing for better probing for invertebrates. The reproductive phase occurs during February, when birds are preparing to migrate, and between August and September, when birds are returning from migration and in the process of establishing winter territories.

The fallow phase is the longest phase of the crop cycle, and can be further subdivided into two stages; ‘stubble’ and ‘re-growth’. The ‘re-growth’ habitat is particularly attractive to a wide range of bird species because the regrowing stems provide a degree of cover and protection, rice grains will be available on the ground as a result of the harvesting process, and the habitat will be moist, providing an environment for invertebrates.

It is evident from the results of this study, that certain stages of crop development are more favourable for particular bird species. It is also evident, that certain times of the year are more favourable for particular bird species. The interactions between stages of crop development and time of year on the abundance and diversity of bird species in the rice crop ecosystem are explored further in Chapter 6.

4.5 Conclusion

The focus of the current study was to provide a baseline of intra- and inter-annual trends in this neglected habitat for both individual species and species groups (i.e. waterbirds). In addition, particular key points have been highlighted that need to be considered in the future.

A number of natural factors appear to influence the abundance and frequency of avian species in the rice field habitat of the Philippines. Both natural life cycles along with farmland management practices influence species richness and diversity. However individual species breeding, moulting and migration patterns need to be fully understood before the full advantages / disadvantages of rice field management can be known. The current study provides a starting point for further studies and raises key points that need to be investigated further.

Establishment of accurate baseline figures of avian frequency and diversity will require further surveys, ideally with a focus on the months of the year and the stages of the crop cycle where there are peaks in avian abundance and diversity. In the Philippines, this information is currently lacking. Different avian communities exist across the Philippine archipelago, producing a wide and complicated web of avian diversity throughout the country. This work is still very much in its infancy, but further time-series of data will provide a clearer understanding of the dynamics of bird species within rice fields of the Philippines. Although this initial work has focused on the more common species of the Philippines, rare bird species were recorded and these records will make a contribution to the overall knowledge of the conservation of avian species in the Philippines. This work has already contributed towards the publication "*Guide to the birds of Philippine rice fields*", published by IRRI in 2015.

Furthermore the baseline data presented in this chapter and the thesis overall are already being used by IRRI field workers in a number of new projects looking at the interactions between avifauna and other groups of organisms in the rice field habitat. In time it is envisaged that the data presented within this study will be augmented by future investigations, with research having an impact across the Philippines and other rice growing countries.

Table 4.4 Annual peak(s) of abundance, with probable reasons, for species with > 50 records over the entire data collection period (February 2012 – April 2014).

Species	Peak(s)	Probable Reason
Yellow bittern (n = 95)	July	Preferable field stages and reduced shelter within crops
Cinnamon bittern (n = 54)	September	After breeding season and reduced shelter within crops
Eastern cattle egret (n = 401)	January	Preferable field stages
White-browed crake (n = 85)	June	After breeding season and reduced shelter within crops
Common moorhen (n = 78)	May, September	Before, and after, breeding season and reduced shelter within crops
Wood sandpiper (n = 327)	January	Preferable field stages
Oriental pratincole (n = 87)	October	Return after breeding season
Zebra dove (n = 77)	April, October	Preferable field stages
Common kingfisher (n = 53)	February, October	Before, and after, migration.
Bluetailed bee-eater (n = 158)	August	Return after breeding season
White-breasted wood swallow (n = 68)	May	Preferable field stage
Brown shrike (n = 204)	April	Individuals flocking before migration
Swallow [sp.] (n = 2815)	October	Preferable field stage and individuals returning from migration
Pacific swallow (n = 305)	February	Preferable field stage
Striated grassbird (n = 214)	April, December	Reduced shelter within crops
Zitting cisticola (n = 219)	June	End of breeding season and reduced shelter within crops
Tree sparrow (n = 1908)	July	End of breeding season and preferable field stage
Chestnut munia (n = 805)	June	Preferable field stage
Munia [sp.] (n = 518)	December	Preferable field stage
Wagtail [sp.] (n = 212)	November	Preferable field conditions

Following on from these baseline data, future work may wish to consider the following:

1. Previous studies (e.g. Elphick, 2004; Elphick & Oring, 1998; Pernollet *et al.,* 2015) identify depth of surface water as an important factor of avian diversity in other rice growing countries. With a high demand for water putting pressure on existing resources, scientists are developing methods of water management which reduce usage with no yield impact. However, as seen above, the presence of water seems to be one of the factors affecting the occurrence of granivorous bird species. How would implementing water management affect the avian diversity?
2. Similarly to that of water management, the need for food security is an international concern. Human populations are increasing rapidly, and so is the demand for food. New methods of crop intensification are being trialled. But with shorter growing periods and the crop stage changing annually, how will this affect the birds which rely on rice fields? This chapter has suggested that crop stage is important, especially for the provision of food and shelter for migratory birds. If these fields are in an alternate crop stage in different years, what effect would this have on their suitability for supporting avian species?
3. Many birds have a bad reputation amongst rice farmers within the Philippines, none more so than the Eurasian tree sparrow; which is one of the most frequently recorded birds within rice fields seen throughout the year. This species has the local name '*Maya*', meaning rice pest. But are they damaging the rice as dogma portrays them, or are they blamed for no reason other than their numbers and visibility within the rice fields? A more extensive investigation into their behaviour, breeding and diet is required to determine if these birds really are a pest or if they actually provide an ecosystem function within rice fields.

*Research detailed in this chapter will be formatted for submission into '*Forktail*', upon completion of this thesis.*

Does Alternate Wetting and Drying (AWD) have an impact on birds in rice fields of the Philippines?

5.1 Introduction

Irrigated rice uses about 40% of the global irrigated water used for agriculture (Dawe, 2005). Large areas of land that are dedicated to rice agriculture are transformed into artificial wetlands for most of the year (Bellio *et al.,* 2009). This habitat attracts a great number of bird species for shelter, breeding, foraging opportunities and/or migratory stop-over (Lourenço & Piersma, 2009; Stafford *et al*., 2010; Wymenga & Zwarts, 2010). Many avian species use the modified rice habitat, although previous literature has concentrated mainly on waterbird communities or on the ecology of a particular species (Elphick & Oring, 2003; Chapter 1).

The majority of rice available on the global market is produced in Asia (Tabbal *et al.,* 2002; GRiSP, 2013), where water is often a limited resource (Gleick, 1993; Postel *et al.,* 1996; Seckler *et al.,* 1999; Tilman *et al.,* 2002; Rejesus *et al.,* 2011). Rice producers are therefore expected to increase rice yields whilst decreasing water usage (Bouman & Tuong, 2001; Rejesus *et al.,* 2011). Tuong and Bouman (2003) predicted that by 2025, 2 million ha of dry-season irrigated rice will be affected by water scarcity. A decrease in water availability could result in further degradation of natural wetlands, as waterways are further diverted to supply agricultural areas (Donald, 2004; Taylor & Schultz, 2010). One method of irrigation management is Alternate Wetting and Drying (AWD) where water is applied periodically, varying between 2 and 10 days, allowing the field surface to dry but to retain sufficient water within the soil to supply the rice plants. This more conservative use of water contrasts with the widely used traditional 'continuous-flooding' methods of rice production. To conserve water, farmers who historically continuously flooded their fields are encouraged to reduce their water use, and thus allow for a more widespread distribution of water, reaching fields that would normally suffer from water scarcity (see Lampayan, 2015 for review).

Previous studies demonstrate how AWD can reduce water input by 10-30% with no yield implications (Tuong & Bouman, 2003; Belder *et al.,* 2004). But how does this water saving technique affect the behaviour of birds that use these rice fields? Past investigations have shown that dry rice fields have a reduced abundance of waterbirds compared to irrigated fields (Day & Colwell, 1998; Fujioka *et al.,* 2001; Maeda, 2001; Tourenq *et al.,* 2003). By reducing water availability and not continuously flooding these fields, does AWD make rice fields unsuitable for the current avian diversity? The objective of this study was to compare the abundance and diversity of the birds in rice fields using AWD compared with other sites using a traditional community irrigation system (CIS).

This study will investigate the following hypotheses;

1) Alternate Wetting and Drying will change the dynamics of the avian community found within rice fields of the Philippines, with a decrease in the number of waterbird species.
2) Fields located near the source of irrigation and now adopting AWD will support a greater community of species, irrespective of whether they employ AWD. As these irrigated rice habitats had previously been able to flood freely, it was hypothesised that birds would be attracted to these sites before AWD enforcement and continued to show site preference. This would result in an increase in abundance at these sites.

5.2 Materials and Methods

5.2.1. Study Area

Within the Philippines, AWD is implemented at a regional scale at four locations; two in the large northern island of Luzon, one on the southern island of Mindanao and the fourth on the island of Bohol in the centre of the Philippine archipelago (Lampayan *et al*., 2015). This study was conducted on the island of Bohol due to the relatively small geographic size of the island that could accentuate the landscape effects of water management on avian populations.

The irrigation network was divided into three categories depending upon their position relative to the source of irrigation; top (BIS1 – 4,960 ha; site elevation between 449 - 548 feet above sea level), middle (BIS2 – 4,140 ha; site elevation between 84 - 143 feet above sea level) and bottom (Capayas – 1,160 ha; site elevation between 103 - 183 feet above sea level). Two sites per management approach (AWD, CIS) were studied at each location. Selected fields within sites were surrounded by other fields subject to the same irrigation management, but each site was divided by other habitats, such as human infrastructure or forests. A minimum distance of 900 m was set between sites for them to be considered statistically independent. The assumption is that a bird recorded at one site was unlikely to be re-recorded at other sites within the same day. Water for the AWD sites was released every 7 days from the Malinao diversion and Bayongan dam by the National Irrigation Administration (NIA). The water was then distributed via the main irrigation channels to supply farms.

It was the responsibility of the farmers to use this water to irrigate their fields when available. Sites adopting the CIS method of irrigation had access to their own dams (some exclusively, others as part of a community) and could irrigate freely. These dams were supplied either through rain water collection, ground-water pumps or natural waterways. One CIS farmer dammed water from the AWD irrigation channel, which allowed him to manage the level of flooding within his fields.

Annual farmer questionnaires were conducted by a local translator to determine methods of pesticide use and the amount of chemical input for each site (Appendix 5). In an earlier pilot study (Chapter 3), pesticide application was considered not to have a significant effect upon avian diversity at a field level. However questionnaires were conducted to determine whether farmers were using similar pesticides and similar application practices upon surveyed fields. During the interviews, farmers were questioned about which species or group of species they considered to be pests and what was their estimated yield loss to each group of pests. Questionnaires were checked to eliminate leading questions before being conducted. All farmers (*n = 12*) were surveyed each year after harvest to record the management of the field, with the exception of one farm in 2014 where the landowner had passed away during that season.

5.2.2. Bird Surveys

To determine differences in irrigation techniques, bird surveys were only conducted during the dry cropping seasons (January – April) of 2013 and 2014, as all sites had sufficient rain water for continuous flooding during the monsoon cropping season. Thus AWD effects would be more pronounced during the dry season. Surveys were conducted over 6 days, twice during the cropping season; once near the beginning (vegetative stage) and another during the later stages of rice growth (booting stage) whilst the crops were still being irrigated. Bird surveys in 2014 were a month later than in 2013 as planting was delayed thereby ensuring that farms were surveyed during the same growth stages in both years. Surveys were conducted between 6:00 am and 12:00 midday, and the order of surveyed sites was changed daily to eliminate any time of day effects.

Twenty minutes of continuous scan sampling was conducted at all sites (as described in Bibby *et al.,* 2000), three times during each 6 day survey period. Surveys were conducted by a single observer in a publically accessed area to minimise damage to the growing crop, aided by binoculars (Bushnell H_2O, 8x42). All birds seen, or heard, within an area of 10 m x 50 m were recorded, using the field bunds as site boundaries. Birds flying low (approximately 1 metre above the canopy) over the crop were included in the survey, as their presence was considered to reflect the attraction of the study site management technique. Birds flying at higher altitudes were not recorded, as they were deemed to be passing over. Human activity and disturbance was recorded on a categorical scale ranging from 1 (only observer in area) to 5 (people working in the field). Those listed as 5 were removed from the analyses. Surveys were not conducted during rain.

5.2.3. Bird Analysis and Statistics

Survey data were analysed using a Generalized Linear Mixed Model (GLMM) with a Poisson's Log distribution. All main terms and 2-way interactions were included. All non-significant factors were removed using a backward stepwise elimination procedure. All statistical analyses were conducted using IBM SPSS Statistics [version 21].

Factors were defined as; Water management as AWD or CIS; water level as top, middle or bottom; species category as waterbird, granivorous or other; and field stage as land preparation, vegetative, reproductive, ripening or fallow. The dependent variable was Total, with water management, water level, species category and field stage as factors.

5.2.4. Species Richness Indices

Two indices were chosen to provide a measure of species diversity within the study sites:

- the Margalef's diversity index (Clifford & Stephenson, 1975), which provides a simple measure of richness from abundance data
- the Simpson's diversity index (Simpson, 1949), which provides a measure of diversity, from the relative abundance of the most commonly recorded species.

The Margalef's diversity index (Clifford & Stephenson, 1975) is determined from abundance data using the following equation:

$$D_{mg} = \frac{(S-1)}{\ln N}$$

Where richness is the number of species (S) divided by the number of individuals (N). This compensates for sampling method bias by only comparing the number of records. The analysis assumes an approximate normal distribution in species numbers, and can be used with a small data set. The index provides a score that is directly proportional to the number of individuals recorded and thus provides a useful measure of species abundance.

The Simpson's diversity index is determined for a finite community using the following equation:

$$D_{sim} = \sum \left(\frac{n_i[n_i - 1]}{N[N-1]} \right)$$

Where n_i is the number of individuals in the *i*th species; and N = total number of individuals. The Simpson's diversity index provides a score that is inversely proportional to species diversity. With this index, 0 represents infinite diversity and 1, no diversity. The Simpson's index gives a probability that two randomly selected individuals from the data set belong to the same species. This index is less sensitive to species diversity, concentrating on the more abundant species, and is not affected by rare sightings or individual birds. Unlike other indices, Simpson's index can be used on a relatively small (< 1000) data set (Magurran, 2004).

5.3 Results

5.3.1. Farmer Questionnaires

It was evident from the farmer questionnaire that management practices at all sites was similar, with the exception of the main factors considered in this investigation. All sites applied pesticides and herbicides, although application rates and brands differed between sites, the active ingredients of those brands were similar throughout. A few of the sites applied either molluscicides or rodenticides, though due to inconsistencies in application rates and brand, this could not be tested for statistically. All farm management questions were answered but some of the pest questions were left blank, either because farmers did not wish to answer or they simply did not have an answer.

Table 5.1 Responses to farmers survey "*Have you experienced any water supply issues?*"

Year	*Have you experienced any water supply issues?*	
	Yes	**No**
2013	2	10
2014	0	11

From the 23 responses, only 2 said they had experienced some kind of water supply issue during the previous season (Table 5.1).

Table 5.2 Responses to farmers survey "*Have you experienced any pest problems?*"

Year	*Have you experienced any pest problems?*	
	Yes	No
2013	10	1
2014	6	5

From the 22 responses, 16 said they had experienced some kind of pest problem during the last season (Table 5.2).

Table 5.3 The seven pest species of rice identified by farmers and ranked in order of their severity (Pest status I, II & III) during the dry season of 2013 (*n = 12*) and 2014 (*n = 11*). Pest status ranked as: I was the most severe, II was moderate and III was the least severe. Columns labelled as: AWD = alternate wetting and drying, and CIS = community irrigated system.

Pest Status	AWD				CIS			
	I	II	III	Total	I	II	III	Total
Rice bug		1	1	2	4		4	8
Rats	3	1	1	5	2		1	3
Stemborer	1	2		3	2	3		5
Birds	2	2		4		2		2
Louse	1	1		2	1			1
Golden apple snail	2			2		1		1
Case worm				0		1		1
Total	9	7	2	18	9	7	5	21

Overall, Rice bug was the most frequently ranked pest from all surveys, although they were recorded predominantly in CIS sites, with rats being the most frequently ranked pest in AWD sites (Table 5.3). This might indicate that AWD provides an environment less favourable to rice bugs compared to CIS.

Table 5.4 Mean yield loss resulting from pest species, as estimated by farmers as a percentage of total yield. Standard error displayed in parenthesis, figures with no standard error are those taken from only one estimate. Cells left blank had no yield loss estimated. Columns labelled as: AWD = alternate wetting and drying, and CIS = community irrigated system.

Pests	AWD - Mean % yield loss	CIS - Mean % yield loss
Rice bug	17.5% (± 12.5)	14.71% (± 8.20)
Rats	11% (± 4.85)	5%
Stemborer	20%	15% (± 4.47)
Birds	38.33% (± 22.05)	2%
Louse	25%	
Golden apple snail	5%	5%
Case worm		2%
Mean Estimated Loss	19.47% (± 4.73)	7.29% (± 2.46)

The farmers were asked to estimate a percentage yield loss due to each pest listed above, though not all farmers completed this part of the survey (Table 5.4). Birds, in the AWD sites, were associated with the highest estimated loss of yield (ranging from 5% to 80%).

5.3.2. Bird Surveys

All other significant interactions are reported in Table 5.5.

Table 5.5 An analysis of all factors that affect avian abundance and significant interactions from a backward stepwise, GLMM ANOVA, with Poisson log distribution.

Factor / Interaction	Wald Chi-Square	Df	P – Value
Water Management	0.013	1	0.910
Water Level	0.239	2	0.887
Species category	7.771	2	0.021
Migration	7.587	2	0.023
Field Stage	11.411	4	0.022
Species category * Field Stage	34.786	8	< 0.001
Water level * Species category * Field stage	80.012	19	< 0.001

Granivorous birds flying in and out of the sites within the Capayas, interspersed with periods of perching within the fields, influenced the '*Water level * Species category * Field stage*'.

5.3.2.1. Effect of Management

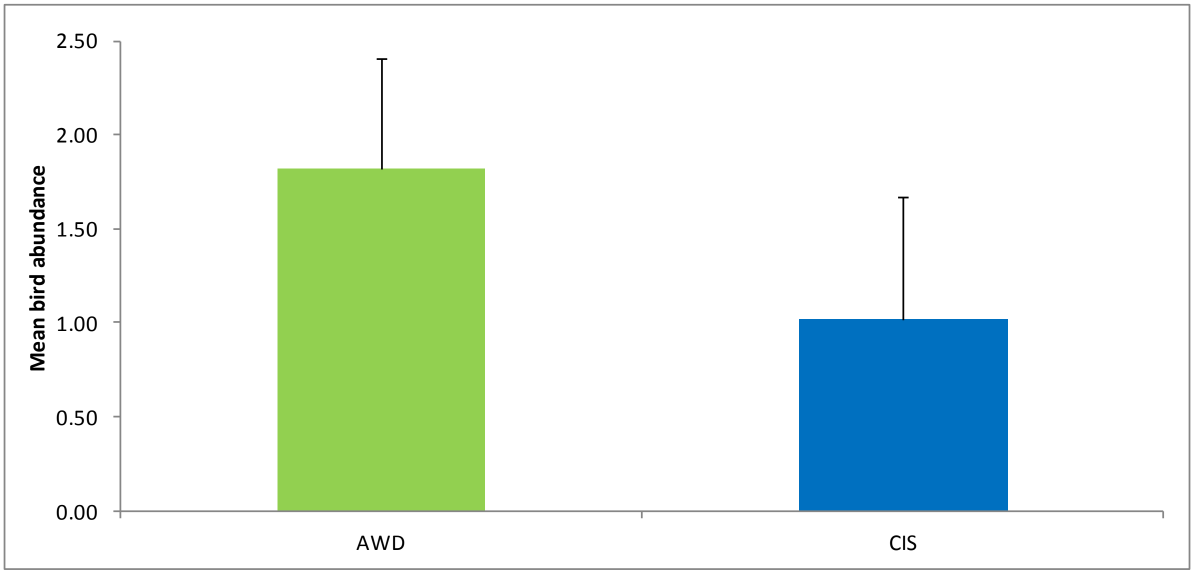

Figure 5.1 Mean bird abundance (± standard error) for the irrigation managed system 'alternate wetting and drying' (AWD) and 'community irrigated systems' (CIS).

There was no significant difference in avian abundance between sites using AWD and those using the CIS [*df = 1, p = 0.188*; Table 5.4] (Figure 5.1).

5.3.2.2. Effect of location on irrigation

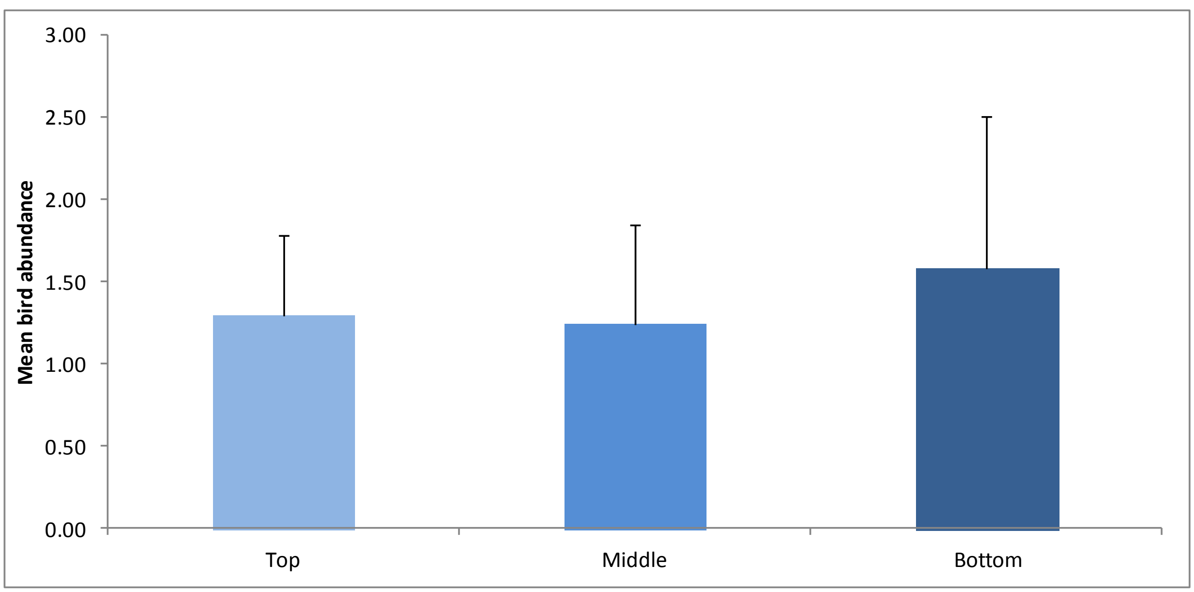

Figure 5.2 Mean bird abundance (± standard error) within three different water level locations; Top, Middle and Bottom. Top is located near the main source of the irrigation system and provides the area with ample water supply. Bottom is located furthest from the main water source and provides the area with a limited water supply. Middle is located in between Top and Bottom, and provides the area with an intermittent water supply.

5.3.3. Species Richness Indices

Overall, AWD sites had higher species diversity but lower species abundance than the CIS sites (Table 5.6).

The site with the most recorded number of individuals for the entire data set was at sites located within the middle of the irrigation network, whereas the highest diversity was recorded within the sites at the top (Table 5.7).

CIS sites closest to the source of the irrigation system had highest species diversity [D_{sim} = 2.53], and AWD sites closest to the source of the irrigation system had the highest species abundance [D_{mg} = 84.12] (Table 5.8).

With reference specifically to waterbirds, AWD sites closest to the source of the irrigation system (BIS1) had highest species abundance [D_{mg} = 24.95], and the AWD sites located at an intermediate position along the irrigation system (BIS2) had the highest species diversity [D_{sim} = 1.44] (Table 5.9).

Table 5.6 Species richness indices of total avian diversity recorded from sites operating the irrigation managed system 'alternate wetting and drying' (AWD) and 'community irrigated systems' (CIS).

	AWD	CIS
Margalef's Diversity Index (D_{mg})	148.72	**151.49**
Simpson's Index (D_{sim})	**22.55**	25.94

Table 5.7 Species richness indices of total avian diversity recorded from sites in three locations; Top, middle and bottom. Top is located near the main source of the irrigation system and provides the area with ample water supply. Bottom is located furthest from the main water source and provides the area with a limited water supply. Middle is located in between top and bottom, and provides the area with an intermittent water supply.

	Top	Middle	Bottom
Margalef's Diversity Index (D_{mg})	105.48	**106.14**	105.42
Simpson's Index (D_{sim})	**10.93**	20.23	15.08

Table 5.8 Species richness indices of total avian diversity recorded from sites operating the irrigation managed system 'alternate wetting and drying' (AWD) and 'community irrigated systems' (CIS) at three locations; Top, middle and bottom. Top is located near the main source of the irrigation system and provides the area with ample water supply. Bottom is located furthest from the main water source and provides the area with a limited water supply. Middle is located in between top and bottom, and provides the area with an intermittent water supply.

	Top		Middle		Bottom	
	AWD	**CIS**	**AWD**	**CIS**	**AWD**	**CIS**
Margalef's Diversity Index (D_{mg})	**84.12**	48.92	65.76	72.62	58.82	77.79
Simpson's Index (D_{sim})	6.57	**2.53**	8.41	8.37	3.74	6.86

Table 5.9 Species richness indices of total Waterbird diversity, recorded from sites operating the irrigation managed system 'alternate wetting and drying' (AWD) and 'community irrigated systems' (CIS) at three locations; Top, middle and bottom. Top is located near the main source of the irrigation system and provides the area with ample water supply. Bottom is located furthest from the main water source and provides the area with a limited water supply. Middle is located in between top and bottom, and provides the area with an intermittent water supply.

	Top		Middle		Bottom	
	AWD	**CIS**	**AWD**	**CIS**	**AWD**	**CIS**
Margalef's Diversity Index (D_{mg})	**24.95**	8.93	10.92	9.25	17.29	21.84
Simpson's Index (D_{sim})	4.38	**1.53**	**1.44**	2.05	6.33	9.25

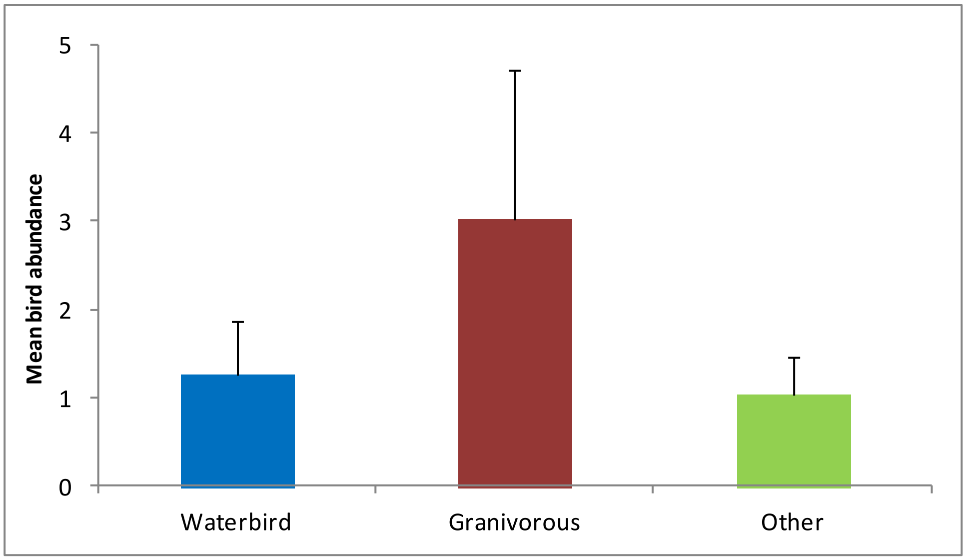

Figure 5.3 Mean abundance (± standard error) of 'Waterbirds', 'Granivorous' birds and 'Other' bird species. Abundance data pooled from both irrigation management regimes.

Combining data from both irrigation systems (AWD and CIS), granivorous birds were the most abundant bird species recorded in the rice crop habitat ($p = 0.006$; Figure 5.3).

5.4 Discussion

5.4.1. Farmer Questionnaires

The farmer questionnaires were primarily designed to record management of the crop to confirm that there were no major differences between sites or years. From 23 surveys, only twice was there an issue with water supply. In reply to "*Do you experience water supply issues?*" the two farmers who answered yes, both in 2013, listed "*Insufficient supply*" and "*Dam cannot continuously supply water*" as reasons. Both of these farms were using AWD, but their farms were at different levels within the irrigation network; one in BIS1 and one within the Capayas. This water supply issue might be due to environmental factors from the previous year. Farmers mentioned that 2012 was a dry year and that the reservoirs were low (with annual recorded rainfalls of; 2012 – 933.99 mm, 2013 – 1366.49 mm and 2014 – 1484.92 mm respectively: The Weather Channel 2015c). The farmers experiencing water supply issues in 2013 answered the same question in 2014 with "*No water supply issues*", therefore suggesting a year effect on the irrigation management. If AWD were affected by rain supply, then it would be assumed that those farms using a CIS might also be affected. None of the CIS farmers who completed the questionnaire however identified water supply as an issue, although many fields in the locality had not been planted because of the dry weather.

Sites located further from the source of the irrigation system, and using CIS, were difficult to locate and establish because many farmers in this locality did not plant rice in 2013. For this reason, the minimum distance between sites was reduced from 1 km to 900 metres in 2013, with only two sites being established. This demonstrates that though water supply might be an issue in the AWD sites during drier conditions, a number of the CIS sites would not be used for agriculture whilst water resources were limited. If the frequency of dry years were to increase, potentially due to climate change, the number of artificial wetlands in areas with no irrigation management would be likely to decrease, thus reducing the area of potential habitat available for birds and other wildlife. Future research should consider the link between rainfall and number of farmers planting rice within CIS and AWD systems to establish the effect rainfall has on habitat availability for birds, predicted to be affected by climate change within the Philippines.

Ten out of eleven respondents surveyed in 2013 indicated that they had problems with pests; while in 2014, only six out of eleven respondents indicated that they had problems with pests. The increase in perceived pest problems, during 2013, might be a result of the drier weather conditions, with reduced areas of flooding providing greater areas of foraging for avian granivorous species at the base of the rice plants (Chapter 4). Drier land means better foraging opportunities for granivorous birds, thereby also increasing their visibility within the fields. A number of farmers did not plant in the dry season of 2013 because of water restrictions that resulted from the prevailing dry conditions. The consequent reduction of suitable rice field habitat would likely result in the concentration of birds into the smaller areas of productive fields available, increasing their possible perception as pest species.

It is of note that one of the AWD sites which reported problems with pests in 2014, planted earlier than the other sites, and thus produced a mature crop that was harvested before the surrounding rice crops reached ‘panicle production’ within the same irrigation network. Thus it is likely that, when the crop was ripening, granivorous birds were drawn to this crop from the surrounding areas.

Birds were the fourth highest perceived pest of rice and were ranked higher in the sites using AWD than CIS (Table 5.3). The AWD site where birds were ranked as the #1 pest was the same site in both years. In the second year, the crop was planted earlier than the others and it was the only site that used deterrents to scare the birds (flags and sound deterrents). This problem with bird pests may have been alleviated if the farmer had planted synchronously with the surrounding fields.

Estimated crop loss to all pests was higher in sites using AWD (19.47% SE ± 4.73) than those using CIS (7.29% SE ± 2.46). Farmers identified birds as having the largest impact on yield loss within the AWD sites (38.33% ± 22.05), but one of the lowest (2%) in CIS sites. This might indicate that AWD promotes a better habitat for granivorous birds to forage, as the ground is dry and grains are not easily lost. However, these figures were heavily influenced by the site which planted earlier, where an 80% yield loss to birds was perceived.

Inconsistencies between estimated yield loss and severity occurred throughout all pests. Rice bug was listed as a moderate and a least severe pest within AWD, yet the farmers estimated a loss of 17.5%, higher than the CIS sites where 8 farmers listed them from high to least severe (Table 5.3). With no quantitative damage estimates available across the sites, and relying on individual estimations, these inconsistencies will occur. The pest severity ranks indicated that rice bug was more prominent within the CIS fields than those adopting AWD management (Table 5.3). A potential benefit of using AWD may be a natural reduction in rice bug occurrence. An investigation of how rice pests differ between AWD and the traditional methods of irrigation (CIS) using damage assessments would help to understand full ecological impact of this method of water management.

Only one of the farmers from the surveyed sites had been trained in using AWD within their fields and none had installed the plastic ‘field water tube’ (Lampayan *et al.,* 2015) which is required to measure water depth within the soil, allowing for better irrigation management (Cabangon *et al.,* 2001; Belder *et al.,* 2004). As a result, water was released by NIA once a week and all farmers would irrigate their fields, regardless of field water level, and not in line with the AWD technique of only flooding when required (Lampayan *et al.,* 2015). Though this investigation can be taken as an indication of how birds react to AWD within rice fields, this might change in a system where fields were individually managed and flooded when needed as opposed to weekly.

5.4.2. Bird surveys

There were significantly more granivorous birds recorded within the study sites than waterbirds or ‘other’ birds. Granivorous birds and specifically the Eurasian tree sparrow (*Passer montanus*), were noted foraging upon the ground in drier fields (Chapter 4). As AWD habitat remains dry for prolonged periods, at least on the surface, this might increase the suitability of the habitat for the birds to hunt more successfully, resulting in an increased abundance. An increase in granivorous birds was noted in non-flooded rice fields during over-wintering water management trials in the USA (Elphick, 2004), suggesting that the attraction of granivorous birds to dry rice fields might be a global trend.

5.4.2.1. Effect of management

There was no significant difference in mean bird abundance between different irrigation methods. Though surprising, this is not unexpected as the results from Chapter 4 showed that rice fields play host to a number of different avian species, not just those associated with water. Different elements of the crop were further tested (crop height, field stage etc.) but overall, changing to an AWD system did not have an effect upon bird abundance.

The trend of higher bird abundance (Figure 5.1) in the AWD sites might be due to the changing effects that AWD has upon the rice field. The moist soil in AWD fields will enable a number of species to probe deeper within the mud whilst hunting sub-surface invertebrates. The absence of standing water promoted the use of the field by more passerines, which now have access to the top soil. This might contribute to the increase in yield loss estimations, as more birds are seen within the fields. The rate of water seepage from the field is dependent upon the characteristics of the soil (Lampayan *et al.,* 2015). All surveyed sites within this investigation had similar soil characteristics (*pers. comm.* R. Lampayan). In future studies, if comparisons are to be made with other areas of the Philippines, soil characteristics should be investigated as they may be an important factor influencing bird abundance. During 2014, 'field water tubes' were fabricated and installed into all of the fields to enable water level measurements from within the soil, along with any surface water depth recordings throughout the season. Water depth is a factor in the occurrence of waterbird species in the USA (Elphick & Oring, 1998; 2003) and might have had an effect within the Philippines. Unfortunately, due to a large earthquake in Bohol, the hired worker responsible for taking these readings was not able to continue and those data were not available for analysis.

Ideally it would have been beneficial to have surveyed these sites before AWD had been adopted, to determine if there were any measureable differences in avian abundance or frequency as a result of landscape features. Elphick (2008) has demonstrated that a number of waterbird densities are affected by landscape features up to 10 km away from the observed field site. Though effort was made here to survey fields that were statistically independent, reducing the chance of counting the same individual bird twice within the same day but at different locations, finding suitable sites separated by 10 km was not possible. Therefore avian abundance and frequency might have been influenced by factors not recorded during the surveys.

5.4.2.2. Effect of location on irrigation

There was no significant difference in mean bird abundance between the different locations within the irrigation network. Mean bird abundance was higher at sites located near the tail end of the irrigation system (Capayas). However, the standard error was high meaning that there was a high degree of variance between sites.

It was expected that the sites near the top of the irrigation network, closer to the dam, would have a higher abundance of birds as these sites suffered less from water stress before AWD was implemented. Unlike the other parts of the system, AWD is enforced near the top to ensure enough water is available for other areas of rice production. If AWD were not enforced, this might have produced a constantly flooded habitat near the dam and little to no irrigated land at the bottom. If it had been like that for some time, it can be hypothesised that the flooded rice habitat near the top of the irrigation system provided for birds more than the dry fields near the bottom, promoting a shift in bird movement to the upper areas. Community irrigated systems would show a higher abundance in mean birds at the top sites and then decreasing down the network, whereas the AWD sites should be equal throughout, as in theory all sites should be uniformly flooded. In reality, all sites within the Capayas showed a slight, though not significant, rise in mean bird abundance whilst those at the BIS1 and BIS2 were very similar. Overall, the AWD sites displayed a higher mean abundance throughout.

5.4.3. Species Richness Indices

Overall the CIS sites supported greater numbers of fewer species, whereas AWD sites supported a lower number of more species. Therefore AWD rice fields supported a wider range of species compared to those adopting a traditional irrigated method of farming.

When site data were pooled and the three levels of irrigation were tested (Table 5.6), BIS1 displayed a higher species diversity. The Margalef's Index values indicated similar bird abundance at all three levels of the irrigation system.

An important hypothesis for this research was that the different water management systems deployed would have an effect on the waterbird communities that utilise the rice crop habitat. Previous research on birds in rice fields has primarily focused on the waterbird communities because the irrigated cropland provides them with an ideal habitat. In the analysis described above, all species were considered in the assessment of species diversity and abundance. A reanalysis of these data was therefore conducted specifically for the waterbird species (Table 5.8).

The highest abundance of waterbirds for AWD (D_{mg} = 24.95) was in the study areas close to the main source of the irrigation system (BIS1) whilst the highest abundance of waterbirds for traditional CIS (D_{mg} = 21.84) was in the study areas furthest from the main source of the irrigation system (Capayas). These results might be an indication that rice fields increase in their importance, within the CIS system for waterbirds. However as other fields within the Capayas were not planted due to water restrictions during early data collection, waterbirds might have been concentrated within the surveyed fields because of a reduction in other suitable habitat.

The highest diversity of waterbirds for AWD (D_{sim} = 1.44) was in the study areas that were an intermediate distance from the main source of the irrigation system (BIS2) and the highest diversity of waterbirds for traditional CIS (D_{sim} = 1.53) was in the study areas close to the main source of the irrigation system (BIS1). This suggests that habitat closer to the irrigation source was more diverse and attracted species inland. Further work should survey other neighbouring habitats for both avian diversity as well as habitat structure to compare these along the irrigation network to determine if they change in relation to distance from the irrigation source, landscape features or a combination of both.

5.5 Conclusions

Sites which adopted AWD to irrigate their rice fields did not show any significant difference in either avian diversity or abundance compared to sites which still used a traditional method of irrigation. Therefore, Hypothesis 1 that the community dynamics will change in rice fields using AWD can be rejected.

Differences in perceived pest occurrences in fields were recorded within farmer surveys. There was a high level of variation in the responses, which indicates that a higher sample size would be required to obtain a clearer indication of differences between water management practices. The perception that rice bug populations decreased within sites using AWD, suggests that this water management technique might provide an environment less favourable to this species.

There was no significant difference in mean bird abundance at sites throughout the irrigation network of Bohol. Sites located near the bottom of the irrigation network were slightly richer in avian abundance suggesting that these sites increased in their importance to waterbirds, as the distance to the water source increases. With only minor differences in overall abundance, likely to be a landscape feature effect, Hypothesis 2 - that rice fields historically had continuous access to water would support a greater community of avian species, can also be rejected. However, there might have been a link between surveyed sites location to the main water source and avian diversity, as higher diversity was recorded inland, potentially attracting in species from other habitats.

These results suggest that AWD does not improve or reduce the quality of rice field habitat for avian species. However, because this study was only conducted in one region of the Philippines, caution is required when interpreting these results. Alternate wetting and drying management is conducted throughout Asia (Tuong & Bouman, 2003), thus further studies of avian diversity in rice fields are needed in different regions to fully understand the effects of water management.

*Research detailed in this chapter will be formatted for submission into '*Agriculture, Ecosystems & Environment*', upon completion of thesis.*

Does an intensified five crops over two years system effect avian diversity compared to a four crops over two years system?

6.1 Introduction

In 2013, rice accounted for an average of 20.54g/per capita/day (34%/per capita/day) of protein and 2.57g/per capita/day (5%/per capita/day) of fat supplied within the Philippines (FAOSTAT, 2015). Currently rice, along with wheat and corn, provides 60% of human food (Tilman *et al.,* 2002). With the human population continuing to accelerate in growth (Tilman *et al.,* 2011), pressure is placed on countries to become more self-sufficient with an international emphasis on food security. From 1880 to 1980, the population of South and Southeast Asia increased by 262% whilst cultivated land expanded by only 86% (Flint, 1994).

In 2012, the Philippines produced 18 million tonnes of rice (FAOSTAT, 2014b), but currently import a large quantity to supply the demand for its population (GRiSP, 2013). In order to meet this demand, more rice needs to be grown. Conversion to agricultural land is the leading cause of natural habitat loss (Fasola & Ruiz, 1997; Donald, 2004), with further land loss predicted as food demands increase (Foley *et al.,* 2011; Lambin & Meyfroidt, 2011). Methods producing higher yields per unit land area are seen as possible solutions to the challenge of increasing food production (Tilman *et al.,* 2002; 2011).

It is well documented that intensification of agriculture leads to a reduction in biodiversity, particularly of plants (Donald *et al.,* 2001; Wright *et al.,* 2012; Guerrero *et al.,* 2014), mammals (Lush *et al.,* 2014) and birds which, as a group, have been studied extensively (Fuller *et al.,* 1995; Wilson *et al*., 1996; Evans *et al.,* 1997; Green *et al.,* 1997; Chamberlain & Gregory, 1999; Brickle *et al.,* 2000; Tourenq *et al.,* 2003; Dänhardt *et al.,* 2010; Phalan *et al.,* 2014). As food production intensifies nations are likely therefore to be negatively affecting their biodiversity (Cunningham *et al.,* 2013). In the Philippines, the continued expansion of agricultural land is predicted to cause a further decline in avian diversity (Phalan *et al.,* 2014). A potential solution to increasing yield with minimal ecological impact is intensifying crop production in existing areas whilst protecting set-aside land to support local biodiversity (Green *et al.,* 2005; Phalan *et al.,* 2011).

Agricultural intensification often requires additional inputs to the land, such as chemicals which accumulate within the soil, often prolonging and exaggerating their effects (Roger, 1996; Stoate *et al.,* 2001; Tourenq *et al.,* 2003) and having a huge impact on species' ecology and abundance. For example, the accumulation of pesticides within the soil prevents plant development (Marin *et al.* 1992) and reduces the availability of invertebrate prey items for chicks over a longer period of time. Due to an increase in pesticide use, in intensified fields, there was a recorded reduction in breeding output of cirl buntings (*Emberiza circlus;* Evans *et al.,* 1997) and corn buntings (*Miliaria calandra*; Brickle *et al.,* 2000) in the UK. Removal of hedgerows and other non-cropping areas within the landscape further reduces habitat heterogeneity (Benton *et al.,* 2003). Reduction in landscape heterogeneity has negative impacts upon skylark (*Alauda arvensis*) densities and overall population size (Chamberlain & Gregory, 1999). Reduced vegetation heterogeneity can cause a reduction in nesting habitat, and the use of faster growing crop varieties will result in a shorter crop life, both of which will result in lower avian productivity (Fuller *et al.,* 1995; Wilson *et al.,* 1996; Green *et al.,* 1997; Newton, 2004).

In Chapter 4, it was recognised that rice field suitability for avian diversity changed as the crop developed. During the early stages, the ground is wet and levelled, making it easier for birds to probe for food, while the later stages provide both shelter and breeding habitat. In an intensified crop the number of times fields are in a particular growth stage will increase but time spent at each stage will decrease resulting in a reduction of potential preferential conditions. How will the avian diversity react to field stages occurring at different times within the year of an intensified crop?

Currently, intensification trials are being conducted in some regions of the Philippines. By using a faster growing variety of rice, the crop season between planting and harvesting is reduced. Reducing the fallow period between crops means that farmers using this variety of rice are now able to plant five crops over a two year period ('5 in 2'), as opposed to four crops over a two year period ('4 in 2'). This study sets out to establish whether there was a difference in avian abundance, or diversity, between sites conducting these two methods of rice field management, and specifically whether increasing rice yield had a negative effect on avian diversity.

This investigation was designed to test the following hypotheses:

1) The '5 in 2' crop will progress through field stages at an accelerated rate, but there will be a decrease in the amount of time spent at each stage. This will attract more individual birds to these fields as any preferred field stages will occur more frequently than in the '4 in 2' sites.
2) Due to a reduction in the time "preferred" field stages are available, such as the fallow period, the intensified crop will be less biologically rich than the '4 in 2' crops, displayed through reduced avian diversity recorded within the fields during surveys.

3) Field stages which support migrating waterbirds, such as land preparation or the vegetative phase, will support a greater number of these species during February and March, or September and August before and after migration, regardless of the management of that site. Birds will display a preference for field stage more than the management technique adopted.

6.2 Methods and Materials

6.2.1. Study Area

Between September 2012 and April 2014, four sites in the province of Isabela, Luzon, were repeatedly surveyed (on each occasion, daily for a period of four consecutive days) with 3 - 5 weeks between successive surveys. Two of the sites were using '5 in 2' and two of the sites were using '4 in 2' production cycles. At each of the sites, two fields were surveyed. Surveyed fields were separated by a minimum of 5.4 m and a maximum of 60.6 m; Data were pooled together to produce a mean frequency for each site. The four sites were separated by a minimum distance of 4 km and interspersed by other habitat (primarily urban). The total area of irrigated rice per districts (Figure 2.2) as of 2014 (Bureau of Agricultural Statistics) was:

4 in 2 cropping: 7,689 ha (Ramon) and 7,673 ha (Mallig)	[*pers comm*. Grace Amar]
5 in 2 cropping: 5,519 ha (Roxas)	[*pers comm*. Grace Amar]

Surveyed fields were positioned within the middle of each district to minimise any 'edge effect'. Mean field size was 1.9 ha (*n = 8, SE = 0.22*) with a survey area of 10 m by 50 m established within each field. All birds seen or heard within this area were recorded.

Sites were established in collaboration with other scientists from the International Rice Research Institute and the Philippine Rice Research Institute (PhilRice) who had previously established links with farmers trialling the '5 in 2' cropping practices. Fields adopting '4 in 2' were chosen from those which fitted site specific criteria, e.g. not bordering other habitat types and a minimum distance of 4 km from '5 in 2' fields. Bird surveys commenced once crop growth became unsynchronised in September, when the first '5 in 2' fields had been harvested and the '4 in 2' continued to mature, being the first time these fields were in different crop stages to one another. After the initial harvest, one site converted back to '4 in 2', so another site (consisting of a pair of '5 in 2' fields) was established, and the original site was no longer surveyed.

In December 2013, all of the remaining '5 in 2' sites converted back to '4 in 2', and as a result, in the dry season of 2014, all sites were surveyed to determine whether or not bird frequency and abundance on sites that had previously been conducting a '5 in 2' cropping practice would synchronise with sites that had continually been conducting a '4 in 2' cropping practice.

Farmer surveys were conducted annually to determine the management techniques used at each site in order to take account of any differences resulting from the management of individual fields by different farmers, and to ensure that this was not having a major impact on avian abundance or frequency.

6.2.2. Bird Surveys

Twenty minutes of continuous scan sampling was conducted at all sites (as described in Bibby *et al.,* 2000) in the morning daily, during each 4 day survey period. Surveys were conducted by a single observer in a publically accessed area to minimise damage to the growing crop, aided by binoculars (Bushnell H_2O, 8x42). All birds seen, or heard, within an area of 10 m x 50 m were recorded, using the field bunds as boundaries. The order of sites changed daily to control for any '*time of day*' effect. Surveys were conducted with the farmers' permission, and either from a vehicle or standing on publically accessed roads or paths.

Every effort was made to record birds to a species level; however at times it was only possible to identify birds to the family level (Chapter 2). Field notes were taken during surveys, and subsequent attempts to identify unknown bird species were made using Kennedy *et al.* (2000). All species seen or heard using the rice fields were recorded. A small number of surveys conducted during undesirable environmental conditions (such as poor weather conditions) or too much human disturbance were removed from analysis *post hoc*.

6.2.3. Analysis and Statistics

Analysis was conducted using a Generalized Linear Mixed Model (GLMM) with a Poisson's log distribution applied. Records of a single species which was ≥70 per survey ($n = 20$) were identified as outliers and removed from the GLMM, but were retained for species richness indices calculations. All main and 2-way interactions were run using all factors tested, in a backward stepwise method, to eliminate all of the non-significant factors. Statistical analysis was conducted using IBM SPSS Statistics (Version 21).

Factors were defined as; Management either Intensified as '5 in 2' or Traditional as '4 in 2'; species category as waterbird, granivorous or other; field stage as land preparation, vegetative, reproductive, ripening or fallow; Month as January – December; and crop height as 0cm, 0 – 15cm, 15 – 30cm or > 30cm. The 2-way interactions were; Management * Species category, Management * Field stage, Management * Month, Management * Crop Height, Species category * Field stage, Species category * Month, Species category * Crop Height, Month * Crop Height.

6.2.4. Species Richness Indices

Species richness indices are calculated from data to produce a quantifiable score of biodiversity, regardless of survey effort, which can be used, and compared, to other scores to measure diversity richness under different conditions.

Indices were calculated for both cropping systems for the total number of individuals and community level. Indices were then compared to a baseline figure calculated from the accumulation of a long-term study (27 months) of 13 rice fields using the more 'traditional' '4 in 2' cropping method of rice agriculture (Chapter 4). Two indices were chosen to determine richness of individuals (Margalef's diversity index) and a measure of species richness (Simpson's Index).

The Margalef's diversity index (Clifford & Stephenson, 1975) provides a simple measure of richness from abundance data:

$$D_{mg} = \frac{(S-1)}{\ln N}$$

Where richness is the number of species (S) divided by the number of individuals (N). The index assumes an approximate normal distribution in species numbers and can be used with a small data set, compensating for sampling method by only comparing the number of records. Margalef's diversity index provides a simple score representing species richness based upon the number of individuals recorded. Thus the highest score represents the highest number of individuals and is used as a measure of avian diversity within this study.

The second species richness index measured variance from an abundance distribution and was calculated using the Simpson's index (Simpson, 1949), for a finite community:

$$D_{sim} = \sum \left(\frac{n_i[n_i-1]}{N[N-1]}\right)$$

Where n_i is the number of individuals in the *i*th species; and N = total number of individuals. The Simpson's index gives a probability that two randomly selected individuals, from the data set, belong to the same species. In a diverse population the probability of this occurring is low and therefore as D_{sim} increases, this represents a decrease in diversity. This index is less sensitive to individual species, such as rare sightings, concentrating on the abundant species. Unlike other indices, Shannon-Weiner for example, Simpson’s index can be used on a relatively small (< 1000) data set (Magurran, 2004).

Comparisons of indices identified times of the year which were biologically richer and differences between field stages, presumably if these conditions were to occur simultaneously (preferential month and crop stage) this would have been when the rice fields recorded the most abundance and diversity. Assumptions were expanded to create ‘*enhanced periods*’, when one of the richest factors (either field stage or month) occurs without the other.

The Baseline figures used for comparison are those which were calculated within Chapter 4, comprising the control data from all of the investigations within this thesis. These are unlikely to accurately represent all seasonal and/or species differences within the rice fields of the Philippines, but are used for comparisons in the absence of any other avian abundance or diversity data.

The large number of Eurasian tree sparrows (*Passer montanus*) recorded during data collection disguised some of the abundance patterns of the avian diversity richness scores. Therefore these scores, over time, have been calculated with and without the inclusion of tree sparrows.

6.3 Results

6.3.1. Total avian abundance and diversity

All significant interactions between tested factors, as a result of the GLMM using a Poisson’s log transformed data, are reported in Table 6.1. Significant differences of bird abundance were; Management * Month ($df = 10, p < 0.001$; Figure 6.1) and Management * Bird Category ($df = 2, p < 0.001$; see Figure 6.2). There was a significant difference in recorded bird abundance between sites, with the ‘5 in 2’ recording more birds than sites using the ‘4 in 2’ cropping practice ($df = 1, p = 0.022$; Figure 6.3).

Table 6.1 All significant factors and interactions from a backward stepwise, GLMM ANOVA, with Poisson log distribution.

Factor / Interaction	Wald Chi-Square	Df	P – Value
Management	5.283	1	0.022
Year	43.015	2	< 0.001
Month	140.959	11	< 0.001
Bird Category	206.488	2	< 0.001
Field Stage	97.517	5	< 0.001
Crop Height	35.368	4	< 0.001
Management * Month	230.919	10	< 0.001
Management * Bird Category	67.381	2	< 0.001
Year * Bird Category	73.633	4	< 0.001
Year * Field Stage	128.736	6	< 0.001
Month * Bird Category	603.775	22	< 0.001
Month * Crop Height	211.015	18	< 0.001
Bird Category * Field Stage	54.470	10	< 0.001
Bird Category * Crop Height	58.587	8	< 0.001
Field Stage * Crop Height	68.849	5	< 0.001

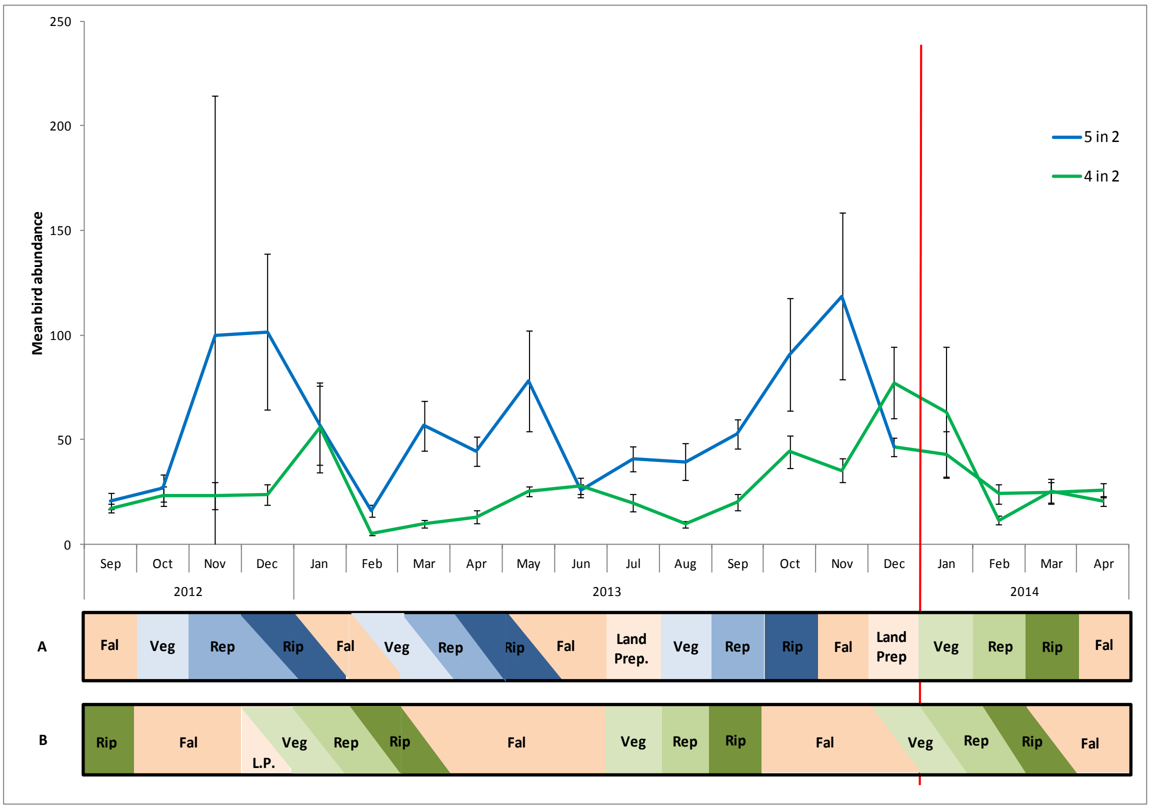

Figure 6.1 Mean monthly bird abundance (± standard error) per site visit, using '5 in 2' or a '4 in 2' cropping practice. Crop stage displayed along the X-axis for (A) '5 in 2' and (B) '4 in 2'; Fal = Fallow, these are fields which have been harvested and are generally dry, Veg = Vegetative Phase, Rep = Reproductive Phase, Rip = Ripening Phase, and L.P. = Land Preparation, when fields are levelled and flooded. Red line indicates when the '5 in 2' farms converted back to '4 in 2'. Diagonal boxes indicate transitional phases when individual fields, at a site, were at different growth stages, but data was pooled for that survey period.

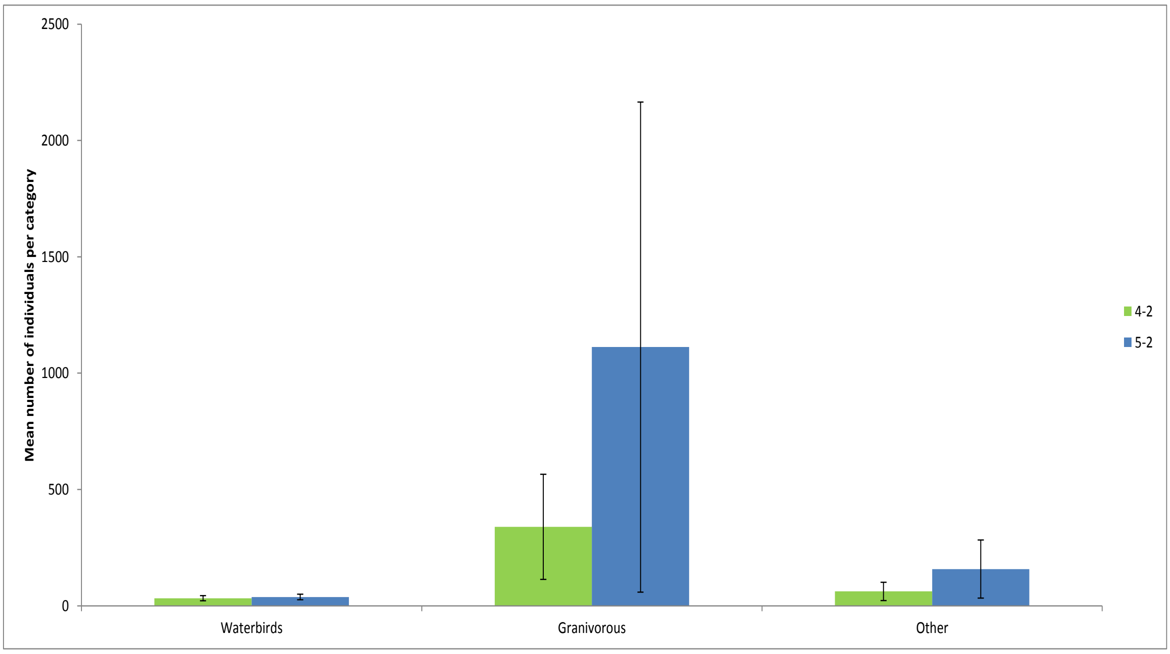

Figure 6.2 Mean number of individuals recorded per bird category (± standard error) for sites using a '5 in 2' or a '4 in 2' cropping practice, using all survey data collected from September 2012 until December 2013.

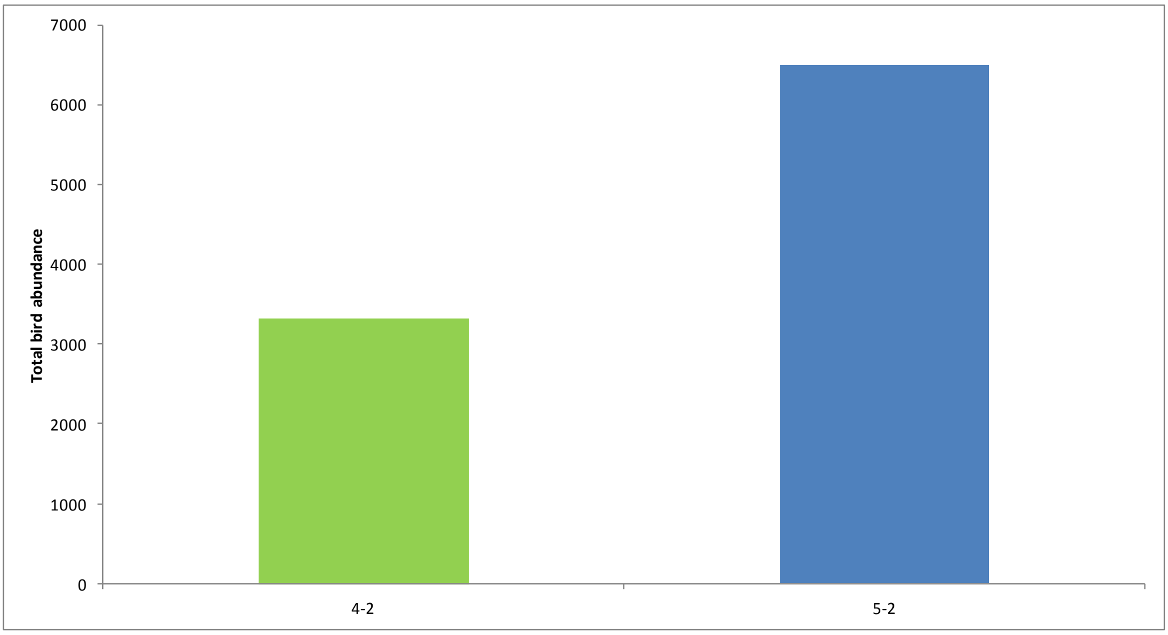

Figure 6.3 Total bird abundance per cropping system, using all survey data collected from September 2012 until December 2013.

Table 6.2 Number of times each stage was recorded and total duration of each stage during study period.

Field Stage	4 in 2		5 in 2	
	Number	Total Weeks	Number	Total Weeks
Land Preparation	1	4	2	8
Vegetative	4	16	4	16
Reproductive	3	12	6	24
Ripening	3	12	4	16
Fallow	9	36	7	28

6.3.2. Species Richness Indices

Species richness indices were calculated for differences in; crop management (Table 6.3); crop management and bird category (Table 6.4); crop management and migration strategy (Table 6.5); and, crop management and crop stage (Table 6.6).

Table 6.3 Margalef's Index as a measure of species richness, and Simpson's Index, as a measure of species diversity for the total avian diversity recorded, for sites operating the management techniques; '5 in 2' and '4 in 2', with data presented for the periods 'September 2012 to December 2013' and 'January 2014 to April 2014'. Simpson's provides an inverse measure of diversity (1 = no diversity and 0 = infinite diversity). Bold is an indication of richest value per row.

September 2012 – December 2013	'5 in 2'†	'4 in 2'
Margalef's Diversity Index D_{mg}	**1705.17**	846.11
Simpson's Index D_{sim}	0.297	**0.159**
January – April 2014	**Return to '4 in 2'†**	**'4 in 2'**
Margalef's Diversity Index D_{mg}	**262.42**	233.57
Simpson's Index D_{sim}	0.195	**0.126**

† the sites operating '5 in 2' in 'September 2012 to December 2013' that converted to '4 in 2' in 'January 2014 to April 2014'.

Table 6.4 Margalef's Index as a measure of species richness, and Simpson's Index, as a measure of species diversity for bird categories of recorded species, for sites operating the management techniques; '5 in 2' and '4 in 2', for the period 'September 2012 to December 2013'. Simpson's provides an inverse measure of diversity (1 = no diversity and 0 = infinite diversity). Bold is an indication of richest value per row, underlined represents richest of the tested index.

September 2012 – December 2013		'5 in 2'	'4 in 2'
Margalef's Diversity Index D_{mg}	**Waterbirds**	**264**	235.4
	Granivorous	<u>**3207**</u>	925.7
	Other	**1108**	492.1
Simpson's Index D_{sim}	**Waterbirds**	<u>**0.146**</u>	0.151
	Granivorous	0.948	**0.628**
	Other	0.641	**0.422**

Table 6.5 Margalef's Index as a measure of species richness, and Simpson's Index, as a measure of species diversity for migratory and resident species, for sites operating the management techniques; '5 in 2' and '4 in 2', for the period 'September 2012 to December 2013'. Simpson's provides an inverse measure of diversity (1 = no diversity and 0 = infinite diversity). Bold is an indication of richest value per row, underlined represents richest of the tested index.

Sep 2012 – Dec 2013		'5 in 2'	'4 in 2'
Margalef's Diversity Index D_{mg}	**Resident**	<u>**1682.59**</u>	735.79
	Both	**251.99**	226.50
	Migratory	104.37	**113.57**
Simpson's Index D_{sim}	**Resident**	0.372	<u>**0.242**</u>
	Both	**0.290**	0.316
	Migratory	0.387	**0.267**

Table 6.6 Margalef's Index as a measure of species richness, and Simpson's Index, as a measure of species diversity for the management techniques; '5 in 2' and '4 in 2', at different field stages. Baseline data was calculated from bird surveys conducted in 2012-2014 at numerous control sites around the Philippines. Simpson's Index provides an inverse measure of diversity (1 = no diversity and 0 = infinite diversity). Bold is an indication of richest value per row, underlined represents richest of the tested index.

		Land Prep.	Vegetation	Reproduction	Ripening	Fallow	
						Stubble	**Regrowth**
Margalef's Diversity Index D_{mg}	**5 in 2**	192.96	193.27	476.38	402.7	**<u>543.17</u>**	71.64
	Baseline	71.91	136.37	52.32	148.15	**<u>183.63</u>**	25.62
	4 in 2	180.01	257.1	63.06	80.21	**<u>365.7</u>**	17.81
Simpson's Index D_{sim}	**5 in 2**	0.3	**<u>0.15</u>**	0.47	0.36	0.47	0.54
	Baseline	0.21	0.25	0.14	0.23	0.15	**<u>0.13</u>**
	4 in 2	0.23	0.19	0.16	**<u>0.08</u>**	0.16	0.14

Field stage was a significant factor when looking at differences in avian abundance recorded during the data collection ($df = 5, p < 0.001$). Total field stage richness per management technique was calculated and displayed with the baseline figure calculated from a number of sites located around the Philippines, which adopted a '4 in 2' cropping practice (see Chapter 4).

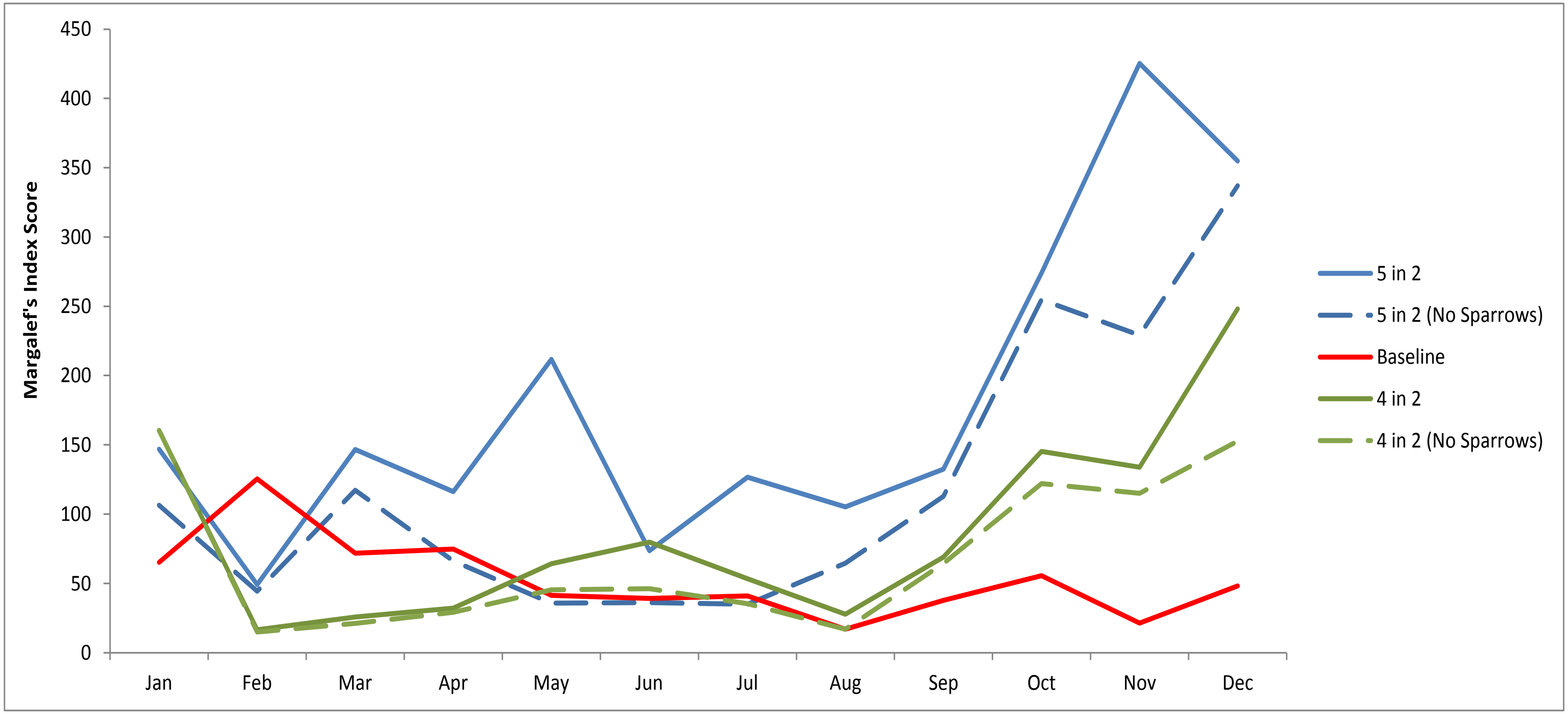

Figure 6.4 Margalef's Index as a measure of avian diversity between sites using '5 in 2' and '4 in 2'. Index values were calculated twice for all bird species (solid line), and for all bird species excluding tree sparrows (dashed line). The baseline data includes tree sparrow data.

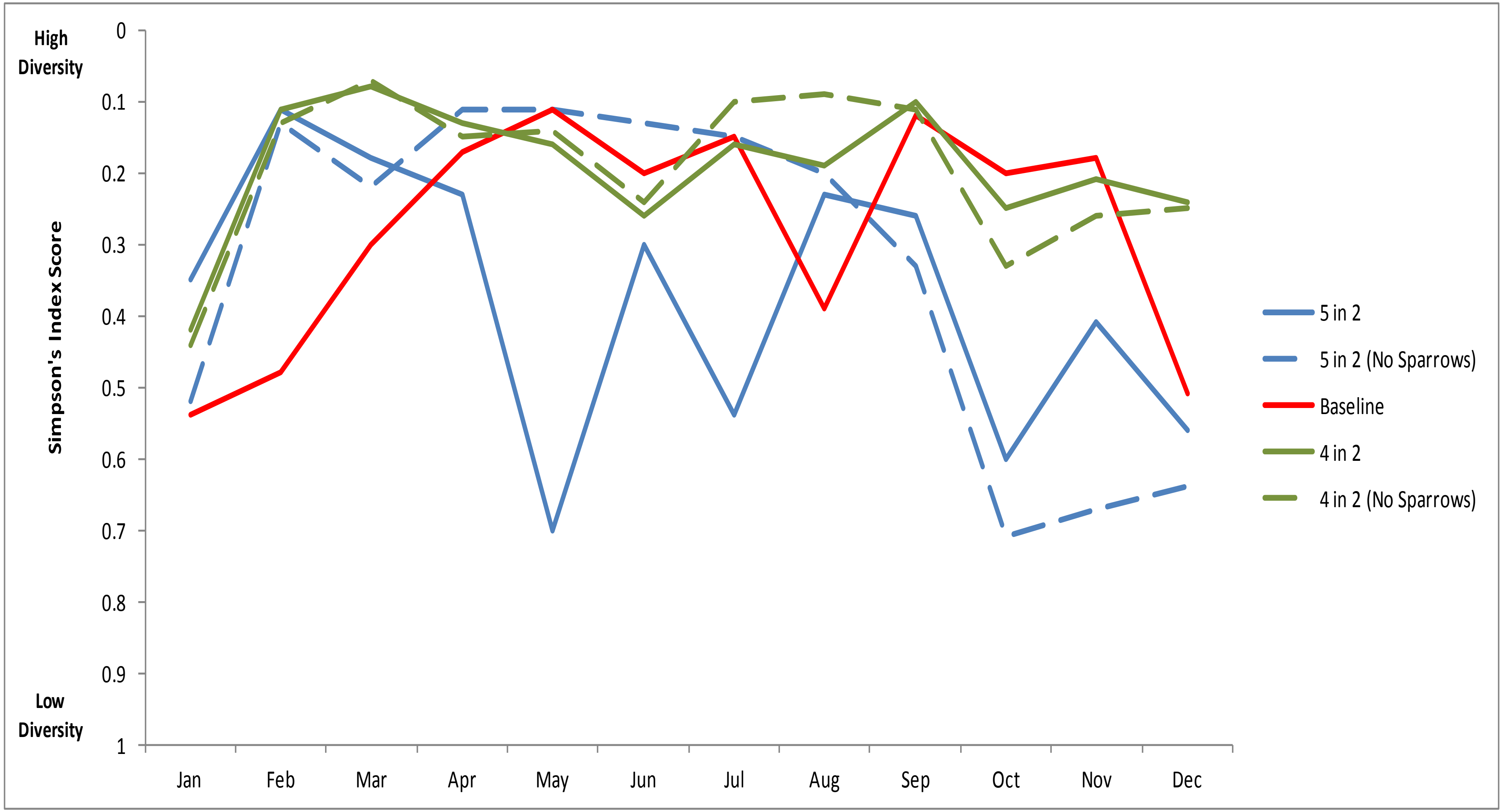

Figure 6.5 Simpson's index as a measure of avian diversity between sites using '5 in 2' and '4 in 2'. Scores were calculated twice; once with all birds (solid line), then again with the total number of tree sparrows removed (dashed line). Baseline data includes tree sparrows. Simpson's Index provides an inverse measure of diversity (1 = no diversity and 0 = infinite diversity).

As shown in Table 6.7, biologically richer months from Figures 6.4 and 6.5 are highlighted in yellow. Field stages identified as biologically rich in Table 6.6 are highlighted in blue. It was presumed that if a crop were to occur when these intercepted (displayed in green), this would be when the rice fields were at their richest due to two preferable conditions occurring at the same time. On this basis, the expectation might be that:

- Avian diversity will peak during the vegetative phase in February
- Avian abundance will peak in the fallow phase in November
- Both avian abundance and diversity will be enhanced in the vegetative phase and the fallow phase during February and November.

Table 6.7 Margalef's Index as a measure of species richness, and Simpson's Index, as a measure of species diversity for rice crops with a '5 in 2' cropping practice, presented on a monthly basis from September 2012 to December 2013. Field stage displayed as; Fal = Fallow, fields that have been harvested and are generally dry, Veg = Vegetative Phase, Rep = Reproductive Phase, Rip = Ripening Phase, and Land Prep. = Land Preparation, when fields are levelled and flooded. Simpsons provides an inverse measure of diversity (1 = no diversity and 0 = infinite diversity). Bold and underlined figures are an indication of richest value per index.

			2012				2013											
			Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5 in 2	Margalef's Diversity Index D_{mg}	Land Prep.								131.5		11.54				20.56	85.11	
		Veg.		29.58								34.61	64.8					105.1
		Rep			134.4	235.2	99.12						103.8	47.96				
		Rip				52.24		218.7			92.08			78.45	38.99			
		Fal	26.9	48.69				47.22	**371.6**	37	69.22	15.53			208.1	60.19	59.93	
			Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Simpson's Index D_{SIM}	Land Prep.								0.39		0.32				0.32	0.67	
		Veg.		0.32								0.15	0.2					0.23
		Rep			0.54	0.8	0.39						0.29	**0.14**				
		Rip				0.23		0.68			0.48			0.3	0.17			
		Fal	0.19	0.44				0.68	0.51	0.75	0.38	0.24			0.88	0.38	0.39	

(N.B. months highlighted in yellow and field stages highlighted in blue were found to have a higher avian diversity, with their intercept in green [see Figures 6.4 and 6.5])

Table 6.8 Margalef's Index as a measure of species richness, and Simpson's Index, as a measure of species diversity for rice crops with a '4 in 2' cropping practice, presented on a monthly basis from September 2012 to December 2013. Field stage displayed as; Fal = Fallow, fields that have been harvested and are generally dry, Veg = Vegetative Phase, Rep = Reproductive Phase, Rip = Ripening Phase, and Land Prep. = Land Preparation, when fields are levelled and flooded. Simpsons provides an inverse measure of diversity (1 = no diversity and 0 = infinite diversity). Bold and underlined figures are an indication of richest value per index

			2012				2013											
			Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4 in 2	Margalef's Diversity Index D_{mg}	Land Prep.			5.77	56.3				**164.44**						18.35		
		Veg.				20.48				100.59	145.96					33.18		
		Rep									39.2	9.14					54.32	
		Rip	37.53				36.97					9.55	8.65					27.77
		Fal		49.73	52.3			109.67	101.18	4.33			21.05	32.11	64.1	50.98		
			Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Simpson's Index (D)	Land Prep.			0.25	0.25				0.33						0.17		
		Veg.				0.2				0.37	0.45					0.37		
		Rep									0.32	0.2					0.17	
		Rip	**0.1**				0.11					0.15	0.11					0.19
		Fal		0.27	0.17			0.27	0.28	0.33			0.11	0.13	0.16	0.57		

(N.B. months highlighted in yellow and field stages highlighted in blue were found to have a higher avian diversity [see Figures 6.4 and 6.5])

As shown in Table 6.8, biologically richer months from Figures 6.4 and 6.5 are highlighted in yellow. Field stages identified as biologically rich in Table 6.6 are highlighted in blue. It was presumed that if a crop were to occur when these intercepted (displayed in green), this would be when the rice fields were at their richest due to two preferable conditions occurring at the same time. On this basis, the expectation might be that:

- Avian diversity will peak during the ripening phase in March
- Avian abundance will peak in the fallow phase in December
- Both avian abundance and diversity will be enhanced in the ripening phase and the fallow phase during March and December.

6.4 Discussion

6.4.1. Total avian abundance and frequency

Conscious effort was made to survey fields under similar habitat conditions, to provide an objective comparison of the two cropping systems. Environmental differences and crop characteristics were recorded during surveys and included within the GLMM to investigate their effects on avian diversity. These factors included; crop height, field irrigation, weather conditions and a disturbance score. All other significant factors from the GLMM are displayed in Table 6.1.

Those fields in which the ‘5 in 2’ cropping practice had been adopted recorded significantly higher bird abundance between September 2012 and December 2013 (Figure 6.3). These sites showed a difference in bird abundance when divided into separate months (Figure 6.1) as well as between different bird categories (Figures 6.2). The probable reason for this is the increased number of field stages available to birds within the ‘5 in 2’ system compared to that of the ‘4 in 2’ sites (Table 6.2). The ‘5 in 2’ adopted a faster growing variety of rice with a reduced fallow period between crops when compared to the ‘4 in 2’. This would indicate an increase in water usage as growing rice would require more water than a fallow field, which are often left dry. This irrigation would make it easier for bird species to probe the ground to hunt for invertebrates.

The X-axis rows labelled A and B of Figure 6.1 display when the ‘5 in 2’ are growing the ‘additional’ crop compared to the ‘4 in 2’. Harvesting and planting of ‘5 in 2’ fields occurs in quick succession during the first few months of the year, with the second crop growing and developing during the later period of the dry season, at a time when the ‘4 in 2’ fields are in the fallow stage. As described in Chapter 4, this is the period of time when migrants have departed and there is a reduced number of species recorded within the rice fields. Over the 20 months of data recording, there are three occasions when land was fallow in the ‘4 in 2’ cropping practice and rice crop was present in the ‘5 in 2’ cropping practice:

- October – November (2012)
- February – May (2013)
- October – November (2013)

During these three occasions, the number of birds using the ‘5 in 2’ cropping system was much greater than that using the ‘4 in 2’ cropping system. This is likely to be due to the increased irrigation providing more productive feeding areas, and increased cover, providing a safer feeding environment, when compared to the dry fallow fields of the ‘4 in 2’ cropping practice. The ‘5 in 2’ cropping practice thus provides optimal bird habitat for longer periods of time throughout the year.

This data is likely to under represent the more rapid succession in field stages during the ‘5 in 2’ crop, as a number of stages were missed. Further work might increase the total number of surveys, either by reducing the time between survey periods, or specifically surveying during specific field stages to ensure all stages are recorded. Does the avian community respond to this rapid turnover in stages or is there any ‘carry-over’, thereby enhancing the diversity effect overall?

From December 2013, all fields were using a ‘4 in 2’ cropping practice. Farmers stated, within the surveys, there were two main reasons as to why they were converting back from ‘5 in 2’; cost and pests. Farmers stated that their yield per crop was similar on both ‘4 in 2’ and ‘5 in 2’, but the expense of having to pay for additional chemicals, labour and other running costs per crop meant they were losing money overall. The farmers mentioned that pests (including invertebrates, mammals and birds) and the occurrence of disease increased in the ‘5 in 2’ cropping practice as some disease management, such as a longer fallow period, were not possible. All of the farmers which used the ‘5 in 2’ cropping practice mentioned the reduction of asynchronous cropping within the districts, increasing the likelihood of loss of yield to pests. A typical belief of rice farmers is that “*all birds eat rice*” and that the increase in avian abundance, as demonstrated in Figure 6.1, might partly account for the belief that the ‘5 in 2’ cropping practice promotes pest species.

The total number of individual birds recorded in the '4 in 2' was less than the total within the '5 in 2' cropping practice (Figure 6.3). However, once separated into different bird orders, there are marginal differences for waterbird and other species, but a large difference for granivorous species (Figure 6.2). The granivorous species, which are most likely to be pests of the rice crop, occurred more frequently within the '5 in 2' cropping practice, which might have a negative effect upon farmers yield.

Once all of the sites returned to the same method of management, the avian abundance started to synchronize between both pairs of sites (Figure 6.1). The '4 in 2' were planted a few weeks ahead of the old '5 in 2', accounting for the initial rise in abundance during December (2013) and January. Once the old '5 in 2' were planted similar trends in abundance were displayed until the end of data collection. This demonstrates how rapidly the birds can react to the prevailing conditions (Krebs *et al.,* 1999). If collection of survey data were to continue, it can be hypothesised that the abundance in both sets of fields would be similar and continue on similar trends as long as the management practice remained consistent.

6.4.2. Species Richness Indices

6.4.2a General

General differences in species richness scores were consistent between sites during and after manipulation. Sites operating a '5 in 2' cropping practice were found to have a higher avian abundance and a reduced avian diversity when compared with sites operating a '4 in 2' cropping regime. This difference was mainly evident during the main survey period of September 2012 - December 2013, when the '5 in 2' cropping practice was in operation (Table 6.3). From January 2014 - April 2014, after the '5 in 2' cropping practice had reverted back to the '4 in 2'cropping practice, the difference was still evident, but to a much lesser extent. If the avian surveys had continued beyond April 2014, the expectation would be for a continued decline in the differences between the Margalef's Index and the Simpson's Index for the two survey areas.

The Margalef's measure of species richness was higher in all categories within the '5 in 2' cropping practice (Table 6.4).

6.4.2b Waterbirds

With the exception of waterbirds, the study sites operating the ‘4 in 2’ cropping practice had a higher diversity than those operating the ‘5 in 2’ system. The higher diversity of waterbirds in study sites operating the ‘5 in 2’ cropping practice is most likely linked to the increased frequency of flooding.

6.4.2c Migratory birds

The Philippines is located in the middle of an important migratory route, and a change of cropping practice is expected to have a negative impact on migratory birds if sites that were once used become unsuitable for foraging during migration. It was expected that migratory species were likely to be most abundant when conditions best suited their feeding, regardless of management. Sites using the ‘4 in 2’ cropping practice had a larger number of migratory individuals and species, indicating that the ‘5 in 2’ might have a negative effect on migratory species, if it was adopted by more farmers.

6.4.2d Crop Stage

The highest Margalef’s index (which provides a measure of the number of individuals) peaked synchronously during the ‘*fallow*’ phase, across both cropping practices. However, the Simpson’s index (which provides a measure of diversity) peaked during different field stages, dependent upon the cropping practices (Table 6.6). This is consistent with results seen in Chapter 4, in that the number of birds increased during the fallow stages, during both stubble and regrowth. This increase mainly consisted of granivorous birds and waterbird species, which were increasingly visible due to reduced sheltering opportunities. Fields under a ‘5 in 2’ cropping practice contained more granivorous individuals which could be due to the increased number of times that the field was harvested.

The Simpson’s index peaked during different field stages, dependent upon the cropping practice (Table 6.6). The highest species diversity for the ‘5 in 2’ and ‘4 in 2’ cropping practices were during the ‘*vegetative*’ stage and the ‘*ripening*’ stage respectively. Neither ‘5 in 2’ nor ‘4 in 2’ cropping practices displayed consistency with the baseline surveys, which peaked in diversity during the ‘*regrowth*’ stage (Table 6.6). Baseline data displayed similarity in Simpson’s scores across all field stages, whereas Simpson’s scores from the ‘5 in 2’ and ‘4 in 2’ indicates a clear biodiversity “preference” for particular field stages (Table 6.6). A difference in Simpson’s scores was expected between the baseline and ‘5 in 2’, as these used different cropping practices, it is unclear why there is variation between the baseline and the ‘4 in 2’ as these cultivation schemes were the same. A possible explanation for these differences in scores is the time of year at which the field stages occurred. The additional crop, over the two years, increased the frequency that fields were in any preferential growth stage. Crops were present on more occasions throughout the year in the '5 in 2' fields. The number of '*vegetative*' stages were equal between cropping practices, but a reduction of '*fallow*' in the '5 in 2' resulted in an 8 week reduction of dry fields and an increase in flooded, wet, fields (Table 6.2). However, the data under represents the rapid turnover of field stages, with a number being missed because of the temporal spacing of the surveys.

6.4.2e Tree sparrows

During most of the year the large number of tree sparrows recorded within both cropping regimes masked the patterns of the other bird numbers and their presence within the rice fields. The tree sparrow records increased the overall birds recorded per month within the rice fields, most noticeably between March - August and November - December. The large number of records represented tree sparrow abundance throughout the year, rather than the trends of the other species that were present. Tree sparrow records were then removed and the remaining data re-analysed (Figure 6.4 and Figure 6.5).

The Margalef's index, which provides a measure of species abundance, differed between both the '5 in 2' and '4 in 2' cropping practices, and the baseline calculated from Chapter 4 (Figure 6.4). The baseline survey data had the highest number of recorded individuals during February which slowly declined over the year, whereas both '5 in 2' and '4 in 2' started low and increased during the year. February displayed the lowest number of individuals overall in '5 in 2' and '4 in 2', with or without the tree sparrow records. The highest number of individuals tended to occur during December, for all species except tree sparrows, and November and December for all species.

The Simpson's index provides a measure of diversity which peaks in February, for '4 in 2', and March for the '5 in 2' cropping practices, with overall higher biodiversity in the '4 in 2' (Figure 6.5). The large decrease in the Simpson's Index displayed in May and July, within the '5 in 2' data, demonstrates the difference that tree sparrow records have upon the overall biodiversity scores. Without tree sparrows, the index scores slowly decreased, indicating an increase of diversity, from April until October, the highest score throughout the entire year.

By consolidating Margalef's index as a measure of species abundance and Simpson's index as a measure of diversity, for month and crop stage, a prediction could be made as to which time of year the rice fields were at their richest. If the richest field stage, for either abundance or diversity, were to occur during one of the months, then conditions were thought to be ideal and would be displayed through an increased measure of abundance and/or diversity (Tables 6.7 and Table 6.8).

The Margalef's index as a measure of species abundance, for the '5 in 2' cropping practice, highlighted two potential periods where biological richness was expected to be at their highest (in green on Table 6.7). Only once were these conditions met, when the field stage '*fallow*' occurred in November (in 2013) and when the highest number of individuals were expected to occur. However, March had the highest Margalef's index score of 371.6 (opposed to November which was 59.93) indicating the highest number of individuals throughout the year. The '5 in 2' cropping stage was in '*fallow*', indicating that field stage is the important factor, not necessarily the month of November. The highest Simpson's index occurred in February, whilst the crops were in the '*vegetative*' phase making it the most diverse. There was no '*vegetative*' crop present during '5 in 2' in February with the highest diversity occurring during the '*reproductive*' phase in August, not coinciding with any of the previous results.

The Margalef's index as a measure of species abundance, for the '4 in 2' cropping practice, highlighted two potential periods (December 2012 and December 2013) where biological richness was expected to be at its highest (in green on Table 6.8). However at neither of these times was the highest number of individuals recorded, that occurred during April 2012, not coinciding with any enhanced periods of time. Using the Simpson's index, September 2012 was the only time when '*ripening*' coincided with the month of March, the richest month previously identified, but no crops were present at these sites during that time; and the most diverse month was found to be September, 2012. This was shortly before the '5 in 2' cropping practices became asynchronous with the '4 in 2'. The '4 in 2' was in the '*ripening*' phase during this period, coinciding with the biologically diverse field stage.

Peaks in the number of individuals seemed to run concurrently between cropping practices, with a peak in abundance in '5 in 2' fields one month, followed by a peak in abundance in '4 in 2' fields the following month. The '5 in 2' cropping practice had the highest number of individuals in November and February, one month before the '4 in 2' had their highest peaks (in December and March), suggesting movements between sites. It is quite likely that the birds are attracted to the damp environments associated with flooded fields. In November (and February) the crops in the '5 in 2' fields were maturing into the ripening phase, and fields were left to dry out in preparation for harvesting. This initiated movement of birds from the '5 in 2' fields into the '4 in 2' fields (in December and March) as they were flooded, levelled and planted with the next cycle of rice.

Caution must however be exercised interpreting these indices with regards to the field level effects of these management techniques. Though field results are a good indication of landscape responses by birds (Jeliazkov *et al.,* 2016), increases in numbers of individuals during this investigation were primarily associated with a single species, the Eurasian tree sparrow (a granivorous bird species). Therefore fields under '5 in 2' have a reduced species diversity within the rice fields but have an increased presence of granivorous individuals, which might have a detrimental effect upon yield.

6.4.3. Conservation implications

Agricultural projections to meet food demands (Alexandratos & Bruinsma, 2012) for maize, rice and wheat are currently unattainable with the current land dedicated to crop production within the Philippines. If intensification cannot close the yield gap in production, the Philippines will need to convert further land into rice fields in an attempt to match these targets (Phalan *et al.,* 2013; Phalan *et al.,* 2014). Even if yield increases were possible, throughout the entire Philippines, more than 10% of the country's non-cropland would need to be converted to achieve the required demand (Phalan *et al.,* 2014). This short-term investigation suggests that, overall, avian diversity in rice fields would decline if an intensified '5 in 2' cropping practice were adopted, although there would be benefits for a small number of species, such as the Eurasian tree sparrow. Chamberlain *et al.* (2000) showed that bird species in the United Kingdom started to decline 6 years after agricultural intensification had started. It is therefore unlikely that the 16 months of data presented here will be able to identify the potential major changes in Philippine bird populations that would result from agricultural intensification. Long-term data sets show contraction of bird ranges (Fuller *et al.,* 1995), yet a specific baseline data set of avian abundance and frequency within the Philippines is lacking. There is, therefore, the need for further work on establishing which avian species use rice fields in Asia (Ibáñez *et al.,* 2010).

6.5 Conclusion

Sites which adopted an intensified '5 in 2' cropping practice had significantly more individuals, whilst the traditional '4 in 2' had higher species diversity. Overall there was a higher number of birds recorded within the '5 in 2' but a third of these were tree sparrows, a perceived pest of rice.

This study supports hypothesis 1, that there were more birds recorded within the ‘5 in 2’ cropping practice. This is likely due to the rapidly changing field stages and increased availability of irrigated fields, rather than an increase in sheltering opportunity. The fields which continued the ‘4 in 2’ cropping practice were more biologically diverse than the ‘5 in 2’, agreeing with hypothesis 2, although this was not due to a reduced fallow phase as hypothesised. The amount of time the crop remains at each field stage is reduced in the intensified crop production system such that the overall frequency of stages increased over the 2 year period with preferential field stages in shorter duration but more frequent.

Hypothesis 3 predicted an increase in waterbirds during the earlier stages of rice growth and that they would occur during key migration times (February to March and September to August). This would have been displayed as a higher number of species at these field stages, regardless of field management. Unfortunately, there were insufficient data during the early field stages (land preparation or the vegetation phase) at these key months, therefore this hypothesis remains untested. However, species indices scores show waterbird abundance and diversity higher in the ‘5 in 2’, probably due to an increased amount of irrigation within these fields.

Finally, all of the farmers which adopted the ‘5 in 2’ management changed back to the traditional ‘4 in 2’ after the monsoon season of 2013. They stated that the increase in labour, as well as having to buy more chemicals, meant they felt financially worse off using the ‘5 in 2’ system. Governments are still keen to increase yield and food security and are looking into different methods of achieving this.

*Research detailed in this chapter will be formatted for submission into '*Bird Study*', upon completion of this thesis.*

The Eurasian tree sparrow (*Passer montanus*) diet and breeding within an agricultural habitat of the Philippines: Friend or Foe?

7.1 Introduction

It is a common belief between rice farmers in the Philippines that "*All birds eat rice*" and that "*If it flaps, scare it away*". Chapter 4 indicated however, that of the 130 species of bird seen or heard only five were granivorous (Eurasian tree sparrow, scaly-breasted munia, white-bellied munia, chestnut munia, and Java sparrow). Therefore total avian diversity presents only a small threat to farmers' yield within lowland irrigated rice field habitat of the Philippines. The species which was most commonly recorded within this study (Chapter 4, Chapter 5 and Chapter 6) was the Eurasian tree sparrow (tree sparrow from here; *Passer montanus*), the second most abundant bird overall in rice fields (Chapter 4).

The tree sparrow is widely distributed in the Philippines, occurring on most islands (Dickinson *et al.,* 1991) and often in close proximity with human infrastructure. It is believed that the species was introduced to the Philippines in 1867 (Summers-Smith, 1995) in Manila, and then spread slowly north through Luzon (Whitehead, 1899). In 1959, Parkes described specimens collected from the Philippines and separated them into two sub-species; *saturatus* (in Manila and the North), and *malaccensis* (in Cebu and the Southeast). This sub-species separation suggested that tree sparrows were introduced into the Philippines twice; once in Manila (reported to be either from Japan or Taiwan) and once in Cebu (reported to be from the Malay Peninsula; Parkes, 1959), although interbreeding between sub-species is likely (Summers-Smith, 1995). Unless otherwise stated within this investigation, 'tree sparrow' refers to *Passer montanus saturatus*.

Similar to others within the genus *Passer*, the tree sparrow is a seed-eating specialist, which during key moments in their life history, specifically during the breeding season, supplement their diet with invertebrates (Summers-Smith, 1995). However, the timing of the breeding season within the Philippines has not been verified. In general, adults tend to specialise, feeding on the seeds of a small number of available plant species which can vary throughout the season (Folk & Kožená, 1982; Krištín, 1984), whereas chicks and young are fed almost exclusively upon invertebrates. In some parts of their range, the bill becomes significantly longer during particular times of year (Clancey, 1948), suggesting a response to a change in diet from grain to invertebrates.

Within the Philippines, the tree sparrow is often seen within the rice field habitat and is routinely blamed for losses in yield. However, establishing the amount of damage caused by tree sparrows is difficult due to a) their large home-range and b) difficulty in being able to distinguish between damage done by other granivores. If tree sparrows feed upon a small number of seeds and invertebrates throughout the year, it might indicate that they are feeding on weed seeds and invertebrate pests of rice. This would mean they are, at least in some part of their range, a significant benefit to the rice farmers.

This investigation aims to develop a better understanding of the breeding ecology, diet and morphological traits of the tree sparrow in lowland irrigated rice ecosystems in the Philippines. This investigation examined the hypothesis that tree sparrows will change from a predominantly granivorous diet to a predominantly invertebrate diet at certain times of the year to coincide with breeding. At these times of high energy demand, tree sparrows will increase their consumption of invertebrates in order to increase diet quality, and protein intake in particular that is required for the production of eggs and young. This will be determined using stable isotope analysis, to identify changes in the ratios of ^{13}C and ^{15}N, over time as an indication of any changes in the bird's diet. The use of caged birds, on a control diet, will provide ratios for three baseline diets which will enable comparisons of ratios collected from wild birds, along with potential prey items (vegetation and invertebrate), for the identification of the trophic level of the diet in the wild.

7.2 Methods and Materials

7.2.1. Biometrics

Target specific mist-netting of tree sparrows was conducted in the first week of every month from January - June 2014. Nets were placed at appropriate locations throughout the International Rice Research Institute (IRRI) experimental station and trapping was continued until the required numbers of individuals had been caught. Individuals were collected either for the diet control group or for dissection (see below). Additional individuals, or those of a different species, captured had their biometrics recorded, were ringed and then released. A small number of surplus tree sparrows had claw samples taken before release ($n = 4$), to provide additional wild diet data.

With little literature available on the spread of the tree sparrow throughout the Philippines, in particular the spread of the sub-species *saturatus*, biometric data were compared with those data available in the literature to determine the sub-species present at IRRI. The sub-species (*Passer montanus saturatus*) were described as having a darker plumage and possessing the longest bill of all tree sparrow sub-species (Summers-Smith, 1995). However, very little information is available on wing-formulae, which could provide a useful method for distinguishing between the different sub-species. Photographs of partly open tree sparrow wings positioned adjacent to a ruler were taken, primarily from birds to be dissected, and were later analysed on a computer screen using "Screen Calipers 4.0" software, to measure the relative lengths of the primary feathers. Biometric measurements were tested for significant differences between the sexes using a one-way ANOVA.

Additional measurements were recorded from dissected birds, including; weight (using a digital balance: g), bill length (from tip until forehead, using calipers: mm), tarsus length (from inter-tarsal joint to the last completed scale on the foot, using calipers: mm), body length (end of bill to the tail tip, using a rule: mm), tail length (base of central tail feathers to tip, using a tail rule: mm), wing length (primary feathers laid against a ruler from the carpel joint: mm), stomach weight (empty and full: g; see Svensson (1992) for details) and sex (identified by dissection where possible).

The primary feathers are numbered 1 – 10 ascending from inner to outer (the wing's leading edge), following the moult sequence (Jenni & Winkler, 2011). The standard measurement of length is in relation to the longest primary feather, recorded within this investigation as P8 (primary feather 8), as stated by Svensson (1992).

A Wildlife Gratuitous Permit (WGP) for wild bird trapping and handling was granted by the Philippine Department of Environment and Natural Resources (DENR) following a detailed review of all the methodologies described and used within this investigation (Appendix 6).

7.2.2. Nesting

A number of nest boxes were erected throughout the IRRI experimental farm between March 2013 and June 2014 to assess the occupation rate by tree sparrows, and to see if they were used by any other hole nesting passerine. Standard nest boxes were manufactured with an approximate height of 15 cm, cross sectional area of 12 cm x 12 cm, and a hole 2.5 cm in diameter positioned on the front. The boxes were placed on coconut trees, 2 - 3 metres above the ground and facing in the direction of the nearest rice field. Originally, 24 boxes were erected in March 2013, with an additional 11 boxes erected in December 2013. An extra 5 boxes were added half way through the dry season of 2014 to assess whether or not the use of a new nest box was influenced by the presence of an occupied next box nearby. To this end, the new nest boxes were placed on the same tree and in close proximity to an occupied nest, and both nest boxes were monitored for the remainder of the season. The new box on each tree was erected after the current nestlings had fledged from the 'old' box to avoid disturbance of that brood. Six of the boxes were lost during data collection, either because of damage (intentional or accidental) or theft.

7.2.2.1. Recording the length of the breeding season

The first nest boxes were erected in May 2013 to allow birds to become accustomed to them in time for the next breeding season. Weekly nest box checks began in February 2014 in an attempt to record the first brood, indicating the beginning of the breeding season (Summers-Smith, 1995). Checks were reduced to fortnightly once new broods had stopped being recorded. When no change had been recorded for a month, this indicated that the breeding season had finished. Random nest box checks were conducted outside of the breeding season to ascertain that no further breeding was going unrecorded.

Within this thesis, breeding season is defined as the time between the first egg being laid and the final young to fledge.

7.2.2.2. Annual Productivity

During checks, the observer accessed the nest box and recorded the nest progress. This ranged from finding a few bits of nesting material, to a completed 'lined' nest. If eggs or young were present, these were recorded, and the offspring ringed. Dead fledglings were removed from the nest but eggs were left.

Nest boxes were erected and then left throughout the season, requiring little maintenance. Two boxes were damaged from falling coconuts and needed to be reinforced, though this was done once the present brood had fledged. Nest boxes were then emptied of any old nests in November as tree sparrows had been observed carrying nesting material at this time.

7.2.3. Diet

To record diet composition of tree sparrows over time, a combination of wild caught and captive individuals had claw samples taken for isotopic analysis to identify the ratios of ^{13}C and ^{15}N. The ratios between the most abundant carbon and nitrogen isotopes (^{12}C and ^{14}N) are compared with the less common forms (^{13}C and ^{15}N). Isotopic analysis of these ratios are commonly used to provide information about likely diet and trophic levels within food webs as both pass successively within trophic levels at step-wise intervals (Ambrose & DeNiro, 1986). During photosynthesis, ^{13}C is differentially fractionated into unique isotopic signatures for C_3, C_4 and Crassulacean Acid Metabolism (CAM) pathways depending upon the plant (Smith, 1972; Ambrose and DeNiro, 1986; Kelly, 2000). Generally, diets consisting of -8.0 parts per mil (‰), or below, represent a pure C_3 diet, that of the higher plants and their fractionation of carbon isotopes during photosynthesis (Farquhar *et al.,* 1989).

Detection of nitrogen isotopes from amino acids can be used to determine dietary intake and trophic level location within a food web, as there is systemic enrichment of at least 2 ‰ between each level (DeNiro & Epstein, 1981; Bockerens & Drucker, 2003). The magnitude of trophic differences in ^{15}N ratios makes this an ideal marker of food web location within trophic levels, whereas the small range of ^{13}C within terrestrial food webs means that on small scale investigations focusing upon single species, such as this one, carbon can generally be ignored (Smith, 1972; Ambrose & DeNiro, 1986; Kelly, 2000).

7.2.3.1. Avian Claws

Claws were used because unlike other animal tissue which can be tested for stable isotope analysis (e.g. blood or muscle tissue) there is no degradation of isotopes over time (Bearhop *et al.,* 2003). Collection of claw material is also a non-invasive method that requires minimal training. An alternative non-invasive method of material collection is the analysis of isotope ratios within feathers. However, the time required for the feathers to grow is species specific and often takes longer than the time available for this investigation. Material which has a high growth rate that covers a period of weeks and/or months is more suitable for diet analysis during the breeding season. Isotopic results from claws are no different to other potential tissues, with a higher rate of growth than feathers (Bearhop *et al.,* 2003). However, claw growth is also species-specific, and there are no published studies reporting the growth rate for tree sparrows.

To determine tree sparrow claw growth rates and test the effect of different diets on the isotope ratios of the claws, ten wild-caught tree sparrows were housed in cages for 1 – 13 weeks. After initial capture, individuals were ringed and their biometrics recorded. Claw samples were collected at capture and the remaining claw was marked with a scalpel; subsequent growth therefore represented the controlled diet. To avoid discomfort to the birds, claw tips were collected from each individual with care as not to cut through the quick, a blood supply which runs through the centre of the claw. Tree sparrows have anisodactyl feet, with 3 toes facing forward and 1 back (the hallux). The largest claws, the hallux and the 3rd toe (front middle), were marked with a scalpel where the claw emerged from the root. These birds were subsequently handled from the cage and the distance between the root and the mark was recorded, using calipers (to an accuracy of ± 0.01 mm). Comparing the mean distance between the scalpel mark and the root over the time between measurements provided an approximate growth rate. Once claw tips had been collected, an approximate timeline for claw growth which represented that particular diet could be determined. Bearhop *et al.* (2003) reported no significant difference in growth rates between different toes of an individual or between individuals within the same species of five Palearctic passerines. Avian claws are unlikely to grow in a simple linear fashion, as in humans. The proposed method of recording claw growth rate was, however, considered accurate for the requirements of this investigation.

Samples were taken from the tip of all claws for stable isotopic analysis. Claw samples were collected within the field and then stored in a freezer before being couriered to the UK for analysis. This method only yields small amounts of material which was problematic for the subsequent analysis (see below).

7.2.3.1.1. Baseline Control Diets

Five cages (with approximate dimensions 500 mm high, with a floor area of 600 mm x 500 mm) were used for this investigation. Each cage was populated with either 1 or 2 birds. The birds in each cage were maintained on one of the monitored diets, and claws were sampled over time to establish reference isotope ratio values for each of the monitored diets. These reference ratios were then used as a comparison to results from wild caught individuals to inform an approximate trophic level of the wild diet. Food and water was prepared and provided in bowls, allowing birds to feed *ad libitum*. Mixed diets were blended to avoid birds '*cherry-picking*' desired or preferable food. Food bowls were weighed twice a day to determine food consumption rates for each cage, taking into account any spillage collected from under the cage. Food was sieved to remove empty husks, along with other food waste and droppings, before weighing. Food was supplemented with a maximum of ⅓ commercially available bird food to ensure that the birds had an adequate nutrient supply. This commercially produced food consisted of both animal (blood meal and fish oils) and vegetable (mixed cereal grains) matter. Diets provided were; rice (⅔ rice, ⅓ supplement), invertebrate (⅔ invertebrate, ⅓ supplement), and mixed (⅓ rice, ⅓ invertebrate, ⅓ supplement). Individuals which died (*n = 3*) or escaped (*n = 2*) were replaced during the next session of mist-netting.

Cages were kept at a secure location on the IRRI experiment station. Handling procedures and husbandry was conducted in accordance with the 'Laboratory birds: refinements in husbandry and procedures' (Laboratory Animals Ltd. 2001). Birds were handled initially every week to record individual weight and claw growth. Weight was collected to monitor the bird's welfare, to measure any weight loss and if more than 30 % of the individual's total weight was lost, birds were released. Claw growth was measured to calculate a rate of claw growth, giving an approximate date as to when the claw grew, used to determine the diet at a specific time.

However this was deemed too stressful on the individuals and was reduced to fortnightly and then halted after 6 weeks. Birds were released on completion of data collection.

7.2.3.1.2. Wild Diet

Mist-netting was conducted between January and June 2014, with intervals of 3 and 4 weeks between sessions, and coincided with the dry season crop at the IRRI experimental station. Mist-nets were erected close to observed flocks of birds, often close to farm infrastructure to give the best chance for capture success. Trapping was conducted on consecutive days until a monthly quota had been filled. The monthly quota was part of the WGP to capture wild birds, approved by the DENR. Birds were either used for diet studies placed in cages, were euthanized or had their claws clipped and then released. All non-target species were ringed and released.

7.2.3.2. Potential Prey Items

Potential food items of the tree sparrow were collected and identified to provide a background reading of the stable isotope ratios for ^{13}C and ^{15}N within the habitat. The plant food items collected were six weed samples (*Alternathera philoxenoides, Chloris Barbara, Cynodon dactylon, Cyperus iria, Echinochloa colona*, and *Panicum repens*). The invertebrate food items were green planthopper (*Siphanta acuta*) and brown planthopper (*Nilaparvata lugens*), which were obtained from captive populations and indicative of free-living populations.

In addition, mealworms were purchased from a local pet store, as a substitute of other potential prey items within the rice fields, and either starved or maintained on a diet of rice, to determine if the invertebrate's diet affects isotope ratio during analysis. They were then analysed to determine levels of ^{13}C and ^{15}N to see if the diet of the invertebrates themselves would have any effect on the claw results.

7.2.3.3. Stable Isotope Analysis

Stable isotope analysis was conducted at two laboratories depending upon the weight of the samples. Baseline diet samples of vegetative matter and invertebrates were processed by the Grain Quality and Nutrition Services Laboratory (GQNSL), IRRI, Los Baños, Philippines. Avian claw samples were processed by the Quaternary Scientific (Quest), School of Archaeology, Geography and Environmental Science, University of Reading, UK.

All stable isotope ratios are reported in standard δ notation, representing parts per mil (‰), calculated by the standard equation:

$$\delta X = \left[\frac{R_{sample}}{R_{standard}} - 1\right] \times 1000$$

Where X is either ^{13}C or ^{15}N, and R is the ratio of either $^{13}C/^{12}C$ or $^{15}N/^{14}N$. For the baseline at GQNSL; $R_{standard}$ used for $\delta^{13}C$ and $\delta^{15}N$ was an in-house rice plant sample (inhouse-IR364WT, ID155.005), and repeated analysis of standards displayed an accuracy of ± 0.04 ‰ (^{13}C) and ± < 0.01 ‰ (^{15}N). For claw samples; $R_{standard}$ used for $\delta^{13}C$ and $\delta^{15}N$ was; RPG (Reading Pig Gelatine), RFS (Reading Fish Skin), and MethR (Reading Methionine). Repeated analysis of standards displayed an accuracy of ± < 0.01 ‰ (^{13}C) and ± < 0.01 ‰ (^{15}N). Different $R_{standard}$ were used in different laboratories to calculate both ^{13}C and ^{15}N, however these different standards were used for analysis of accuracy within the samples and have no overall effect on the sample ratios produced, meaning comparisons of the results from the two different laboratories can be made.

7.3 Results

7.3.1. Biometrics

The wing formulae for tree sparrows captured on the IRRI experimental station between January and August 2014 is presented in Table 7.1 and Figure 7.1.

Table 7.1 Mean difference of feather length in relation to the longest primary (P8) in centimetres. Standard error in parenthesis, for all birds measured, divided into sexes.

	10	9	7	6	5	4	3	2	1
All birds (*n = 36*)	4.32 (± 0.09)	0.16 (± 0.01)	0.08 (± 0.01)	0.2 (± 0.02)	0.59 (± 0.03)	0.91 (± 0.04)	1.15 (± 0.04)	1.34 (± 0.05)	1.59 (± 0.06)
Female (*n = 12*)	4.23 (± 0.16)	0.15 (± 0.02)	0.10 (± 0.02)	0.31 (± 0.05)	0.55 (± 0.04)	0.81 (± 0.06)	1.09 (± 0.08)	1.28 (± 0.10)	1.58 (± 0.10)
Male (*n = 24*)	4.37 (± 0.11)	0.16 (± 0.02)	0.08 (± 0.01)	0.24 (± 0.02)	0.62 (± 0.03)	0.97 (± 0.04)	1.18 (± 0.05)	1.38 (± 0.06)	1.60 (± 0.07)

To test for any sexual dimorphism within the wing formula, differences between primary feathers were compared (Table 7.2).

Table 7.2 Mean differences between individual feather lengths in centimetres. Standard error in parenthesis, for all birds measured and divided into sexes. Diff. = difference between labelled feathers, e.g. 'Diff. 10 - 9' is the difference between feathers 10 and 9.

	Diff. 10 - 9	Diff. 9 - 8	Diff. 8 - 7	Diff. 7 - 6	Diff. 6 - 5*	Diff. 5 - 4	Diff. 4 - 3	Diff. 3 - 2	Diff. 2 - 1
Total (*n = 36*)	4.17 (± 0.09)	0.16 (± 0.01)	-0.09 (± 0.01)	-0.18 (± 0.02)	-0.33 (± 0.03)	-0.32 (± 0.02)	-0.24 (± 0.02)	-0.20 (± 0.01)	-0.24 (± 0.01)
Female (*n = 12*)	4.09 (± 0.16)	0.15 (± 0.02)	-0.10 (± 0.02)	-0.21 (± 0.04)	-0.24 (± 0.03)	-0.26 (± 0.04)	-0.28 (± 0.04)	-0.20 (± 0.03)	-0.24 (± 0.02)
Male (*n = 24*)	4.22 (± 0.11)	0.16 (± 0.02)	-0.08 (± 0.01)	-0.16 (± 0.02)	-0.37 (± 0.03)	-0.35 (± 0.02)	-0.21 (± 0.02)	-0.20 (± 0.02)	-0.24 (± 0.02)

N.B. * indicates a significant difference between the sexes (t_{32} = -2.492, *p = 0.018*)

Each measurement was compared, between the sexes, in a one-way ANOVA. A single significant difference was recorded in the mean feather measurements between sexes. The distance between the 6th and 5th primary ($t_{32} = -2.492$, $p = 0.018$), where the difference was significantly larger in male wings than female wings. This difference slightly alters the shape of the wing between sexes (Figure 7.1).

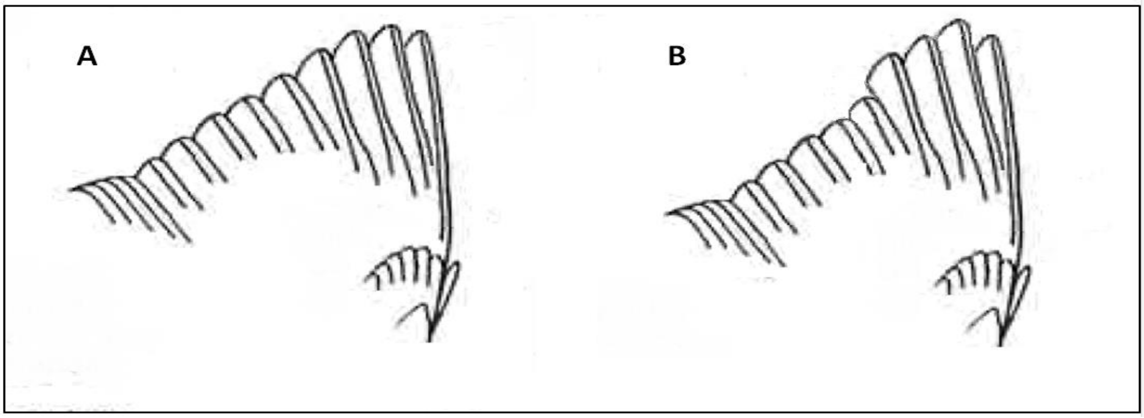

Figure 7.1a Illustration of different wing shapes recorded within Eurasian tree sparrows in the Philippines. The rounded wing (A) represents Female wing measurements, whereas the pointed wing with a clear difference between the 5th and 6th Primary (B) represents the male measurements. Image from Svensson (1992) and edited using Microsoft Paint, not to scale.

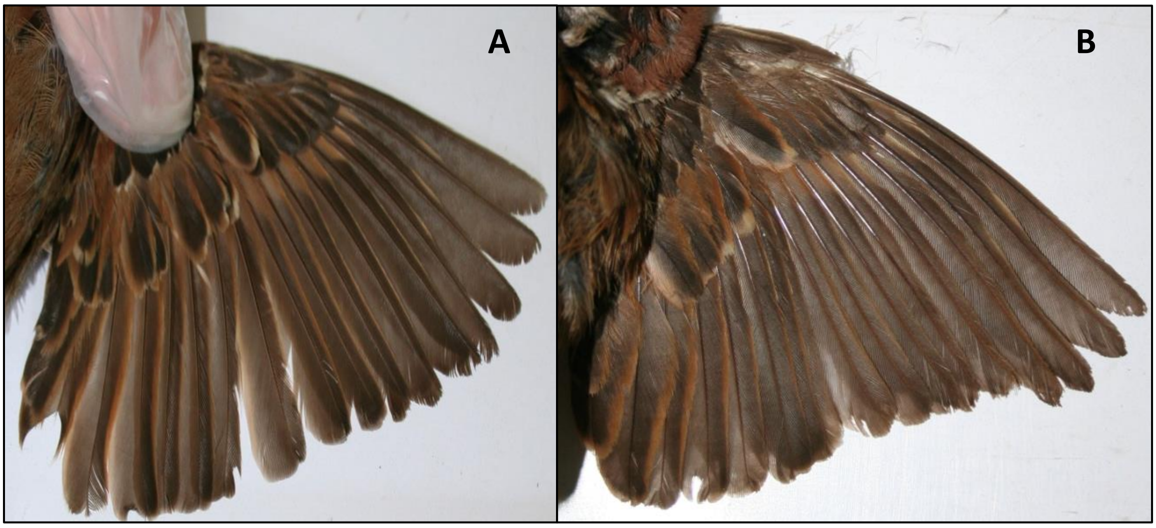

Figure 7.1b Examples of the different wing shapes between sexes in tree sparrows of the Philippines. Picture A is from a female, with more rounded wings, whilst picture B is male, with the large significant difference between the 5th and 6th primary, producing a 'pointed' wing.

Table 7.3 Collected biometric data of dissected Eurasian tree sparrows and reference measurements (Summers-Smith. 1988). Means displayed with standard errors in parenthesis.

Feature	Sub-species	Reference data				Collected data			
		Males		Females		Males (*n = 29*)		Females (*n = 14*)	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
Body Length (mm)	*malaccenis*								
	Saturates					120-146	135.3 (±1.17)	122-149	134.7 (±2.20)
Weight (g)	*malaccenis*	17.5-21.4	19.5	16.8-24	20.4				
	Saturates	22.8-28.7	25.2			12.43-24.02	20.5 (±0.51)	15.09-23.68	21.0 (±0.64)
Wing length (mm)	*malaccenis*	64-76	70	66-74	70				
	Saturates	65-71	68.7	61-69	67.2	61-72	67.6 (±0.54)†	62-69	65.5 (±0.48)†
Tail (mm)	*malaccenis*	52-57	54.5	50-56	53				
	Saturates					46-56	52.1 (±0.50)	46-58	51.2 (±0.89)
Tarsus (mm)	*malaccenis*	15-19*	17*						
	Saturates					12.8-19.5	17.0 (±0.31)	15.4-18.5	17.1 (±0.24)
Culmen (mm)	*malaccenis*	12.5-14*	13.1*						
	Saturates	12.5-16.0*	14.1*			8.2-13.7	11.3 (±0.25)	8.9-12.9	11.7 (±0.31)

*** Not sexed, † significantly different between sexes** $p < 0.05$

Wing length was the only measurement significantly different between the sexes ($F = 5.759$, $df = 1, 40$, $p = 0.021$). Therefore, wing measurement can be used as a rough indication of sex, in the field, for *Passer montanus saturatus* within the Philippines (Table 7.4). However care should be taken as some crossover exists.

Table 7.4 Mean and range of the biometrics of all the Eurasian tree sparrows (*Passer montanus saturatus*) caught in the Philippines. Featured measurements are not sexually dimorphic and include data from unsexed individuals.

Feature	Range	Mean
Body Length (mm)	120 – 149 (*n = 42*)	135.1 (±1.04)
Weight (g)	12.43 – 26 (*n = 56*)	20.8 (±0.34)
Tail (mm)	46 – 58 (*n = 41*)	51.8 (±0.44)
Tarsus (mm)	12.8 – 19.5 (*n = 43*)	17.1 (±0.22)
Culmen (mm)	8.2 – 13.7 (*n = 43*)	11.4 (±0.20)

7.3.2. Nesting

Out of a total of 112 nesting events, monitored in the nest boxes during 2014, two events involved unknown species, and were not considered in the subsequent analysis.

During nest box checks, a number of adult tree sparrows were noted 'fighting' over empty boxes. With high egg productivity in the area, nest box location and nest-site availability as a limiting factor for breeding was considered. These boxes were subsequently checked for signs of activity. Details of the new placement, in relation to the existing nest boxes, can be found in Table 7.5.

Table 7.5 Outcome of erecting 5 additional nest boxes upon the same tree as previously successful nest boxes. Change is in relation to existing nest box as either: Height or Direction of the box (facing of the entrance hole).

Additional Nest box	Changes in relation to existing nest box: Height	Direction	Outcome
1	Same	Different	Continued to use first nest box.
2	Same	Same	Continued to use first nest box.
3	Above	Different	A new nest was built in the new nest box, abandonment of original box.
4	Above	Same	Built new nest in new nest box, abandonment of original box.
5	Above	Different	One brood started in the first box. After, a new brood was laid in each before the typhoon disturbed both nests.

Of the five nest boxes which were erected close to pre-existing boxes (Table 7.5), three of these were used subsequently. The direction in which the nest box was facing did not determine which box was used. In the three boxes which were erected higher, nesting started in the higher boxes and the old boxes were abandoned and did not produce any further broods.

7.3.2.1. Recording the length of the breeding season

The first brood of 2014 was observed on the 28th February 2014. However, the study sites were disrupted by Typhoon Rammasun which had a major effect on nest box brood survival (Figure 7.2).

Typhoon Rammasun (local name: *Glenda*) made landfall in the Philippines in the evening of the 15th July. Approximately 150 km in size, with a sustained wind speed of 150 kmh near the centre but peaking at 232 kmh, the typhoon was given a category 3 rating (Mühr *et al.,* 2014). Losses to agriculture (rice, corn and high value crops) were estimated at PHP4,529,620,307 ($104 million USD; Mühr *et al.,* 2014).

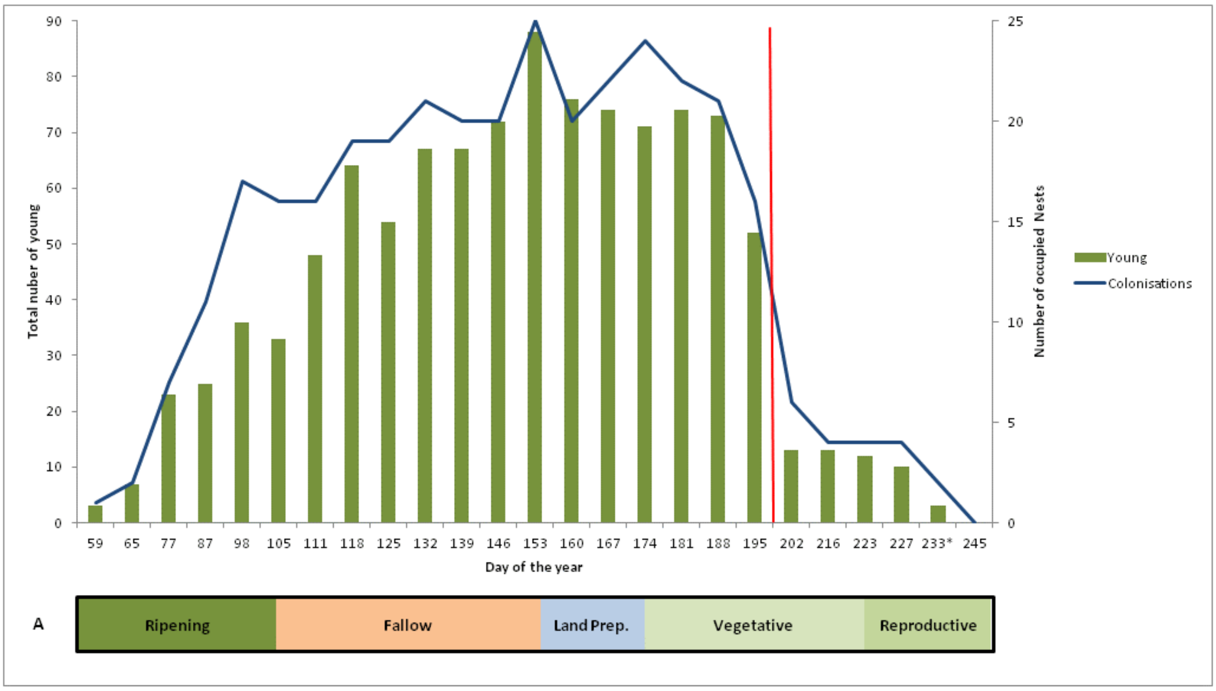

Figure 7.2 Total number of viable eggs and fledglings in the nest boxes, and the number of occupied nest boxes from 28th February 2014 (day 59) to the 2nd September 2014 (day 245). Colonisation is the number of occupied boxes with active nests. Crop stage displayed along the X-axis (A); Fallow = Fallow, these are fields which have been harvested and are generally dry, Vegetative = Vegetative Phase, Reproductive = Reproductive Phase, Ripening = Ripening Phase, and Land Prep. = Land Preparation, when fields are levelled and flooded. Red line represents the date of Typhoon Rammasun. * indicates an audible check of nest boxes, where sounds of chicks in the boxes was noted but not visually checked.

7.3.2.2. Annual Productivity

During 2014, 30 out of a total of 35 nest boxes erected had at least 1 brood, providing an overall occupancy rate of 85.7% (Table 7.6).

Table 7.6 Mean annual tree sparrow nest box productivity (± standard error) of occupied nest boxes, at the IRRI experimental station.

No. of Broods	Clutch Size	Breeding success (%)	No. of fledglings per clutch
3.6 (± 0.21)	3.67 (± 0.09)	52	1.90 (± 0.13)

There was a higher number of broods recorded per nest box when compared to published literature. The number of broods produced within each nest box is displayed in Figure 7.3.

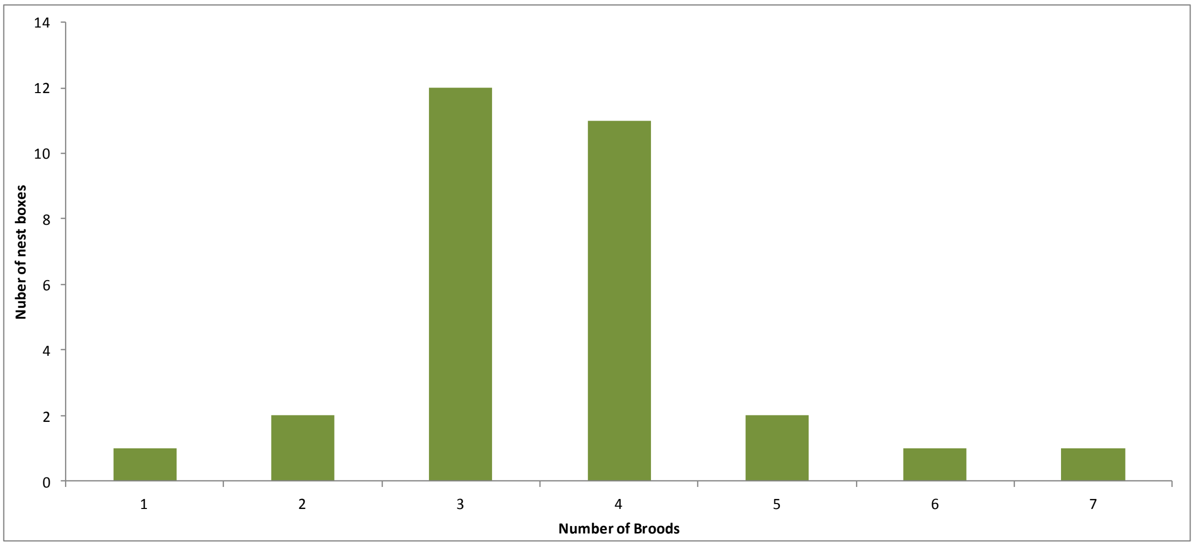

Figure 7.3 Frequency of nest boxes which produced up to seven broods in a single breeding season (*n = 109*).

The mean number of broods was 3.6 (± 0.21) per nest box, (Figure 7.3). However, the success rate was more variable, as displayed through the error bars, within broods from nest boxes with more than 4 broods across the year (Figure 7.4).

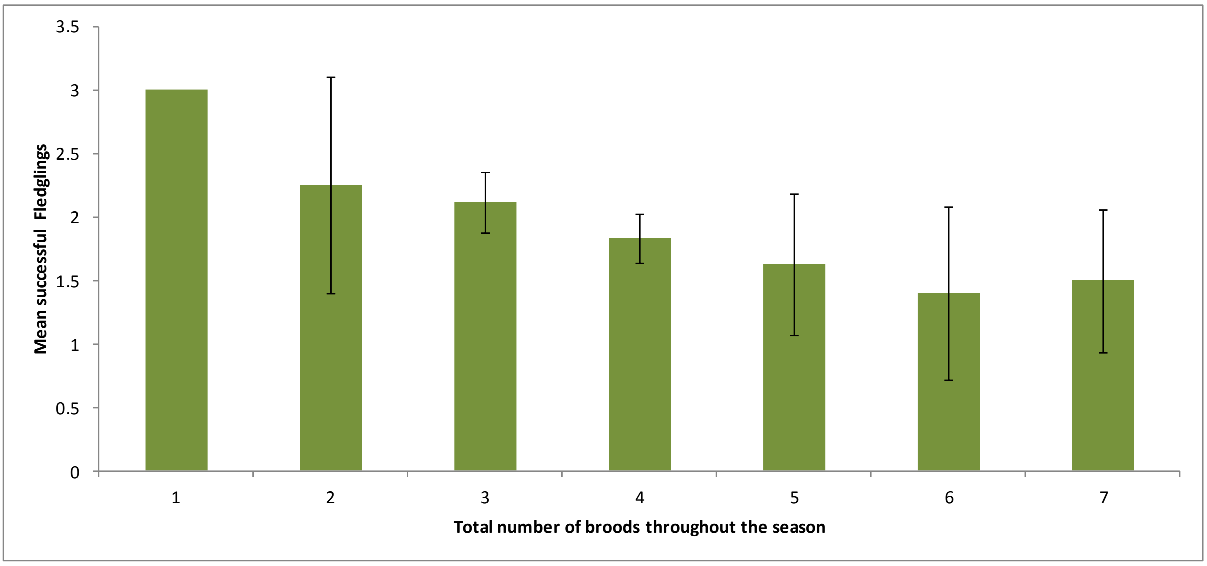

Figure 7.4 Mean number of successfully fledged young by the number of broods (± standard error; *n = 99*). Broods affected by Typhoon Rammasun are not included.

Mean success rate was calculated for; egg to chick, chick to fledgling and egg to fledgling to provide an overall success rate within the Philippines (Table 7.7).

Table 7.7 Nesting success of tree sparrows from egg to chick to fledgling for nest boxes that had between 1 and 7 nesting attempts in the 2014 season. Data are presented both numerically and as a percentage as they progress from eggs to chicks, to fledglings (broods; *n = 99*). Nesting attempts that were affected by Typhoon Rammasun are not included.

Brood Number	Total Number			Percentage Success (%)		
	Egg	Chick	Fledgling	Egg - Chick	Chick - Fledge	Egg – Fledge
1	3	3	3	100	100	100
2	12	9	9	75	100	75
3	121	87	72	72	83	60
4	156	82	75	53	91	48
5	36	20	13	56	65	36
6	12	8	7	67	88	58
7	25	11	9	44	82	36
Total	365	220	188	60	85	52

7.3.2.3. Typhoon Effects

Tree sparrow nesting success was compared before and after the occurrence of Typhoon Rammasun by comparing the percentage of eggs that hatched and chicks that fledged (Table 7.8). All offspring which survived as eggs (*n = 6*) during the typhoon, went on to successfully fledge, the implication that offspring losses was primarily due to chicks in the nest dying.

Table 7.8 Success of young from the nest boxes during a typhoon compared to the total success rate from the earlier season, number of active broods shown in parenthesis. Data is presented as a percentage of those which successfully progressed from eggs to chicks, or chicks to fledglings, based on development (egg or chick) at the time of the typhoon (broods; *n = 99*). Fledglings ready to leave on last visit (1 day before the typhoon), which were missing from boxes after typhoon, were assumed to have fledged and survived.

Conditions (no. of broods)	Percentage Success (%)		
	Egg – Chick	Chick - Fledge	Egg – Fledge
Normal (*n = 99*)	60	85	52
Typhoon (*n = 10*)	29	18	25

7.3.3. Diet

7.3.3.1. Avian Claws

The mean daily growth of claws over the seven day period following initial marking was 0.155mm (± 0.02 mm, *n = 29*), and would thus require 6.45 days for 1 mm of growth. However, subsequent measurements taken between 14 and 29 days after initial marking showed that the apparent growth rate had declined (Figure 7.5). For the remaining calculations, the mean daily rate of 0.155mm was used.

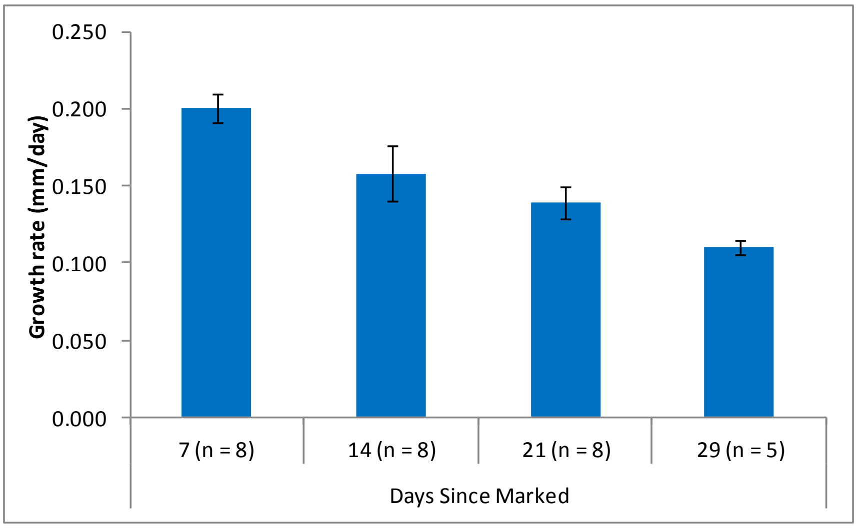

Figure 7.5 Daily claw growth rates (± standard error) of captured tree sparrows at various times since initial capture.

Measurements of the complete hallux and the 3rd toe (front middle) were taken from dissected specimens, with a mean total length of 4.51mm (± 0.08 mm). Assuming consistency in the mean length of the claws and that there was no excessive '*wear and tear*' then 1 mm taken from the tip of a claw represents 6.45 days' worth of growth, approximately 23 days prior to collection.

7.3.3.1.1. Baseline control diets

Diets were adjusted to include 33% of a commercially available maintenance diet (⅓). Thus for welfare considerations, the results relate to a control diet consisting of 66% of the investigated food item and 33% of the maintenance diet (Figure 7.6).

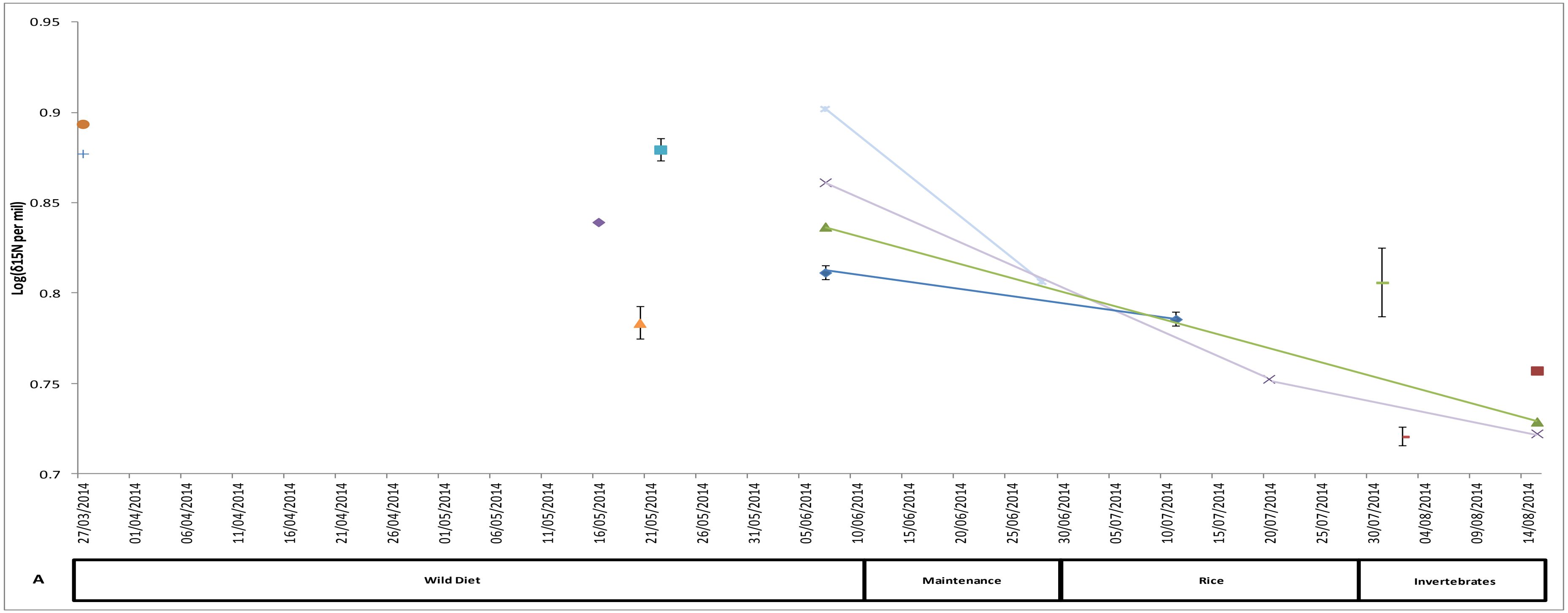

Figure 7.6 Log($\delta^{15}N$) of claws for control birds trapped from the wild between 27/03/2014 and 07/06/2014, when habitats were predominantly in the fallow / land preparation phase. Isotope ratios, shown as a unique symbol for each individual bird, on date of collection. Diet 23 days previous, displayed on row A of the X - axis.

There was a significant difference in the mean claw $\delta^{15}N$ content between the three diet groups (*$F = 21.38$, $df = 2, 20$, $p < 0.001$*). Highest $\delta^{15}N$ content was in the wild diet group and the lowest $\delta^{15}N$ content was in the invertebrate diet group (Figure 7.7).

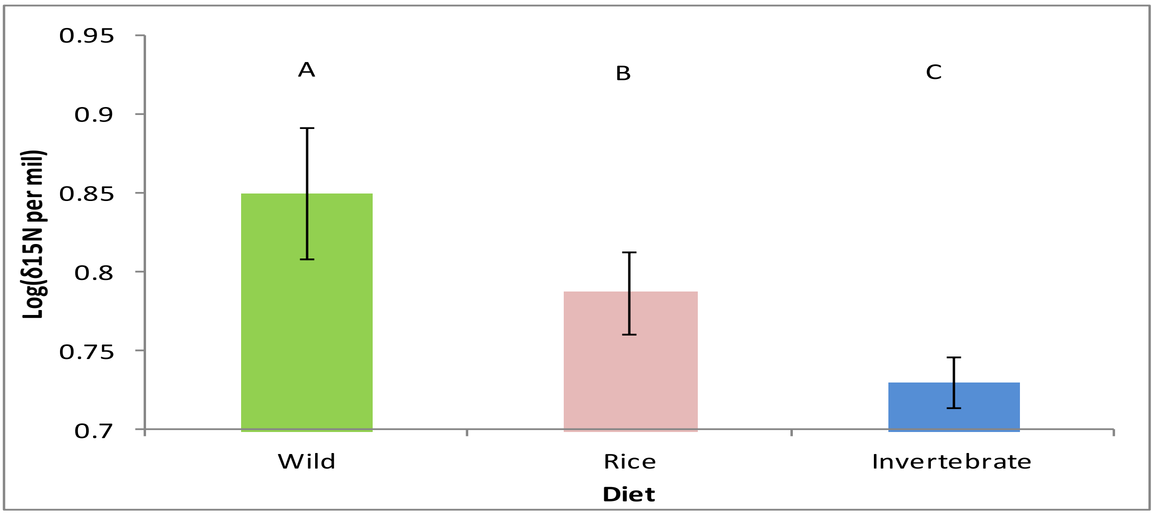

Figure 7.7 The mean Log($\delta^{15}N$) content of tree sparrow claw samples taken from groups presented with three different diets. Group A were control birds captured from the wild, which had previously been feeding on a natural diet (*$n = 11$*), and group B and C were test birds that had been fed diets that were predominantly rice (*$n = 5$*) and invertebrates (*$n = 5$*) respectively, for the preceding 23 days.

7.3.3.1.2. Wild Diet

Ratios of $\delta^{15}N$ and $\delta^{13}C$ were analysed and compared between the different field stages, at time of capture (Figure 7.8).

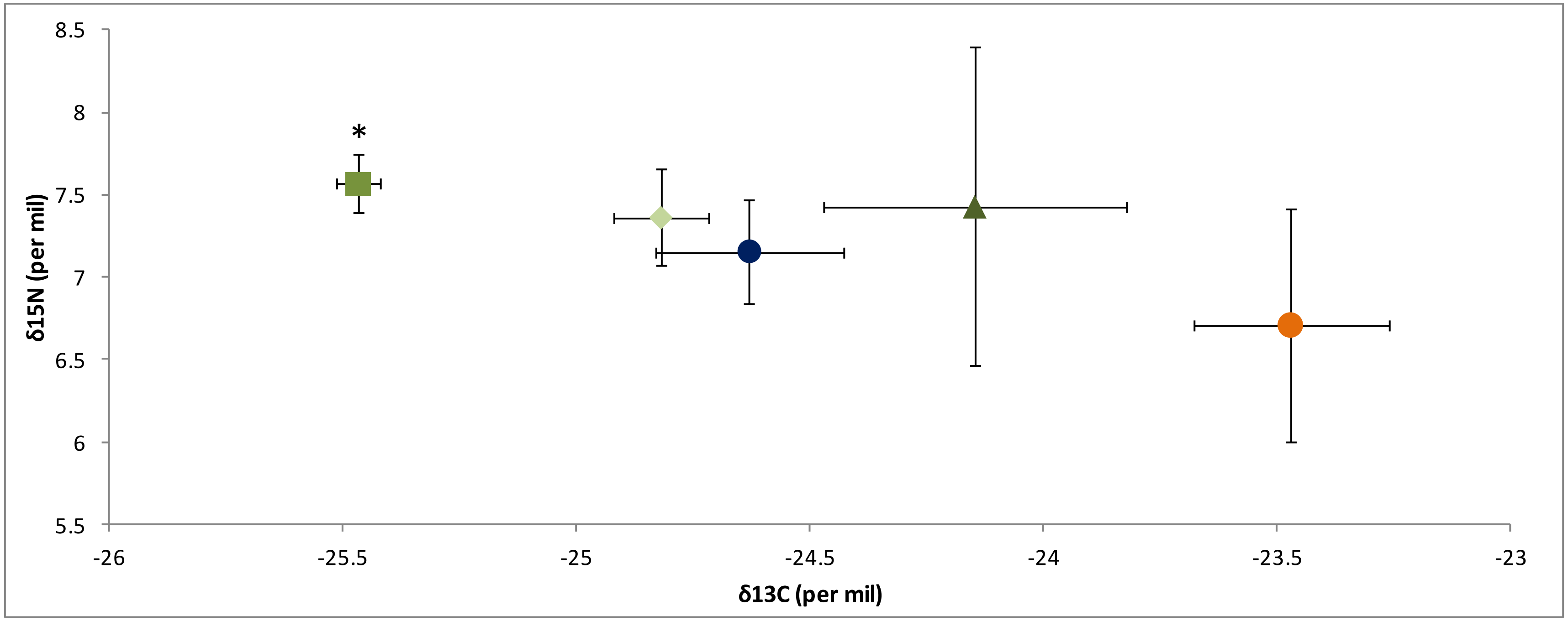

Figure 7.8 Mean $\delta^{13}C$ and $\delta^{15}N$ (± standard error) content of tree sparrow claw samples of wild-caught tree sparrows (*n = 38*), per crop stage. Colours are indications of field stage at capture; blue circle = land preparation, light green diamond = vegetative phase, bright green square = reproductive phase, dark green triangle = ripening phase, orange circle = fallow fields. The data marked with an asterisk (*), from the reproductive phase, are displayed here but were not used during analysis due to insufficient sample size.

There was no significant difference in $\delta^{15}N$ values, from the claws of wild birds collected during different crop stages (*F = 0.56, df = 4, 33, p = 0.693*; Figure 7.8). As only 3 samples were collected during the reproductive phase, these were removed from the analysis. The samples are unlikely to represent the field stage during capture, but the 23 days prior to capture. However, as differences between field stages were not significant, results are displayed against field stage at capture.

Individual tree sparrows which had rice grain noted within their digestive system (either in the crop or stomach) during dissection, are displayed per field stage below (Table 7.9).

Table 7.9 Number of dissected tree sparrows found with rice within their digestive tract during different field stages. Fallow = Fallow, these are fields which have been harvested and are generally dry, Vegetative = Vegetative Phase, Reproductive = Reproductive Phase, Ripening = Ripening Phase, and Land Prep. = Land Preparation, when fields are levelled and flooded.

	Land Prep.	**Vegetative**	**Reproductive**	**Ripening**	**Fallow**
Number of birds dissected	8	8	3	11	8
Number of birds with rice found in digestive tract	7	5	0	4	4
Percentage of birds eating rice per field stage.	87.5 %	62.5 %	0 %	36 %	50 %

7.3.3.2. Prey Items

Ratios of $\delta^{15}N$ and $\delta^{13}C$ for all collected potential prey items of the tree sparrow were analysed to create a '*background map of ratios*' available within a lowland irrigated rice habitat (Figure 7.9).

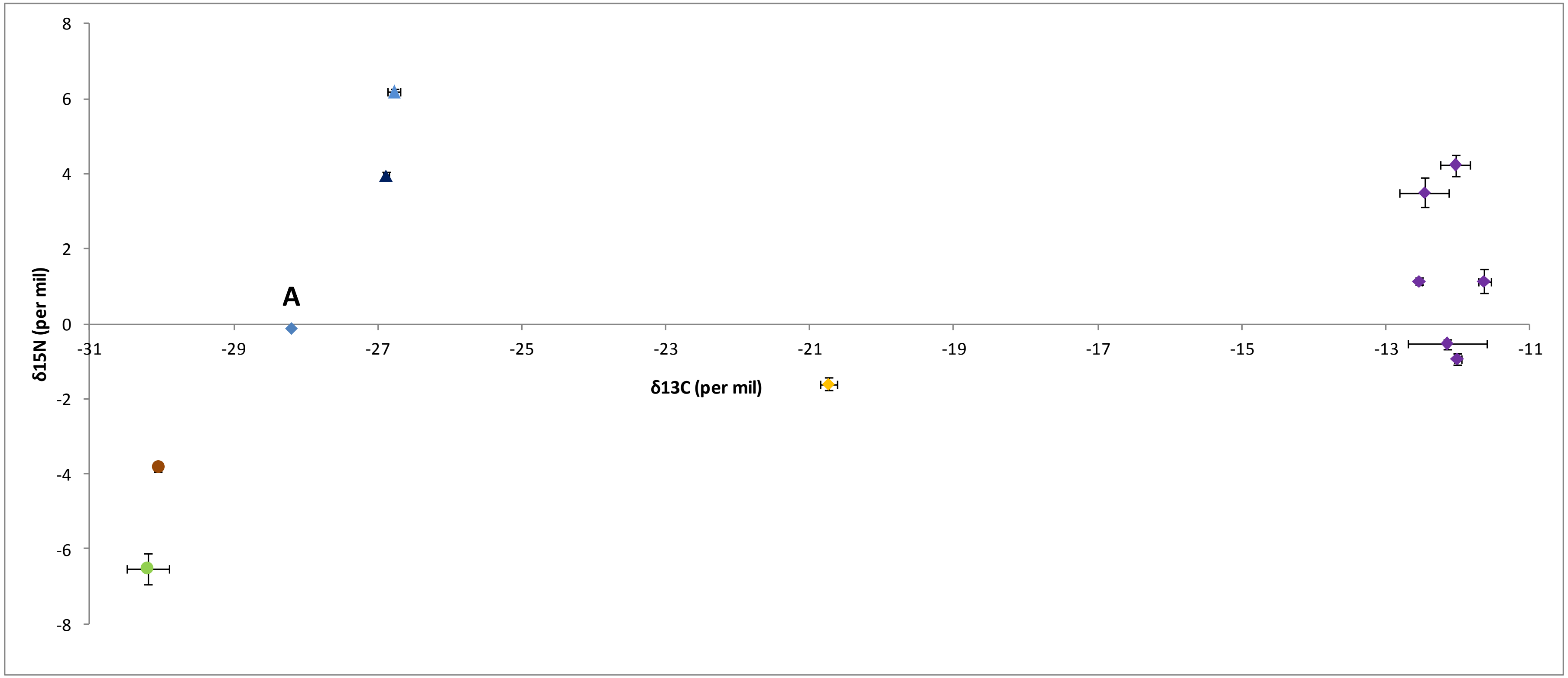

Figure 7.9 Mean $\delta^{13}C$ and $\delta^{15}N$ (± standard error) of potential prey items found within a lowland irrigated rice field habitat. Colours indicate differences in items; purple diamonds= weeds, blue triangles = mealworms (lighter = starved, dark = fed on rice); orange = commercial bird food, brown circle = brown planthopper; and green circle = green planthopper. Stable isotope standard '*155.05 rice*' labelled 'A'

Post-hoc analysis revealed the mean amount of daily food taken was dependent upon which food was available. Diets consisting of a single food item (rice or invertebrates) had more daily food taken than the mixed diets (Figure 7.10).

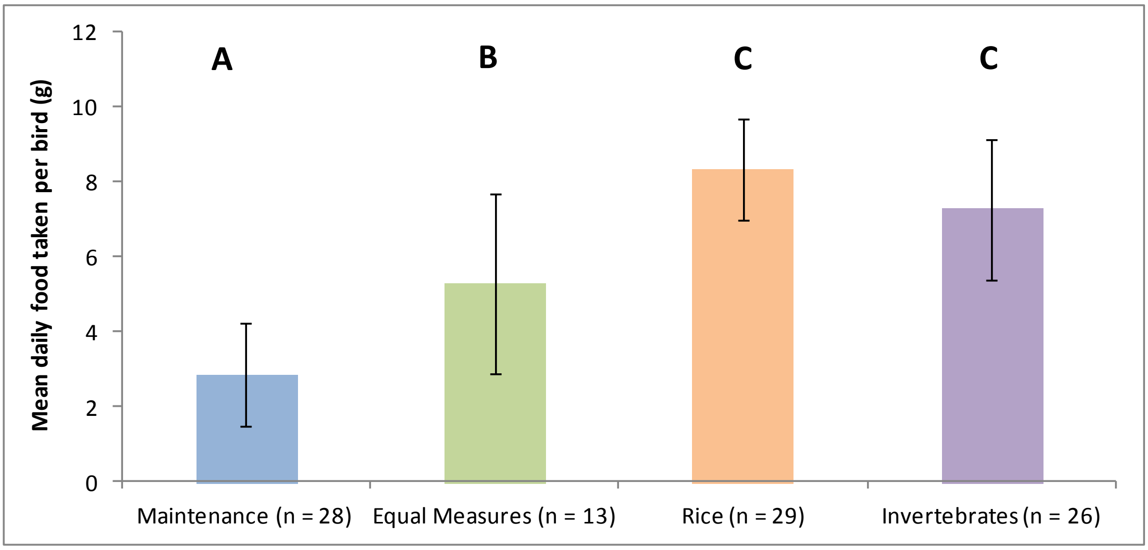

Figure 7.10 Mean daily food intake (± standard error) per bird in grams. Equal measures diet was; ⅓ rice, ⅓ invertebrates and ⅓ bird food, ground to avoid bird preference in food choice. Alphabetised labels represent *post hoc* groupings.

There was a significant difference in the mean amount of food taken per food item ($F = 56.738$, $df = 95$, $p < 0.001$). Groupings A, B and C represent significant differences in amounts taken per individual, with Group C indicating that the amount of rice and invertebrates taken were similar in their total amount, but different from the maintenance and equal measures diet.

All tree sparrow claw results were displayed in relation to the other collected samples for ^{13}C and ^{15}N (Figure 7.11).

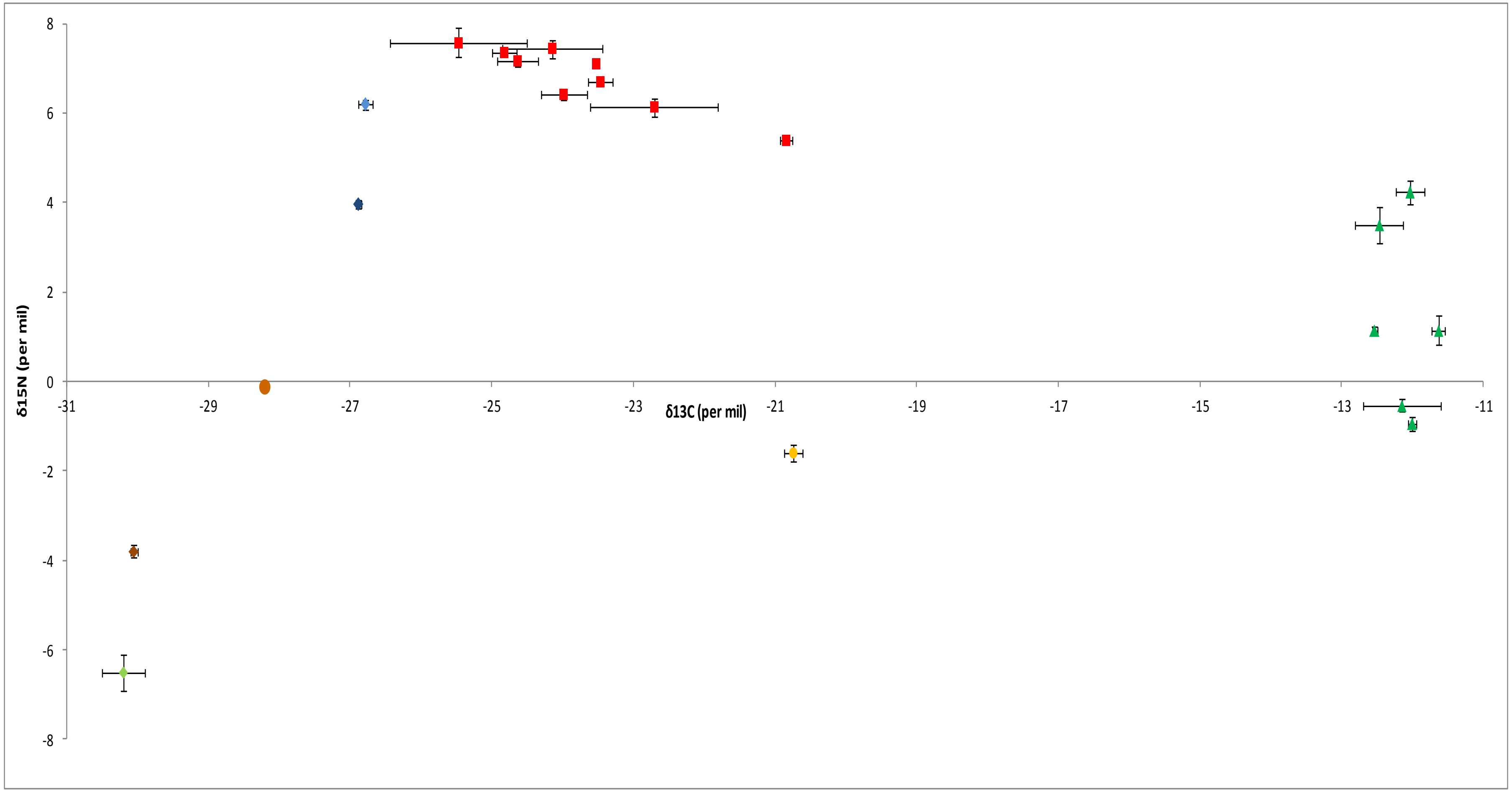

Figure 7.11 Mean $\delta^{13}C$ and $\delta^{15}N$ (± standard error) for all bird claws compared to tested prey items. Colours indicate different items; green triangles = weeds, blue diamond= mealworms (lighter = starved, dark = fed on rice); orange circle = rice (isotope standard); Yellow circle = commercial bird food; brown diamond = brown planthopper; green diamond = green planthopper and red squares = avian claws (data from Figure 7.8 and Figure 7.9).

7.4 Discussion

7.4.1. Biometrics

It is believed that this is the first documented wing formula for *Passer montanus saturatus* within the Philippines (Table 7.1). The significant differences between males and females recorded (Table 7.2) is unusual as, unlike other passerine birds, there is no sexual dimorphism currently recognised within tree sparrows (*Passer montanus*). Both sexes displayed a 'rounded' wing formation but the significant difference in the male wing formula elongates the wing and causes the 9^{th}, 8^{th}, 7^{th} and 6^{th} primaries to protrude. This pointed wing is often associated with migratory species (Marchetti *et al.,* 1995; Burns, 2003), as the shape aids long-distance flight (Baltag & Ion, 2012). The more rounded female wing is associated with shorter bursts of flight and better predator avoidance (Swaddle & Lockwood, 2003). The differences recorded within this study might indicate a difference in life cycles between the sexes. Males may move longer distances within the Philippines, potentially during seasonal migration, but females may stay within the same areas throughout the year. Senar *et al.* (1994) found that wintering resident siskins (*Carduelis spinus*) had shorter primaries than those which moved continuously throughout winter, though both sexes migrated.

Many studies have been conducted on wing shape in relation to migration strategy, but suggest that relative fuel load, the optimum feeding weight for predator avoidance, is a better predictor of shape (Burns, 2003). Weight effects manoeuvrability (Hedenström, 1992) and can have an effect upon predator avoidance. Heavier blackcaps have a lower angle of flight, which is the angle of the wing in relation to the air stream (as angle increases, so does lift), which increases their chance of being hunted (Kullberg *et al*., 1996; 2000). This was also found in European robins (Lind *et al*., 1999). However, with no significant differences in weight recorded between the sexes within this investigation it is unlikely to explain the differences in wing formula.

There is limited biometric information available for the different sub-species of tree sparrow that was introduced to the Philippines, or in its native range. Reference skin collections are unavailable, and there is no information available on the degree of hybridisation that occurs between the different sub-species; certain measurements were consistent with *P. montanus malaccenis* and other measurements consistent with *P. montanus saturatus* (Table 7.3). The data collected here appear to correspond more with *Passer montanus saturatus* than with *Passer montanus malaccenis.*

7.4.2. Tree Sparrow Nesting Productivity

Only 2 of 112 nesting attempts recorded within the nest boxes were not tree sparrows. Unfortunately, neither of these broods survived to hatching and it was not possible to confirm their identification. During a previous check, before one of these broods was laid, a pair of yellow-vented bulbuls (*Pycnonotus goiavier*) was noted close to the box. They appeared to be agitated and started calling when an observer came close. However these birds tend to form a cup shaped nest out of vegetation, (Kennedy *et al.,* 2000) and therefore it is unlikely that this species accounts for one of the unknown broods.

Unlike other sparrows, the tree sparrows in this investigation were not recorded nesting communally even when an empty nest box was close by. Nest boxes were placed approximately 2 to 3 metres above the ground, but when given a higher option, birds moved to the new higher box. Elsewhere within their range tree sparrows are known to nest between 2 and 8 metres above ground, although this is likely to occur because of the availability of nest sites (Summers-Smith, 1995). When nest boxes were at an equal height and close together, only one was used. The behaviour of the birds suggests a form of territorial behaviour, as adult birds were seen 'chasing' other adults away (*pers. obs.*). This seems to contradict published evidence from elsewhere within their range (Ticehurst & Whistler, 1930; Summers-Smith, 1995).

7.4.2.1. Recording the Length of the Breeding Season

The collection of nesting material was observed from November 2013 and the first clutches of eggs (*n = 3*) were found in a nest box on the 28th February 2014. Assuming an egg had been laid on the day of discovery, and that a female produces a single egg each day (Summers-Smith, 1988), this would make the 26th February as the date for the laying of the first egg. The number of breeding attempts increased in the surrounding nest boxes in the following week, providing a clear indication of the onset of breeding. A single individual, caught on the 26th February as part of the diet analysis study, had a small number of eggs developing internally upon dissection, providing further evidence of the start of the breeding season.

Summers-Smith (1995) reviewed literature on the effect of latitude on the start of the tree sparrow breeding season and produced the following linear regression for latitudes, ranging from close to the equator to 55°N:

$$y = 32.7 + 1.61x$$

(Summers-Smith, 1995)

Where y is the day of the year and x is the latitude of the study site.

The IRRI experimental station is located at 14°N which produces a y value of 55.24. In 2014, day 55 was equal to the 24th February, only two days before the 26th February (Day 57) which was when the first egg was thought to have been laid during this investigation. Although there were only limited data points available for lower latitudes in the Summers-Smith (1995) regression analysis, the data collected in this investigation provides further evidence to support his conclusions.

In European countries, tree sparrows display three clearly defined peaks of production throughout the season, with synchronised laying (Summers-Smith 1995). This pattern was not observed in this investigation (Figure 7.2), with only a single peak at day 153 (June 2nd). It might be that the tree sparrows are not as restricted in food availability as those found within Europe (Field & Anderson, 2004) allowing them to breed over a longer time period. Alternatively, synchronised breeding might be associated with the European populations and not those which occur within the Philippines.

If single pairs of tree sparrows repeatedly used the same nest boxes throughout each breeding season, each brood would have the same parents and any changes in inter-brood success rates would primarily be a product of environmental factors rather than parenting skill. However, this assumption is most likely untrue. The rapid turnover in the majority of nest boxes, with new breeding attempts quickly following the fledging of the previous brood of chicks would strongly suggest different parents successively using the same nest boxes, with either one or both parent changing with each breeding attempt. In the present study, establishing the individual identities of the parent birds was not possible, and it is likely that a dominance hierarchy will determine exactly which individuals are able to occupy each nest box at any particular time.

This investigation assumed all clutches of eggs and broods of chicks found within the nest boxes were produced by a single pair of adult birds. However, if multiple pairs were using the same box because potential nest sites were a limiting factor, different breeding pairs may be using the same nest sites. This would suggest that as one pair is still caring for fledged young outside of the box, another pair takes the opportunity to use the now vacant nest box. If true, then nest site availability appears to be a limiting factor for breeding in tree sparrows of the Philippines. Thus breeding will coincide with available space opposed to synchronised breeding, as displayed in literature.

The end of the breeding season is difficult to determine with any accuracy. Unlike other breeding populations of tree sparrows, there was only one peak in nest box occupation throughout the breeding season, and the total number of occupied nest boxes was already in decline on the 2nd June. A large drop in the number of active nest boxes and young was recorded on the 14th July (Day 195), the last check before typhoon Rammasun passed over, which is strong evidence that tree sparrow breeding activity was naturally decreasing at this time of year. However, the typhoon may have brought on this reduction in overall breeding activity sooner, when compared to other breeding seasons with no typhoons.

An interesting observation is that parental birds tended to spend more time on top of the nest box rather than inside (*pers. obs.*). Deckert (1962) found that eggs were incubated for 71 – 86% (mean 79%) of the daylight hours. The birds observed and recorded during this investigation were regularly seen outside of the box and, with the exception of one record, never found within the box during nest checks. Deckert (1962) noted a reduction in time spent brooding hatchlings, and reported no brooding when temperatures were around 28°C, although there was no mention of reductions in incubation time as a result of temperature. The mean temperature during data collection was 27.3°C (± 3.4; The Weather Channel 2015d). Avian egg development requires a minimum temperature, between 25 and 27°C for a number of passerine species (Drent, 1975). Although a number of other species do raise the temperature of the eggs higher than this (Podlas & Richner, 2013). Studies on passerine species within the United States of America (USA) reported positive correlations between ambient temperatures and time spent away from the nest (Conway & Martin, 2000a), although time away from the nest tended to be species-specific (Conway & Martin, 2000b). No further literature could be found on reduced incubation periods for tree sparrows and it is believed this is the first time it has been recorded.

7.4.2.2. Annual Productivity

Tree sparrows in a lowland irrigated rice system of the Philippines produced more clutches of eggs than elsewhere within its range. In combination with a much lower number of eggs being laid per clutch (Table 7.6) these data indicate that the population of tree sparrows within the Philippines uses a different breeding strategy than breeding populations in other countries. Tree sparrows have a widespread global distribution and across their range the number of clutches laid each year ranges between 1.53 and 2.76 (Summers-Smith, 1995). This was considerably lower than the mean brood number of 3.6 (± 0.21) recorded in the present study. However, the mean size of the clutch (number of eggs) was smaller at 3.67 (± 0.09) than the 4.54 – 5.56 reported by Summers-Smith (1995).

When considering productivity per nest box, the Philippine population produced slightly more fledglings per nest box (mean of 6.8 fledglings) compared with the global data presented by Summers-Smith (1995). This phenomenon, of tropical birds laying a reduced number of eggs compared to temperate regions is not new (Lack, 1947; Skutch, 1948), but the reason why is still not clear (Skutch, 1985).

Summers-Smith (1995) reported data on tree sparrow productivity from a number of sources covering the species global distribution, with the exception of the Philippines. Indeed, the closest single study was Pantuwatana *et al.* (1969) in Bang Phra, Thailand (13°12'N; 100°57'E), who noted nests being built from December through until June, although no data were presented. Comparisons were therefore made between the data of Summers-Smith (1995) and those from the present study. Overall, tree sparrow success rate within the Philippine study sites was lower (52%; Table 7.6, Table 7.7) than the global average (62.5%; Summers-Smith, 1995). This difference was due to a reduced success rate in hatched eggs (Philippines: 60%; Global: 78.1%) though there was an increase in the success rate of fledged chicks (Philippines: 85%, Global: 80%). The loss of eggs, either through infertility or predation, has the strongest influence on productivity as the study data suggests that if an egg were to hatch, then it was likely to fledge. The rice fields therefore provide a good habitat for raising young, with an abundance of food available to the parents so that they can achieve a high fledgling success.

Parental birds could not be colour ringed during this investigation to determine pair-bonds or potential monogamy, as adult birds were often recorded on top of the nest boxes rather than inside. In previous literature, the majority of which is from temperate regions, adult birds resided within the nest box, making capture and colour-ringing an effective method of tracking individuals. With the Philippine birds on top of the box, human disturbance prompted these birds to fly into the over-head canopy, out of reach. Furthermore, mist-netting conducted in the vicinity of the nest boxes was not successful. It is proposed that for tree sparrows in nest boxes, egg brooding in a tropical climate is less critical than in temperate regions, and does not rely on the presence of the parent birds to the same degree. In future work, colour ringing of adult birds would be of great help in understanding the breeding dynamics of the parent birds that successively occupy the nest boxes.

For logistical reasons, this investigation only considered tree sparrow nesting attempts within nest boxes. The tree sparrow is predominantly a hole breeder (Summers-Smith, 1995), and in the Philippines is often recorded nesting around human infrastructure and less so in tree holes (Ruan & Zheng, 1991), especially where the species does not overlap with house sparrow (*Passer* *domesticus*) populations (Summers-Smith, 1995). Few natural nests were found during this investigation, but small flocks were seen in infrastructure (e.g. air conditioning units) along with tree crowns in the area, mostly coconut palms (*pers. obs.*). Therefore the figures given here may be higher than the success rate of tree sparrows which breed in 'naturally established' nest sites (Nilsson, 1975).

7.4.2.3. Typhoon Effects

During the second week of July (15th – 16th) 2014 Typhoon Rammasun passed directly over the IRRI experimental station, effecting all active nest boxes. The typhoon made land-fall at 17:00, 15th July, and emerged into the South China Sea around 00:00 on the 16th July, with a maximum recorded 1-minute sustained wind speed of 193 kph. Within the study areas, the effect of a typhoon passing directly over active nests reduced the productivity by over half (52% to 25%). The hatching success rate of tree sparrow eggs within the Philippines was estimated to be 60%, but following the passage of typhoon Rammasun this figure dropped to 29% (Table 7.8). In nests where chicks were present, the fledging success rate dropped from 85% prior to the typhoon, to 18% following the passage of the typhoon. These results are not surprising, as eggs only need to be kept warm to survive, while young birds require regular feeding, an activity that is very likely to be affected by the typhoon.

Investigating the direct effects of severe weather events is logistically difficult (Jones *et al.,* 2001), with many studies concentrating on waterbirds (McNicholl & Hogan, 1979; Shepherd *et al.,* 1991; Wiley & Wunderle, 1993). Other studies have investigated post-typhoon effects, such as reduced food availability (Shepherd *et al.,* 1991), impacts on avian community structure (Seki, 2005) and availability of nest sites (Jones, 1980; Jones *et al.,* 2001). However, the present study is believed to provide the first quantifiable data set demonstrating the direct effect of a typhoon on tree sparrow breeding success.

7.4.3. Diet

7.4.3.1. Avian Claws

The 1 mm tip of the claw was calculated to represent 6.45 days of food digested 23 to 29 days previously (Figure 7.5). The above calculations were made using mean claw lengths, and based on the assumption that the claw growth rate is consistent for all toes, with no significant difference between individual birds. However, caution is advised when interpreting these results as the measured growth rate over time was not consistent, and it is unlikely that the claws are growing in a single linear direction. Unlike previous studies, which relied on the recapture of marked wild-caught individuals, having a captive population for this investigation allowed growth rates to be calculated periodically for a small number of individuals. The change in growth rate could be due to measuring error over time. The mark on the claw was made laterally, down the side of the claw, running along the root. Measurements to the root were taken from the centre of the scalpel line as it was suspected that the top of the claw would grow quicker than the underside, due to the claw's curvature. Therefore this measurement was susceptible to measuring error. The change in growth rate might be due to a change in conditions such as being caged, indicating that captivity might have had a negative effect upon the individuals.

The growth direction of the claw might contribute to this change in rate, as over time, marks on the claw were difficult to identify. This might represent growth of an avian claw over two dimensions; from the root, adding to the length, but also outwards from the quick, adding to the girth of the claw. Therefore as keratin is replaced under the mark of the claw, it moves away from the quick and either is filled in over time, or simply the surrounding claw is eroded away, reducing the size of the mark.

The mean daily claw growth rate calculated here is much greater than that reported for other species. Bearhop *et al.* (2003) recorded mean growth in 5 Palearctic species at 0.04 ± 0.01 mm day^{-1} ($n = 43$, ranging from 0.02 – 0.06 mm day^{-1}). Bearhop *et al.* (2003) states that there is a species level difference in growth rates between some bird species which might explain the difference recorded here.

7.4.3.1.1. Baseline Control Diets

At the beginning of the diet investigation the initial control group were captured and biometrics taken, including the collection of some claw material. However, most birds lost a considerable amount of body weight (≤ 20% of capture weight) within their first week of captivity, when their diet consisted of a single food item.

Many wild vertebrates will readily lose body weight when confined in an artificial enclosure, and this is believed to be partly as a result of being maintained in a stressful artificial environment. The food consumption of the animal is also reduced because of the induced stress. As a consequence, it is very difficult to establish to what extent the loss in body weight of recently captured wild animals is due to the nutritional quality of a particular food.

As insurance and for welfare reasons, supplementary food consisting of vegetable and fish matter was added to the control diet in an attempt to reduce the loss in body weight. However, further birds captured for the control trials also lost a considerable amount of body weight after capture.

This is similar to Feare and McGinnity (1986) who found that to maintain weight, captive starlings needed half of their daily food intake to consist of invertebrates and could not live on a diet of maize alone. With a mixed diet of the tested substance (67%) plus the supplementary food (33%), the weight loss was never more than 15% of their initial body weight. Fish oils generally display higher ratios of $\delta^{15}N$ when tested due to the nature of aquatic food webs. Therefore diets fed to the control group generally displayed higher figures of $\delta^{15}N$, within the claw, than they would on a pure diet. As previously mentioned, the magnitude of trophic differences in ^{15}N ratios makes this an ideal marker for trophic levels, whereas the small range of ^{13}C means carbon can be ignored (Smith, 1972; Ambrose & DeNiro, 1986; Kelly, 2000).

Control birds were provided with different diets, and claw samples were taken and analysed for Log($\delta^{15}N$) ratios. Log($\delta^{15}N$) ratios of claws taken on the day of capture were much higher than Log($\delta^{15}N$) ratios of claws taken after a minimum of 23 days feeding on the test diet (Figure 7.6).

There was a significant decline in Log($\delta^{15}N$) ratios for claw samples taken from birds that had been fed on a '*rice diet*' (Figure 7.7). It is likely that the ratios for the rice diet are artificially reduced as a result of the addition of the supplementary food (which itself had a very low Log($\delta^{15}N$) ratio), so a '*pure*' rice only diet may be expected to have a higher Log($\delta^{15}N$) ratio. There was still a significant drop in the transition from a '*wild diet*' to the '*rice diet*', suggesting that wild tree sparrows were ingesting much higher levels of $\delta^{15}N$ than they would through a 100% pure diet of rice. It is unusual, however, that the claw results from the invertebrate diet were significantly lower than the rice diet, as it is assumed that the ingested invertebrates would display higher $\delta^{15}N$ ratios, being a trophic level higher than the rice. Considering this, it can be theorised that wild birds were eating other invertebrates, grains and seeds, potentially rice, when they had free feeding choice.

7.4.3.1.2. Wild Diet

Results in Figure 7.8 indicate little variation in food intake throughout the dry growing season within a lowland irrigated rice habitat in the Philippines. Results were expected to show an increase in rice in the diet during the fallow period as the availability of dropped grain increased. These results did display the lowest $\delta^{15}N$ values at the fallow phase which would confirm this (Figure 7.8, Figure 7.9). However it was not found to be statistically significant.

The home range of the tree sparrow is up to 5 km (Summers-Smith, 1995), and with such a large range it is unlikely that all rice fields within that defined area were planted synchronously. Therefore a small overlap of field stages is expected. However, certain field stages such as the vegetative and reproductive phases are not expected to contain any available rice grain within the habitat. This would suggest that tree sparrows were feeding from other prey items during these stages. With no significant differences displayed between the claw ratios at different field stages, it suggests that tree sparrows do not rely on rice for sustenance. Individual birds displayed differences within their $\delta^{15}N$ ratios that were not significant, but suggest a potential choice and preference in food items taken by these birds.

It might be argued that during periods where no rice is available birds are substituting other plant seeds to replace rice. This level of change, between different vegetation types, could not be identified based on the data presented here. The differences in plant material stable isotopes within the claw samples from the control group were not tested. It is likely that the only other plant materials available to the birds are those plants considered weeds within the agricultural habitat. If a change in isotope ratios was present this might suggest that tree sparrows are beneficial to rice farmers, at least during some periods of the year.

Dissections of tree sparrows revealed rice within their digestive tract, both in the crop and stomach (Table 7.9). Rice was identified as it was easier to identify than other plant material (Field & Anderson, 2004). From the five field stages birds were captured in (Land preparation, vegetative, reproductive, ripening and fallow), birds had rice in their digestive tract in 4 stages. The stage when no rice was present within the dissected birds was the reproductive phase. It is during this time that bird scaring devices are sometimes employed. However isotope analysis suggested that the birds are less likely to be eating rice when it is available on the plant, and are more likely to be feeding on the rice once the fields have been harvested. The ripening phase had the lowest percentage of birds with rice in their digestive system (36 %: Table 7.9). The highest percentage of birds with rice in their digestive system was during the land preparation phase (87.5%), when fields had been levelled and often flooded. Therefore, it is likely that the grain was taken from spilled grain on the ground rather than directly from the plants.

7.4.3.2. Prey Items

The claw $\delta^{13}C$ ratios of the tree sparrows were more similar to the $\delta^{13}C$ ratios of the rice reference sample than they are to the $\delta^{13}C$ ratios of the weed reference samples. Without a full breakdown of all weeds and vegetation that occurs within an area of 5 km^2 around the experimental station, it is not possible to be certain which plant species the tree sparrows were feeding from.

The ratios for invertebrates (green and brown planthoppers, and mealworms) covered a potential range of isotopic values expected if they were feeding upon invertebrates. The $\delta^{15}N$ ratios for the planthopper samples were much lower down the $\delta^{15}N$ scale than the mealworms. This difference might be explained by their respective diets. Planthoppers feed on the rice plant sap, whereas the mealworms were fed on rice grains. Information on differences of stable isotope ratios in rice plants during growth, along with the different parts of the plant, might help explain these differences.

The difference between the mealworms fed on a rice diet and those starved demonstrates the ability of prey diet to influence isotope ratios. The rice fed mealworms have a reduced $\delta^{15}N$ ratio compared to the starved individuals.

The birds kept within the control group needed to take in significantly more food when the diet consisted only of a single food item. This was important even when the birds were provided with additional maintenance bird food (Figure 7.10) as measured by the mean daily amount of food taken per bird. The birds were potentially compensating for a reduction in any nutritional value that they were receiving from that food. When the food items (rice and invertebrates) were combined, and ground down. The amount taken per bird decreased, thus supporting the view that the birds require a mixed diet to survive, and cannot maintain body weight or survive when fed on a single food item.

The total $\delta^{15}N$ ratios were higher for all of the wild diet and control groups than the other prey items which were tested (Figure 7.11). Claws displayed the highest $\delta^{15}N$ ratios, placing them above the invertebrates within the trophic levels, though the differences in results were not significant. All claw samples were + 6 ‰ above the rice standard, separating them by a considerable distance on the trophic level (DeNiro & Epstein, 1981; Bockerens & Drucker, 2003). Unfortunately there was not enough information on the invertebrate ratios to positively identify their trophic levels within the food web. It was expected that invertebrates would display higher $\delta^{15}N$ ratios than the weed samples, and predator invertebrates (such as dragonflies and grasshoppers) would display even higher ratios. Considering the overall claw results, the tree sparrows were likely to be on a mixed diet of both vegetation and invertebrates. Considering there was no significant difference over time, this would suggest that the diet did not change during the breeding season. Unfortunately, very few birds were caught outside of the breeding season.

7.5 Conclusion

This investigation focused on two aims: firstly to collect biometric and breeding data for the tree sparrow (*Passer montanus*), specifically the sub-species '*saturatus*' which has been the focus of very little previous work; Secondly to determine if the tree sparrow is a significant pest to rice farmers within the Philippines, by quantifying its diet and whether this changes throughout the dry rice season.

Data presented here outline the probable start and finish dates of the breeding cycle, within the Philippines. The significant difference between wing formula in the males and females suggest a difference in life-style strategies between the two sexes. Information from other passerine species, which show similar differences, suggests females stay in close vicinity to their home-ranges, whilst males travel further and often throughout the year. Information on annual productivity has shown that birds found within Luzon produce, on average, more broods and more eggs per season when compared to other sub-species of tree sparrow. However, the difference in the number which they successfully fledge is only slightly higher overall.

The analysis of claws showed that individual tree sparrows on a restricted diet did have significant differences in $\delta^{15}N$ between different diets. However, comparisons between individuals on a wild diet did not display significant differences in their $\delta^{15}N$ ratios, indicating their diet in the field is likely to be a combination of items, consisting of both invertebrates and vegetation. There was no detectable difference in diet throughout the entire dry season; suggesting their diets were similar throughout and they do not only eat rice but probably a number of other botanical items available to them, such as weed seeds. It is difficult to demonstrate any change in diet outside of the breeding season as data were only collected during the first 8 months of the year, which as noted here, the birds were breeding throughout the majority of this time. However, no change in diet was detected throughout this entire period and is therefore unlikely to change at all. On this basis, hypothesis 1 can be rejected. From the $\delta^{15}N$ ratio data it appears that the diet did not change over the 8 months of data collection, and consequently, the diet does not consist of more invertebrates during the breeding season. Without further data, during the monsoon season, hypothesis 1 is left unanswered.

The methodology used during this investigation was able to detect differences within the diet of the control group. Not enough trials were conducted on the different food items at different ratios to create a definitive answer of whether tree sparrows change their diet over time. A longer control period, with more birds, may provide further information, along with further testing of different combinations of food items to determine if percentages of diets can be detected through claw sampling. The results of this investigation show that rice only forms a small proportion of the diet with peaks in rice consumption following harvest when abundant spilled grain is available. Further testing on control groups may be able to answer what percentages of invertebrate prey are present within the tree sparrow diet in the Philippines.

This chapter will be formatted into three papers for submission into different journals, upon completion of the thesis. 'Biometrics and breeding calendar' as a small note on the sub-species saturatus, *a paper on 'A perceived pest of rice fields and an analysis of their diet using stable isotopes' and a short note 'Typhoon effects on the breeding success of the Eurasian tree sparrow (*Passer montanus saturatus*)'.*

General Discussion

This general discussion integrates the main findings of the previous chapters and discusses the general trends which link them, as well as providing suggestions as to how this work can be expanded in the future. This thesis was the first to specifically document all of the avian diversity present within rice fields of Southeast Asia and provides a foundation for future research. These investigations have recorded factors affecting avian diversity; a preliminary study into the effects of insecticide on avian abundance and diversity (Chapter 3), the avian diversity of rice fields in the Philippines (Chapter 4), recorded the effects of management upon populations (Chapter 5 and Chapter 6) and investigated whether a perceived pest is as bad as it was assumed to be, along with trialling a novel approach to diet analysis using avian claws (Chapter 7). Recommendations for management strategies are given alongside suggestions of future work that can be used to increase our understanding of avian diversity within the rice fields of Southeast Asia.

8.1 Avian diversity of rice fields in Southeast Asia

Previous knowledge about the avian diversity of rice fields in Southeast Asia and its impact on crop productivity was extremely limited, and relied primarily on field observations and dogma within the agricultural community. Mentioned throughout this thesis was the belief that "*all birds eat rice*", a common saying expressed either directly to the researcher or through farmer surveys as part of the work conducted for Chapter 5 and Chapter 6. Birds are visually more obvious in rice fields than other groups of animals, and as a result they are perceived to have a negative effect upon yield although this has not been substantiated (Elphick *et al.*, 2010a).

One general aim of this research was to identify and record the abundance and diversity with which different bird species occurred within the rice field habitat. A total of 130 avian species were recorded within lowland irrigated rice habitats from a combination of surveys and unpublished historical records (2009 – 2014: Bourdin unpublished data: Chapter 4). Only five of the species recorded within rice fields were granivorous, with the potential to feed directly upon the rice and have a negative impact on crop yields. The most abundant granivorous species was the Eurasian tree sparrow (*Passer montanus*). It is an introduced species to the Philippines, and was found to have the second highest abundance of all bird species, second only to swallows. Chapter 7 focused on the diet of the tree sparrow which indicated that the wild diet consisted of a number of items, including rice grains, invertebrates and plant matter throughout the year. No measureable change in diet was recorded between January and August, (the breeding season). As rice grain, developing either upon the plants or dropped as wasted grain during harvest, is not available throughout this period, it is unlikely that the plant matter within the tree sparrows diet is predominantly rice. It is more likely that the tree sparrows are consuming other seeds as they become available throughout the year, e.g. weed seeds. Thus tree sparrows may be providing a beneficial service for the farmers, at least during certain times of the year.

A total of 49 waterbird species were recorded within the rice field habitat, accounting for 37.7% of the total birds recorded (Chapter 4). Most research on avian diversity in rice fields has focused on waterbirds and other bird species associated with wetland habitats (Chapter 1), primarily because of the flooded conditions required for the production of rice. Considering only 38 % of the species recorded in the present study were waterbirds, it is recommended that future work should focus upon the entire community of birds that are present, in order to understand the full impact that changes in practices, specifically new water management, may have.

Thirty one species were considered transient, occurring briefly within the habitat. Although these records were not included in the analyses described above, they do provide an indication of the potential value of the rice crop habitat for birds across the Philippines, and in Asia as a whole.

One of the general research aims of this thesis was to identify annual abundance patterns within the rice fields. The highest numbers of individuals were recorded in the months of February and December, and the highest number of species was recorded in the months of February, March and May (Chapter 4 and Chapter 5). It is however possible that these differences are restricted to the localities of the study sites, and do not reflect the situation across the country as a whole.

At the end of the breeding season tree sparrows are reported to move away from their breeding territory to moult (Summers-Smith, 1995); and this would account for the large drop in numbers observed in the study sites in the month of August (Chapter 4). Work on moulting strategy has been conducted on the tree sparrow in other parts of their range, but to date, there is no published data available for the tree sparrows of the Philippines. During the course of this research, no birds were trapped that were in wing or tail moult (where individual birds possessed both old and new primary tail feathers).

Typhoons are common events in the Philippines. During the course of data collection for this research, two major climatic events occurred:

- Super-typhoon Haiyan (category 5) known in the Philippines as Typhoon Yolanda, occurred in November 2013. It was one of the strongest tropical cyclones ever recorded, devastating large areas of Southeast Asia, and killing at least 6,300 people in the Philippines alone.
- Typhoon Rammasun (category 3), known in the Philippines as Typhoon Glenda, occurred in July 2014, causing a great deal of damage across the Philippines, South China and Vietnam.

Although Haiyan did not pass directly over any of the surveyed sites, peaks in avian abundance during the few months following the typhoon were thought to be birds moving away from affected areas (Chapter 4). These birds had most likely been displaced and were seeking habitat that would provide both shelter and food.

Typhoon Rammasun did pass directly over surveyed sites. Abundance and frequency data were not collected during this time but information on tree sparrow breeding and nest productivity was under investigation. The effect of the typhoon on tree sparrow productivity was to reduce fledgling success from 52% to 25% (Chapter 7). The end of the breeding season was approaching when typhoon Rammasun arrived, rapidly bringing the season to an end. One year of breeding data were collected from the study sites, and it is unclear whether breeding seasons naturally terminate on arrival of the first typhoon or whether the 2014 breeding season was truncated by the arrival of typhoon Rammasun. Further research along similar lines to the work described above, conducted both in similar locations and in areas that are more frequently affected by extreme weather events, would provide a clearer understanding of the duration of the tree sparrow breeding season. It would also aid in the explanation of the strategies that tree sparrows (and other avian species) adopt to compensate for major climatic events, such as typhoons.

8.2 Effect of rice management upon avian diversity

The management of rice fields and the effects upon avian diversity has been well documented (Table 1.1), although these studies have primarily been conducted in the USA or Europe (Elphick *et al*., 2010b; Ibáñez *et al*., 2010; Elphick, 2015). With such research it is unlikely that a '*one rule fits all*' conservation strategy is possible across continents because bird communities differ substantially over large geographic areas.

The aims of these investigations were to determine the effect that different field management strategies have on the avian diversity in the rice fields of the Philippines and use this information to explore methods of farming which might support avian diversity with no detrimental effect upon rice yield.

One consequence of rice growth, which has been investigated little within avian studies, is the effects of the changing growth stages of the rice crop on the characteristics of the avian assemblage / community. There are a number of stages in rice development which may or may not be attractive to different groups of bird species during the course of their annual cycle. In this research, field stages were found to have a significant effect on avian diversity (Chapter 6); peaks in avian abundance and / or diversity for each phase of the rice crop are summarised in Table 8.1.

Table 8.1 Peaks in Avian Abundance and Diversity for each phase of the rice crop. '*Diversity*' represents the field stage which recorded the highest number of species, '*Individuals*' represents the field stage which recorded the highest number of individuals, '*Granivorous*' represents the field stage which recorded the highest abundance and frequency of Granivorous species, and '*Waterbirds*' represents the field stage which recorded the highest abundance and frequency of Waterbird species.

Land Preparation	Vegetative Phase	Reproductive Phase	Ripening Phase	Fallow Phase	Fallow and/or Land preparation
	Diversity	Diversity	Diversity	Granivorous Individuals	Waterbirds
Reference	Chapter 6	Chapter 4	Chapter 5	Chapter 4	Chapter 4

The Fallow phase is clearly very important to a number of bird species, in particular the granivorous birds and waterbirds. The Fallow phase is where the crop has been harvested and the fields were left either dry or flooded, stubble or as levelled ground. This produces a wide range of conditions between fields, creating a mosaic in the landscape which is a benefit to avian diversity (Chamberlain & Gregory, 1999; Benton *et al.*, 2003). There has been much literature on management of fallow rice fields as a benefit to avian diversity (Fujioka *et al.,* 2001; Sizemore & Main, 2012). Flooded fields that were left as stubble were found to support the highest numbers of birds (Chapter 4).

Rice fields provide an artificial wetland for most of the year (Elphick *et al.*, 2010a) which supports a large number of avian species (Chapter 4). These rice fields become increasingly important to the birds as the dry season progresses and natural wetlands dry out, either intentionally or seasonally (Ramsen *et al.*, 1991; Donald, 2004; Lee *et al.*, 2007a; Taylor & Schultz, 2010). Rice fields in the

Philippines are always susceptible to water scarcity, but with effective water management, as used in the Alternate Wetting and Drying (AWD) rice production system, the use of water is optimised, allowing larger areas of rice to be planted. During times of water shortage, a number of farmers relying on Community Irrigation Systems (CIS), that deploy a traditional method of continuously flooding the crop, were not able to plant crops thereby reducing rice production along with available avian habitat. There was no significant difference in avian diversity between AWD and the CIS methods of irrigation management and no significant difference in diversity in AWD rice production relative to the location along the irrigation channels (see Chapter 5). This suggests that optimising the use of water by adopting the AWD rice production system should (a) optimise crop production, (b) increase the useable available land area for rice, and thus (c) optimise the avian habitat, particularly as the dry season progresses. In this way, AWD would allow rice farming over a larger geographic area, which in turn would provide an increased resource for a range of bird species.

Increased numbers of granivorous species were recorded in study sites that contained drier fields, a result also reported by Elphick (2004). The perceived pest status of granivorous bird species has always been a concern to the Philippine rice farmers. However, in the dietary studies of tree sparrows (Chapter 7), the birds were consuming both invertebrates and plant material, and their diet did not appear to change throughout the dry season, at a time when the mature rice seeds become available.

During trials where rice was grown as an intensified crop (where five crops were grown in a two year period - '5 in 2'), there was a significant increase of overall avian diversity within the intensified crop (Chapter 6). It was proposed that the additional moisture within the soil, required to grow the additional crop made it easier for birds, particularly waterbirds, to probe for food and, in addition there would be an increase in the abundance of invertebrates.

8.3 Effect of Eurasian tree sparrow on rice fields within the Philippines

The Eurasian tree sparrow (*Passer montanus*) is considered by most within the Philippines as the 'enemy' of rice fields, often referred to as '*Maya*', meaning '*rice pest*'. Few studies have been conducted upon this species in Asia, specifically the sub-species '*saturatus*', which occurs within the northern part of the Philippines (Summers-Smith, 1995). Large numbers of this bird were recorded in both the dry fields (Chapter 5) and within the intensified fields (Chapter 6). As a highly invasive introduced species to Asia, the tree sparrow can quickly adapt to changing conditions and this accounts for its success in spreading throughout the Philippines. The visibility of the tree sparrow within the rice fields, as it flies in and out of the crop, often draws attention from farmers who presume this species is feeding exclusively on the crop. One farmer suggested they mainly occurred on Sunday mornings when all of the '*bird boys*', responsible for scaring birds away, were in church and the fields were left unprotected. However, the tree sparrow has been of conservation concern in other parts of its range, resulting in extensive work having been conducted to support wild populations.

As with many granivorous species, the tree sparrow is known to alter its diet during the breeding season, increasing the invertebrate component of its diet. In European studies between 94.5 - 100 % of food items presented to nestlings were "*animal food*" (Summers-Smith, 1995). Nestlings were not tested within this study; yet stable isotope work did not support these findings for adult tree sparrows in the Philippines (Chapter 7). Between January and August, in the dry season rice crop prior to and during the tree sparrow breeding season, there were minimal differences detected within their diet according to the stable isotope study. These preliminary results suggest that, throughout this period, the diet was most probably a mixture of grain and invertebrate matter. It is acknowledged however that these were preliminary studies, and this area of research does require further exploration in order to verify these conclusions.

Granivorous bird species were recorded much more frequently during the Fallow phase of the rice crop, and were observed utilising rice fields when the soils were either dry or moist; for example, in fields that had adopted the AWD irrigation management practice. Thus, one recommendation that could be implemented to manage damage by granivorous species during the harvest period is to leave fields dry immediately after harvest, thus providing an attractive alternative feeding area away from the mature crops that are still to be harvested. It is thought that birds would prefer to feed on the 'waste' rice that has invariably been deposited on the ground during the harvesting process. Once all the fields have been harvested, the fields can then be flooded to allow other bird species to take advantage of the fallow land. Tree sparrows typically feed on the ground, but it was observed that, if they could perch on a post or structure next to the rice plants (such as on bird scaring devices or on rat barrier fences), they would feed directly from the growing rice panicles. Another recommendation would therefore be to ensure that no such structures are erected in close proximity to the rice plants.

Finally, this investigation found differences in the wing formula of males and females (a form of sexual dimorphism) suggesting some form of lifestyle difference between the sexes (Chapter 7). The male birds had longer and more pointed wings than female birds, possibly indicating that males travel larger distances than females, either during local migrations or to reduce competition with female birds around the nest sites during the breeding season. It is believed that this is the first documented account of sexual dimorphism within any sub-species of tree sparrow.

8.4 Do tree sparrows provide a service for the farmer?

This research initially investigated whether tree sparrows were the pest which they were perceived to be. However, as survey data highlighted that they were more abundant within rice fields during the fallow phase and information on their dietary requirements was collected. The question of whether tree sparrows provide a service to rice farmers, at least during periods of the year, was considered.

Tree sparrow diet did not change significantly during the 8 months of data collection for the diet investigation (Chapter 7) and was unlikely to be predominantly rice, indicating that tree sparrows are feeding on other seeds within their home range. Within a lowland irrigated rice field habitat, these seeds would be considered, by rice farmers, to be weed seeds. Therefore, the tree sparrow may be providing a service in feeding on the weed seeds present in and around the rice field habitat.

This idea can be extended into the fallow period, when tree sparrows are most abundant within rice fields. During this time it is assumed that the tree sparrows are feeding on wasted dropped rice. Feeding upon this wasted rice clears the sites of further rice growth into the next season, a problem in rice fields. Dropped rice is also a food source for other pests within the rice fields, such as rats. As the tree sparrows create competition for this food source, it can be suggested that they are reducing the availability to other pests, potentially having an impact, albeit small, on rodent numbers.

The investigation into diet suggested that the tree sparrow diet consisted, at least in part, of invertebrates. If the tree sparrow spends the majority of its time hunting and foraging within rice fields, it is assumed that the invertebrates which they are consuming will be coming from this habitat, reducing the amount of invertebrates within the rice crop, of which some will be pests. This indicates that the tree sparrows are helping to potentially reduce damage to crops from invertebrate pests.

The potential positive impacts of tree sparrows within the rice field habitat of the Philippines warrant further investigation. Establishment of replicated large-scale fields with either exclusion netting or nest boxes can be used to investigate their impact on crop yield and the incidences of weed and invertebrate pests. If positive, farmers could be encouraged to erect tree sparrow nest boxes to reap the benefit associated with these birds in their fields. With their high occupancy and reproductive rate (Chapter 7), another possible potential is that tree sparrows could be harvested as a cheap food source for local people.

8.5 Current impact of research

As one of the first studies to investigate avian diversity within rice fields of Southeast Asia, this research has attempted to develop an understanding of the birds that occur within the lowland irrigated rice habitat. This work provides initial background knowledge and identifies further work to be conducted upon birds within rice fields for scientists at the International Rice Research Institute who have expressed an interest in continuing this research.

During the course of this research, initial results were presented at; two international conferences (37th Annual Meeting of the Waterbird society, Germany, and the 26th International Ornithological Congress, Tokyo); a local conference (IRRI Young Scientists conference, Philippines); numerous workshops; at a number of farmers meetings; and at demonstrations at the 2013 Ecological Pest Management course, run regularly at IRRI.

Information on bird occurrence and general avian ecology (from Chapter 4), contributed towards: an article in *RiceToday* (Smedley, 2013 – Appendix 7); to an IRRI bird photography exhibition (which was open to the public); to the 2014 IRRI calendar; and to the publication of '*Guide to the birds of Philippine rice fields*' (Bourdin *et al.* 2015), of which I was a co-author. This field guide will be published in the native dialect '*Tagalog'* at a later date. It was developed primarily to assist farmers and rice field workers to identify the common bird species they are likely to encounter in rice fields, with the important objective of eradicating the myth that '*all birds eat rice*' and are pests.

In order to communicate with more 'end users', such as the rice farmers of the Philippines, this research has contributed to a revised web page on birds in the "Rice Knowledge Bank" website (www.knowledgebank.irri.org/step-by-step-production/growth/pests-and-diseases/birds). This is a free resource which provides advice and guidance on all aspects of rice production, including pest control. This web page now identifies just a few granivorous species of bird that pose a potential threat to the rice crop, and provides some advice on preventative measures that can be taken to reduce damage. Since going live in May 2014, the page has been visited 1,743 times from 49 countries (*pers. comm*. B. Blackman, 2015).

After a number of workshops, the baseline survey data presented in this thesis are being used by IRRI field workers in a number of new projects looking at the interactions between avifauna and other groups of organisms in rice field habitats. In time it is envisaged that the data sets will be augmented, and the research will have considerable impact across the Philippines and other rice growing countries of Asia that benefit from IRRI research.

8.6 Management of avian diversity

On the basis of this research, the following recommendations are proposed for the management of bird populations, on both field and community scales, within the Philippines.

- To encourage further research and to educate field workers and farmers in the development of target-specific bird scaring techniques. Few bird species recorded within the rice fields are likely to have any effect on rice crop yield, and the species that are likely to cause a problem will only do so during certain phases of the crop cycle. Scaring all birds throughout the year is costly, time consuming, unnecessary and dangerous, as birds become habituated to methods and learn that they are harmless. A reduction of avian persecution, including hunting and egg collection within the rice crop habitat, will increase the conservation value of this internationally important habitat across the Filipino archipelago and elsewhere, with no likely impact on crop production.
- The use of scaring devices only during key times of the crop because birds habituate to devices quickly within rice fields. If a device is implemented whilst the rice is still developing, by the time the crop is most at risk (when panicles are exposed upon the plant), individuals have become habituated to the device. Although no work has been conducted upon the effectiveness of the different bird scaring techniques, metallic tape positioned across maturing rice crops were seen to have a short term effect on birds using the field.
- An increase in tall perching opportunities above the periphery of rice crops might encourage predatory birds into the area. The brown shrike (*Lanius cristatus*) was observed attacking granivorous species which flocked within rice fields. Encouraging such species could be a useful deterrent against granivorous species. The perches might also encourage kingfishers, which feed on golden apple snails and raptors that would potentially predate on mammalian pests.

- Leaving rice fields dry immediately after harvesting might provide an attractive alternative feeding area for granivorous species that pose a threat to crops which are still to be harvested. Leaving the field fallow and dry ensures that all grain that falls from the rice panicle during the course of the harvest is available to the birds. This would not be the case if the field was either flooded or tilled. In such fields, the birds would also gain access to other food items such as weed seeds and invertebrates that become available in the fields after harvest.
- After a short dry fallow period, fields should be flooded and left irrigated for as long as possible, or as long as water is available, as flooded fallow fields were recorded to have the highest diversity of all field stages. Whilst the fields are fallow and not producing a crop they could be used to support the birds.

8.7 Future work

- Although the data set for this research was collected over a time frame of 32 months, this only represents three annual seasons of the typical avian life-cycle (i.e. of breeding, moulting, migration etc.). For a more accurate baseline of avian frequency and abundance within the rice field habitat, extensive long-term monitoring is required. Further surveys should record all bird species in all habitats in and around the rice crop ecosystem at all times of the year. Such data will provide a better understanding of how avian species utilise the rice crop ecosystem, and should provide insight into how future changes to management practices are likely to influence avian diversity (in either a positive or negative way). Further work is required on species that occur in high abundance in the rice crop habitat, such as the tree sparrow, munias, and brown shrike, to fully understand any interactions that occur between the species, and to understand their potential impact on rice crop productivity. Long-term monitoring could also contribute to the small amount of work conducted in this research on the likely effects of extreme weather events on the population dynamics of certain bird species.
- Further bird surveying techniques should be developed to assess waterbird populations within the lowland irrigated rice field habitats, plus any neighbouring habitats that these species are likely to be utilising. Elphick (2008) states that waterbird abundance can be influenced by landscape features separated by 10 km, therefore requiring additional thought when planning future investigations. More effective survey techniques will provide a more accurate assessment of the impact of different management techniques on avian diversity.

- The development of an accurate method of avian damage assessment will contribute to the knowledge of the impact of birds on crop yield. Current methods include crude farmer estimations and more complex mathematical models. No damage assessments were conducted within this research but farmer estimations were found to be highly subjective and inconsistent. A standardised method of damage assessment would identify which species cause damage and how much this damage compares to other pests. Work might focus on issues such as compensatory re-growth on the rice plant if there was a small amount of damage during the milky stage. Minor predator disturbance may cause the rice plants to fill all grains during growth, reducing the number of half-filled grains which naturally occur during growth, indirectly increasing yield.
- The results and conclusions from this research should be expanded into other rice growing areas throughout the Philippines and across Asia as a whole. Between study sites, small differences in avian diversity and abundance were recorded and further differences would be expected throughout the Philippine archipelago and beyond, most likely driven by the changing geography. Myanmar has recently become integrated within Asia, and has been using traditional methods of farming for decades (*pers. comm.* K L Heong, 2013). It is likely that new technologies and methodologies will soon be introduced to that country, and if surveys of avian diversity and abundance were to be conducted in carefully selected study areas, any changes in avian diversity during this transition could be recorded.
- For all migratory species, international collaboration is required to fully understand the potential effect of changes in rice field management practices on the population dynamics of those species. For example, the common kingfisher (*Alcedo atthis*) over-winters within the Philippines but breeds within mainland China (Birdlife International, 2015). If changing agricultural management techniques were having an effect upon the population dynamics of that species, either by changing the distances the bird must travel during migration or by affecting reproductive output, this would not be evident from a study restricted to the Philippines.
- Probably the most important future work will involve educating local farmers, field workers and schoolchildren about bird species that inhabit the rice fields, and about their likely impact on the rice crop. The impact birds have on invertebrate fauna (including molluscs), and about their potential impact on weed species that grow in and around the rice fields. For most farmers, the impact of birds on the rice crop yield is an unknown, and after using pesticides, molluscicides, rodenticides and fertilisers, when their optimal strain of rice does not achieve the expected crop

yield, it is common for them to blame the birds. This potentially could mean the establishment of citizen science projects, allowing for wider community involvement and further education.

- With further education and an accepted method of damage assessment, along with longer periods of bird surveying and investigations into ecosystem services, scientists can start to communicate the message that most bird species play a positive role for the rice farmer (and are ecosystem service providers). There are very few species that will actually consume rice from the plant panicle, and the few species that do, are only problematic during a short period of the growing season.

Ideally in the long term, the rice workers of Asia will perceive birds on the whole as a positive component of the rice crop ecosystem, and will take steps to minimise rice consumption by the granivorous species (such as tree sparrows) during critical times within the rice crop cycle. They will encourage waterbird species throughout the rice crop cycle, and will encourage granivorous species during the fallow and land preparation phases.

In the longer term, future ornithological surveys will eventually be able to assess the importance of the rice crop ecosystem as wetland habitat across Asia. I predict that the importance of this habitat will be ranked very highly.

REFERENCES

Acosta, M., Mugica, L., Blanco, D., López-Lanús, B., Dias, R.A., Doodnath, L.W. and Hurtado, J., 2010. Birds of rice fields in the Americas. *Waterbirds*, *33*(1), pp.105-122.

Alexandratos, N. and Bruinsma, J., 2012. World agriculture towards 2030/2050: the 2012 revision. *ESA Work. Pap*, *3*.

Allen, A.A. and Griscom, L., 1914. *The Red-winged Blackbird: a study in the ecology of a cat-tail marsh*. Linnaean society of New York.

Amano, T., Ushiyama, K., Fujita, G. and Higuchi, H., 2004. Alleviating grazing damage by white-fronted geese: an optimal foraging approach. Journal of Applied Ecology, 41(4), pp.675-688.

Amano, T., Ushiyama, K., Fujita, G.O. and Higuchi, H., 2007. Predicting grazing damage by white-fronted geese under different regimes of agricultural management and the physiological consequences for the geese. *Journal of Applied Ecology*, 44(3), pp.506-515.

Ambrose, S.H. and DeNiro, M.J., 1986. The isotopic ecology of East African mammals. *Oecologia*, *69*(3), pp.395-406.

Amundson, R., Austin, A.T., Schuur, E.A.G., Yoo, K., Matzek, V., Kendall, C., Uebersax, A., Brenner, D. and Baisden, W.T., 2003. Global patterns of the isotopic composition of soil and plant nitrogen. *Global biogeochemical cycles*, *17*(1).

Anderson, C. and Cabana, G., 2005. δ15N in riverine food webs: effects of N inputs from agricultural watersheds. *Canadian Journal of Fisheries and Aquatic Sciences*, *62*(2), pp.333-340.

Askham, L.R., 1990, March. Effect of artificial perches and nests in attracting raptors to orchards. In *Proceedings of the Fourteenth Vertebrate Pest Conference 1990* (p. 2).

Baillie, S.R., Marchant, J.H., Leech, D.I., Massimino, D., Sullivan, M.J.P., Eglington, S., Barimore, C., Dadam, D., Downie, I.S., Harris, S. and Kew, A., 2014. BirdTrends 2014: trends in numbers, breeding success and survival for UK breeding birds.

Baker, K., 2010. *Warblers of Europe, Asia and North Africa*. A&C Black.

Balmford, A. and Long, A., 1994. Avian endemism and forest loss. *Nature*, *372*(6507), pp.623-624.

Bamford, M., Watkins, D., Bancroft, W., Tischler, G. and Wahl, J., 2008. *Migratory shorebirds of the East Asian-Australasian flyway: Population estimates and internationally important sites*. Wetlands International, Oceania.

Baltag, E. and Ion, C., 2012. Morphometric pattern of European Reed Warblers (Aves, Sylviidae) during spring migration in eastern Romania.*Italian Journal of Zoology*, *79*(2), pp.273-279.

Batáry, P., Matthiesen, T. and Tscharntke, T., 2010. Landscape-moderated importance of hedges in conserving farmland bird diversity of organic vs. conventional croplands and grasslands. *Biological Conservation*, *143*(9), pp.2020-2027.

Bateman, A.S. and Kelly, S.D., 2007. Fertilizer nitrogen isotope signatures. *Isotopes in Environmental and Health Studies*, *43*(3), pp.237-247.

Bateman, A.S., Kelly, S.D. and Jickells, T.D., 2005. Nitrogen isotope relationships between crops and fertilizer: implications for using nitrogen isotope analysis as an indicator of agricultural regime. *Journal of Agricultural and Food Chemistry*, *53*(14), pp.5760-5765.

Baumgartner, A.M., 1938. Seasonal variations in the Tree Sparrow. *The Auk*, pp.603-613.

Bearhop, S., Furness, R.W., Hilton, G.M., Votier, S.C. and Waldron, S., 2003. A forensic approach to understanding diet and habitat use from stable isotope analysis of (avian) claw material. *Functional Ecology*, *17*(2), pp.270-275.

Bellio, M.G., Kingsford, R.T. and Kotagama, S.W., 2009. Natural versus artificial-wetlands and their waterbirds in Sri Lanka. *Biological Conservation*, *142*(12), pp.3076-3085.

Belder, P., Bouman, B.A.M., Cabangon, R., Guoan, L., Quilang, E.J.P., Yuanhua, L., Spiertz, J.H.J. and Tuong, T.P., 2004. Effect of water-saving irrigation on rice yield and water use in typical lowland conditions in Asia. *Agricultural Water Management*, *65*(3), pp.193-210.

Benton, T.G., Vickery, J.A. and Wilson, J.D., 2003. Farmland biodiversity: is habitat heterogeneity the key? *Trends in Ecology & Evolution*, *18*(4), pp.182-188.

Bibby, C.J., 2000. *Bird census techniques*. Elsevier. 302 p.

BirdLife International, 2001. *Threatened birds of Asia: the BirdLife International Red Data Book*. BirdLife International.

Birdlife International. 2012. *Common Kingfisher* Alcedo atthis. Species factsheet. Available online: http://www.birdlife.org (Accessed 17/04/2015)

Birdlife International. 2016. Species Factsheet: *Common Sandpiper* Actitis hypoleucos. Species factsheet. Available online: http://www.birdlife.org (Accessed 22/01/2016)

Blanco, D.E., López-Lanús, B., Dias, R.A., Azpìroz, A. and Rilla, F., 2006. Use of rice fields by migratory shorebirds in southern South America: implications for conservation and management. *Wetlands International, Buenos Aires, Argentina*, p.56.

Bocherens, H. and Drucker, D., 2003. Trophic level isotopic enrichment of carbon and nitrogen in bone collagen: case studies from recent and ancient terrestrial ecosystems. *International Journal of Osteoarchaeology*, *13*(1-2), pp.46-53.

Boncompagni, E., Muhammad, A., Jabeen, R., Orvini, E., Gandini, C., Sanpera, C., Ruiz, X. and Fasola, M., 2003. Egrets as monitors of trace-metal contamination in wetlands of Pakistan. *Archives of Environmental Contamination and Toxicology*, *45*(3), pp.399-406.

Boonstra, R., Eadie, J.M., Krebs, C.J. and Boutin, S., 1995. Limitations of far infrared thermal imaging in locating birds (limitaciones en el uso de imágenes termales con radiación infraroja extrema para localizar aves) .*Journal of field ornithology*, pp.192-198.

Bos, D., Grigoras, I. and Ndiaye, A., 2006. *Land cover and avian biodiversity in rice fields and mangroves of West Africa*. Wetlands International.

Boulet, M. and Norris, D.R., 2006. Introduction: the past and present of migratory connectivity. *Ornithological Monographs*, pp.1-13.

Bouman, B.A.M. and Tuong, T.P., 2001. Field water management to save water and increase its productivity in irrigated lowland rice. *Agricultural water management*, *49*(1), pp.11-30.

Bourdin, P., Paris, T., Serrano, T., Smedley, R., Hettel, G. 2015. *Guide to the birds of Philippine rice fields. Los Baños (Philippines)*: International Rice Research Institute. 116 p.

Brickle, N.W., Harper, D.G., Aebischer, N.J. and Cockayne, S.H., 2000. Effects of agricultural intensification on the breeding success of corn buntings Miliaria calandra. *Journal of Applied Ecology*, *37*(5), pp.742-755.

Brown, J.S., Kotler, B.P., Smith, R.J. and Wirtz II, W.O., 1988. The effects of owl predation on the foraging behavior of heteromyid rodents. *Oecologia*,*76*(3), pp.408-415.

Brzęk, P., Kohl, K., Caviedes-Vidal, E. and Karasov, W.H., 2009. Developmental adjustments of house sparrow (Passer domesticus) nestlings to diet composition. *Journal of Experimental Biology*, *212*(9), pp.1284-1293.

Burns, J.G., 2003. Relationship of Calidris sandpiper wing shape with relative fuel load and total migration distance. *The Auk*, *120*(3), pp.827-835.

Bye, S.L., Robel, R.J. and Kemp, K.E., 2001. Effects of human presence on vocalizations of grassland birds in Kansas. *Prairie Naturalist*, *33*(4), pp.249-256.

Cabangon, R.J., Castillo, E.G., Bao, L.X., Lu, G., Wang, G.H., Cui, Y.L., Tuong, T.P., Bouman, B.A.M., Li, Y.H., Chen, C.D. and Wang, J.Z., 2001. Impact of alternate wetting and drying irrigation on rice growth and resource-use efficiency. *Barker R, Loeve R, Li YH, Tuong TP, editors*, pp.55-80.

Caveney, S., Scholtz, C.H. and McIntyre, P., 1995. Patterns of daily flight activity in onitine dung beetles (Scarabaeinae: Onitini). *Oecologia*, *103*(4), pp.444-452.

Chamberlain, D.E. and Gregory, R.D., 1999. Coarse and fine scale habitat associations of breeding Skylarks Alauda arvensis in the UK. *Bird Study*, *46*(1), pp.34-47.

Chamberlain, D.E., Fuller, R.J., Bunce, R.G.H., Duckworth, J.C. and Shrubb, M., 2000. Changes in the abundance of farmland birds in relation to the timing of agricultural intensification in England and Wales. *Journal of applied ecology*, *37*(5), pp.771-788.

Clancey, P.A., 1948. Seasonal bill variation in Tree-Sparrow. *British Birds*, *41*, pp.115-116.

Clark, L., 1987. Thermal constraints on foraging in adult European Starlings. *Oecologia*, *71*(2), pp.233-238.

Clifford, H.T. and Stephenson, W., 1975. *An introduction to numerical classification* (Vol. 229). New York: Academic Press.

Conway, C.J. and Martin, T.E., 2000a. Evolution of passerine incubation behavior: influence of food, temperature, and nest predation. *Evolution*,*54*(2), pp.670-685.

Conway, C.J. and Martin, T.E., 2000b. Effects of ambient temperature on avian incubation behavior. *Behavioral Ecology*, *11*(2), pp.178-188.

Croon, G.W., McCullough, D.R., Olson Jr, C.E. and Queal, L.M., 1968. Infrared scanning techniques for big game censusing. *The Journal of Wildlife Management*, pp.751-759.

Crosby, M.J. and Chan, S., 2006. *Threatened waterbird species in eastern and southern Asia and actions needed for their conservation*. Waterbirds around the world*. Eds. GC Boere, CA Galbraith & DA Stroud. The Stationery Office, Edinburgh, UK*, pp.332-338.

Cummings, J., Shwiff, S. and Tupper, S., 2005. Economic impacts of blackbird damage to the rice industry. *Wildlife Damage Management Conferences – Proceedings*. Paper 126.

Cunningham, S.A., Attwood, S.J., Bawa, K.S., Benton, T.G., Broadhurst, L.M., Didham, R.K., McIntyre, S., Perfecto, I., Samways, M.J., Tscharntke, T. and Vandermeer, J., 2013. To close the yield-gap while saving biodiversity will require multiple locally relevant strategies. *Agriculture, ecosystems & environment*, *173*, pp.20-27.

Dänhardt, J., Green, M., Lindström, Å., Rundlöf, M. and Smith, H.G., 2010. Farmland as stopover habitat for migrating birds – effects of organic farming and landscape structure. *Oikos*, *119*(7), pp.1114-1125.

Dawe, D., 2005. Increasing water productivity in rice-based systems in Asia - past trends, current problems, and future prospects. *Plant Production Science*, *8*(3), pp.221-230.

Day, J.H. and Colwell, M.A., 1998. Waterbird communities in rice fields subjected to different post-harvest treatments. *Colonial Waterbirds*, pp.185-197.

De Grazio, J.W. and Besser, J.F., 1970, March. Bird damage problems in Latin America. In *Proceedings of the 4th Vertebrate Pest Conference (1970)* (p. 33).

de Mey, Y. and Demont, M., 2013. 19 Bird Damage to Rice in Africa: Evidence and Control. *Realizing Africa's rice promise*, p.241.

de Mey, Y., Demont, M. and Diagne, M., 2012. *Estimating bird damage to rice in Africa: evidence from the Senegal River Valley*. Journal of Agricultural Economics, 63(1), pp.175-200.

Deckert, G., 1962. Zur Ethologie des Feldsperlings (Passer m. montanus L.). *Journal für Ornithologie*, *103*(4), pp.428-486 (in German, Google Chrome translated)

DeNiro, M.J. and Epstein, S., 1981. Influence of diet on the distribution of nitrogen isotopes in animals. *Geochimica et cosmochimica acta*, *45*(3), pp.341-351.

Dickinson, E.C., Kennedy, R.S., Parkes, K.C. and McGowan, E., 1991. *The birds of the Philippines: an annotated check-list* (Vol. 12). Tring: British Ornithologists' Union.

Donald, P.F., 2004. Biodiversity impacts of some agricultural commodity production systems. *Conservation biology*, *18*(1), pp.17-38.

Donald, P.F., Green, R.E. and Heath, M.F., 2001. Agricultural intensification and the collapse of Europe's farmland bird populations. *Proceedings of the Royal Society of London B: Biological Sciences*, *268*(1462), pp.25-29.

Drent, R., 1975. Incubation. *Avian biology*, *5*, pp.333-420.

Elliott, C.C.H., 1979. The harvest time method as a means of avoiding quelea damage to irrigated rice in Chad/Cameroun. *Journal of Applied Ecology*, pp.23-35.

Elphick, C.S., 2004. Assessing conservation trade-offs: identifying the effects of flooding rice fields for waterbirds on non-target bird species. *Biological Conservation*, *117*(1), pp.105-110.

Elphick, C.S., 2008. Landscape effects on waterbird densities in California rice fields: taxonomic differences, scale-dependence, and conservation implications. *Waterbirds*, *31*(1), pp.62-69.

Elphick, C. S., 2010. Why Study Birds in Rice Fields? *Waterbirds* 33(sp1), pp1-7.

Elphick, C.S., 2015. A history of ecological studies of birds in rice fields. *Journal of Ornithology*, pp.1-7.

Elphick, C.S. and Oring, L.W., 1998. Winter management of Californian rice fields for waterbirds. *Journal of Applied Ecology*, *35*(1), pp.95-108.

Elphick, C.S. and Oring, L.W., 2003. Conservation implications of flooding rice fields on winter waterbird communities. *Agriculture, Ecosystems & Environment*, *94*(1), pp.17-29.

Elphick, C.S., Parsons, K. C., Fasola, M., Mugica, L., 2010a. Ecology and Conservation of Birds in Rice Fields: A Global Review. *Waterbirds* 33(sp1), pp1-243.

Elphick, C.S., Baicich, P., Parsons, K.C., Fasola, M. and Mugica, L., 2010b. The future for research on waterbirds in rice fields. *Waterbirds*, *33*(sp1), pp.231-243.

Elphick, C.S., Taft, O. and Lourenço, P.M., 2010c. Management of rice fields for birds during the non-growing season. *Waterbirds*, *33*(sp1), pp.181-192.

Evans, A.D., Smith, K.W., Buckingham, D.L. and Evans, J., 1997. Seasonal variation in breeding performance and nestling diet of cirl buntings Emberiza cirlus in England. *Bird Study*, *44*(1), pp.66-79.

FAOSTAT. 2014a. Data derived from: 'The Philippines: Area Harvested'. Available at: http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor (Accessed: 16th June 2015)

FAOSTAT. 2014b. Data derived from: 'The Philippines: Crops Primary Equivalent'. Available at: http://faostat.fao.org/browse/FB/CC/E (Accessed: 29th June 2015)

FAOSTAT. 2015. Data derived from: 'Countries by Commodity: Rice, Paddy'. Available at: http://faostat3.fao.org/browse/rankings/countries_by_commodity/E (Accessed: 5th August 2015)

Farquhar, G.D., Ehleringer, J.R. and Hubick, K.T., 1989. Carbon isotope discrimination and photosynthesis. *Annual review of plant biology*, *40*(1), pp.503-537.

Fasola, M. and Ruiz, X., 1996. The value of rice fields as substitutes for natural wetlands for waterbirds in the Mediterranean region. *Colonial Waterbirds*, pp.122-128.

Fasola, M. and Ruiz, X., 1997. *Rice farming and waterbirds: integrated management in an artificial landscape*. Farming and Birds in Europe. Academic Press, London, United Kingdom, pp.210-235.

Fasola, M. and Brangi, A., 2010. Consequences of rice agriculture for waterbird population size and dynamics. *Waterbirds*, *33*(sp1), pp.160-166.

Feare, C., 1984. The Starling.

Feare, C.J. and McGinnity, N., 1986. The relative importance of invertebrates and barley in the diet of Starlings Sturnus vulgaris. *Bird Study*, 33(3), pp.164-167.

Fellers, J.H., 1989. Daily and seasonal activity in woodland ants. *Oecologia*, *78*(1), pp.69-76.

Ferguson-Lees, J., Castell, R. and Leech, D., 2011. *A Field Guide to Monitoring Nests*. Norfolk (UK): British Trust for Ornithology.

Field, R.H. and Anderson, G.Q., 2004. Habitat use by breeding Tree Sparrows Passer montanus. *Ibis*, *146*(s2), pp.60-68.

Flint, E.P., 1994. Changes in land use in South and Southeast Asia from 1880 to 1980: a data base prepared as part of a coordinated research program on carbon fluxes in the tropics. *Chemosphere*, *29*(5), pp.1015-1062.

Foley, J.A., Ramankutty, N., Brauman, K.A., Cassidy, E.S., Gerber, J.S., Johnston, M., Mueller, N.D., O'Connell, C., Ray, D.K., West, P.C. and Balzer, C., 2011. Solutions for a cultivated planet. *Nature*, *478*(7369), pp.337-342.

Folk, C. and Kozena, I., 1982. Winter food resource partitioning among three granivorous bird species in agricultural farms [feeding habits, grain losses]. *Folia Zoologica*.

Forman, R.T., Reineking, B. and Hersperger, A.M., 2002. Road traffic and nearby grassland bird patterns in a suburbanizing landscape. Environmental management, 29(6), pp.782-800. McClure, C.J., Ware, H.E., Carlisle, J., Kaltenecker, G. and Barber, J.R., 2013. An experimental investigation into the effects of traffic noise on distributions of birds: avoiding the phantom road. *Proceedings of the Royal Society of London B: Biological Sciences*, 280(1773), p.20132290.

Frommolt, K.H. and Tauchert, K.H., 2014. Applying bioacoustic methods for long-term monitoring of a nocturnal wetland bird. *Ecological Informatics*, *21*, pp.4-12.

Fujioka, M., James Jr, W.A., Yoshida, H. and Maeda, T., 2001. Value of fallow farmlands as summer habitats for waterbirds in a Japanese rural area. *Ecological Research*, *16*(3), pp.555-567.

Fujioka, M., Don Lee, S., Kurechi, M. and Yoshida, H., 2010. Bird use of rice fields in Korea and Japan. *Waterbirds*, *33*(sp1), pp.8-29.

Fuller, R.J., 2000. Relationships between recent changes in lowland British agriculture and farmland bird populations: an overview. *Ecology and conservation of lowland farmland birds*, pp.5-16.

Fuller, R.J. and Langslow, D.R., 1984. Estimating numbers of birds by point counts: how long should counts last? *Bird study*, *31*(3), pp.195-202.

Fuller, R.J., Gregory, R.D., Gibbons, D.W., Marchant, J.H., Wilson, J.D., Baillie, S.R. and Carter, N., 1995. Population declines and range contractions among lowland farmland birds in Britain. *Conservation Biology*, 9(6), pp.1425-1441.

Gibbons, D., Morrissey, C. and Mineau, P., 2015. A review of the direct and indirect effects of neonicotinoids and fipronil on vertebrate wildlife. *Environmental Science and Pollution Research*, *22*(1), pp.103-118.

Ginn, H.B. and Melville, D.S., 1983. *Moult in birds (BTO guide)*. British Trust for Ornithology. 112 p

Gleick, P.H., 1993. Water and conflict: Fresh water resources and international security. *International security*, 18(1), pp.79-112.

Gopi Sundar, K.S., 2009. Are rice paddies suboptimal breeding habitat for Sarus Cranes in Uttar Pradesh, India? *The Condor*, *111*(4), pp.611-623.

Gonthier, D.J., Ennis, K.K., Farinas, S., Hsieh, H.Y., Iverson, A.L., Batáry, P., Rudolphi, J., Tscharntke, T., Cardinale, B.J. and Perfecto, I., 2014. Biodiversity conservation in agriculture requires a multi-scale approach. *Proceedings of the Royal Society of London B: Biological Sciences*, *281*(1791), p.20141358.

Graves, H.B., Bellis, E.D. and Knuth, W.M., 1972. Censusing white-tailed deer by airborne thermal infrared imagery. *The Journal of Wildlife Management*, pp.875-884.

Green, R.E., Tyler, G.A., Stowe, T.J. and Newton, A.V., 1997. A simulation model of the effect of mowing of agricultural grassland on the breeding success of the corncrake (Crex crex). *Journal of Zoology*, *243*(1), pp.81-115.

Green, R.E., Cornell, S.J., Scharlemann, J.P. and Balmford, A., 2005. Farming and the fate of wild nature. *Science*, *307*(5709), pp.550-555.

Gregory, R.D., Noble, D., Field, R., Marchant, J., Raven, M. and Gibbons, D.W., 2003. Using birds as indicators of biodiversity. *Ornis hungarica*, *12*(13), pp.11-24.

GRiSP (Global Rice Science Partnership). 2013. *Rice almanac*, 4th Edition. Los Baños (Philippines): International Rice Research Institute. 283 p.

Guerrero, I., Carmona, C.P., Morales, M.B., Oñate, J.J. and Peco, B., 2014. Non-linear responses of functional diversity and redundancy to agricultural intensification at the field scale in Mediterranean arable plant communities. *Agriculture, Ecosystems & Environment*, *195*, pp.36-43.

Handley, L.L., Austin, A.T., Stewart, G.R., Robinson, D., Scrimgeour, C.M., Raven, J.A. and Schmidt, S., 1999. The 15N natural abundance (δ15N) of ecosystem samples reflects measures of water availability. *Functional Plant Biology*, *26*(2), pp.185-199.

Hardy, J., Crick, H., Wernham, C., Riley, H., Etheridge, B., Thompson, D., 2009. *Raptors: A Field Guide for Surveys and Monitoring* 2nd Edition. Scottish Natural Heritage. 370 p.

Haribon Foundation, 2014. *The State of the Philippine Birds*. Haribon Foundation for the Conservation of Natural Resources Inc. 45 p.

Harvey, C.A., Komar, O., Chazdon, R., Ferguson, B.G., Finegan, B., Griffith, D.M., Martínez-Ramos, M.I., Morales, H., Nigh, R., Soto-Pinto, L.O. and Van Breugel, M., 2008. Integrating agricultural landscapes with biodiversity conservation in the Mesoamerican hotspot. *Conservation biology*, *22*(1), pp.8-15.

Hedenström, A., 1992. Flight performance in relation to fuel load in birds. *Journal of Theoretical Biology*, *158*(4), pp.535-537.

Henderson, I.G., Cooper, J., Fuller, R.J. and Vickery, J., 2000. The relative abundance of birds on set-aside and neighbouring fields in summer. *Journal of Applied Ecology*, *37*(2), pp.335-347.

Hinsley, S.A. and Bellamy, P.E., 2000. The influence of hedge structure, management and landscape context on the value of hedgerows to birds: a review. *Journal of environmental management*, *60*(1), pp.33-49.

Hohman, W.L., Stark, T.M. and Moore, J.L., 1996. Food availability and feeding preferences of breeding fulvous whistling-ducks in Louisiana ricefields. *The Wilson Bulletin*, pp.137-150.

Holm, E. and Edney, E.B., 1973. Daily activity of Namib Desert arthropods in relation to climate. *Ecology*, pp.45-56.

Horgan, F.G., Ramal, A.F., Villegas, J.M., Almazan, M.L.P., Bernal, C.C., Jamoralin, A., Pasang, J.M., Orboc, G., Agreda, V. and Arroyo, C., Ecological engineering with high diversity vegetation patches enhances bird activity and ecosystem services in Philippine rice fields. Regional Environmental Change, pp.1-13.

Horgan, F.G., Felix, M.I., Portalanza, D.E., Sánchez, L., Rios, W.M.M., Farah, S.E., Wither, J.A., Andrade, C.I. and Espin, E.B., 2014. Responses by farmers to the apple snail invasion of Ecuador's rice fields and attitudes toward predatory snail kites. *Crop Protection*, *62*, pp.135-143.

Htwe, N.M. and Singleton, G.R., 2014. Is quantity or quality of food influencing the reproduction of rice-field rats in the Philippines? *Wildlife Research*, *41*(1), pp.56-63.

Htwe, N.M., Singleton, G.R. and Nelson, A.D., 2013. Can rodent outbreaks be driven by major climatic events? Evidence from cyclone Nargis in the Ayeyawady Delta, Myanmar. *Pest management science*, *69*(3), pp.378-385.

Huhta, A., Muotka, T. and Tikkanen, P., 2000. Nocturnal drift of mayfly nymphs as a post-contact antipredator mechanism. *Freshwater Biology*,*45*(1), pp.33-42.

Ibáñez, C., Curcó, A., Riera, X., Ripoll, I. and Sánchez, C., 2010. Influence on birds of rice field management practices during the growing season: a review and an experiment. *Waterbirds*, *33*(sp1), pp.167-180.

Jeliazkov, A., Mimet, A., Chargé, R., Jiguet, F., Devictor, V. and Chiron, F., 2016. Impacts of agricultural intensification on bird communities: New insights from a multi-level and multi-facet approach of biodiversity. *Agriculture, Ecosystems & Environment*, *216*, pp.9-22.

Jenni, L. and Winkler, R., 2011. *Moult and ageing of European passerines*. A&C Black.

Jones, J., DeBruyn, R.D., Barg, J.J. and Robertson, R.J., 2001. Assessing the effects of natural disturbance on a Neotropical migrant songbirds. *Ecology*, *82*(9), pp.2628-2635.

Kay, B.J., Twigg, L.E., Korn, T.J. and Nicol, H.I., 1994. The use of artifical perches to increase predation on house mice (Mus domesticus) by raptors. *Wildlife research*, *21*(1), pp.95-105.

Kelly, J.F., 2000. Stable isotopes of carbon and nitrogen in the study of avian and mammalian trophic ecology. *Canadian Journal of Zoology*, *78*(1), pp.1-27.

Kendall, C. 1998. *Tracing nitrogen sources and cycles in catchments.* In Isotope Tracers in Catchment Hydrology, C. Kendall and J.J. McDonnell (Eds), p. 839, Elsevier, Amsterdam

Kennedy, R.S., Gonzales, P.C., Dickinson, E.C., Miranda Jr., H.C., Fisher, T.H. 2000. *A Guide to the Birds of the Philippines*. Oxford University Press. 392 p.

King, S., Elphick, C.S., Guadagnin, D., Taft, O. and Amano, T., 2010. Effects of landscape features on waterbird use of rice fields. *Waterbirds*, *33*(sp1), pp.151-159.

Kisimoto, R., 1968. Yellow pan water trap for sampling the small brown planthopper, Laodelphax striatellus (Fallen), a vector of the rice stripe virus. *Applied Entomology and Zoology*, *3*(1), pp.37-48.

Krebs, J.R., Wilson, J.D., Bradbury, R.B. and Siriwardena, G.M., 1999. The second silent spring? *Nature*, *400*(6745), pp.611-612.

Krištín, A., 1984. Ernährung under ernährungsökologie des Feldsperlings Passer montanus in der umgebung von Bratislava. *Folia zoologica*, *33*(2), pp.143-157. (in German, Google Chrome translated)

Kullberg, C., Fransson, T. and Jakobsson, S., 1996. Impaired predator evasion in fat blackcaps (Sylvia atricapilla). *Proceedings of the Royal Society of London B: Biological Sciences*, *263*(1377), pp.1671-1675.

Kullberg, C., Jakobsson, S. and Fransson, T., 2000. High migratory fuel loads impair predator evasion in sedge warblers. *The Auk*, *117*(4), pp.1034-1038.

Kushlan, J.A., 1993. Colonial waterbirds as bioindicators of environmental change. *Colonial waterbirds*, pp.223-251.

Laboratory Animals Ltd., 2001. *Laboratory birds: refinements in husbandry and procedures*. Laboratory Animals 35 (Suppl. 1).

Lack, D., 1947. The significance of clutch-size. *Ibis*, *89*(2), pp.302-352.

Lahm, G.P., Cordova, D. and Barry, J.D., 2009. New and selective ryanodine receptor activators for insect control. *Bioorganic & medicinal chemistry*, *17*(12), pp.4127-4133.

Lambin, E.F. and Meyfroidt, P., 2011. Global land use change, economic globalization, and the looming land scarcity. *Proceedings of the National Academy of Sciences*, *108*(9), pp.3465-3472.

Lampayan, R.M., Rejesus, R.M., Singleton, G.R. and Bouman, B.A., 2015. Adoption and economics of alternate wetting and drying water management for irrigated lowland rice. *Field Crops Research*, *170*, pp.95-108.

Lane, S.J., Azuma, A. and Higuchi, H., 1998. Wildfowl damage to agriculture in Japan. *Agriculture, ecosystems & environment*, *70*(1), pp.69-77.

Larsen, F.W., Bladt, J., Balmford, A. and Rahbek, C., 2012. Birds as biodiversity surrogates: will supplementing birds with other taxa improve effectiveness? *Journal of Applied Ecology*, *49*(2), pp.349-356.

Lefranc, N., 1997. *Shrikes: a guide to the shrikes of the world*. A&C Black.

Lemly, A.D., Kingsford, R.T. and Thompson, J.R., 2000. Irrigated agriculture and wildlife conservation: conflict on a global scale. *Environmental management*, *25*(5), pp.485-512.

Lind, J., Fransson, T., Jakobsson, S. and Kullberg, C., 1999. Reduced take-off ability in robins (Erithacus rubecula) due to migratory fuel load. *Behavioral Ecology and Sociobiology*, *46*(1), pp.65-70.

Longoni, V., 2010. Rice fields and waterbirds in the Mediterranean region and the Middle East. *Waterbirds*, *33*(sp1), pp.83-96.

Longoni, V., Rubolini, D. and Bogliani, G., 2007. Delayed reproduction among Great Bitterns Botaurus stellaris breeding in ricefields: Capsule Great Bitterns bred successfully in ricefields in northern Italy, despite a marked delay to the breeding season compared to natural wetlands in the same geographical area. *Bird Study*, *54*(2), pp.275-279.

Lourenco, P.M. and Piersma, T., 2009. Waterbird densities in South European rice fields as a function of rice management. *Ibis*, *151*(1), pp.196-199.

Lush, L., Ward, A.I. and Wheeler, P., 2014. Opposing effects of agricultural intensification on two ecologically similar species. *Agriculture, Ecosystems & Environment*, *192*, pp.61-66.

Maeda, T., 2001. Patterns of bird abundance and habitat use in rice fields of the Kanto Plain, central Japan. *Ecological Research*, *16*(3), pp.569-585.

Magurran, A.E., 2013. *Measuring biological diversity*. John Wiley & Sons.

Manning, J.A. and Kaler, R.S., 2011. Effects of survey methods on burrowing owl behaviors. *The Journal of Wildlife Management*, *75*(3), pp.525-530.

Marchetti, K., Price, T. and Richman, A., 1995. Correlates of wing morphology with foraging behaviour and migration distance in the genus Phylloscopus. *Journal of Avian Biology*, pp.177-181.

Marin, A.R., Masscheleyn, P.H. and Patrick Jr, W.H., 1992. The influence of chemical form and concentration of arsenic on rice growth and tissue arsenic concentration. *Plant and Soil*, 139(2): 175-183.

Marion, L., 1989. Territorial feeding and colonial breeding are not mutually exclusive: the case of the Grey Heron (Ardea cinerea). *The Journal of Animal Ecology*, pp.693-710.

Martin, E.A., Viano, M., Ratsimisetra, L., Laloë, F. and Carrière, S.M., 2012. Maintenance of bird functional diversity in a traditional agroecosystem of Madagascar. *Agriculture, Ecosystems & Environment*, *149*, pp.1-9.

McClelland, J.W., Valiela, I. and Michener, R.H., 1997. Nitrogen-stable isotope signatures in estuarine food webs: a record of increasing urbanization in coastal watersheds. *Limnology and Oceanography*, *42*(5), pp.930-937.

McNicholl, M.K. and Hogan, G.G., 1979. Wind-caused death of Great Cormorant. *Canadian Field-Naturalist*, *93*(2), pp.175-175.

Medway, L. and Wells, D.R., 1976. *The birds of the Malay Peninsula*, vol. V: Conclusions, and Survey of Every Species. HF & G. Witherby Ltd., London.

Merkens, M., Bradbeer, D.R. and Bishop, C.A., 2012. Landscape and field characteristics affecting winter waterfowl grazing damage to agricultural perennial forage crops on the lower Fraser River delta, BC, Canada. *Crop Protection*, *37*, pp.51-58.

Mesléard, F., Garnero, S., Beck, N. and Rosecchi, É., 2005. Uselessness and indirect negative effects of an insecticide on rice field invertebrates. *Comptes Rendus Biologies*, *328*(10), pp.955-962.

Mineau, P. and Whiteside, M., 2013. Pesticide acute toxicity is a better correlate of US grassland bird declines than agricultural intensification. *PLOS ONE*. Vol 8(Issue 2): pp1-8. [accessed 8/6/2015]

Moog, F.A. 2006. Country Pasture/Forage Resource Profiles: Philippines. FAO: Rome. Available online [26-3-2017] at: http://www.fao.org/ag/agp/agpc/doc/counprof/PDF%20files/Philippines.pdf

Motai, T. 1970. *The Fan-Tailed Warbler*. Pp 717-721, *in* K. Haneda, ed. Animals in Kamimiochi District in Nagano Prefecture. Shinkyo-Shippan, Nagano. (in Japanese, Google Chrome translated).

Mühr, B., Daniell, J., Bessel, T., Brink, S., and Kunz, M., 2014. Typhoon 09W "RAMMASUN" – Short Summary. Center for Disaster Management and Risk Reduction Technology (CEDIM) Forensic Disaster Analysis Group (FDA). Retrieved January 9, 2016, from http://www.cedim.de/download/CEDIM_FDA_Rammasun_Rep1_update.pdf.

Muzaffar, S.B., Takekawa, J.Y., Prosser, D.J., Newman, S.H. and Xiao, X., 2010. Rice production systems and avian influenza: interactions between mixed-farming systems, poultry and wild birds. *Waterbirds*, *33*(sp1), pp.219-230.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A. and Kent, J., 2000. Biodiversity hotspots for conservation priorities. *Nature*, *403*(6772), pp.853-858.

Newton, I., 2004. The recent declines of farmland bird populations in Britain: an appraisal of causal factors and conservation actions. *Ibis*, *146*(4), pp.579-600.

Niles, L.J., Burger, J., Porter, R.R., Dey, A.D., Minton, C.D., González, P.M., Baker, A.J., Fox, J.W. and Gordon, C., 2010. First results using light level geolocators to track Red Knots in the Western Hemisphere show rapid and long intercontinental flights and new details of migration pathways. *Wader Study Group Bull*, *117*(2), pp.123-130.

Nilsson, S.G., 1975. Clutch size and breeding success of birds in nest boxes and natural cavities. *Var Fagelvarld*, *34*, pp.207-211.

Pantuwatana, S., Imlarp, S. and Marshall, J.T., 1969. Vertebrate ecology of Bang Phra. *Nat. Hist. Bull. Siam Soc*, *23*(1-2), pp.132-183.

Parkes, K.C., 1959. Subspecific identity of introduced tree sparrows Passer montanus in the Philippine Islands. *Ibis*, *101*, pp.243-244.

Parsons, K.C., Mineau, P. and Renfrew, R.B., 2010. Effects of pesticide use in rice fields on birds. *Waterbirds*, *33*(sp1), pp.193-218.

Perfecto, I., Vandermeer, J.H., Bautista, G.L., Nunez, G.I., Greenberg, R., Bichier, P. and Langridge, S., 2004. Greater predation in shaded coffee farms: the role of resident neotropical birds. *Ecology*, *85*(10), pp.2677-2681.

Pernollet, C.A., Guelmami, A., Green, A.J., Masip, A.C., Dies, B., Bogliani, G., Tesio, F., Brogi, A., Gauthier-Clerc, M. and Guillemain, M., 2015. A comparison of wintering duck numbers among European rice production areas with contrasting flooding regimes. *Biological Conservation*, *186*, pp.214-224.

Peterson, A.T., 2006. Taxonomy is important in conservation: a preliminary reassessment of Philippine species-level bird taxonomy. *Bird Conservation International*, *16*(02), pp.155-173.

Peterson, A.T., Ball, L.G. and Brady, K.W., 2000. Distribution of the birds of the Philippines: biogeography and conservation priorities. *Bird Conservation International*, *10*(02), pp.149-167.

Phalan, B., Green, R. and Balmford, A., 2014. Closing yield gaps: perils and possibilities for biodiversity conservation. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *369*(1639), p.20120285.

Phalan, B., Onial, M., Balmford, A. and Green, R.E., 2011. Reconciling food production and biodiversity conservation: land sharing and land sparing compared. *Science*, *333*(6047), pp.1289-1291.

Phalan, B., Bertzky, M., Butchart, S.H., Donald, P.F., Scharlemann, J.P., Stattersfield, A.J. and Balmford, A., 2013. Crop expansion and conservation priorities in tropical countries. *PloS one*, *8*(1), p.e51759.

Philippines Statistics Authority's CountrySTAT Philippines, *Palay and Corn: Volume of Production by Ecosystem/Croptype, Geolocation, Year and Period.* 2015. Online at: http://countrystat.bas.gov.ph/selection.asp. [Accessed 17/03/2015]

Pierluissi, S., 2010. Breeding waterbirds in rice fields: a global review. *Waterbirds*, *33*(sp1), pp.123-132.

Pimentel, D., Stachow, U., Takacs, D.A., Brubaker, H.W., Dumas, A.R., Meaney, J.J., O'Neil, J.A., Onsi, D.E. and Corzilius, D.B., 1992a. Conserving biological diversity in agricultural/forestry systems. *BioScience*, pp.354-362.

Pimentel, D., Acquay, H., Biltonen, M., Rice, P., Silva, M., Nelson, J., Lipner, V., Giordano, S., Horowitz, A. and D'amore, M., 1992b. Environmental and economic costs of pesticide use. *BioScience*, pp.750-760.

Podlas, K. and Richner, H., 2013. Partial incubation and its function in great tits (Parus major)—an experimental test. *Behavioral Ecology*, *24*(3), pp.643-649.

Postel, S.L., Daily, G.C. and Ehrlich, P.R., 1996. Human appropriation of renewable fresh water. *Science-AAAS-Weekly Paper Edition*, *271*(5250), pp.785-787.

Princé, K., Moussus, J.P. and Jiguet, F., 2012. Mixed effectiveness of French agri-environment schemes for nationwide farmland bird conservation. *Agriculture, Ecosystems & Environment*, *149*, pp.74-79.

Puan, C.L., Goldizen, A.W., Zakaria, M., Hafidzi, M.N. and Baxter, G.S., 2011. Absence of differential predation on rats by Malaysian barn owls in oil palm plantations. *Journal of Raptor Research*, 45(1), pp.71-78.

Quinn, J.E., Brandle, J.R. and Johnson, R.J., 2012. The effects of land sparing and wildlife-friendly practices on grassland bird abundance within organic farmlands. *Agriculture, ecosystems & environment*, *161*, pp.10-16.

Rejesus, R.M., Palis, F.G., Rodriguez, D.G.P., Lampayan, R.M. and Bouman, B.A., 2011. Impact of the alternate wetting and drying (AWD) water-saving irrigation technique: evidence from rice producers in the Philippines. *Food Policy*, *36*(2), pp.280-288.

Riegert, J., Sedláček, O. and Hutterer, R., 2008. Diet of sympatric African grass owl (Tyto capensis) and spotted eagle owl (Bubo africanus) in the Bamenda Highlands, NW Cameroon. *African Journal of Ecology*, *46*(3), pp.428-431.

Robinson, R.A. and Sutherland, W.J., 2002. Post-war changes in arable farming and biodiversity in Great Britain. *Journal of applied Ecology*, *39*(1), pp.157-176.

Roger, P.A., 1996. *Biology and management of the floodwater ecosystem in rice fields*. Int. Rice Res. Inst.

Ruan, X. and Zheng, G., 1991. *Breeding ecology of the tree sparrow (Passer montanus)* in Beijing. Nestling mortality of granivorous birds due to microorganisms and toxic substances. PWN, Warsaw, pp.99-109.

Sawangproh, W., Philip, D. and Poonswad, P., Asian openbill stork Anastomus oscitans as a predator of the invasive alien gastropod Pomacea canaliculata in Thailand. *IIberus* 30(1), pp.111-117

Seckler, D., Barker, R. and Amarasinghe, U., 1999. Water scarcity in the twenty-first century. *International Journal of Water Resources Development*, *15*(1-2), pp.29-42.

Sekercioglu, C.H., 2006. Increasing awareness of avian ecological function. *Trends in ecology & evolution*, *21*(8), pp.464-471.

Seki, S.I., 2005. The effects of a typhoon (9918 Bart, 1999) on the bird community in a warm temperate forest, Southern Japan. *Ornithological Science*, *4*(2), pp.117-128.

Senar, J.C., Lleonart, J. and Metcalfe, N.B., 1994. Wing-shape variation between resident and transient wintering Siskins Carduelis spinus. *Journal of Avian Biology*, pp.50-54.

Shepherd, P., Crockett, T., De Santo, T.L. and Bildstein, K.L., 1991. The impact of Hurricane Hugo on the breeding ecology of wading birds at Pumpkinseed Island, Hobcaw Barony, South Carolina. *Colonial Waterbirds*, pp.150-157.

Sidle, J.G., Nagel, H.G., Clark, R., Gilbert, C., Stuart, D., Willburn, K. and Orr, M., 1993. Aerial thermal infrared imaging of sandhill cranes on the Platte River, Nebraska. *Remote Sensing of Environment*, *43*(3), pp.333-341.

Simpson, E.H., 1949. Measurement of diversity. *Nature*. 163: pp.688

Sizemore, G.C. and Main, M.B., 2012. Quality of flooded rice and fallow fields as foraging habitat for little blue herons and great egrets in the everglades agricultural area, USA. *Waterbirds*, *35*(3), pp.381-393.

Skutch, A.F., 1949. Do tropical birds rear as many young as they can nourish. *Ibis*, *91*(3), pp.430-458.

Skutch, A.F., 1985. Clutch size, nesting success, and predation on nests of Neotropical birds, reviewed. *Ornithological Monographs*, pp.575-594.

Smedley, R., 2013. Don't Scare Away the Birds. *Rice Today 12*(2013), pp.24-25 (see Appendix 7)

Smith, B.N., 1972. Natural abundance of the stable isotopes of carbon in biological systems. *BioScience*, *22*(4), pp.226-231.

Sodhi, N.S., Koh, L.P., Brook, B.W. and Ng, P.K., 2004. Southeast Asian biodiversity: an impending disaster. *Trends in Ecology & Evolution*, *19*(12), pp.654-660.

Sodhi, N.S., Koh, L.P., Clements, R., Wanger, T.C., Hill, J.K., Hamer, K.C., Clough, Y., Tscharntke, T., Posa, M.R.C. and Lee, T.M., 2010. Conserving Southeast Asian forest biodiversity in human-modified landscapes. *Biological Conservation*, *143*(10), pp.2375-2384.

Stafford, J.D., Kaminski, R.M. and Reinecke, K.J., 2010. Avian foods, foraging and habitat conservation in world rice fields. *Waterbirds*, *33*(sp1), pp.133-150.

Stickel, W.H., Stickel, L.F., Dyrland, R.A. and Hughes, D.L., 1984. DDE in birds: lethal residues and loss rates. *Archives of environmental contamination and toxicology*, *13*(1), pp.1-6.

Streby, H.M., Kramer, G.R., Peterson, S.M., Lehman, J.A., Buehler, D.A. and Andersen, D.E., 2015. Tornadic storm avoidance behavior in breeding songbirds. *Current Biology*, *25*(1), pp.98-102.

Stuart, A.M., Prescott, C.V., Singleton, G.R. and Joshi, R.C., 2011. Knowledge, attitudes and practices of farmers on rodent pests and their management in the lowlands of the Sierra Madre Biodiversity Corridor, Philippines. *Crop protection*, *30*(2), pp.147-154.

Stuart, A.M., Palenzuela, A.N., Bernal, C.C., Ramal, A.F. and Horgan, F.G., 2014. Effects of fertiliser applications on survival and recruitment of the apple snail, Pomacea canaliculata (Lamarck). *Crop Protection*, *64*, pp.78-87.

Subramanya, S., 1994. Non-random foraging in certain bird pests of field crops. *Journal of biosciences*, *19*(4), pp.369-380.

Summers-Smith, J.D., 1988. *The Sparrows*. JD Summers-Smith.

Summers-Smith, J.D., 1995. *The tree sparrow*. JD Summers-Smith.

Sundar, K.G. and Subramanya, S., 2010. Bird use of rice fields in the Indian subcontinent. *Waterbirds*, *33*(sp1), pp.44-70.

Svensson, L., 1992. *Identification Guide to European Passerines*. British Trust of Ornithology. 368 p.

Svensson, E. and Nilsen, J.Å., 1997. The trade-off between molt and parental care: a sexual conflict in the blue tit? *Behavioral Ecology*, *8*(1), pp.92-98.

Swaddle, J.P. and Lockwood, R., 2003. Wingtip shape and flight performance in the European Starling *Sturnus vulgaris*. *Ibis*, *145*(3), pp.457-464.

Syroechkovskiy Jr, E.E., 2006. *Long-term declines in Arctic goose populations in eastern Asia*. Waterbirds around the world, eds. GC Boere, CA Galbraith, and DA Stroud, pp.649-662.

Tabbal, D.F., Bouman, B.A.M., Bhuiyan, S.I., Sibayan, E.B. and Sattar, M.A., 2002. On-farm strategies for reducing water input in irrigated rice; case studies in the Philippines. *Agricultural Water Management*, *56*(2), pp.93-112.

Tarwater, C.E. and Brawn, J.D., 2010. The post-fledging period in a tropical bird: patterns of parental care and survival. *Journal of Avian Biology*, *41*(4), pp.479-487.

Taylor, I.R. and Schultz, M.C., 2010. Waterbird use of rice fields in Australia. *Waterbirds*, *33*(1), pp.71-82.

Teo, S.S., 2001. Evaluation of different duck varieties for the control of the golden apple snail (Pomacea canaliculata) in transplanted and direct seeded rice. *Crop Protection*, *20*(7), pp.599-604.

The Weather Channel, 2015a. Search: *Weather History* [various]. Wunderground.com. Available online at: http://www.wunderground.com/q/locid:RPDD0021?-MR=1 [accessed 19/03/2015]

The Weather Channel, 2015b. *Hurricane and Tropical Cyclones: Tropical Storm Haiyan*. Wunderground.com. Available online at: www.wunderground.com/hurricane/western-pacific/2013/Tropical-Storm-Haiyan [accessed 24/04/2015]

The Weather Channel, 2015c. *Weather History for RPVM*. Wunderground.com. Available online at: http://www.wunderground.com/history/airport/RPVM/2011/1/1/CustomHistory.html [accessed 12/12/2015]

The Weather Channel, 2015d. *Monthly Calendar: Los Baños, Philippines*. Wunderground.com. Available online at: www.wunderground.com/history/airport/RPLL/2014/2/15/MonthlyCalendar.html?req_city=Los%20Banos&req_state=&req_statename=Philippines&reqdb.zip=00000&reqdb.magic=57&reqdb.wmo=98432 [accessed 25/08/2015]

Ticehurst, C. and Whistler, H., 1930. A Spring Tour in Eastern Spain and the Pityusæ Islands. *Ibis*, *72*(4), pp.638-677.

Tilman, D., Balzer, C., Hill, J. and Befort, B.L., 2011. Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences*, *108*(50), pp.20260-20264.

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R. and Polasky, S., 2002. Agricultural sustainability and intensive production practices. *Nature*, *418*(6898), pp.671-677.

Tokumoto, J., Danjo, M., Kobayashi, Y., Kinoshita, K., Omotehara, T., Tatsumi, A., Hashiguchi, M., Sekijima, T., Kamisoyama, H., Yokoyama, T. and Kitagawa, H., 2013. Effects of exposure to clothianidin on the reproductive system of male quails. *Journal of Veterinary Medical Science*,*75*(6), pp.755-760.

Tourenq, C., Sadoul, N., Beck, N., Mesléard, F. and Martin, J.L., 2003. Effects of cropping practices on the use of rice fields by waterbirds in the Camargue, France. *Agriculture, ecosystems & environment*, *95*(2), pp.543-549.

Tourenq, C., Aulagnier, S., Durieux, L., Lek, S., Mesleard, F., Johnson, A. and Martin, J.L., 2001. Identifying rice fields at risk from damage by the greater flamingo. *Journal of applied ecology*, *38*(1), pp.170-179.

Tscharntke, T., Klein, A.M., Kruess, A., Steffan-Dewenter, I. and Thies, C., 2005. Landscape perspectives on agricultural intensification and biodiversity–ecosystem service management. *Ecology letters*, *8*(8), pp.857-874.

Tuong, T.P. and Bouman, B.A.M., 2003. Rice production in water-scarce environments. *Water productivity in agriculture: Limits and opportunities for improvement*, *1*, pp.13-42.

Vickery, J., Carter, N. and Fuller, R.J., 2002. The potential value of managed cereal field margins as foraging habitats for farmland birds in the UK. *Agriculture, Ecosystems & Environment*, *89*(1), pp.41-52.

Ward, P. and Poh, G.E., 1968. Seasonal breeding in an equatorial population of the tree sparrow Passer montanus. *Ibis*, *110*(3), pp.359-363.

Warnock, N., Takekawa, J.Y. and Bishop, M.A., 2004. Migration and stopover strategies of individual Dunlin along the Pacific coast of North America. *Canadian Journal of Zoology*, *82*(11), pp.1687-1697.

Way, M.J. and Heong, K.L., 1994. The role of biodiversity in the dynamics and management of insect pests of tropical irrigated rice—a review. *Bulletin of Entomological Research*, *84*(04), pp.567-587.

Whelan, C.J., Wenny, D.G. and Marquis, R.J., 2008. Ecosystem services provided by birds. *Annals of the New York Academy of Sciences*, *1134*(1), pp.25-60.

Whitehead, C.H.T. 1899. Field-notes on birds collected in the Philippine Islands in 1893-96. Part II. *Ibis* 5(7), pp.210-246.

Wild Bird Club of the Philippines. 2016. *Checklist of the Birds of the Philippines 2016*. Available online at: http://www.birdwatch.ph

Wiley, J.W. and Wunderle, J.M., 1993. The effects of hurricanes on birds, with special reference to Caribbean islands. *Bird Conservation International*, *3*(04), pp.319-349.

Wilson, J.D., Taylor, R. and Muirhead, L.B., 1996. Field use by farmland birds in winter: an analysis of field type preferences using resampling methods. *Bird Study*, *43*(3), pp.320-332.

Wilson, J.D., Evans, A.D. and Grice, P.V., 2009. *Bird conservation and agriculture* (Vol. 6). Cambridge: Cambridge University Press.

Wilson, J.D., Evans, A.D. and Grice, P.V., 2010. Bird conservation and agriculture: a pivotal moment? *Ibis*, *152*(1), pp.176-179.

Wood, B.J. and Fee, C.G., 2003. A critical review of the development of rat control in Malaysian agriculture since the 1960s. *Crop Protection*, *22*(3), pp.445-461.

Wood, C., Qiao, Y., Li, P., Ding, P., Lu, B. and Xi, Y., 2010. Implications of rice agriculture for wild birds in China. *Waterbirds*, *33*(sp1), pp.30-43.

Wright, H.L., Lake, I.R. and Dolman, P.M., 2012. Agriculture—a key element for conservation in the developing world. *Conservation Letters*, *5*(1), pp.11-19.

Wymenga, E. and Zwarts, L., 2010. Use of rice fields by birds in West Africa. *Waterbirds*, *33*(sp1), pp.97-104.

Yamagishi, S. and Ueda, K., 1986. Simultaneous territory mapping of male Fan-tailed Warblers (Cisticola juncidis). *Journal of Field Ornithology*, pp.193-199.

Yong, D.L., Liu, Y., Low, B.W., Espanola, C.P., Choi, C.Y. and Kawakami, K., 2015. Migratory songbirds in the East Asian-Australasian Flyway: a review from a conservation perspective. *Bird Conservation International*,*25*(01), pp.1-37.

APPENDICES

List of Appendices

Appendix 1.

List of commonly mentioned birds (common and taxonomic names)

Table A1. Table of most commonly mentioned species throughout the thesis. Common and scientific names checked against the Catalogue of life – 2016 Annual Checklist, available online *at* http://www.catalogueoflife.org/annual-checklist/2015/.

Name	Scientific classification	Name	Scientific classification
Little Grebe	*Tachybaptus ruficollis*	Common Kingfisher	*Alcedo atthis*
Intermediate Egret	*Egretta intermedia*	Indigo-Banded Kingfisher	*Ceyx cyanopectus*
Little Egret	*Egretta garzetta*	Bluetailed Bee-eater	*Merops philippinus*
Grey Heron	*Ardea cinerea*	Philippine Pigmy Woodpecker	*Dendrocopos maculatus*
Black-Crowned Night-Heron	*Nycticorax nycticorax*	Coppersmith Barbet	*Megalaima haemacephala*
Javan/Chinese Pond Heron	*Ardeola speciosa/Ardeola bacchus*	Barn Swallow	*Hirundo rustica*
Eastern Cattle Egret	*Bubulcus coromandus*	Pacific Swallow	*Hirundo tahitica*
Yellow Bittern	*Ixobrychus sinensis*	Striated Swallow	*Cecropis striolata*
Cinnamon Bittern	*Ixobrychus cinnamomeus*	Horsfield's/Singing Bushlark	*Mirafra javanica*
Wandering Whistling Duck	*Dendrocygna arcuata*	Large-billed Crow	*Corvus macrorhynchos*
Ruddy Breasted Crake	*Porzana fusca*	Pied Bush Chat	*Saxicola caprata*
White-Browed Crake	*Porzana cinerea*	Striated Grassbird	*Megalurus palustris*
Common Moorhen	*Gallinula chloropus*	Clamorous Reed Warbler	*Acrocephalus stentoreus*
Greater Painted Snipe	*Rostratula benghalensis*	Oriental Reed Warbler	*Acrocephalus orientalis*
Little Ringed Plover	*Charadrius dubius*	Tawny Grassbird	*Megalurus timoriensis*
Kentish Plover	*Charadrius alexandrinus*	Zitting Cisticola	*Cisticola juncidis*
Pacific Golden-Plover	*Pluvialis fulva*	Goldenheaded/Brightcap Cisticola	*Cisticola exilis*

Table A1 (cont.).Table of most commonly mentioned species throughout the thesis. Common and scientific names checked against the Catalogue of life – 2016 Annual Checklist, available online *at* http://www.catalogueoflife.org/annual-checklist/2015/

Name	Scientific classification	Name	Scientific classification
Oriental Plover	*Charadrius veredus*	Eastern Yellow Wagtail	*Motacilla tschutschensis*
Wood Sandpiper	*Tringa glareola*	Grey Wagtail	*Motacilla cinerea*
Common Sandpiper	*Actitis hypoleucos*	Paddyfield Pipit	*Anthus rufulus*
Pintail/Swinhoe's Snipe	*Gallinago stenura/megala*	White-Breasted Wood Swallow	*Artamus leucorynchus*
Red Necked Stint	*Calidris ruficollis*	Brown Shrike	*Lanius cristatus*
Oriental Pratincole	*Glareola maldivarum*	Long Tailed Shrike	*Lanius schach*
Black-Winged Stilt	*Himantopus himantopus*	Asian Glossy Starling	*Aplonis panayensis*
Red-Necked Phalarope	*Phalaropus lobatus*	Crested Myna	*Acridotheres cristatellus*
Whiskered Tern	*Chlidonias hybrida*	Eurasian Tree Sparrow	*Passer montanus*
Eastern Grass Owl	*Tyto longimembris*	Scaly-Breasted Munia	*Lonchura punctulata*
Philippine Nightjar	*Caprimulgus manillensis*	White-Bellied Munia	*Lonchura leucogastra*
Asian Palm-Swift	*Cypsiurus balasiensis*	Chestnut Munia	*Lonchura atricapilla*
House Swift	*Apus nipalensis*	Java Sparrow	*Lonchura oryzivora*

Appendix 2.

References used in Table 1.1.

Ackerman, J. T., J. Y. Takekawa, D. L. Orthmeyer, J. P. Fleskes, J. L. Yee and K. L. Kruse. 2006. Spatial use by wintering Greater White-fronted Geese relative to a decade of habitat change in California's Central Valley. *Journal of Wildlife Management* 70: 965–976.

Acosta, M., L. Mugica, C. Mancina and X. Ruiz. 1996. Resource partitioning between Glossy Ibis and American White Ibis in a rice field system in south-central Cuba. *Colonial Waterbirds* 19: 65–72.

Acosta, M., L. Mugica, D. Blanco, B. López-Lanús, R. Antones Dias, L. W. Doodnath and J. Hurtado. 2010. Birds of rice fields in the Americas. *Waterbirds* 33 (Special Publication 1): 105–122.

Aguero, D. A. and Y. Poleo. 2000. Predator potential of Barn Owl (*Tyto alba*) on rat populations in rice crops. *Investigacion Agricola* 5: 5.

Aguilera, E. 1996. Food and feeding sites of the Eurasian Spoonbill (*Platalea leucorodia*) in southern Spain. *Colonial Waterbirds* 19: 159–166.

Ali, S. 1949. Bird friends and foes of the cultivator. *Indian Farming* 10: 385–387.

Amano, T., 2009. Conserving bird species in Japanese farmland: past achievements and future challenges. *Biological Conservation*, *142*(9): 1913-1921.

Amano, T., K. Ushiyama, G. Fujita and H. Higuchi. 2004. Alleviating grazing damage by White-fronted Geese: an optimal foraging approach. *Journal of Applied Ecology* 41: 675–688.

Amano, T., Y. Kusumoto, Y. Tokuoka, S. Yamada, E.-Y. Kim and S. Yamamoto. 2008. Spatial and temporal variations in the use of rice-paddy dominated landscapes by birds in Japan. *Biological Conservation* 141: 1704– 1716.

Azuma, A., K. Takeuchi and A. Tsunekawa. 1998. Behavior of Gray-faced Buzzard Eagles and their habitat use in yatsu-environment. *Papers on Environmental Information Science* 12: 239–244. (In Japanese with English summary)

Azuma, A., K. Tokita, K. Takeuchi and A. Tsunekawa. 1999. Land condition of Gray-faced Buzzard, *Butastur indicus* habitats in watershed of Tega Marsh, Chiba Prefecture. *Journal of Rural Planning Association* (Special Issue 1): 253–258. (In Japanese with English summary)

Bambaradeniya, C. N. B., J. P. Edirisinghe, D. N. De Silva, C. V. S. Gunatilleke, K B. Ranawana and S. Wijekoon. 2004. Biodiversity associated with an irrigated rice agro-ecosystem in Sri Lanka. *Biodiversity and Conservation* 13: 1715–1753.

Barbosa, A. 1996. Foraging habitat use in a Mediterranean estuary by Dunlin, *Calidiis alpina. Journal of Coastal Research* 12: 996–999.

Beilfuss, R. D., T. Dodman and E. K. Urban. 2007. The status of cranes in Africa in 2005. *Ostrich* 78: 175–184.

Benton, T. G., J. A. Vickery and J. D. Wilson. 2003. Farmland biodiversity: is habitat heterogeneity the key? *Trends in Ecology and Evolution* 19: 182–188.

Bird, J. A., G. S. Pettygrove and J. M. Eadie. 2000. The impact of waterfowl foraging on the decomposition of rice straw: mutual benefits for rice growers and waterfowl. *Journal of Applied Ecology* 37: 728–741.

Blanco, D. E., B. López-Lanús, R. Antunes Dias, A. Azpiroz and F. Rilla.2006. *Use of rice fields by migratory shorebirds in southern South America.* Wetlands International, Buenos Aires, Argentina.

Boano, G. and R. Toffoli. 2002. A line transect survey of wintering raptors in the western Po plain of northern Italy. *Journal of Raptor Research* 36: 128–135.

Boncompagni, E., A. Muhammad, R. Jabeen, E. Orvini, C. Gandini, C. Sanpera, X. Ruiz and M. Fasola. 2003. Egrets as monitors of trace-metal contamination in wetlands in Pakistan. *Archives of Environmental Contamination & Toxicology* 45: 399–406.

Borad, C. K., A. Mukherjee and B. M. Parasharya. 2000. Conservation of the avian biodiversity in paddy *(Oryza sativa)* crop ecosystem. *Indian Journal of Agricultural Sciences* 70: 378–381.

Borad, C. K., A. Mukherjee and B. M. Parasharya. 2001. Damage potential of Indian Sarus Crane in paddy crop agroecosystem in Kheda District, Gujarat, India. *Agriculture, Ecosystems and Environment* 86: 211– 215.

Bos, D., I. Grigoras and A. Ndiaye. 2006. *Land cover and avian biodiversity in rice fields and mangroves of West Africa.* A&W-report 824, Altenburg & Wymenga ecological consultants/Wetlands International, Dakar, Senegal/Veenwouden, Netherlands.

Bostan, N., M. Ashraf, A. S. Mumtaz and I. Ahmad. 2007. Diagnosis of heavy metal contamination in agro-ecology of Gujranwala, Pakistan using Cattle Egret (*Bubulcus ibis)* as bioindicator. *Ecotoxicology* 16: 247–251.

Bourne, G. R. 1981. Food habits of Black-bellied Whistling Ducks occupying rice culture habitats. *Wilson Bulletin* 93: 551–554.

Bourne, G. R. and D. R. Osborne. 1978. Black-bellied Whistling Duck utilization of a rice culture habitat. *Interciencia* 3: 152–159.

Campos, F. and J. M. Lekuona. 2001. Are rice fields a suitable foraging habitat for Purple Herons during the breeding season? *Waterbirds* 24: 450–452.

Carpegna, F., G. Alessandria and M. Delia Toffola. 2003. Note on the wintering of the Marsh Harrier *Circus aeruginosus* in the paddy fields of Vercelli. *Avocetta* 27: 30.

Chan, S.-F., L. L. Severinghaus and C.-K. Lee. 2007. The effect of rice field fragmentation on wintering waterbirds at the landscape level. *Journal of Ornithology* 148 (Supplement 2): 333–342.

Comín, F. A., J. A. Romero, O. Hernández and M. Menéndez. 2001. Restoration of wetlands from abandoned rice fields for nutrient removal, and biological community and landscape diversity. *Restoration Ecology* 9: 201–208.

Cummings, J. L., S. S. Shwiff and S. K. Tupper. 2005. Economic impacts of blackbird damage to the rice industry. Proceedings of the 11th Wildlife Damage Management Conference. (D. L. Nolte and K. A. Fagerstone, Eds.) 11: 317–322.

Custer, C. M. and J. Galli. 2002. Feeding habitat selection by Great Blue Herons and Great Egrets nesting in east central Minnesota. *Waterbirds*25: 115–124.

Czech, H. A. and K. C. Parsons. 2002. Agricultural wetlands and waterbirds: a review. *Waterbirds* 25 (Special Publication 2): 56–65.

Daniels, R. J. R., N. V. Joshi and M. Gadgil. 1990. Changes in the bird fauna of Uttara Kannada, India, in relation to changes in land use over the past century. *Biological Conservation* 52: 37–48.

Day, J. H. and M. A. Colwell. 1998. Waterbird communities in rice fields subjected to different post-harvest treatments. *Colonial Waterbirds* 21: 185–197.

del Hoyo, J., A. Elliott and J. Sargatal. 1992. *Handbook of the Birds of the World.* Vol. 1. Lynx Edicions, Barcelona, Spain.

Delaney, S. and D. Scott. 2006. *Waterbird Population Estimates.* Fourth Edition. Wetlands International, Wageningen, Netherlands.

Dhindsa, M. S. and H. K. Saini. 1994. Agricultural ornithology: an Indian perspective. *Journal of Bioscience* 19: 391–402.

Dhindsa, M. S. and H. S. Toor. 1980. Extent of bird damage to rice nurseries in the Punjab and its control. *Indian Journal of Agricultural Sciences* 50: 715–719.

Dhindsa, M. S. and H. S. Toor. 1990. Feeding ecology of three sympatric species of Indian weaverbirds in an intensely cultivated area. Pages217–236 *in* Granivorous Birds in the Agricultural Landscape. Proceedings of General Meetings of the Working Group on Granivorous Birds (J. Pinowski and J. D. Summers-Smith, Eds.). INTECOL. PWN - Polish Scientific Publishers, Warszawa, Poland.

Dies, J. I., N. Ramon and J. Prosper. 2003. Winter breeding by Black-crowned Night Heron in eastern Spain. *Waterbirds* 26: 379–382.

Dies, J. I., J. Marin and C. Perez. 2005. Diet of nesting Gull-billed Terns in eastern Spain. *Waterbirds* 28: 106–109.

Donald, P. F. 2004. Biodiversity impacts of some agricultural commodity production systems. *Conservation Biology* 18: 17–37.

Donald, P.F., Green, R.E. and Heath, M.F., 2001. Agricultural intensification and the collapse of Europe's farmland bird populations. *Proceedings of the Royal Society of London B: Biological Sciences*, *268*(1462): 25-29.

Donald, P.F., Sanderson, F.J., Burfield, I.J. and Van Bommel, F.P., 2006. Further evidence of continent-wide impacts of agricultural intensification on European farmland birds, 1990–2000. *Agriculture, Ecosystems & Environment*, *116*(3): 189-196.

Eadie, J.M., Elphick, C.S., Reinecke, K.J. and Miller, M.R., 2008. Wildlife values of North American ricelands.

Elphick, C. S. 2000. Functional equivalency between rice fields and seminatural wetland habitats. *Conservation Biology* 14: 181–191.

Elphick, C. S. 2004. Assessing conservation trade-offs: Identifying the effects of flooding rice fields for waterbirds on non-target bird species. *Biological Conservation* 117: 105–110.

Elphick, C. S. and L. W. Oring. 1998. Winter management of Californian rice fields for waterbirds. *Journal of Applied Ecology* 35: 95–108.

Elphick, C. S. and L. W. Oring. 2003. Conservation implications of flooding rice fields on winter waterbird communities. *Agriculture, Ecosystems and Environment* 94: 17–29.

Elphick, C. S., A. F. Zuur and E. N. Ieno. 2007. Investigating the effects of rice farming on aquatic birds with mixed modelling. Pages 417–434 *in* Analyzing Ecological Data (A. F. Zuur, E. N. Ieno, and G. M. Smith, Eds.). Springer, New York, New York.

Fanslow, G. 2006. Balanced on a wing. *Rice Today, July–September*2006: 34–36.

Fasola, M. 1983. Nesting populations of herons in Italy depending on feeding habitats. *Bollettino di Zoologia* 50: 21–24.

Fasola, M. and R. Alieri. 1992. Conservation of heronry Ardeidae sites in north Italian agricultural landscapes. *Biological Conservation* 62: 219–228.

Fasola, M. and X. Ruiz. 1996. The value of rice fields as substitutes for natural wetlands for waterbirds in the Mediterranean region. *Colonial Waterbirds* 19 (Special Publication 1): 122–128.

Fasola, M. and X. Ruiz. 1997. Rice farming and waterbirds: integrated management in an artificial landscape. Pages 210–235 *in* Farming and Birds in Europe: The Common Agricultural Policy and its Implications for Bird Conservation (D.J. Pain and M. W. Pienkowski, Eds.). Academic Press, San Diego, California.

Fasola, M. and A. Brangi. 2010. Consequences of rice agriculture for waterbird population size and dynamics. *Waterbirds* 33 (Special Publication 1): 160–166.

Fasola, M., P. Galeotti, G. Bogliani and P. Nardi. 1981. Food of Night Heron (*Nycticorax nycticorax*) and Little Egret (*Egretta garzetta*) feeding in rice fields. *Rivista Italiana di Ornitologia* 51: 97–112.

Fasola, M., V. Gouter and J. Walmsley. 1983. Comparative breeding biology of the gulls and terns in the four main deltas of the northern Mediterranean. Pages 11–123 *in* Status and Conservation of Seabirds (J. S. Aguilar, X. Monbaillu and A. Paterson, Eds.). SEO, Madrid, Spain.

Figuerola, J., R. Mateo, A. J. Green, J. Y. Mondain-Monval, H. Lefranc and G. Mentaberre. 2005. Grit selection in waterfowl and how it determines exposure to ingested lead shot in Mediterranean wetlands. *Environmental Conservation* 32: 226–234.

Fleury, B. E. and T. W. Sherry. 1996. Long-term population trends of colonial wading birds in the southern United States: The impact of crawfish aquaculture on Louisiana populations. *Auk* 113: 613–632.

Frolking, S., J. B. Yeluripati and E. Douglas. 2006. New district-level maps of rice cropping in India: a foundation for scientific input into policy assessment. *Field Crops Research* 98: 164–177.

Fujioka, M. and S. J. Lane. 1997. The impact of changing irrigation practices in rice fields on frog populations of the Kanto Plain, central Japan. *Ecological Research* 12: 101–108.

Fujioka, M., J. W. Armacost, Jr., H. Yoshida and T. Maeda. 2001. Value of fallow farmlands as summer habitats for waterbirds in a Japanese rural area. *Ecological Research* 16: 555–567.

Fujioka, M., S. D. Lee, M. Kurechi and H. Yoshida. 2010. Bird use of rice fields in Korea and Japan. *Waterbirds* 33 (Special Publication 1): 8–29.

Furuno, T. 2001. *The Power of the Duck - Integrated Rice and Duck Farming.* Tagari Publications (The Permaculture Institute), Sister's Creek, Tasmania, Australia.

Gans, C. 1994. Frogs and paddy: problems of management. *Journal of Bombay Natural History Society* 91: 3–36.

Gaston, A. J. 1984. Is habitat destruction in India and Pakistan beginning to affect the status of endemic passerine birds? *Journal of Bombay Natural History Society* 81: 636–641.

Gilary, J. K. 2006. *Health status of water birds in the southern districts of Tamilnadu.* Unpublished Ph.D. Dissertation, Tamilnadu Veterinary and Animal Sciences University, Chennai, India.

González-Solís, J., X. Bernadí and X. Ruiz. 1996. Seasonal variation of waterbird prey in the Ebro Delta rice fields. *Colonial Waterbirds* 19: 135–142.

Gopal, B. and M. Chauhan. 2006. Biodiversity and its conservation in the Sundarban Mangrove ecosystem. *Aquatic Science* 68: 338–354.

Grimmett, R., C. Inskipp and T. Inskipp. 1998. *Birds of the Indian Subcontinent.* Christopher Helm, London, UK.

Guadagnin, D. L., L. F. C. Perello and J. O. Menegheti. 2007. A situação atual da caça de lazer e manejo de áreas úmidas no Rio Grande do Sul (Current situation of leisure hunting and wetland management in Rio Grande do Sul State, South Brazil). *Neotropical Biology and Conservation*2: 63–70.

Guzman, J., A. Garcia, C. Amado and A. Viejo. 1999. Influence of farming activities in the Iberian Peninsula on the winter habitat use of Common Crane (*Grus grus*) in areas of its traditional migratory routes. *Agriculture, Ecosystems and Environment* 72: 207–214.

Hafner, H. and M. Fasola. 1997. Long-term monitoring and conservation of herons in France and Italy. *Colonial Waterbirds* 20: 298–305.

Hafner, H., P. J. Dugan and V. Boy. 1986. Use of artificial and natural wetlands as feeding sites by Little Egrets (*Egretta garzetta*) in the Camargue, southern France. *Colonial Waterbirds* 9: 149–154.

Hafner, H., R. E. Bennetts and Y. Kayser. 2001. Changes in clutch size, brood size and numbers of nesting Squacco Herons *Ardeola ralloides* over a 32-year period in the Camargue, southern France. *Ibis* 143: 11–16.

Henry, G. M. 1998. *A Guide to the Birds of Sri Lanka.* Third edition. Oxford University Press, Delhi, India.

Hicklin, P. W. and A. L. Spaans. 1993. *The birds of the SML rice fields in Suriname: species composition, numbers and toxichemical threats. Technical Report Series No. 174.* Canadian Wildlife Service, Ottawa, Canada.

Hirano, T., K. Gotanda and T. Takamatsu. 1997. The changes of the breeding status of Ruddy Crakes *Porzana fusca* in Tochigi Prefecture.*Accipiter* 3: 1–6. (In Japanese with English summary)

Hirano, T., M. Kimijima, M. Kobori, M. Kobori and Y. Shiga. 2003. Status of Ruddy Crakes in Tochigi Prefecture, central Japan in 2002. *Accipiter* 9: 1–9. (In Japanese with English summary)

Hobaugh, W. C., C. D. Stutzenbaker and E. L. Flickinger. 1989. The rice prairies. Pages 367–384 *in* Habitat Management for Migrating and Wintering Waterfowl in North America (L. M. Smith, R. L. Pederson and R. M. Kaminski, Eds.). Texas Tech University Press, Lubbock, Texas.

Hou, Y., L. Zhou, C. Yang and Q. S. Wang. 2007. Disturbance to the Oriental White Stork (*Ciconia boyciana*) breeding in the wintering area. *Zoological Research* 28: 344–352. (In Chinese with English abstract)

Ibáñez, C., A. Curcó, X. Riera, I. Ripoll and C. Sánchez. 2010. Influence on birds of rice field management practices during the growing season: a review and an experiment. *Waterbirds* 33 (Special Publication 1): 167–180.

Inskipp, T., N. Lindsey and J. W. Duckworth. 1996. *An Annotated Checklist of the Birds of the Oriental Region.* Oriental Bird Club, Sandy, Bedfordshire, UK.

Iwata, T. and M. Fujioka. 2006. Effects of winter flooding on aquatic fauna in lotus and rice fields during the growing season. *Japanese Journal of Conservation Ecology* 11: 94–104. (In Japanese with English summary)

Jeganathan, P., A. R. Rahmani and R. E. Green. 2005. Construction of Telugu-Ganga Canal in and around two protected areas in Cuddapah District, Andra Pradesh, India. Immediate threat to the world population of the critically endangered Jerdon's Courser Rhinoptilus bitorquatus. Unpublished report, *Bombay Natural History Society*. Mumbai, India.

Jónsson, J. E. and A. D. Afton. 2006. Different time and energy budgets of Lesser Snow Geese in rice-prairies and coastal marshes in Southwest Louisiana. *Waterbirds* 29: 451–458.

Kaphalia, B. A., M. M. Husain, T. D. Seth, A. Kumar and C. R. K. Murti.1981. Organochlorine pesticide residues in some Indian wild birds. *Pesticides Monitoring Journal* 15: 9–13.

Kazantzidis, S. and V. Goutner. 1996. Foraging ecology and conservation of feeding habitats of Little Egrets (*Egretta garzetta*) in the Axios River Delta, Macedonia, Greece. *Colonial Waterbirds* 19: 115–121.

Kazantzidis, S., V. Goutner, M. Pyrovetsi and A. Sinis. 1997. Comparative nest site selection and breeding success in 2 sympatric Ardeids, Black-crowned Night-Heron (*Nycticorax nycticorax*) and Little Egret (*Egretta gaizetta*) in the Aries Delta, Macedonia, Greece. *Colonial Waterbirds* 20: 505–517.

King, S., C. S. Elphick, D. Guadagnin, O. Taft and T. Amano. 2010. Effects of landscape features on waterbird use of rice fields. *Waterbirds* 33 (Special Publication 1): 151–159.

Kingsford, R. T. and R. F. Thomas. 1995. The Macquarie Marshes in arid Australia and their waterbirds: a 50 year history of decline. *Environmental Management* 19: 867–878.

Kunisue, T., M. Watanabe, A. Subramanian, A. M. Titenko and S. Tanabe. 2003. Congener-specific patterns and toxic assessment of polychlorinated biphenyls in resident and migratory birds from southern India and Lake Baikal in Russia. *Archives of Environmental Contamination & Toxicology* 45: 547–561.

Lane, S. J. and M. Fujioka. 1998. The impact of changes in irrigation practices on the distribution of foraging egrets and herons (Ardeidae) in the rice fields of central Japan. *Biological Conservation* 83: 221–230.

Lane, S. J., A. Azuma and H. Higuchi. 1998. Wildfowl damage to agriculture in Japan. *Agriculture, Ecosystems and Environment* 70: 69–77.

Lawler, S. P. 2001. Rice fields as temporary wetlands: a review. *Israel Journal of Zoology* 47: 513–528.

Lawler, S. P. and D. A. Dritz. 2005. Straw and winter flooding benefit mosquitoes and other insects in a rice agroecosystem. *Ecological Applications* 15: 2052–2059.

Lee, S. D., P. G. Jabłonski and H. Higuchi. 2007a. Winter foraging of threatened cranes in the Demilitarized Zone of Korea: behavioral evidence for the conservation importance of unplowed rice fields. *Biological Conservation* 138: 286–289.

Li, X., D. Li, Y. Li, Z. Ma and T. Zhai. 2002. Habitat evaluation for Crested Ibis: A GIS-based approach. *Ecological Research* 17: 565–573.

Lombardini, K., R. E. Bennetts and C. Tourenq. 2001. Foraging success and foraging habitat use by Cattle Egrets and Little Egrets in the Camargue, France. *Condor* 103: 38–44.

Longoni, V., D. Rubolini and G. Bogliani. 2007. Delayed reproduction among Great Bitterns *Botarus stellaris* breeding in ricefields. *Bird Study*54: 275–279.

Longoni, V. 2010. Rice fields and waterbirds in the Mediterranean region and the Middle East. *Waterbirds* 33 (Special Publication 1): 83–96.

López-Lanús, B., I. Roesler, D. E. Blanco, P. F. Petracci, M. Serra and M. E. Zaccagnini. 2007. Bobolink (*Dolichonyx oryzivorus*) numbers and non-breeding ecology in the rice fields of San Javier, Santa Fe province, Argentina. *Ornitologia Neotropical* 18: 493–502.

Lourenço, P. M. and T. Piersma. 2008. Stopover ecology of Black-tailed Godwits *Limosa limosa limosa* in Portuguese rice fields: a guide on where to feed in winter. *Bird Study* 55: 194–202.

Lu, B. Z. 1989. Supplemented natural food for the wild Crested Ibis. *Chinese Wildlife* 6: 23–24. (In Chinese with English summary)

Ma, Z. J., W. J. Li and Z. J. Wang. 2000. *Conservation of Red-crowned Crane.* Tsinghua University Press, Beijing, China.

Ma, Z., Cai, Y., Li, B. and Chen, J., 2010. Managing wetland habitats for waterbirds: an international perspective. *Wetlands*, *30*(1): 15-27.

Macias, M., A. J. Green and M. I. Sanchez. 2004. The diet of the Glossy Ibis during the breeding season in Doñana, southwest Spain. *Waterbirds*27: 234–239.

Maeda, T. 2001. Patterns of bird abundance and habitat use in rice fields of the Kanto Plain, central Japan. *Ecological Research* 16: 569–585.

Maeda, T. 2005. Bird use of rice field strips of varying width in the Kanto Plain of central Japan. *Agriculture, Ecosystems and Environment* 105: 347–351.

Mañosa, S., R. Mateo and R. Guitart. 2001. A review of the effects of agricultural and industrial contamination on the Ebro delta biota and wildlife. *Environmental Monitoring and Assessment* 71: 187–205.

Mañosa i Rifé, S. 1997. *A review of rice farming and waterbird conservation in the three western Mediterranean areas, the Camargue, the Ebro Delta and the North-western Po Plain.* Station Biologique Tour de Valat, Arles, France.

Marchant, S. and P. J. Higgins. 1990. *Handbook of Australian, New Zealand and Antarctic Birds.* Vol. 1.Oxford University Press, Melbourne, Australia.

Marin, A.R., Masscheleyn, P.H. and Patrick Jr, W.H., 1992. The influence of chemical form and concentration of arsenic on rice growth and tissue arsenic concentration. *Plant and Soil*, 139(2): 175-183.

Marques, P. A. M. and L. Vicente. 1999. Seasonal variation of waterbird prey abundance in the Sado Estuary rice fields. *Ardeola* 46: 231–234.

McAtee, W. L. 1923. Ducks useful in Arkansas as scavengers of red rice. *Auk* 40: 527–528.

McKay, W. D. 1981. Notes on Purple Gallinules in Colombian rice fields.*Wilson Bulletin* 93: 267–271.

Men, B. X., B. R. Ogle and J. E. Lindberg. 2002. Studies on integrated duck-rice systems in the Mekong Delta of Vietnam. *Journal of Sustainable Agriculture* 20: 27–40.

Mesléard, F., S. Garnero, N. Beck and E. Rosecchi. 2005. Uselessness and indirect negative effects of an insecticide on rice field invertebrates. *Comptes Rendus Biologies* 328: 955–962.

Miller, M. R. and G. D. Wylie. 1996. Preliminary estimate of rice present in strip-harvested fields in the Sacramento Valley, California. *California Fish and Game* 82: 187–191.

Miller, M. R., D. E. Sharp, D. S. Gilmer and W. R. Mulvaney. 1989. Rice available to waterfowl in harvested fields in the Sacramento Valley, California. *California Fish and Game* 75: 113–123.

Mishra, A., S. D. Sharma and G. H. Khan. 2002. Rehabilitation of degraded sodic lands during a decade of *Dalbergia sissoo* plantation in Sultanpur district of Uttar Pradesh, India. *Land Degradation ScDevelopment* 13: 375–386.

Momose, H., M. Ueta, N. Fujiwara, T. Uchiyama, T. Ishizaka, K. Morissaki and M. Matsue. 2005. Factors affecting the number of breeding Grey-faced Buzzard-Eagles *Butastur indicus*. *Landscape Research Journal* 68:555–558. (In Japanese with English summary.)

Muralidharan, S. 1993. Aldrin poisoning of Sarus Cranes (*Gins antigone)*and a few granivorous birds in Keoladeo National Park, Bharatpur, India. *Ecotoxicology* 2: 196–202.

Muzaffar, S. B., J. Y. Takekawa, D. J. Prosser, S. H. Newman and X. Xiao. 2010. Rice production systems and avian influenza: Interactions between mixed-farming systems, poultry and wild birds. *Waterbirds* 33 (Special Publication 1): 219–230.

Nathan, S. P. F. and B. Rajendran. 1982. Bird fauna of the rice crop ecosystem in Pondicherry region. *Journal of Bombay Natural History Society* 79: 204–206.

Neale, G. 1918. Ducks vs. rice. *California Fish and Game* 4: 70–72.

Neff, J. A. 1957. *Blackbirds and the Arkansas rice crop.* Agricultural Experiment Station Publication, University of Arkansas, Fayetteville, Arkansas.

Nemeth, E., P. Bossew and C. Plutzar. 2005. A distance-dependent estimation of foraging ranges of neighbouring bird colonies. *Ecological Modelling* 182: 67–73.

Pain, D. J., R. Gargi, A. A. Cunningham, A. Jones and V. Prakash. 2004. Mortality of globally threatened Sarus Cranes *Grus antigon* from monocrotophos poisoning in India. *Science of the Total Environment* 326:55–61.

Papadopoulou-Mourkidou E., D. G. Karpouzas, J. Patsias, A. Kotopoulou, A. Milothridou, K. Kintzikoglou and P. Vlachou. 2004. The potential of pesticides to contaminate the groundwater resources of the Axios river basin. Part II. Monitoring study in the south part of the basin. *Science of the Total Environment* 321: 147–164.

Parejo, D. and J. M. Sánchez-Guzmán. 1999. Effects of agricultural development on colonial ardeid populations in southwestern Spain. *Waterbirds* 22: 302–306.

Peach, W. J., G. M. Siriwardena and R. D. Gregory. 1999. Long-term changes in over-winter survival rates explain the decline of Reed Bunting *Embeiiza schoeniclus* in Britain. *Journal of Applied Ecology* 36: 798–811.

Perennou, C., R. V. Lansdown and J. A. Hancock. 2000. Herons in south and west Asia. Pages 55–72 *in* Heron Conservation (J. A. Kushlan and H. Hafner, Eds.). Academic Press, New York, New York.

Pierluissi, S. 2010. Breeding waterbirds in rice fields: a global review. *Waterbirds* 33 (Special Publication 1): 123–132.

Piper, S. E. 1944. *Depredations on crops by mudhens.* California Department of Food and Agriculture Preliminary Report B-26, Sacramento, California.

Prosper, J. and H. Hafner. 1996. Breeding aspects of the colonial ardeidae in the Albufera de Valencia, Spain: population changes, phenology and reproductive success of the three most abundant species. *Colonial Waterbirds* 19: 98–107.

Rahmani, A. R. and R. G. Soni. 1997. Avifaunal changes in the Indian Thar Desert. *Journal of Arid Environments* 36: 687–703.

Ramesh, A., S. Tanabe, K. Kannan, A. N. Subramaniam, P. L. Kumaran and R. Tatsukawa. 1992. Characteristic trend of persistent organochlorine contamination in wildlife from a tropical agricultural watershed, south India. *Archives of Environmental Contamination & Toxicology* 23: 26–36.

Remsen, J. V., Jr., M. M. Swan, S. W. Cardiff and K. V. Rosenberg. 1991. The importance of the rice-growing region of south-central Louisiana to winter populations of shorebirds, raptors, waders, and other birds. *Journal of Louisiana Ornithology* 1: 35–46.

Rendón, M. A., A. J. Green, E. Aguilera and P. Almaraz. 2008. Status, distribution and long-term changes in the waterbird community wintering in Doñana, south-west Spain. *Biological Conservation* 141: 1371–1388.

Richardson, A. J. and I. R. Taylor. 2003. Are rice fields in southeastern Australia an adequate substitute for natural wetlands as forging areas for egrets? *Waterbirds* 26: 353–363.

Richardson, A. J., I. R. Taylor and J. E. Growns. 2001. The foraging ecology of egrets in rice fields in southern New South Wales, Australia. *Waterbirds* 24: 255–264.

Roberts, T. J. 1991. *The Birds of Pakistan. Volume 1. Regional Studies and Non-Passeriformes.* Oxford University Press, Karachi, Pakistan.

Roberts, T. J. 1992. *The Birds of Pakistan. Volume 2. Passeriformes: Pitta to Buntings.* Oxford University Press, Karachi, Pakistan.

Robertson, D. G. and R. D. Slack. 1995. Landscape change and its effects on the wintering range of a Lesser Snow Goose *Chen caerulescens caerulescens* population: a review. *Biological Conservation* 71: 179–185.

Sahrawat, K. L. 2006. Freshwater shortages and strategy for wetland rice cultivation. *Current Science* 90: 1457– 1458.

Sánchez-Guzmán, J. M., R. Morán, J. A. Masero, C. Corbacho, E. Costillo, A. Villegas and F. Santiago-Quesada. 2007. Identifying new buffer areas for conserving waterbirds in the Mediterranean basin: the importance of the rice fields in Extremadura, Spain. *Biodiversity and Conservation* 26: 3333–3344.

Sanpera, C., X. Ruiz, L. Jover, G. Lorente, R. Jabeen, A. Muhammad, E. Boncompagni and M. Fasola. 2003. Persistent organic pollutants in Little Egret eggs from selected wetlands in Pakistan. *Archives of Environmental Contamination Sc Toxicology* 44: 360–368.

Sato, N. and N. Maruyama. 1996. Foraging site preference of Intermediate Egrets *Egretta intermedia* during the breeding season in the eastern part of the Kanto Plain, Japan. *Journal of Yamashina Institute for Ornithology* 28: 19–34.

Scott, D. A. 1989. *A Directory of Asian Wetlands.* IUCN, Gland, Switzerland & Cambridge, UK.

Shimada, T. 1999. Comparison of the food abundance for wintering geese of different harvesting methods in rice fields near Lake Izunuma-Uchinuma. *Strix* 17: 111–117. (In Japanese with English summary)

Shimada, T. 2002. Daily activity pattern and habitat use of Greater White-fronted Geese wintering in Japan: factors of the population increase. *Waterbirds* 25: 371– 377.

Shimada, T., Y. Suzuki and M. Ishida. 2002. Food items of Greater White-fronted Geese by fecal analysis. *Strix* 20: 137–141. (In Japanese with English summary)

Shuford, W. D., G. D. Page and J. E. Kjelmyr. 1998. Patterns and dynamics of shorebird use of California's Central Valley. *Condor* 100: 227–244.

Shyama, S. K. 1997. Studies on the avian pests of rice (*Oryza sativa*) in Goa. *Pavo* 35: 129–133.

Stafford, J. D., R. M. Kaminski and K. J. Reinecke. 2010. Avian foods, foraging, and habitat conservation in world rice fields. *Waterbirds* 33 (Special Publication 1): 133–150.

Subramanya, S. 1991. *Studies on birds of rice fields with special reference to certain pest species.* Unpublished Ph.D. Dissertation, University of Agricultural Sciences, Bangalore, India.

Subramanya, S. 1994. Non-random foraging in certain bird pests of field crops. *Journal of Biosciences* 19: 369–380.

Subramanya, S. and G. K. Veeresh. 1998a. Avifaunal patterns in the rice fields of Bangalore. Pages 30–53 *in* Birds in Agricultural Ecosystem (M. S. Dhindsa, P. S. Rao and B. M. Parasharya, Eds.). Society for Applied Ornithology, Hyderabad, India.

Sundar, K. S. G. 2004. Group size and habitat use by Black-necked Storks *Ephippiorhynchus asiaticus* in an agriculture-dominated landscape in Uttar Pradesh, India. *Bird Conservation International* 14: 323–334.

Sundar, K. S. G. 2005. Effectiveness of road transects and wetland visits for surveying Black-necked Storks *Ephippiorhynchus asiaticus* and Sarus Cranes *Grus antigone* in India. *Forktail* 21: 27–32.

Sundar, K. S. G. 2006. Flock size, density and habitat selection of four large waterbirds species in an agricultural landscape in Uttar Pradesh, India: implications for management. *Waterbirds* 29: 365–374.

Sundar, K. S. G. 2009. Are rice paddies suboptimal breeding habitat for Sarus Cranes in Uttar Pradesh, India? *Condor* 111: 611–623.

Sundar, K. S. G. and S. Subramanya. 2010. Bird use of rice fields in the Indian subcontinent. *Waterbirds* 33 (Special Publication 1): 44–70.

Takahashi, M. and K. Ohkawara. 2007. Breeding behavior and reproductive success of Grey-headed Lapwing *Vanellus cinereas* on farmland in central Japan. *Ornithological Science* 6: 1–9.

Taylor, I. R. and M. C. Schultz. 2006. Foraging ecology of wading birds (Ciconiiformes) in rice fields in the Murrumbidgee Irrigation Area, south-east Australia. Pages 135–149 *in* Wetlands of the Murrumbidgee River Catchment: Practical Management in an Altered Environment (I. R. Taylor, C. A. Murray and S. G. Taylor, Eds.). Fivebough and Tuckerbil Wetlands Trust, Leeton, New South Wales, Australia.

Taylor, I. R. and M. C. Schultz. 2008. Rice fields as a feeding habitat for waders in inland south-east Australia. *Wader Study Group Bulletin* 115: 110–115.

Tomar, I. S. and O. P. Singh. 1980. Note on the contribution of the Indian Ring Dove in the control of winter weeds of major crops in Meerut district of Uttar Pradesh. *Indian Journal of Agricultural Sciences* 50: 728–729.

Tourenq, C., R. E. Bennetts, N. Sadoul, F. Mesleard, Y. Kayser and H. Hafner. 2000. Long-term population and colony patterns of four species of tree-nesting herons in the Camargue, South France. *Waterbirds* 23: 236–245.

Tourenq, C., R. E. Bennetts, H. Kowalski, E. Vialet, J.-L. Lucchesi, Y. Kayser and P. Isenmann. 2001. Are ricefields a good alternative to natural marshes for waterbird communities in the Camargue, southern France? *Biological Conservation* 100: 335–343.

Tourenq, C., C. Barbraud, N. Sadoul, A. Sandoz, K. Lombardini, Y. Kayser and J.-L. Martin. 2001. Does foraging habitat quality affect reproductive performance in the Little Egret, *Egrettagarzetta? Animal Biodiversity and Conservation* 24: 107–116.

Tourenq, C., S. Aulagnier, L. Durieux, S. Lek, F. Mesléard, A. Johnson and J.-L. Martin. 2001. Identifying rice fields at risk from damage by the Greater Flamingo. *Journal of Applied Ecology* 38: 170–179.

Tourenq, C., S. Benhamou, N. Sadoul, A. Sandoz, F. Mesléard, J.-L. Martin and H. Hafner. 2004. Spatial relationships between tree-nesting heron colonies and rice fields in the Camargue, France. *Auk* 121: 192–202.

Van der Weijden, W. 2010. Rice fields. Pages 63–81 *in* Farmland Birds Across the World (W. van der Weijden, P. Terwan and A. Guldemond, Eds.). Lynx Edicions, Barcelona, Spain.

Vermeer, K., R. W. Risenbrough, A. L. Spaans and L. M. Reynolds. 1974. Pesticide effects on fishes and birds in rice fields of Suriname, South America. *Environmental Pollution* 7: 217–236.

Vickery, J. A., A. R. Watkinson and W. J. Sutherland. 1994. The solution to the Brent Goose problem: an economic analysis. *Journal of Applied Ecology* 31: 371–382.

Wagner, K. K., R. H. Schmidt and M. R. Conover. 1997. Compensation programs for wildlife damage in North America. *Wildlife Society Bulletin* 25: 312–319.

Watanabe, T. 2001. Habitat selection of Pacific Golden Plovers at a rice field in spring. *Strix* 19: 181–185. (In Japanese with English summary)

Watanabe, T. 2006. Differences in foraging behavior of Pacific Golden Plovers *Pluvialis fulva* between rice field types in spring. *Strix* 24: 23–30. (In Japanese with English summary)

Weber, T. P., A. I. Houston and B. J. Ens. 1999. Consequences of habitat loss at migratory stopover sites: a theoretical investigation. *Journal of Avian Biology* 30: 416–426.

Wen, D. Z., Y. G. Tang, X. H. Zheng and Y. Z. He. 1992. Sustainable and productive agricultural development in China. *Agriculture, Ecosystems and Environment* 39: 55–70.

Wilson, E. A., E. A. LeBoeuf, K. M. Weaver and D. J. LeBlanc. 1989. Delayed seeding for reducing blackbird damage to sprouting rice in southwestern Louisiana. *Wildlife Society Bulletin* 17: 165–171.

Wilson, A. L., R. J. Watts and M. M. Stevens. 2008. Effects of different management regimes on aquatic invertebrate diversity in Australian rice fields. *Ecological Research* 23: 565–572.

Wood, C., Y. Qiao, P. Li, P. Ding, B. Lu and Y. Xi. 2010. Implications of rice agriculture for wild birds in China. *Waterbirds* 33 (Special Publication 1): 30–43.

Xi, Y. M., B. Z. Lu, Z. Z. Geng and W. K. Fu. 1997. The rescue of the Crested Ibis. *Chinese Wildlife* 18: 28–30.

Yamamoto, H., K. Oohata and Y. Yamamoto. 1999. Habitat selection of ducks wintering in agricultural landscapes: a preliminary study for establishing a stable wintering duck population at Katano-kamoike. *Strix* 17: 127–132. (In Japanese with English summary)

Yamamoto, H., K. Oohata and K. Yamamoto. 2003. The effects of water flooding and provision of the food for wintering ducks on rice fields - a preliminary study for establishing a stable wintering duck population at Katano-kamoike. *III. Strix* 21: 111–123. (In Japanese with English summary)

Yu, X. P., N. F. Liu, Y. M. Xi and B. Z. Lu. 2006. Reproductive success of the Crested Ibis *Nipponia nippon*. *Bird Conservation International* 16: 325–343.

Zaccagnini, M. E. and J. J. Venturino. 1992. Ducks in Argentina - a pest or a tourist hunting resource? A lesson for sustainable use. Pages 97–101 *in* Waterfowl and Wetland Conservation in the 1990s - A Global Perspective (M. Moser, R. C. Prentice and J. Van Vessem, Eds.).Proceedings of an IWRB Symposium, St. Petersburg Beach, Florida (USA). IWRB Special Publication 26. Slimbridge, UK.

Zöckler, C., 2005. Migratory bird species as indicators for the state of the environment. *Biodiversity*, *6*(3): 7-13.

Zuo, P., S. W. Wan, P. Qin, J. Du and H. Wang. 2004. A comparison of the sustainability of original and constructed wetlands in Yancheng Biosphere Reserve, China: implications from energy evaluation. *Environmental Science & Policy* 7: 329–343.

Appendix 3.

Copy of a blank data collection sheet

Date:___/___/201__ **Site:**________________________ **Cropping Cycle:** 4/2 / 5/2
Weather:______________________ˣ **Site No.** 1 / 2
Crop Stage: ____________________ **Dist. (None) 1 / 2 / 3 / 4 / 5** **Start Time:**______:_______
Bird Deterences Y / N **App. Crop Hgt:** __________ **Order: 1 2 3 4**
Water Depth:_1)_________ **2)**_________ **3)**_________**mm** **Irrigation: Wet/ Pud^/ Moist/ Dry**

Time Period (1-4*)	Frequency	Bird	Activity

Date:___/___/201__ **Site:**________________________ **Cropping Cycle:** 4/2 / 5/2
Weather:______________________ˣ **Site No.** 1 / 2
Crop Stage: ____________________ **Dist. (None) 1 / 2 / 3 / 4 / 5** **Start Time:**______:_______
Bird Deterences Y / N **App. Crop Hgt:** __________ **Order: 1 2 3 4**
Water Depth:_1)_________ **2)**_________ **3)**_________**mm** **Irrigation: Wet/ Pud^/ Moist/ Dry**

Time Period (1-4*)	Frequency	Bird	Activity

* Time period: D=Disturbed, 1=0-4mins, 2=5-9mins, 3=10-14, 4=15-19mins
^ Irrigation: Pud. = Puddling, not irrigated, yet not dry. Some surface water
ˣ Weather; Bright/sunny, clear, cloudy spells, cloudy, dull/overcast, D/OC/Slight rain OR Foggy/Misty

Net effect within insecticide preliminary study

During the final 5 weeks of growth, small avian exclusion nets (1.5 m x 1.5 m) were erected inside two of the three plots surveyed for the '*Preliminary Study: Insecticide application*' (Chapter 3), to determine if avian damage could be measured (unpublished data). Any effect on behavior caused by the introduction of the nets was recorded. Surveys continued for the insecticide preliminary study using these plots until harvest. To determine if the presence of a net had an effect upon avian frequency or abundance of that site, net effect was calculated in a Generalized Linear Mixed Model (GLMM) ANOVA, with a Poisson log distribution applied. The dependent variable was total birds recorded with the following factors; site, management (spray/unsprayed), net (presence/absence), species category and activity.

When results were pooled together, the presence of nets had no significant effect upon overall avian diversity ($df = 3, p = 0.932$) or frequency ($df = 1, p = 0.618$). However, two factorial interactions, which including the presences of nets, were significant. These were; '*site * net*' ($df = 3, p < 0.001$) and '*activity * net*' ($df = 14, p < 0.001$) (Figures A4.1 and A4.2 respectively).

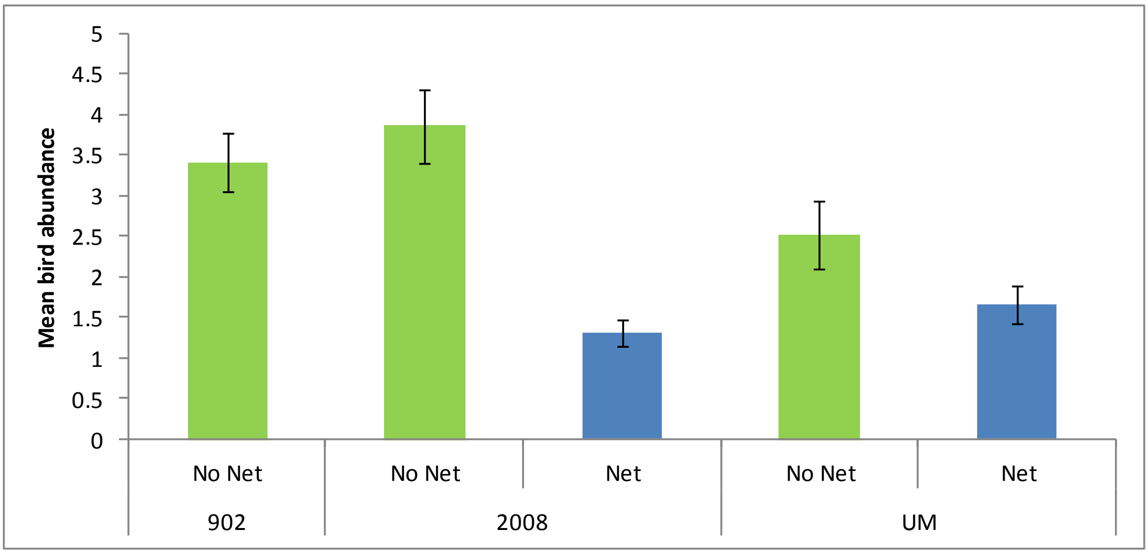

Figure A4.1. Net effect on mean bird frequency per site ($df = 1, p = 0.001$). Sites were named '*902*', '*2008*' and '*UM*' indicating their location within the farm. '*No Net*' was the mean bird frequency before the net was introduced, '*Net*' was afterwards. Site '*902*' had no nets throughout data collection.

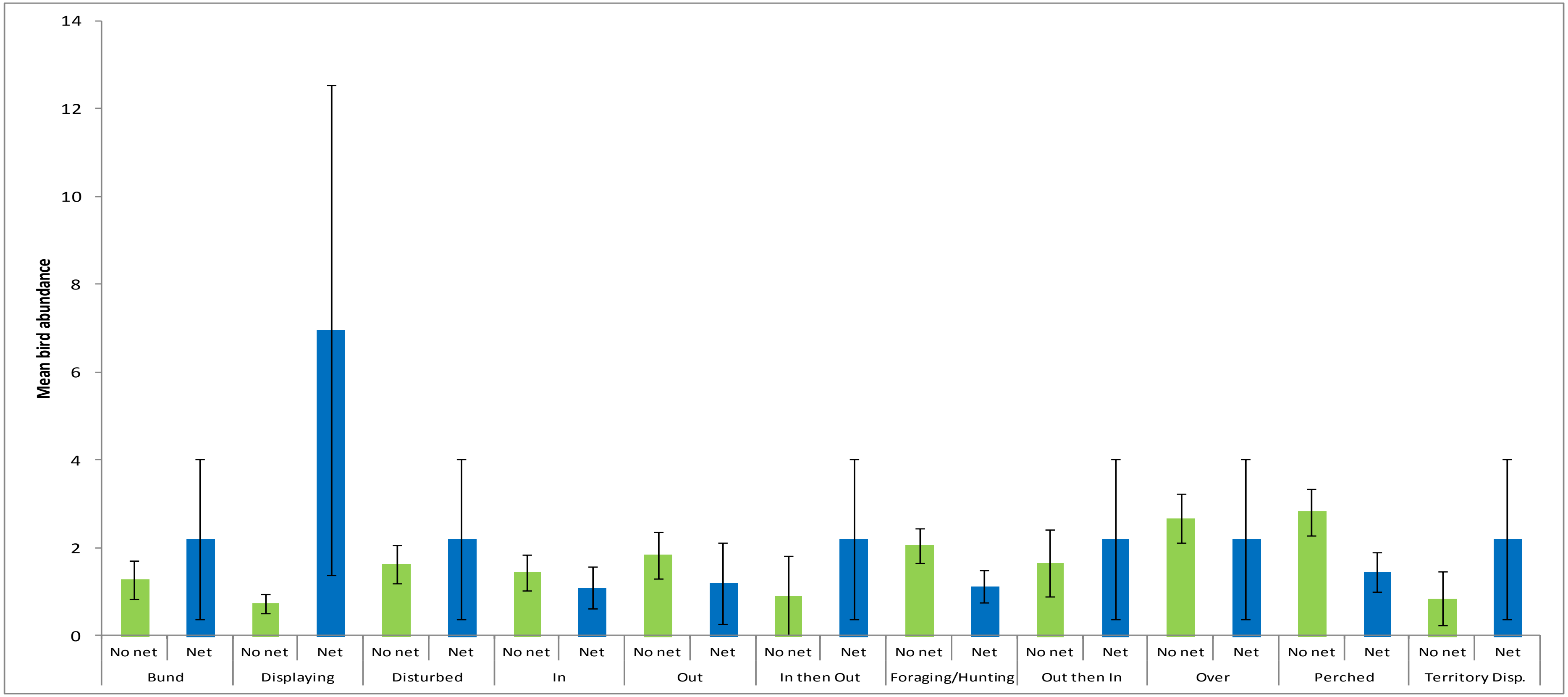

Figure A4.2. Effect of exclusion-netting on mean bird abundance by activity (*$df = 5$, $p < 0.001$*). Abundance displayed as mean birds recorded per survey. Definitions of activities are; '*Bund*' observed bird occurs upon the bund hunting, perching etc. '*Displaying*' birds are those conducting behaviour believed to be for mating such as singing, song-flights etc. '*In*' is the bird entering the site, either on foot or by flight. '*Out*' is the bird leaving the site, either on foot or by flight. '*In then Out*' means the bird enters but immediately leaves either through disturbance or is being flighty. '*Foraging/Hunting*' is the bird searching for food; on the ground, hunting from a perch or in flight. For species hunting on the wing it is defined as an individual flying low over the fields, sometimes with sharp directional changes to attack prey. '*Out then In*' is the bird moving within the site using flight. '*Over*' is the bird flying over but not a species which hunts on the wing. '*Perched*' is the bird standing on a bamboo stick, the net or the top of the crop. '*Territory Disp.*' is Territorial behaviour such as attacking other individuals of the same species.

As an independent factor, the erection of the exclusion nets had no effect upon bird abundance within the fields, when compared to previous counts in the same fields before the nets were introduced. However, the nets did produce significant differences when placed in an interaction with site and activity.

Total bird abundance significantly dropped with the erection of the nets. The nets stopped any species of bird from having access to the crop, though the mesh size was large enough for other biodiversity, e.g. invertebrates, to travel in and out of the enclosed areas. The introduction of nets reduced the available area to forage for all avian feeding categories, not just the granivorous birds which was the target for this study. The nets increased perching availability within the fields, though occurrences of perching did not significantly increase (see below). It was observed that net location created obstacles for species which hunt on the wing (*pers. obs.*). Swallows were recorded as they hunted along a field, flying over the crop, rarely changing direction, unless to capture prey. The nets broke-up these hunting '*fly-ways*', requiring many changes in direction, which might explain the reduction in the numbers of these species when the nets were erected.

The results in Figure A4.1 are expected if the nets were to cover the entire field, yet these covered plots were only 1.5 m x 1.5 m. Birds were seen to adapt quickly to the introduction of bird scaring devices within rice fields (*pers. obs.*) but the introduction of these smaller nets significantly reduced the avian diversity using the sites, when compared to previous surveys ($df = 1, p = 0.001$). The use of nets should be explored further as a potential deterrent, regardless of size.

Bird activity was significantly affected by the nets within the field (Figure A4.2). Many recorded bird behaviours dropped after the inclusion of nets (n = 5 of 11). Displaying and movement within the rice fields (*In and Out*) increased after net introduction. Nets provided a new element to the fields which birds could utilise, giving them a higher perch to hunt or display from. However, accounts of perching behaviour dropped overall, dismissing this theory.

The reduction in available habitat for foraging and the new obstacles within the fields might account for the increase in numbers of birds flying in or out. The birds became more visual as they could no longer move directly through the crop on the ground. Birds hunting from a perched, or soaring, position might not hunt in the same location because the nets reduced the available hunting area. The amount of '*disturbed*' recordings of birds reduced, as the nets might have shielded those already in the field from other disturbances, indicating birds were either less aware of danger or felt secure with the net between them and the threat. Without understanding the community of birds present within a rice field and the individual behaviour and ecology of different species, only assumptions can be made as to the reasons for the changes in behaviour observed after the nets were placed within the surveyed fields.

As an independent factor, nets had no overall effect upon avian abundance or frequency and was therefore removed from further statistical analysis during the preliminary study of insecticide application.

Appendix 5.

Copy of a blank farmer questionnaire

<u>Field Management Survey</u>

Dear Sir,
This short survey is to provide us with information on your field management. This is to assist us in our analysis of the data we have collected at your farm. The data collected will be stored securely and NOT passed onto anyone else, without seeking your permission first.

Farmer Name

Site name ________ Management 5-2 / 4-2 AWD / NIA

Site Number ________ 1 / 2

Farmers:

Contact Number: Rice Variety: ________

Mob (if different): ________ Planting: Direct / Transplanted

Address: ________

________ Field Area: ________ Ha (Approx.)

GPS Coordinates: ________

Fields Continuously Flooded? Yes / No

____

Any Crop Rotation?

Yes / No If Yes: ________

Are there water supply issues? Yes / No

If Yes: What? ________

Herbicide Input Name: ________ Application Frequency: ________

Pesticide Input Name: ________ Application Frequency: ________

Fertiliser Input Name: ________ Application Frequency: ________

Any other Chemical Input Name: ________ Application Frequency: ________

Name: ________ Application Frequency: ________

________ Application Frequency: ________

Any Pest Problems?

Yes / No If Yes: ________

Any Pest Control?

Yes / No If Yes: ________

In your opinion, what pest causes the most significant damage to your yield?	
Do you use the manipulation? (5-2 / AWD) What are your thoughts on the manipulation?	Yes / No If Yes: Why? ____________ ____________
Other Comments:	____________
Thank You for taking the time to answer these questions.	

Appendix 6.

Copy of the Wildlife Gratuitous Permit from the Department of Environment and Natural resources (DENR).

Department of Environment and Natural Resources
Regional Office No. IV-A, CALABARZON

WILDLIFE GRATUITOUS PERMIT
NO. R4A-WGP-09-2012-LAG-005

Holder **RICHARD E. SMEDLEY**
PhD Scholar, IRRI

GRATUITOUS PERMIT TO COLLECT EURISIAN TREE SPARROWS (*Passer mountanus)* AND MIXED WATERBIRDS FOR THE RESEARCH ON"AVIAN BIODIVERSITY WITHIN RICE FIELDS OF SOUTH EAST ASIA"

Pursuant to Republic Act 9147, otherwise known as the Wildlife Resources Conservation and Protection Act of 2001, and Section 15 of the Joint DENR-DA-PCSD Administrative Order No. 01 dated May 18, 2004, **MR. RICHARD E. SMEDLEY** of the International Rice Research Institute-Crop and Environmental Sciences Division, Los Banos, Laguna is hereby granted this **WILDLIFE GRATUITOUS PERMIT** relative to his research study entitled "Avian Biodiversity Within Rice fields of South East Asia". This permit covers the following terms and conditions herein specified:

1. That the Permittee shall be allowed to collect Eurasian Tree Sparrows (*Passer mountanus)* and mixed species of water birds in rice fields of International Rice Research Institute (IRRI)-Los Banos, Laguna;
2. That the Permittee shall be allowed to collect 400 individuals of (*Passer mountanus)* and 200 individuals of waterbirds within the entire research. Collection shall be done monthly depending on the availability of the bird species in the collection site;
3. That the Permittee shall employ indigenous technique in trapping the birds which will not cause injury/disturbance to other wildlife species and damage to habitat/landscape ecosystem;
4. That all birds caught shall be well-handled and immediately released to the wild;
5. That the Permittee shall ensure that the specimens collected are used strictly for research study and shall not in any manner be used for commercial purposes;
6. That the Permittee shall coordinate with the concerned DENR PENRO and CENRO in Laguna prior to the actual collection;
7. That all specimens collected shall not be transported without the Local Wildlife Transport Permit that will be issued by PENRO/CENRO Laguna;
8. That the initial report shall be submitted by the Permittee to the DENR Regional Office through PENRO/CENRO Laguna after collection activity and in case certain technology is developed from the research study, the same should be made available to Philippine Government through this Office;

9. That the DENR shall be acknowledged in all publications and/or articles as a result of the research project. Further, the Permittee shall furnish this Office through Regional Technical Director (RTD) of Protected Areas, Wildlife and Coastal Zone Management Service (PAWCZMS) copies of all published or unpublished reports and articles about the research project;
10. That the Permittee shall provide this Office through RTD for PAWCZMS copy of the research outputs or final manuscript with photographs of the specimens collected, processed and identified;
11. That the deliberate disregard or violation of any of the terms and conditions herein set forth shall be a ground for cancellation of this Permit including the confiscation of all collected specimens in favor of DENR, without prejudice to the application of other measures as provided for under Republic Act 9147.
12. That this Permit is non transferable and shall expire within one (1) year from the date of issuance and /or after the collection of the specimens is completed, whichever comes first;
13. That in securing renewal or extension, the original copy of the Permit shall be surrendered to this Office through RTD for PAWCZMS; and
14. This Permit shall take effect from the date of issuance hereof.

OCT 04 2012

Issued this ___ day of _____ ,20__ at **DENR CALABARZON** Region at Brgy. Halang, Calamba City, Philippines.

BY THE AUTHORITY OF THE SECRETARY

REYNULFO A. JUAN, CESO V
OIC, Regional Executive Director

Recommending Approval

ARNULFO A. HERNANDEZ
OIC, Regional Technical Director
for PAWCZMS

"Tungo sa Matapat, Matuwid at Mabilis na Serbisyo"

DENCRIS Building, National Highway, Brgy. Halang, Calamba City, Laguna

Appendix 7.

A copy of '*Don't scare away the birds*!' from Rice Today, reproduced with permission.

Don't scare away the birds!

by **Richard E. Smedley**

Most birds are not enemies of rice farmers; some actually help control pests

As the sun rises and casts its first beams of light over the experimental rice fields at the International Rice Research Institute (IRRI), there is a flurry of activity of birds coming in to feed, or leaving the rice fields to roost for the day. They are everywhere—in the air, on the roads, and between the fields. This usually occurs between 5:30 and 6:30 in the morning.

Rice fields create a unique habitat within agriculture. Unlike other crops, rice is almost constantly flooded—an artificial wetland, which is very attractive to birds of all kinds, especially if the local natural wetland is drier than usual or has been lost.

Rural myth

Studies have been conducted on birds in rice fields although research has been mostly within the U.S. or Europe. In Asia, however, little work has been conducted on this topic. Thus, knowledge gathered by farmers on birds and their effect on the crop comes through hearsay and speculation.

What exactly do these feathered creatures do in rice fields and do we want to keep them or eradicate them?

The biggest myth about birds is that *all* of them eat rice. This just isn't true. Observations conducted within the IRRI experimental farm, during the reproductive and ripening phases of the rice crop, found more than 50 different bird species, but only four are known to feed on rice. The majority of the others feed on insects only.

Easy targets

"If it flaps, scare it away!" This idea common in rice farming might be causing more harm than good, especially at certain times of the year. Different birds have different diets, and distinguishing the "good guys" from the "bad guys" can become difficult.

Intermediate egret

Little egret

Yellow bittern

Here are some of the "good guys":

- Egrets, the white birds often seen in rice fields, eat some invertebrates as well as fish, crustaceans, frogs, and reptiles.
- Herons and bitterns, often scared out of rice fields, also eat fish, crustaceans, frogs, reptiles and aquatic insects, snails, and some small mammals.
- Finally, birds of prey that can be found in a rice habitat, such as pied harriers and grass owls, hunt mammals within the fields, but also keep the number of smaller birds down.

All of these are easily targeted by farmers as they are large and relatively easy to catch, but they could be helping the crop through pest management. For example, the tree sparrow is common throughout the Philippines, but is endangered in the United Kingdom, with many conservation programs trying to save the remaining population. There are even farmer incentives to promote the habitat the birds require in an effort to entice them back. Studies in the UK have shown that they eat only invertebrates during breeding, as they require more protein in their diet.

Convicted without evidence

The alleged bad guys are those that are known as *maya*. This Tagalog word is used to describe a particular bird that feeds on rice grain. However, there is a

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> The biggest myth about birds is that all of them eat rice. This just isn't true.

common misconception within the Philippines in the use of that word. *Maya* actually refers to four different bird species, all of which can be found at IRRI. These are tree sparrows (*Passer montanus*) and three species of munias (*Lonchura* spp.) that are in the Philippines: chestnut, scaly-breasted, and white-bellied. Although these birds eat rice grains in at least part of the year, effective species management requires a better understanding of their lifestyle and behavior.

These birds are seen periodically feeding in rice fields and sometimes from the plants directly. However, how much damage they are actually causing is unknown. With birds able to fly great distances and no systematic method of feeding (that we know of), recording this damage would require surveying a large number of rice fields over a long time. Indirect methods of damage assessment include mathematical models and farmer estimations. However, these all rely on farmers' ability to accurately record bird flocks, movements, and locations, as well as all the other factors that contribute to yield loss. A standard method of quantifying bird damage in rice fields still needs to be developed.

Winged scapegoats

Why do birds get blamed? Maybe it has something to do with their skill, which we all wish we had—they can fly! It seems that their major advantage in the wild is one of the main reasons they have gained a reputation for damaging rice.

Farmers often point out flocks of birds flying out of their fields. More often than not, farmers have not seen where these birds have come from,

Chinese pond heron

Tree sparrow "maya"

Scaly-breasted munia

White-bellied munia

and they do not know what these birds have been eating, but they *do* see them leaving the fields.

Although other pests, such as rats, display physical and measurable damage to rice, birds do not. Farmers cannot always see rats move within the fields, but they do see birds.

To ponder upon

With few bird deterrents available, little can be done to prevent birds from flying in or out of fields and methods of control need to be enhanced. All birds are so incredibly intelligent that they can habituate themselves to new stimuli quickly. For example, standing a flag close to a field in an attempt to scare birds only provides them with a new perch on which they can sit. The use of "bird scarers" will work only as long as the method of scaring, either rattling tin cans or shouting, is ever-changing.

It would also help if one understood which birds to scare and which ones to leave alone. To completely "bird-proof" a rice crop, planting in greenhouses or under nets is the only option. But, this will disable the positive effects that some birds provide—a delicate balancing act that will be understood only if further research into the species seen in rice, particularly their behavior and lifestyle, is conducted.

So, the next time you are in a rice field, take a moment to look up and see what is close by. Chances are you will be very close to some of our feathered friends. Watch as the egrets chase aquatic prey between the rice hills or as the swallows sweep over the top, collecting flying insects as they go. Take a moment to marvel as they duck and dive through the air and just think of how rice provides a benefit to many species, not just by providing food.

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