UNIVERSITI PUTRA MALAYSIA

TOXICITY AND SUB-LETHAL EFFECTS OF BROMADIOLONE AND CHLOROPHACINONE ON BARN OWL, Tyto alba javanica Gmelin IN OIL PALM PLANTATIONS

HASBER BIN SALIM

FP 2014 18

TOXICITY AND SUB-LETHAL EFFECTS OF BROMADIOLONE AND CHLOROPHACINONE ON BARN OWL, *Tyto alba javanica* Gmelin IN OIL PALM PLANTATIONS

By

HASBER BIN SALIM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

March 2014

This thesis is dedicated to my parents C'emmak and C' enak for their love, and my wife and my son for supporting me all the way

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

TOXICITY AND SUB-LETHAL EFFECTS OF BROMADIOLONE AND CHLOROPHACINONE ON BARN OWL, *Tyto alba javanica* Gmelin IN OIL PALM PLANTATIONS

By

HASBER BIN SALIM

March, 2014

Chairman: Associate Professor Hafidzi Mohd. Noor, PhD
Faculty: Agriculture

The toxicity and sub-lethal effects of two anticoagulant rodenticides; bromadiolone and chlorophacinone on barn owls, *Tyto javanica* were evaluated through aviary and field studies. In aviary study, *T. alba* showed behavioural aberrations less frequently took to flight and losing weight as early as on the fifth day after a meal of three rodenticide fed rats. Bromadiolone and chlorophacinone were found to have high degree of toxicity to *T. alba*. This finding is crucial since *T. alba* had been reported to consume up to three rats per night and this would certainly increase their potential exposure to secondary poisoning. HPLC analysis showed detection of residue in pellets regurgitated by *T. alba* can be used to indicate exposure of the latter to both compounds. However, blood residue method is limited to exposure duration of the compounds; the technique can only detect recent exposure to bromadiolone and chlorophacinone. The amounts of residue detected in the pellet samples for chlorophacinone were 69.9 to 81.6 µg/day or equivalent to 17.2 % to 27.4 % of the compound consumed and corresponding values for bromadiolone were 27.2 % to 34.5 % (72.24 ï 85.77 µg/day). This suggests that the amounts of bromadiolone retained in the tissue of the rat were higher than chlorophacinone. Thus, a greater potential for secondary poisoning of bromadiolone than chlorophacinone can be deduced from this study.

Field studies were conducted to evaluate the sub-lethal effects of bromadiolone and chlorophacinone on breeding performance, growth performance of nestling, thinning of eggshell and home range of *T. alba* in oil palm plantations. The breeding performances (clutch size, brood size and fledging success) of *T. alba* in rodenticides treated areas were lower in comparison to rodenticide free area. The lower reproductive performance was the consequence of secondary poisoning on *T. alba.* This is substantiated by the detection of high residues in the pellets collected in both the rodenticide treated plots. Rodenticide free plot recorded the highest fledging success i.e. 71.42 % (n = 14) compared to chlorophacinone and bromadiolone treated plots at 42.85 % (n=14) and 35.71 % (n = 14) respectively. Liver autopsy of dead nestlings showed bromadiolone and chlorophacinone residue ranged from 0.18 µg/g to 0.41 µg/g wet weights indicating high exposure. Growth performance study indicated nestlings in the rodenticide free area recorded a higher body mass, longer tarsus, culmen and wings compared to the rodenticide treated plots. The study on the

effects of anticoagulant rodenticide on eggshell thickness showed 29.73 % (n= 37) and 5.35 % (n=56) of eggs collected from the treated plots contained bromadiolone and chlorophacinone residues respectively. The mean residue of bromadiolone and chlorophacinone ranged from 0.009 to 0.031 µg/g wet weight. Bromadiolone and chlorophacinone residues can be transferred to the eggs of *T. alba.* However, the lower residue present in the albumen and the yolk did not seem to affect significantly egg shape, eggshell mass and eggshell thickness. The home range study that uses radio telemetry equipments showed home range sizes of *T. alba* in rodenticide free areas were larger compared to their counterparts in bromadiolone and chlorophacinone treated areas.

In conlusion both bromadiolone and chlorophacinone were found to have high degree of toxicity to *T. alba*. The field studies showed secondary poisoning risks produces detrimental sub-lethal effect on breeding performance and nestling growth of *T. alba.* The detection of residues in albumen and yolk showed residues from secondary poisoning can be transferred to egg of *T. alba*. The secondary poisoning risk of anticoagulant rodenticide also affects the home range size of *T. alba.*

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KETOKSIKAN DAN KESAN SUB-MAUT BROMADIOLONE DAN CHLOROPHACINONE TERHADAP BURUNG PUNGGUK, *Tyto alba javanica* Gmelin DI LADANG KELAPA SAWIT

Oleh

HASBER BIN SALIM

Mac 2014

Pengerusi: Profesor Madya Hafidzi Mohd. Noor, PhD
Fakulti: Pertanian

Ketoksikan dan kesan sub-maut racun tikus anticoagulant, bromadiolone dan chlorophacinone terhadap burung pungguk, *Tyto alba javanica* telah dikaji melalui kajian dalam sangkar dan lapangan. Pada kajian sangkar, *T. alba* mengalami perubahan lakuan seperti kurang aktiviti penerbangan serta penurunan berat badan seawal lima hari selepas memakan tiga tikus-beracun yang diberikan. Bromadiolone dan chlorophacinone didapati memberi kesan ketoksikan yang tinggi terhadap *T. alba.* Penemuan ini penting kerana di lapangan *T. alba* telah dilaporkan mengambil sehingga tiga tikus semalaman dan ini akan meningkatkan potensi keracunan sekunder. Analisis HPLC menunjukkan pengesanan residu dalam pelet boleh digunakan untuk menentukan paras pendedahan racun anticoagulant terhadap *T. alba* di lapangan. Namun residu pada darah adalah terhad kepada tempoh pendedahan yang singkat. Jumlah residu dalam pelet bagi chlorophacinone adalah 69.9 to 81.6 µg/hari iaitu 17.2 % - 27.4 % daripada jumlah racun anticoagulan yang dimakan tikus. Sementara bagi bromadiolone sebanyak 27.2 % - 34.5 % iaitu bersamaan dengan nilai residu sebanyak 72.24 ï 85.77 µg/hari. Keadaan ini menunjukkan bromadiolone disimpan lebih lama dalam badan tikus berbanding chlorophacinone dan ini akan memberi potensi keracunan sekunder yang lebih tinggi.

Kajian lapangan juga telah dijalankan untuk menilai kesan sub-maut bromadiolone dan chlorophacinone terhadap prestasi pembiakan, tumbesaran anak burung, penipisan kulit telur dan tingkah laku penerbangan *T. alba* di ladang kelapa sawit. Prestasi pembiakkan (purata telur, purata anak dan anak burung berjaya terbang) *T. alba* di kawasan yang dirawat dengan racun antikoagulan adalah lebih rendah berbanding dengan kawasan bebas racun antikoagulan. Prestasi pembiakan yang lebih rendah adalah disebabkan oleh kesan keracunan sekunder terhadap *T. alba*. Ini dibuktikan oleh pengesanan residu yang tinggi dalam pelet yang diambil dari kedua-dua kawasan kajian yang diumpan dengan racun antikoagulan. Kawasan tanpa rawatan menunjukkan jumlah anak burung yang kekal hidup adalah tinggi iaitu 71.42 % (n = 14) berbanding kawasan umpanan chlorophacinone dan bromadiolone iaitu hanya 42.85 % (n = 14) dan 35.71 % (n = 14). Autopsi ke atas hati anak burung menunjukkan residu bromadiolone dan chlorophacinone menunjukkan julat dari 0.18 ε g/g hingga 0.41 ε g/g berat basah menunjukkan tahap keracunan sekunder yang tinggi. Selain itu, kajian tumbesaran menunjukkan anak burung di kawasan tanpa

rawatan mempunyai kadar pertumbuhan dan pertambahan yang lebih tinggi bagi berat badan, tarsus, culmen dan panjang sayap berbanding anak burung dikawasan rawatan racun antikoagulan. Keputusan kajian kesan racun antikoagulan terhadap penipisan cengkerang telur menunjukkan 29.73 % (n = 37) dan 5.35 % (n=56) telur terbiar dari kawasan pengumpanan dengan bromadiolone dan chlorophacinone mengandungi residu diantara 0.009 ï 0.031 ε g/g berat basah. Ini menujukkan residu bromadiolone dan chlorophacinone boleh dipindahkan kepada telur *T. alba*. Namun, kuantiti residu yang rendah di dalam telur tidak menjejaskan secara ketara bentuk telur, berat kulit telur mahupun menyebabkan penipisan kulit telur *T. alba.* Kajian banjaran kediaman yang menggunakan peralatan radio telemetri menunjukkan *T. alba* di kawasan tanpa pengumpanan mempunyai banjaran kediaman lebih besar berbanding kawasan rawatan yang dirawat dengan bromadiolone dan chlorophacinone.

Secara kesimpulannya, kedua-dua racun antikoagulan iaitu bromadiolone dan chlorophacinone mempunyai kesan ketoksikan yang tinggi terhadap *T. alba.* Kajian lapangan juga menunjukkan keracunan sekunder memberi kesan sub-maut yang negatif terhadap prestasi pembiakkan dan tumbesaran anak burung. Pengesanan residu pada putih dan kuning telur juga menunjukkan residu boleh dipindahkan ke dalam telur *T. alba*. Akhir sekali, Risiko keracuanan sekunder juga mmberi kesan terhadap saiz banjaran kediaman *T. alba*

ACKNOWLEDGEMENTS

In the name of Allah SWT, most Gracious, most Compassionate,

My deepest appreciation to my respectful supervisor, Associate Professor Dr. Hafidzi Mohd Noor for his constructive criticisms, suggestions, encouragement and valuable advice as well as his contribution towards the completion of this study. My deep appreciation also goes to my co-supervisors and members of supervisory committee, Professor Dr. Dzolkhifli Omar and Associate Professor Dr. Azhar Kasim for their guidance, suggestion and support throughout my study.

My heartiest gratitude to the Head of Crop Protection Division, FASSB, Mr. Noor Hisham Hamid for his permission, guidance, invaluable advice and knowledge in experimental design set-up in the field. My sincere thanks to all the staff in FELDA FASSB Pusat Penyelidikan Pertanian Tun Razak, FELDA FASSB Kota Gelanggi 5, 6, FELDA FASSB Jengka 24 and all the staff in Crop proctection Division, FASSB for their valuable contributions in identifying study sites, providing logistics and field assistance during the study. Word of thanks also goes to the chemist and technical staffs of Agrichem laboratory, Cerakinan Laboratory PPPTR, FASSB and Forensic Division, Deparment of Chemistry, Kuantan branch, Pahang, and Toxicology laboratory, Plant Protection Department Faculty of agriculture, UPM for their help and guidance in my laboratory analysis.

I would like to extend my gratitude to Dr. Ahmad bin Selamat, Department of Crop Science, UPM for his kind technical suggestion for statistical analysis technique. It is my greatest pleasure to acknowledge Office of the Deputy Vice Chancellor (Research & Innovation) who provide research fund (vote no: 9199728) under Research University Grand Scheme (RUGS 5) for funding this research.

Special thanks t*o Tyto alba* research team and Vertebrate Ecology Laboratory members, especially Cik Mohd Rizuan, Sukri Taib Ismail, Samsudin Ahmad, Sham Rodzi, Dr. Mohd Naȋm, Raden Isra Wardani, Mohd Huzaifah Arif, Siti Aishah, Hafizah and Maisarah for invaluable discussion and cooperation towards the completion of this project. Last but not least, my greatest appreciation to my parents, c-emmaȏ and c-ennaȏ, beloved wife Noor Anggerainie Andi Matalatta and my son Muhammad Airiel Khwarizmi for their endless love, sacrifices, patience, emotional support and physical presence to make this dissertation a reality.

I certify that a Thesis Examination Committee has met on 05 Mac 2014 to conduct the final examination of Hasber bin Salim on his thesis entitled "Toxicity and sub-lethal effects of bromadiolone and chlorophacinone on barn owl, *Tyto alba javanica* Gmelin in oil palm plantations" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

Lau Wei Hong, PhD
Senior Lecturer
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Rita Muhamad Awang @ Rita Suryadi, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Mohammed Zakaria Hussein, PhD
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Internal Examiner)

Graham Richard Martin, PhD
Professor
Centre for Ornithology Research
University of Birmingham
United Kingdom
(External Examiner)

NORITAH OMAR, PhD
Associate Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 21 April 2014

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Hafidzi Mohd Noor, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Dzolkhifli Omar, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Azhar Kasim, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

_____
BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by graduate student

I hereby confirm that:

- This thesis is my original work;
- Quotations, illustrations and citations have been duly referenced;
- This thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- Intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- Written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- There is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: _____ Date: 19 Mac 2014

Name and Matric No.: Hasber Bin Salim (GS 28250)

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature:_____	Signature: _____
Name of Chaiman of Supervisory Committee:_____	Name of Member of Supervisory Committee:_____
Signature:_____	Signature: _____
Name of Chaiman of Supervisory Committee:_____	Name of Member of Supervisory Committee:_____

TABLE OF CONTENTS

		Page
ABSTRACT		iii
ABSTRAK		v
ACKNOWLEDGEMENTS		vii
APPROVAL		viii
DECLARATION		x
LIST OF TABLES		xv
LIST OF FIGURES		xvii
LIST OF ABBREVIATIONS		xix
CHAPTER		
1	**GENERAL INTRODUCTION**	1
1.1	Anticoagulant rodenticides and barn owls, *Tyto alba*	1
1.2	The problem	1
1.3	Toxicity and sub-lethal risks	2
1.4	Justification and objectives	2
2	**LITERATURE REVIEW**	4
2.1	Anticoagulant rodenticides	4
2.2	Barn owls, *Tyto alba javanica* in oil palm plantations	6
2.3	Integrated Pest Management (IPM) against rats	7
2.4	Toxicity and secondary poisoning to non target animals	8
2.5	Rodenticide selected for the study	9
2.6	Secondary poisoning of bromadiolone to non target animals	12
2.7	Secondary poisoning of chlorophacinone to non target animals	12
2.8	Sub-lethal of chronic exposure	20
2.9	Non destructive methods	21
3	**SUB-LETHAL TOXICITY EFFECTS OF BROMADIOLONE AND CHLOROPHACINONE TO CAPTIVE *Tyto alba javanica***	25
3.1	Introduction	25
3.2	Materials and Methods	25
3.2.1	Aviary	25
3.2.2	Feeding trials	26
3.2.3	Data collection and sampling procedure	27
3.2.4	HPLC analysis	28
	3.2.4.1 Reagents and rodenticide	28
	3.2.4.2 Apparatus and HPLC conditions	28
	3.2.4.3 Preparation of standard solution	28
	3.2.4.4 Samples preparation for analysis	29
	3.2.4.5 Method validation	29
3.3	Results and Discussion	30
3.3.1	HPLC method validation	30
	3.3.1.1 Standard calibration curve	30
	3.3.1.2 Extraction efficiency and % mean recovery	34
3.3.2	Residue of anticoagulant offered to owls	34

3.3.3 Effects on *Tyto alba* 38
3.3.4 Residue analysis 41
3.3.4.1 Regurgitated pellets 41
3.3.4.2 Residue and coagulation time of blood samples 43
3.4 Conclusion 45

4 SUB-LETHAL EFFECTS OF BROMADIOLONE AND CHLOROPHACINONE ON BREEDING PERFORMANCES OF *Tyto alba javanica* IN OIL PALM PLANTATION. 46
4.1 Introduction 46
4.2 Materials and Methods 45
4.2.1 Study site and treatments 46
4.2.2 Breeding performance 46
4.2.3 Regurgitated pellets collection 46
4.2.4 Rat damages 46
4.2.5 HPLC analysis 46
4.2.6 Data analysis 46
4.3 Results and Discussion 48
4.3.1 Occupancy rate of nest boxes 48
4.3.2 Clutch size 49
4.3.3 Brood size of *Tyto alba* 50
4.3.4 Nestling success and productivity 51
4.3.5 Rodenticide residue in pellets 52
4.3.6 Relationship of residue and breeding performances 54
4.3.7 Effect of food availability on breeding performances 57
4.4 Conclusion 58

5 TOXICITY AND SUB-LETHAL EFFECTS OF CHLOROPHACINONE AND BROMADIOLONE ON SURVIVAL AND NESTLING GROWTH OF *Tyto alba javanica* 59
5.1 Introduction 59
5.2 Materials and Methods 59
5.2.1 Study site and treatment 59
5.2.2 Sampling procedure. 59
5.2.3 Nestling growth metrics 60
5.2.4 Liver analysis 61
5.2.5 HPLC analysis 61
5.2.5.1 Reagents and chromatographic conditions 61
5.2.5.2 Preparation of standard stock solution 62
5.2.5.3 Samples preparation and clean-up 62
5.2.5.4 Method validation 62
5.2.6 Data analysis 62
5.3 Results and Discussion 63
5.3.1 HPLC method validation 63
5.3.1.1 Standard calibration curve 63
5.3.1.2 Extraction efficiency and % mean recovery 64
5.3.2 Survival and mortality of selected nestlings 65
5.3.3 Growth performances of nestling 67
5.3.2.1 Body mass 67
5.3.2.2 Tarsus and culmen length 72

5.3.2.3 Wing length 80
5.4 Conclusion 84

6 EVIDENCE OF SECONDARY POISONING FROM THE RODENTICIDES RESIDUES DEPOSITED IN *Tyto alba javanica* EGGS 85
6.1 Introduction 85
6.2 Materials and Methods 85
6.2.1 Study site and Treatment 85
6.2.2 Collection of eggs 85
6.2.3 Preparing the eggshells 86
6.2.4 HPLC analysis 86
6.2.4.1 Reagents and chromatographic conditions 86
6.2.4.2 Preparation of standard stock solution 86
6.2.4.3 Samples Preparation and clean-up 86
6.2.4.4 Method validation 86
6.3 Results and Discussion 87
6.3.1 HPLC method validation 87
6.3.1.1 Standard calibration curve 88
6.3.1.2 Extraction efficiency and % mean recovery 89
6.3.2 Rodenticide residue in eggs of *Tyto alba* 90
6.3.3 Egg shape, eggshell mass and eggshell thickness 92
6.4 Conclusion 95

7 SUB-LETHAL EFFECTS OF THE RODENTICIDES ON THE HOME RANGE SIZE AND RANGING BEHAVIOUR OF *Tyto alba javanica* IN OIL PALM PLANTATION 96
7.1 Introduction 96
7.2 Materials and Methods 96
7.2.1 Study sites and treatment 96
7.2.2 Radio telemetry equipment 96
7.2.3 Regurgitated pellets collection 97
7.2.4 HPLC analysis 98
7.2.5 Data analysis 98
7.3 Results and Discussion 98
7.3.1 Tracking of *Tyto alba* 98
7.3.2 Home range size of *Tyto alba* 99
7.3.3 Core areas of *Tyto alba* 103
7.4 Conclusion 104

8 GENERAL DISSCUSSION, CONCLUSION AND RECOMMENDATIONS 105

REFERENCES 109
APPENDICES 125
BIODATA OF STUDENT 160
LIST OF PUBLICATIONS 160

LIST OF TABLES

Table		Page
2.1	List of anticoagulant rodenticides registered in Malaysia	5
2.2	Acute oral toxicity of bromadiolone to mammals and birds	11
2.3	Acute oral toxicity of chlorophacinone to mammals and birds	11
2.4	Secondary poisoning risks of bromadiolone to non target animals in laboratory studies	13
2.5	Evidence of secondary poisoning to bromadiolone in non target animals	14
2.6	Secondary poisoning risks of chlorophacinone to avian in captive studies	16
2.7	Secondary poisoning risks of chlorophacinone to mammals in captive studies	18
2.8	Secondary poisoning from chlorophacinone to non target animals in field studies	19
2.9	Studies of sub-lethal effects of pesticides and rodenticides on eggshell thickness of owl populations	22
3.1	Percentage of recovery (Means ± S.E) of bromadiolone and chlorophacinone residue in pellets samples	34
3.2	Percentage of recovery (Means ± S.E) of bromadiolone and chlorophacinone residue in bloods samples	34
3.3	Rodenticide consumption by *Rattus tiomanicus* over 2 days feeding and estimated residue in faeces	36
3.4	Calculated maximum amount of rodenticide consumed by paired caged *Tyto alba* offered bromadiolone and chlrophacinone-fed for 2 days	37
3.5	Toxicity effects of anticoagulant rodenticide to *Tyto alba* fed with 4 poisoned-rats in 7 day period	39
3.6	Rodenticide residue in regurgitated pellets in captivate paired owls	42
3.7	Concentration of anticoagulant (µg/g) and coagulantion time (minute) in blood samples	44
4.1	Occupancy rate (mean % ± S.E) of *Tyto alba*	49
4.2	Clutch size (Mean ± S. E) of *Tyto alba*	49
4.3	Brood size of *Tyto alba*	51
4.4	Fledging success (Mean ± S.E) of *Tyto alba*	51
4.5	Residual concentration of rodenticide (Mean ± S.E) in collected	53
4.6	Mean ± S. E monthly rat damage on fruit bunches of oil palm	57
5.1	Percentage of recovery (Means ± S.E) of bromadiolone and chlorophacinone residue in liver samples	65
5.2	Numbers of samples and success to fledge	66
5.3	Death of nestling based on their group age and residue of anticoagulants in liver (µg/g wet weight)	66
5.4	Growth body mass patterns (Mean ± S.E) for 9 selected measurements of nestlings in three treatment plots	68
5.5	Body mass fitted parameters obtained by the logistic equation. The equation was fitted to each individual nestling.	69
5.6	Tarsus length (Mean ± S.E) for 9 selected measurements of	74

	nestlings in three treatment plots	
5.7	Culmen Length (Mean ± S.E) for 9 selected measurements of nestlings in three treatment plots	75
5.8	Tarsus length fitted parameters obtained by the logistic equation for nestlings. The equation was fitted to each individual nestling.	76
5.9	Culmen length fitted parameters obtained by the logistic equation for nestlings. The equation was fitted to each individual nestling.	78
5.10	Wing Length (Mean ± S.E) of nestlings for 9 selected measurements of nestlings in three treatment plots	81
5.11	Wing length fitted parameters obtained by the logistic equation for nestlings. The equation was fitted to each individual nestling.	82
6.1	Percentages of recovery (Means ± S.E) of bromadiolone and chlorophacinone residues in egg samples	90
6.2	Residues of rodenticides detected (Mean ± S.E) in addled eggs of *Tyto alba*	91
6.3	Egg shape (Mean ± S.E) of eggs of *Tyto alba*	92
6.4	Eggshell mass (Mean ± S.E) of eggs of *Tyto alba*	93
6.5	Eggshell Thickness (Mean ± S.E) of eggs of *Tyto alba* in untreated control plot and rodenticide treated plots	94
7.1	Mean home range (ha) of *Tyto alba* in treated and free rodenticide area	100
7.2	Residue concentration of rodenticide (Mean ± S.E) in collected pellets	101
7.3	Mean core area (ha) of *Tyto alba* in treated and free rodenticides area	103

LIST OF FIGURES

Figure		Page
2.1	Chemical structures and selected physical/chemical properties of the bromadiolone	10
2.2	Chemical structures and selected physical/chemical properties of the chlorophacinone	10
3.1	Aviary used in the exsperiments	26
3.2	The procedure for bloodletting	27
3.3	Linear calibration curve of bromadiolone for pellet analysis (n = 6; correlation $r^2 = 0.999$)	30
3.4	Linear calibration curve of chlorophacinone for pellet analysis (n = 6; correlation $r^2 = 0.999$)	30
3.5	Linear calibration curve of bromadiolone for blood analysis (n = 6; correlation $r^2 = 0.999$)	31
3.6	Linear calibration curve of chlorophacinone for blood analysis (n = 6; correlation $r^2 = 0.999$)	31
3.7	Overlaid chromatograms of bromadiolone standard solution at 0.05, 0.1, 0.5, 1.0, 5.0 and 10.0 ppm for pellets analysis	32
3.8	Overlaid chromatograms of chlorophacinone standard solution at 0.05, 0.1, 0.5, 1.0, 5.0 and 10.0 ppm for pellets analysis	32
3.9	Overlaid chromatograms of bromadiolone standard solution at 0.05, 0.1, 0.5, 1.0, 5.0 and 10.0 ppm for blood analysis	33
3.10	Overlaid chromatograms of chlorophacinone standard solution at 0.05, 0.1, 0.5, 1.0, 5.0, and 10.0 ppm for blood analysis	33
4.1	Layout of sampling point for assessment of fruit bunch damages	48
4.2	Relationship between level of residues (ug/g) and clutch size	54
4.3	Relationship between percent of pellets detected with residues and clutch size	54
4.4	Relationship between level of residues (ug/g) and brood size	55
4.5	Relationship between percent of pellets detected with residues and brood size	55
4.6	Relationship between level of residues (ug/g) and fledging success	56
4.7	Relationship between % of pellets detected with residues and fledging success	56
5.1	Measurements of growth of nestlings	61
5.2	Linear calibration curve for bromadiolone (n = 6; correlation $r^2 = 0.999$)	63
5.3	Linear calibration curve for chlorophacinone (n = 6; correlation $r^2 = 0.999$)	63
5.4	Overlaid chromatograms of bromadiolone standard solution from 0.05 ppm to 10.0 ppm	64
5.5	Overlaid chromatograms of chlorophacinone standard solution from 0.05 to 10.0 ppm	64
5.6	Logistic growth curves of the changes in body mass of nestlings in rodenticide free (A), bromadiolone (B) and chlorophacinone (C) treated plots	71
5.7	Logistic growth curves of the changes in tarsus length of	79

	nestlings in rodenticide free (A), Bromadiolone (B) and chlorophacinone (C) plot	
5.8	Logistic growth curves of the changes in culmen length of nestling in rodenticide free (A), Bromadiolone (B) and chlorophacinone (C) plot	79
5.9	Logistic growth curves of the changes in wing length of nestling in rodenticide free (A), Bromadiolone (B) and chlorophacinone (C) plot	84
6.1	The procedures for eggs preparation	87
6.2	Linear calibration curve for bromadiolone (n = 6; correlation r^2 = 0.999)	88
6.3	Linear calibration curve for chlorophacinone (n = 6; correlation r^2 = 0.999)	88
6.4	Overlaid chromatograms of bromadiolone standard solution from 0.05 ppm to 10.0 ppm under recommended HPLC-Florescence conditions	89
6.5	Overlaid chromatograms of chlorophacinone standard solution from to 10.0 ppm under recommended HPLC-UV conditions	89
7.1	Attachment of radio transmitter to *Tyto alba* using back pack technique	97
7.2	Tracking of *Tyto alba* radio tagged during the day and at night	97
7.3	Collection of pellet samples in nest box of tagged *Tyto alba*	98
7.4	The correlation of home range size (ha) of female (A) and male (B) *Tyto alba* with the level of anticoagulant residue present in pellet samples.	102
7.5	The correlation of core area (ha) of female (A) and male (B) *Tyto alba* with the level of anticoagulant residue present in pellet samples.	104

LIST OF ABBREVIATIONS

FELDA	Federal Land Development Authorities
FASSB	Felda Agricultural Services Sdn Bhd
PPPTR	Pusat Penyelidikan Pertanian Tun Razak (Tun Razak Research Center)
HPLC	High Performance Liquid Chromatography
a.i.	Active Ingredient
ANOVA	Analysis of Variance
SAS	Statistical Analysis System
LD_{50}	Lethal Dose
LOD	Limit of Detection
LOQ	Limit of Quantitation
QC	Quality Control
UV	Ultra Violet
IUPAC	International Union of Pure and Applied Chemistry
g	Gram
µg	Microgram
kg	Kilogram
mg	Milligram
µL	Microliter
mL	Mililliter
L	Liter
mm	Millimeter
cm	Centimeter
km	Kilometer
PPM	Part Per Million
Ha.	Hectare
v/v	Volume/volume
w/w	Weight/weight
S.P.E	Solid Phase Extraction
EDTA	Ethylenediaminetetraacetic acid
e.g.	*exempli gratia,* for example
et al.	et alii, and other
S.E	Standard Error

CHAPTER 1

INTRODUCTION

1.1 Anticoagulant rodenticides and barn owls, *Tyto alba*

In Malaysia, anticoagulant rodenticides have become a key solution to the threat of rodent pest particularly in the agricultural sector such as paddy fields and oil palm plantations. Anticoagulant rodenticides, in particular bromadiolone and chlorophacinone has been reported as the most effective and widely used in rat control practice in oil palm plantations (Noor Hisham *et al.,* 2007). However, in line with the Malaysian oil palm industry and its commitment to produce sustainable palm oil through the implementation of the Integrated Pests Management (IPM), effective anticoagulant rodenticides has been employed in combination with biological control using barn owls, *Tyto alba javanica* (Lam, 1982). Ducket (1984) proposes the idea of using IPM for controlling rat pest in which anticoagulant rodenticides were recommended to ensure that the pest was controlled while sustaining sparing the natural predator, *T. alba* for an environmental friendly rodent pest approach.

1.2 The Problem

Chemical control using anticoagulant rodenticides integrated with biological control using *T. alba* has been adopted since the late 80ôs against rat populations in Malaysian oil palm plantations (Wood and Chung, 2003). However application of anticoagulant rodenticides (e.g. bromadiolone and chlorophacinone) in combination with the natural propagation barn owls has raised concerns of potential secondary poisoning to the latter. Monitoring programmes on exposure of anticoagulant rodenticides in United States, Canada and Europe have shown evidence of extensive contamination of anticoagulant rodenticides in raptors (e.g. Stone *et al.,* 2003; Thomas *et al.,* 2011; Sanchez-Barbudo *et al.,* 2012). Contamination with anticoagulant rodenticides is considered to be one of the most detrimental threats to wildlife.

Raptor and predator populations have been reported declining in numbers when anticoagulant rodenticides were introduced in farmlands against rodent pests (e.g. Elmeros *et al.,* 2011; Gabriel *et al.,* 2012). In Malaysia, researchers have proposed combining *T. alba* with application of first generation anticoagulant rodenticide warfarin to control rats; speculating that the poison was not hazardous to barn owls (Ducket, 1984). However, prolonged exposure triggers resistant of rats to warfarin (Lam, 1982). New and more toxic anticoagulant e.g. chlorophacinone, and bromadiolone have been introduced in the early 1980ôs to deal with rodenticide resistance (Khoo *et al*., 1991).

The actions of more recent rodenticides are more toxic and exhibit relatively longer biological half-lives in tissues (e.g. liver) (Erickson & Urban, 2004). Both characteristics enhance the potential of compounds to cause secondary poisoning to *T. alba* that takes rats in 98 % of their diet (Ducket, 1984).

1.3 Toxicity and sub-lethal risks

There is growing concern about the risk of secondary poisoning of anticoagulant rodenticides to non target animals (e.g. Gabriel *et al.,* 2012). Reports of non- target wildlife contamination and toxicosis following the use of anticoagulant rodenticides has increased worldwide (Eason *et al*., 2002). In North America and Europe, secondary poisoning of first and second generation anticoagulant rodenticides (e.g. chlorophacinone and bromadiolone) to non-target species that ingest poisoned-rodent have been documented in a variety of wild birds (e.g. Walker *et al.,* 2008b; Thomas *et al*., 2011) and mammals (e.g. Fournier-Chambrillon *et al.,* 2004; Elmeros *et al*., 2011). However, all anticoagulants residue data are derived from opportunistic sampling of tissue, particularly liver, from those animals found dead in field situations. Therefore, the impact of poisoning on predator populations could be underestimated. Thus, captive studies approach have been used to determine the real risks of secondary poisoning by chlorophacinone and bromadiolone to predatory and scavenger birds (e.g. Wylie, 1995) and mammals (e.g. Sage *et al.,* 2010).

Destructive method through sampling of tissue (e.g. liver) from respective non targets that required the animal to die has been employed in order to investigate secondary poisoning hazards of anticoagulant rodenticides. However, this method is less favoured due to ethical reasons (Fisher *et al.,* 2004; Ward, 2008). Hence, several non-invasive techniques have been developed to determine the risks of anticoagulant rodenticides exposure in animals, such as evaluation of residue presents in eggs (Fisher, 2009; Mario and Grazia, 2010) and in pellets regurgitated by barn owls (e.g. Eadsforth *et al.,* 1996). However, the study of sub-lethal effects of anticoagulant rodenticides (bromadiolone and chlorophacinone) to barn owls by using non invasive technique (egg, blood and regurgitated pellet) is largely unexplored.

An ecological assessment to study secondary poisoning has been evaluated and proposed These include changes in population (Brown *et al.,* 2002; Ward, 2008), study on reproductive performances of animals (Mendenhall *et al.,* 1983), foraging and ranging behaviour (Hegdal *et al.,* 1986; Naim *et al.,* 2012b), and growth performances of nestling (Naim *et al.,* 2011). Yet again, the information on ecological assessment on the effects of anticoagulant rodenticides, chlorophacinone and bromadiolone through secondary poisoning to *T. alba* in oil palm plantations is still limited.

1.4 Justification and Objectives

Anticoagulant rodenticides, chlorophacinone and bromadiolone have been used and integrated with biological control using barn owls, *T. alba* since late 80ôs and 90ôs for rat control in Malaysia (Noor Hisham *et al.,* 2007). However, comprehensive information on the lethal and sub-lethal effects of anticoagulant rodenticides from chronic secondary exposure to *T. alba* in oil palm environment are largely unexplored. There is a lacking of information on toxicity, sub-lethal effects, health status, reproductive and breeding performance and growth developments on *T. alba*. Based on this information, it is pertinent to evaluate probable secondary poisoning of *T. alba* as a result of rodenticides (chlorophacinone and bromadiolone) baiting in oil palm. The specific objectives of this study are

1. To study the toxicity and sub-lethal risks of bromadiolone and chlorophacinone exposure in captive barn owls, *T. alba*;
2. To determine the sub-lethal effects of bromadiolone and chlorophacinone on breeding performances of *T. alba* in oil palm plantations;
3. To investigate the sub-lethal exposure of bromadiolone and chlorophacinone on the survival and the growth rate of nestlings of *T. alba* in oil palm plantations;
4. To trace evidence of secondary poisoning from the rodenticides residues deposited in *T. alba* eggs and their symptoms as measured in the thinning of those eggshells;
5. To evaluate the effects of the bromadiolone and chlorophacinone on the home range size of *T. alba* in oil palm plantation environments.

REFERENCES

Adison, J. B. 1982. Improved method for high pressure liquid chromatography determination of chlorophacinone in mouse tissue. *Journal Association of Analytical Chemistry* 65: 1299 ï 1301.

Ahmed, M. S., Baroch J., Carlet, L. and Whaley, D. 1996. Secondary hazard study using chlorophacinone-killed laboratory rats fed to domestic ferrets (*Mustela putorius furo*). Report submitted to EPA by LiphaTech, Inc., Milwaukee. In Suárez E., Fernández, C. *et al.* (2008). Assessing the environmental risk for primary and secondary poisoning in birds and mammals of the rodenticide chlorophacinone. Annex to the Chlorophacinone Environmental Risk Assessment Report. 18 pp. Available at:http://www.inia.es/gcontrec/pub/Annex_chlorophacinone_environmental_risk_assessment_1220614981640.pdf.

Albert, C. A, Williams, T. D., Morrissey, C. A., Lai, V. W. M., Cullen, W. C. and Elliott, J. E. 2008. Tissue uptake, mortality, and sub-lethal effects of *Monomethylarsonic Acid (MMA(V*)) in nestling Zebra Finches (*Taeniopygia guttata*). *Journal of Toxicology and Environmental Health* 71 (6): 353ï 360.

Albert, C. A. and Wilson, L. K. 2009. Anticoagulant rodenticides in three owl species from Western Canada, 1988ï 2003. *Arch Environment Contamination Toxicology* 34:112-132.

Andrusiak, L. A. and Cheng, K. M. 1997. Breeding biology of the Barn owl (*Tyto alba*) in the Lower Mainland of British Columbia. In: Duncan, James R.; Johnson, David H.; Nicholls, Thomas H., eds. Biology and conservation of owls of the Northern Hemisphere: 2nd International owl symposium. Pp 38-46.

Askham, L. R. 1988. Chlorophacinone - secondary hazard evaluation of chlorophacinone in raptors. Report submitted to EPA by Lipha Chemicals, Inc., Milwaukee. In Erickson, W. 2001. Chlorophacinone (067707): secondary hazard studies. United States Environmental Protection Agency. Office of Prevention, Pesticides and Toxic Substances. Avaiable at http://www.epa.gov/opp00001/chem_search/cleared_reviews/csr_PC-067707_18 Apr-01_a.pdf.

Askham, L. R. and Poche, R. M. 1992. Biodeterioration of chlorophacinone in voles, hawks and an owl. *Mammalia* 56: 145-150.

Asmundson, V. S. 1943. Relations between the parts of birds' eggs. *Auk* 60: 34-44

Asokan, S., Ali, M. S., Manikanan, R. and Radhakrisnan, P. 2009. Observation on nest-sites, eggs and nestling growth pattern of the small Bee-eater (*Merops orientalis*) in India. *World Journal of Zoology* 4(3):163 - 168.

Bachhuber, E. and Beck, C. 1988. The effect of some anticoagulants on mice relevant in forestry and on mice predators. Thesis, Munchen (DE) (in German). In Erickson,W. and Urban, D. 2004. Potential Risks of Nine Rodenticides to Birds and Nontarget Mammals: a comparative approach. Washington, DC, USA, United States Enviromental Protection Agency, Office of Pesticides Programs Environmental Fate and Effects Division. 225 pp. Available at: http://www.fluoridealert.org/pesticides/EPA-HQ-OPP-2006-0955-0005.pdf.

Bailey, C., Fisher, P. and Eason, C. T. 2005. Assessing anticoagulant resistance in rats and coagulation effects in birds using small-volume blood samples. *Science for Conservation* 249.

Basri, M. W., Suboh, I. and Norman, K. 1996. The extent of biological control of rats with barn owls, *Tyto alba javanica* in Malaysian oil palm plantations. *The Planter* 72: 5-18.

Baudvin, H. 1986. La reproduction de la Chouette Efffraie (*Tyto alba*) (Abstract in English). *Le Fean le Blanc* 25: 1-125.

Becker, P. H., Cifuentes, J. M., Behrends, B. and Schmieder, K. R. 2001. Contaminants in Bird Eggs in the Wadden Sea Spatial and Temporal Trends 1991-2000. Common Wadden Sea Secretariat, Trilateral Monitoring and Assessment Group, Wilhelmshaven. 10 pp.

Becker, P. H., Dale, M. S and Hull, C. 1987. Eggshell quality and organochlorine residues in eggs of merlins (*Falco columbarius*) in southeastern Montana. *Canadian Field Naturalist* 101(3): 369-372.

Becker, P. H. and Munoz Cifuentes, J. 2004. Contaminant in bird eggs: Recent spatial and temporal trends. *Wadden Sea Ecosystem* 18: 5-24.

Belleville, M. J. 1981. Absorption, distribution, metabolism and excretion studies in the rat using 14C-labeled chlorophacinone. In Erickson,W. and Urban, D. 2004. Potential Risks of Nine Rodenticides to Birds and Nontarget Mammals: a comparative approach. Washington, DC, USA, United States Enviromental Protection Agency, Office of Pesticides Programs Environmental Fate and Effects Division. 225 pp. Available at: http://www.fluoridealert.org/pesticides/EPA-HQ-OPP-2006-0955-0005.pdf.

Benson, J., Suryan, R. M. and Piatt, J. F. 2003. Assessing chick growth from a single visit to a seabird colony. *Marine Ornithology* 31: 181-184

Berny, B. J. and Oliveira, A. 2005. Assessment of ruminal degration, oral bioavailability, and toxic effects of anticoagulant rodenticides in sheep. *American Journal Veterinary Research* 67: 363- 371.

Berny, P. J., Buronfosse. T., Buronfosse, F., Lamarque, F and Lorgue, G. 1997. Field evidence of secondary poisoning of foxes *(Vulpes vulpes*) and buzzards (*Buteo buteo*) by bromadiolone, a 4-year survey. *Chemosphere* 35(8): 1817-1829

Best, L. B. 1977. Nestling biology of the Field Sparrow. *Auk* 94: 308-319.

Birks, J. D. S. 1998. Secondary rodenticide poisoning risk arising from winter farmyard use by the European polecat (Mustela putorius). *Biological Conservation* 85(3): 22-29.

Boermans, H. J., Johnstone, I., Black, W. D. and Murphy, M. 1991. Clinical signs, laboratory changes and toxicokinetics of brodifacoum in the horse. *Canadian Journal Veterinary Research* 55: 11ï 27.

Borst, G. H. A. and Counotte, G. H. M. 2002. Shortfall using Anticoagulant Rodenticide. *Journal of Zoo and Wildlife Medicine* 33(1): 85.

Brakes, C. and Smith, R. 2005. Exposure of non-target small mammals to rodenticides: short-term effects, recovery and implications for secondary poisoning. *Journal Applied Ecology* 42: 118ï 128.

British Trust for Ornithology. 2007. British Trust for Ornithology, Breeding birds of the wider countryside: tawny owl. Available at: http://www.bto.org/birdtrends2003/wcrtawow.htm (2007).

Brown, P. R., Chambers, L. K. and Singleton, G. R. 2002. Pre-sowing control of house mice (*Mus domesticus*) using zink phosphide: efficacy and potential non target effects. *Wildlife Research* 29: 27-37.

Buckle, A. P., Prescott, C. V., and Ward, K. J. 1994. Resistance to the first and second generation anticoagulant rodenticides ï A new perspective. Proceedings of the

sixteenth Vertebrate Pest Conference ï University of Nebraskaï Lincoln. Available at http://digitalcommons.unl.edu/vpc16/7.

Bukacinski, D., Bukacinska, M. and Spaans, A. L. 1998. Experimental evidence for the relationship between food supply, parental effort and chick survival in the Lesser black-backed gull (*Larus fuscus*). *Ibis* 140: 422-430.

Bunn, D. S., Warburton, A. B. and Wilson, R. D. S. 1982. *The Barn Owl*. T & A. D. Poyser. Carlton, UK. 80 pp.

Burger, J. and Gochfeld, M. 1993. Lead and cadmium accumulation in eggs and fledgling seabirds in the New York bight. *Environmental Toxicology and Chemistry* 12: 261-267.

Burger, J. and Gochfeld, M. 1996. Heavy metal and selenium levels in Franklinôs gulls (*Larus pipixcan*) parents and their eggs. *Arch Environment Contamination Toxicology* 30: 487ï 491.

Cain, B. W., Silie, L., Franson, J. C. and Moore, J. 1983. Effects of dietary cadmium on mallard ducklings. *Environmental Research* 32: 286-297.

Castilla, A. M., Herrel, A., Van Dongen, S., Furio, N. and Negro, J. 2009. Determinants of eggshell strength in endangered raptors. *Journal Experimental Zoology* 311A: 303ï 311.

Chalermchaikit, T., Felice, L. J., and Murphy. M. J. 1993. Simultaneous determination of eight anticoagulant rodenticides in blood serum and liver. *Journal of Analytical Toxicology* 17: 56-61.

Chung, G. F. 2012. Rat management in oil palm. In Proceedings of 4th MPOB-IOPRI international seminar: Existing and emerging pests and diseases of oil palm advances in research and management. 13-14 December. Grand Royal Penghegar Hotel, Bandung, Indonesia.

Clapperton, B. K. 2006. A review of the current knowledge of rodent behavior in relation to control devices. *Science for Conservation* 263. 55 pp.

Colvin, B. A. 1984. Barn owl foraging behavior and secondary poisoning hazard from rodenticide use on farms. Bowling Green State University, Bowling Green, Ohio. Ph.D. Thesis (unpublished). 326 pp.

Colvin, B. A., Hegdal, P. L. and Jackson, W. B. 1988. Review of non-target hazards associated with rodenticide use in the USA. *EPPO bulletin* 18: 301-208.

Coueurdassier, M., Poirson, C., Paul, J., Rieffel, D., Michelat, D., Reymond, D., Legay, P., Giraudoux, P. and Scheifler, R. 2012. The diet of migrant Red Kites (*Milvus milvus)* during a Water Vole (*Arvicola terrestris)* outbreak in eastern France and the associated risk of secondary poisoning by the rodenticide bromadiolone. *Ibis* 154: 136-146.

Cowan, D., Dunsford, G., Gill, E., Jones, A., Kerins, G. and Mac Nicoll, A. 1995. The impact of resistance on the use of second-generation anticoagulants against rats on farms in southern England. *Pesticides Sciences* 43: 83ï 93.

Cox, P. and Smit, R. H. 1992. Rodenticide ecotoxicology: pre-lethal effects of anticoagulant on rat behaviour: in Borrecon, J. E. And Marsh, R. E. (EDS.), Proceedings of the 15th Vertebrate Pest Conference, University California, Davis, California. Pp 165-170.

Crop Protection Division, FASSB. 2011. Prosedur dan kaedah memelihara burung hantu dalam sangkar. Felda Agriculture Services Sdn Bhd. 12 pp.

Crowley, T. A. 1963. Calcium deficiency is associated with thinner shells. *Poultry Science* 54: 350-368.

Dauwe, T., Bervoets, L., Blust, R., Pinxten, R. and Eens, M. 1999. Are eggshells and egg contents of great and blue tits suitable as indicators of heavy metal pollution? *Belgian Journal of Zoology* 19 (2): 439-447.

Dauwe, T., Janssens, E. and Eens, M. 2006. Effects of heavy metal exposure on the condition and health of adult great tits (*Parus major*). *Environment Pollution* 140: 71-78.

Del Piero, F. and Poppenga, R. H. 2006. Chlorophacinone exposure causing an epizootic of acute fatal hemorrhage in lambs. *Journal Veterinary Diagnostic Investigation* 18: 483ï 485.

Dirksen, S. and Boudewijn T. J. 2010. Eggshell thickness measurements of Cormorant eggs: methods and some backgrounds. Wisconsin Cormorant Research Group Study. Available at: http://cormorants.freehostia.com/ /eggshell.htmm.

Dowding, C. V, Shore R. F, Worgan, A., Baker, P. J, and Harris, S. 2010. Accumulation of anticoagulant rodenticides in a non-target insectivore, the European hedgehog (*Erinaceus europaeus*). *Environmental Pollution* 158: 161ï 6.

Duckett, D. E. 1981. Barn owls (*Tyto alba*) ï a proven natural predator of rats in oil palm. In The Oil Palm in Agriculture in the Eighties. International Conference. Kuala Lumpur. Malaysia. pp 1-14.

Duckett, D. E. 1984. Barn Owls (*Tyto alba*) and the ñsecond generationò rat-baits utilised in oil palm plantations in Peninsular Malaysia. *The Planters* 60: 3-11.

Duckett, D. E. 1989. Barn owls (*Tyto alba*) as a biological control agent of rats in oil palm plantations. In Selangor Plantersô Association Annual Journal/Report 88. pp 68-74.

Duckett, D. E. 2008. The expansion of range and population of the Barn Owls (*Tyto alba javanica*) in Peninsular Malaysia and Sumatra and adjacent Islands ï A review and update on the current situation. *The Planter* 84 (993): 799-807.

Duckett, D. E. and Karuppiah, S. 1990. A guide to the planter in utilizing Barn Owls (*Tyto alba*) as an effective Biological control of Rats in Mature oil palm Plantation. In PORIM International Conference. Module II. Agriculture. Eds: Kuala Lumpur. Malaysia. 120 pp.

Durant, J. M. and Handrich, Y. 1998. Growth and food requirement flexibility in captive chicks of the European barn owl (*Tyto alba*). *Journal of Zoology* 245 (2): 137-145.

Durham, W. F. and Williams, C. H. 1972. Mutagenic, teratogenic, and carcinogenic properties of pesticides. *Annual Review of Entomology* 17: 123-148.

Dzoma, B. M. 2010. Some factors affecting fertility and hatchability in farmed ostrich: A review. *Journal of Animal and Veterinary Advances* 9 (2): 229-239.

Eadsforth, C. V., Dutton, A. J. and Harrison, E. G., 1991. A barn owl feeding study with (14C) flocoumafen-dosed mice: validation of a non-invasive method of monitoring exposure of barn owls to anticoagulant rodenticides in their prey. *Pesticides Science* 32: 105ï 119.

Eadsforth, C. V., Gray, A. and Harrison, G. 1996. Monitoring the exposure of barn owls to second generation rodenticides in Southern Eire. *Pesticide Science* 47: 225-233.

Eason, C. T and Spurr, E. B. 1995. Review of the toxicity and impacts of brodifacoum on non-target wildlife in New Zealand. *New Zealand Journal Zoology* 22: 371ï 379.

Eason, C. T. and Murphy, E. C. 2001. Recognising and reducing secondary and tertiary risks associated with brodifacoum. Pages 157-163 in J. J. Johnston (ed.), Pesticides and Wildlife. American Chemical Society Symposium Series 771.

Eason, C. T., Murphy, E. C., Wright, G. R. G., and Spurr, E. B. 2002. Assessment of risks of brodifacoum to non-target birds and mammals in New Zealand. *Ecotoxicology* 11: 35-48.

Eeva, P. and Lehikoinen, E. 1995. Egg shell quality, clutch size and hatching success of the great tit (*Parus major*) and the pied flycatcher (*Ficedula hypoleuca*) in an air pollution gradient. *Oecologia* 102: 312-323.

Eeva, T. and Lehikoinen, E. 1996. Growth and mortality of nestling great tits (*Parus major*) and pied flycatchers (*Ficedula hypoleuca*) in a heavy polluted metal pollution gradient. *Oecologia* 108: 631-639.

Eeva, T., Lehikoinen, E. and Pohjalainen, T. 1997. Pollution-related variation in food supply and breeding success in two hole-nestling passerines. *Ecology* 78: 1120-1131.

Elmeros, M., Christensen, T. K. and Lassen, P. 2011. Concentrations of anticoagulant rodenticides in stoats (*Mustela ermine*) and weasels (*Mustela nivalis*) from Denmark. *Science of the Total Environment* 409: 2373ï 2378.

Erickson, W. and Urban, D. 2004. Potential Risks of Nine Rodenticides to Birds and Nontarget Mammals: a comparative approach. Washington, DC, USA, United States Enviromental Protection Agency, Office of Pesticides Programs Environmental Fate and Effects Division. 225 pp. Available at: http://www.fluoridealert.org/pesticides/EPA-HQ-OPP-2006-0955-0005.pdf.

Erlinge, S., G. Gbransson, G. Hogstedt, G. Jansson, 0. Liberg, J. Loman, I. Nilsson, N. Von Schantz, T. and Sylvkn, M. 1984. Can vertebrate predators regulate their prey? *American Naturalist* 23: 125-133.

Fagerstone, K. A. and P. L. Hegdal. 1998. Risk assessment of rodenticides through use of telemetry and other methods: 5 examples. Pages 49-66 in L.W. Brewer and K. A. Fagerstone (eds), Radio telemetry Applications for Wildlife Toxicology Studies. SETAC Press. Proceedings from a Pellston workshop on avian radio telemetry in support of pesticide field studies (January 5 -8, 1993, Pacific Grove, Califoria, USA) SETAC Special Publications Series, Society of Environmental Toxicology and Chemistry, Pensacola, Florida, USA.

Fimreite, N., Brevik, E. M. and Torp, R. 1982. Mercury and organochlorines in eggs from a Norwegian gannet colony. *Bulletin Environment Contamination Toxicology* 28: 58ï 60.

Fisher, P. M. 2006. Persistence of residual diphacinone concentrations in pig tissues following sub-lethal exposure. Department of Conservation, Wellinton, New Zealand. *Research and Development Series* 249. 19 pp.

Fisher, P. M. 2009. Residual concentration and persistence of the anticoagulant rodenticides brodifacoum and diphacinone in Fauna. Lincoln University. Ph.D. Thesis. Unpublished. 155 pp.

Fisher, P. M., Eason, C. T., Connor, C. E. O., Lee, C. H., Smith, G. B. and Endepols, S. 2003. Coumatetralyl residues in rats and hazard to barn owl. In_*Rats, Mice and People*; Rodent Biology and Management: Eds: Singleton, G. R., Hynds, L. A., Krebs, C. J., Spratt, D. M. ACIAR Monograph. Pp 457-460.

Fisher, P. M., OõConnor, C., Wright, G and Eason, C. T. 2004. Anticoagulant residues in rats and secondary non-target risk. *Department of Conservation, Science Internal Series* 188. 18 pp.

Fisher, P. M. and Timm, R. M. 1987. Laboratory Trial of Chlorophacinone as a prairie dog toxicant. Wildlife Damage Management, Internet Center for Great Plains Wildlife Damage Control Workshop Proceedings (Internet version): Available at: http://digitalcommons.unl.edu/gpwdcwp/65.

Fournier-Chambrillon, C., Berny, P. J., Coiffier, O., L Barbedienne, P., Dasse, P., Delas, G., Galineau, H., Mazet, A., Pouzenc, P., Rosoux, R. and Fournier, P. 2004. Evidence of secondary poisoning of free-ranging Riparian mustelids by anticoagulant rodenticides in France: implications for conservation of European mink (*Mustela lutreola*). *Journal of Wildlife Diseases* 40(4): 688ï 695.

Frank, D. S., Mora, M. A., Sericano, J. L., Blankenship, A. L., Kurunthachalam, K. and Giesy, J. P. 2001. Persistent organochlorine pollutants in eggs of colonial water birds from Galveston Bay and east Texas, USA. *Environmental Toxicology Chemistry* 20: 608ï 617.

Fry, D. M. 1995. Reproductive effects in birds exposed to pesticides and industrial chemicals. *Environmental Health Perspective* 103: 165-171.

Gabriel, M. W., Woods, L. W., Poppenga, R., Sweitzer, R. A., and Thompson, C. 2012. Anticoagulant rodenticides on our public and community lands: Spatial distribution of exposure and poisoning of a rare forest carnivore. Available at: http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fj.

Gese, E. M. and Knowlton, F. F. 2001. The Role of Predation in Wildlife Population Dynamics. USDA National Wildlife Research Center - Staff Publications 542. Internet version available at: http://digitalcommons.unl.edu/icwdm_usdanwrc/542.

Gochfeld, M. and Burger, J. 1998. Temporal trends in metal levels in eggs of the endangered roseate tern (*Sterna dougallii*) in *New York. Environmental Research* 77: 36ï 42.

Godfrey, M. E. R. 1985. Non-target and secondary poisoning hazards of second generation anticoagulant. *Acta Zoologica Fennica* 173: 209-212.

Gómez, R. P., Martínez-López, E., García-Fernández, A. J. Zweers A. J. and Van den, N. W. 2012. Organohalogen exposure in a Eurasian Eagle owl (*Bubo bubo*) population from South-eastern Spain: Temporalï spatial trends and risk assessment Brink. *Chemosphere* 88: 903ï 911.

Gray, A., Eadsforth, C.V. and Dutton, A. J., 1994a. Non-invasive method for monitoring the exposure of barn owls to second-generation rodenticides. *Pesticides Science* 41: 339ï 343.

Gray, A.; Eadsforth, C.V., Dutton, A.J. and Vaughan, J. A. 1992: Toxicity of second generation rodenticides to barn owls. Pp. 781ï 786 in Proceedings, Brighton Crop ProtectionConference, Pests and Diseases, Brighton, UK, 23ï 26 November 1992. 12 pp.

Gray, A., Eadsforth, C. V. Dutton., A. J. and Vaughan, J. A. 1994b. Toxicity of three second generation rodenticides to barn owls. *Pesticide Science* 42: 179-184.

Greaves, J. H. 1994. Resistence to anticoagulant rodenticides. In_Rodent Pests and Their Control. Eds: Buckle, A. P., and Smith, R. H. CAB International. Wallingford. Pp 197-217.

Green, R. E. 1998. Long-term decline in the thickness of eggshells of thrushes, *Turdus* spp., in Britain. Proceedings of Royal Society. *Biological Sciences* 265: 679-684.

Grolleau, G., Lorgue, G. and Nahas, K. 1989. Toxiciti secondairee n laboratoire, dun rodenticide anticoagulant (bromadiolone) pour des pridateurs de rongeurs

champres: buse variable *(Buteo buteo)* et hermine *(Mustela erminea).* Summary in English. *Bulletin OEPP/EPPO* 19 (4): 633-648.

Hafidzi, M. N., Naim, M. and Akbar, Z. 2003. Feeding Ecology of Barn owl in Rice field. *Journal of Malaysian Applied Biology* 32 (2): 41-46.

Hafidzi M.N., Naim, M. and Akbar, Z. 2007. Influence of wet and dry season on Barn owl propagation and its relation on rat damage. *Pertanika Journal of Tropical Agricultural Science* 30 (1): 45-50.

Hafidzi, M. N. and Saayon, M. K. 2001. Status of Rat Infestation and Recent Control Strategies in Oil Palm Plantations in Peninsular Malaysia. *Pertanika Journal of Tropical Agricultural Science* 24(2): 109-114

Hafidzi, M. N., Zulkifli, A. and Kamaruddin, A. A. 1999. Barn owl as a biological control agent of rats in paddy fields. Symposium on Biological Control in the Tropics. Mardi Training Centre. Serdang. Malaysia. Pp 85-88.

Haresign, T. and Moiseff, A. 1988. Early growth and development of the common barn owlôs facial ruff. *Auk* 105: 699-705.

Harrison, E. 1991. Rodenticides and Barn Owl. Assessing the Hazard. *MAPPS Newsletter* 15(2): 18-20.

Hawkins, D. R., Brodie, R. R., Clarke, D. and Brindley, C. 1991. Determination of the residues and half-life of the rodenticides brodifacoum, bromadiolone, and flocoumafen in the livers of rats during 200 days after a single oral dose of each at a dose level of 0.2 mg/kg. In Erickson,W. and Urban, D. 2004. Potential risks of nine rodenticides to birds and nontarget mammals: a comparative approach. Washington, DC, USA, United States Enviromental Protection Agency, Office of Pesticides Programs Environmental Fate and Effects Division. 225 pp. Available at: http://www.fluoridealert.org/pesticides/EPA-HQ-OPP-2006-0955-0005.pdf.

Hegdal, P. L. and Blaskiewicz, R. W. 1984. Evaluation of the potential hazard to Barn Owls of Talon (brodicacoum bait) used to control rats and house mice. Environmental Toxicology Chemistry 3:167-179.

Hegdal, P. L and Colvin, B. A. 1998. Potential hazard to Eastern screech owls and other raptors of bradiofacoum bait used for vole vontrol in onchards. *Environmental Toxicological Chemistry* 7: 245-260.

Hegdal, P. L., Fagerstone, K. A., Gatz, T. A., Glahn, J. F. and Matschke, G. H. 1986. Hazards to wildlife associated with 1080 baiting for California ground squirrels. *Wildlife Society Bulletin* 14: 11-21.

Heikkila, R., Nygren, K., Harkonen, S. and Mykkanen, A. 1996. Characteristics of habitats used by female moose in the managed forest area. *Acta Theriologica* 41: 321-326.

Henny, C. J. 1969. Geographical variations in mortality rates and production requirements of the Barn Owl (*Tyto alba). Bird-Banding* 40: 277-290.

Heru, S. B., Siburian, J., Wanasuria, S., Chong, K. C. and Thiagarajan, S. 2000. Large scale use of barn owl (*Tyto alba*) for controlling rat population in oil palm plantation in Riau, Sumatra. In: Proceedings of the International Planters Conference on Plantation Tree Crops in the New Millennium: The Way Ahead (ed E. Pushparajah). Incorporated Society of Planters, Kuala Lumpur. P 529-544.

Hickey, J. J. and Anderson, D. W. 1968. Chlorinated hydrocarbons and eggshell changes in raptorial and fish-eating birds. *Science* 162: 271-273.

Hoffman, D. J., Pattee, O. H. and Wiemeyer, S. N. 1985. Effects of fluoride on screech owl reproduction: teratological evaluation growth, and blood chemistry in hatchingss. *Toxicity letters* 26: 19-24.

Howard, G., Minear, P., Elliott, J. E. and Cheng, K. M. 1999. Badiofacum poisoning of avian scavengersô during rat control on a seabirds colony. *Ecotoxicology* 816: 431-448.

Hussel, D. J. T. 1972. Factors affecting clutch size in arctic passerines. *Ecological Monographs* 42: 317-364.

James, S. B., Raphael, B. L., Cook, R. A. 1998. Brodifacoum toxicity and treatment in a white-winged wood duck (*Cairina scutulata*). *Journal Zoo and Wildlife Medicine* 29 (3), 324-327.

Janssens, E., Tom Dauwe, T., Pinxten, R., Bervoet, L., Blust, R. and Eens, M. 2003. Effects of heavy metal exposure on the condition and health of nestlings of the great tit (*Parus major*), a small songbird species. *Environmental Pollution* 126: 267ï 274.

Jason, M. Martin, Richard, N. R. and Lyn, C. Branch. 2005. Barn Owl (*Tyto alba*). Department of Wildlife Ecology and Conservation, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences (IFAS), University of Florida.

Jaspers, V., Covaci, A., Maervoet, J., Dauwe, T., Voorspoels, S., Schepens, P. and Eens, M. 2005. Brominated flame retardants and organochlorine pollutants in eggs of little owls (*Athene noctua*) from Belgium. *Environmental Pollution* 136: 81-88.

Jenssen, B. M., Aames, J. B., Murvoll, K. M., Herzke, D. and Nygard, T. 2010. Fluctuating wing asymmetry and hepatic concentrations of persistent organic pollutants are associated in European shag (*Phalacrocorax aristotelis*) chicks. *Science Total Environment* 408(3): 578-585.

Jobsen, J. A. 1978. Study on the possibility of secondary poisoning of ferrets by chlorophacinone-poisoned muskrats. Internal report of the Dutch Plant Protection. 25 pp.

Jodice, P. G. R., Roby, D. D., Turco, K. R., Suryan, R. M., Irons, D. B., Piatt, J. F., Shultz, M. T., Roseneau, D. G. and Kettle, A. B. 2008. Growth of Black-legged kittiwake (*Rissa Tridactyla*) chicks in relation to delivery rate, size, and energy density of meals. *Marine Ornithology* 36: 107ï 114.

Joermann, G. 1998. A review of secondary-poisoning studies with rodenticides. *Bulletin OEPP/ EPPO Bulletin* 28: 157ï 176.

Kamil, N. 1987. Kinetics of bromodialone, anticoagulant rodenticide, in the Norway rat (*Rattus norvegicus*). *Pharmacology Research Communications* 19:767ï 775.

Kammerer, M., Pouliquen, H., Pinault, L., and Loyau, M. 1999. Residues depletion in egg after warfarin ingestion by laying hens. *Veterinary and Human Toxicology* 41(2): 78-84.

Kenward, R. E. 2001. A manual for wildlife radio tagging. Academic Press, San Diego, California. 311 pp.

Khoo, C. K. and Dubock, A. C. 1981. Brodifacoum, a potent anticoagulant for the control of oil palm rats. In_*Proceeding of the International Conference on Oil Palm inAgriculture in the Eighties*. Eds: Pusparajah, E. and Chew, P. S. Kuala Lumpur. 17-20 June. PORIM. Pp 543-561.

Khoo, K. C., Peter A. C. O. and Ho, C. T. 1991. Crop Pests And Their Management in Malaysia. Tropical Press Sdn. Bhd. Kuala Lumpur. 242 pp.

Klass, E. E., Wiemeyer, S. N., Ohlendorf, H. M. and Swineford, D. M. 1978. Organochlorine residues, eggshell thickness and nest success in barn owls from the Chesapeake Bay. *Estuaries* 1: 46-53.

Koelkebeck, K. W. 2012. What is eggshell quality and how to preserve it?. Cheva-Eggs program 8 (4):1-2 Available at: Http://www.thepoultrysite.com/focus/contents/ceva/OnlineBulletins.

Koeman, J. H., Bothof, T., Vries, R., Velzen-Blad, H. and Vos, J. G. 1972. The impact of persistent pollutants on piscivorous and molluscivorous birds. *TNO-nieuws,* 27(10): 561-569.

Krebs, J. R. and Avery, M. I. 1984. Chicks growth and prey quality in European Bee-eater (*merops apiaster*). *Oecologia* 64: 363-368.

Lambert, O., Pouliquen, H., Larhantec, M., Thorin, C., and Hostis, M. 2007. Exposure of raptors and water birds to anticoagulant rodenticides: Epidemiological survey in Loire Atlantique (France). *Bulletin Environmental Contamination Toxicology* 79: 91-94.

Lam, Y. M. 1982. Chemical control of rodents. In Rodent pests of agricultural crops in Malaysia. Eds : Khoo, K. C., Lam, Y. M., Teoh, C. H., Lim, W. H. and Mohammad, B. M. The Malaysian Plant Protection Society. Pp. 33-56.

Lander, E., Lopez, J., Diaz, C. and Colmenares, M. 1991. Population biology of the barn owl (*Tyto alba*) in Guarico State, Venezuela. *Birds of Prey Bulletin* 4: 167-173.

Larsen, H. R. 2011. Living with walfarin. The AFIB report. 15 pp.

Languy, M. and Vansteewegen. D. 1989. Influence of parental age on the growth of nestling Swallows (*Hirundo rustica*). *Ardea* 77(2): 227-232.

Leary, A. W., Mazaika, R. and Bechard, M. J. 1998. Factors affecting the size of Ferruginous Hawk Home Range. *Wilson Bulletin* 110(2): 198-205.

Lee, C. H. 1994. Secondary toxicity of some rodenticides to barn owls. 4th International Conference of Plant Protection in the Tropics, 28-31 March, Kuala Lumpur, Malaysia, pp. 161-163.

Lee, C. H. and Ho, C. T. 1999. Barn Owl ï Field Biology and Rat Control. Symposium on Biological Control in the Tropics. MARDI Training Centre. Serdang. Malaysia. 18-19 March. Pp 77-81.

Lemus, J. A., Bravo, C., Garcia-Montijano, M., Palacin, C., Ponce, C., Magana, M. M. and Alonso, J. C. (2011). Side effects of rodent control on non-target species: Rodenticides increase parasite and pathogen burden in great bustards. *The Science of the Total Environment* 409: 4729-4734.

Lenton, G. M. 1984. The Feeding and Breeding ecology of Barn Owl (*Tyto alba*) in Peninsular Malaysia. *Ibis* 126: 551-575.

Lepczyk, C. A. and Karasov, W. H. 2000. Effect of ephemeral food restriction on growth of House Sparrows. *Auk* 117: 164-174.

Lund, M. 1981. Hens, eggs and anticoagulant. *International Pest Control* 5: 126.

Lund, M. 1984. Resistance to the second generation anticoagulant rodenticides. Proceedings of the eleventh vertebrate pest conference ï University of Nebraskaï Lincoln. Available at http://digitalcommons.unl.edu/vpc11/21.

Lundholm, C. E. 1997. DDE-Induced Eggshell Thinning in Birds: Effects of p,pô-DDE on the Calcium and Prostaglandin Metabolism of the Eggshell Gland. *Comparative Biology and Physiology* 118C (2): 113-128.

Makarieva, A. M., Gorshkov, V. G. and Li, B. L. 2005. Why do population density and inverse home range scale differently with body size? Implications for ecosystem stability. *Ecological Complexity* 2: 259ï 271.

Marsh, R. E. and Howard, W. E. 1986. Ground squirrel-coyote secondary toxicity studies with chlorophacinone and bromadiolone (an administrative report of laboratory findings). In Erickson,W. and Urban, D. 2004. Potential Risks of Nine Rodenticides to Birds and Nontarget Mammals: a comparative approach. Washington, DC, USA, United States Enviromental Protection Agency, Office of Pesticides Programs Environmental Fate and Effects Division. 225 pp. Available at: http://www.fluoridealert.org/pesticides/EPA-HQ-OPP-2006-0955-0005.pdf.

Mario, G. and Grazia, M. 2010. An HPLC Method for the Determination of Bromadiolone Plasma Kinetics and its Residues in Hen Eggs. *Journal of Chromatographic Science* 48 (9):714-720.

Marshall, J. D., Hager G. H. and Mckee. G. 1986. The barn owl egg: weight loss characters, fresh weight prediction, and incubation period. *Raptor Research* 20: 108-112.

Marti, C. D. 1992. ñBarn Owl (*Tyto alba*).ò *The Birds of North America* 1: 1-13

Mc Carty, J. P. and Winkler, D. W. 1999. Relative importance of environmental variables in determining the growth of nestling Three Swallow (*Tachy cineta*) bicolor. *Ibis* 141: 286-296.

Mc Donald, R. A., Harris, S., Turnbull G., Brown, P. and Fletche. M. 1998. Anticoagulant rodenticides in stoats (*Mustelaerminea*) and weasels (*Mustela nivali*s) in England. *Environmental Pollution* 103: 17-23.

Mc Millin, S. C. and Brian F. F. 2010. Investigation of chlorophacinone-related goose deaths in Monterey County, California. In proceeding 24th Vertebrate pest conference, Sacramento Califonia. pp 178-180.

Mendenhall, V. M., Klass, E. E. and Mc Lane, M. A. R. 1983. Breeding success of of Barn Owls (*Tyto alba*) fed low levels of DDE and Dieldrin. *Archieves in Environmental Contamination and Toxicology* 12: 235-240.

Mendenhall, V. M. and Pank, L. F. 1980. Secondary poisoning of owls by anticoagulant Rodenticides. *Wildlife Society Bulletin* 8(4): 311-315.

Misra, A. K. 2011. Effect of pesticides on growth and development of male rain quail (*Coturnix coromandelica*). International Consortium of Contamporary Biologists (ICCB).

Mohd Din, A. 1991. The use of the barn owl as a biological control agents. In *Palm Oil Development* 15: 1.

Murphy, M. J. 2007. Anticoagulant rodenticides. In Veterinary Toxicology: Basics and Clinical Principles, Edited by Ramesh C. Gupta. New York, Elsevier, pp 525-547.

Nagarajan, R., Thiyagesan, K., Natarajan, R. and Kanakasai, R. 2002. Patterns of growth in nestling Indian barn owl. *The Condor* 104: 885ï 890.

Naim, M. 2010. Evidence and effects of secondary poisoning from two anticoagulants and a biological rodenticides on barn owl. Universiti Putra Malaysia. Ph.D Thesis. Unpublished. 167 p.

Naim, M., Hafidzi, M. N., Kassim, A. and Abu, J. 2010. Growth performance of nestling barn owls, *Tyto alba javanica* in rat baiting area in Malaysia. *ARPN Journal of Agricultural and Biological Science* 5(6): 1-13.

Naim, M., Hafidzi, M. N., Kassim, A. and Abu, J. 2011. Comparison of the breeding performance of the barn owl *Tyto alba javanica* under chemical and bio based rodenticide baiting in immature oil palms in Malaysia. *Dynamic Biochemistry, Process Biotechnology and Molecular Biology @ Global Science Books* 5 (2): 5-11.

Naim, M., Hafidzi, M. N ., Sudharto P. S. and Caliman, J. P. 2012a. Detection of rodenticide residues for Raptor conservation. 3rd International Conference on Oil Palm and Environment (ICOPE), 22-24 February 2012, Bali, Indonesia.

Naim, M., Umar, U. J. and Hafidzi, M. N. 2012b. The ranging behaviour of *Tyto alba* in oil palm under baiting with anticoagulant rodenticides, warfarin and brodifacoum and a biorodenticide *Sarcocystis singaporensis*. *Pertanika Journal of Tropical Agricultural Science* 35 (2): 209 ï 221.

Nam, D. H. and Lee, D. P. 2006. Reproductive effects of heavy metal accumulation on breeding feral pigeons (*Columba livia*). *Science Total Environmental* 366: 682-687.

Nelson, P. C. and G. J. Hickling. 1994. Pindone for rabbit control: efficacy, residue, and costs. *Proceedings of Vertebrate Pest Conference* 16:217-222. Internet version available at: http://digitalcommons.unl.edu/vpc16/39/

Newton, I. 1979. *Population Ecology of Raptors*. T. and A. D. Poyser. Berkhamsted. U. K.

Newton, I. 1986. *The Sparrow hawk*. Calton, UK. Poyser.

Newton, I., Willie, I., and Freestone, P. 1990. Rodenticides in British barn owl. *Environmental Pollution* 68: 101-117.

Newton, I., Willie, I., and Asher, A. 1991. Mortality causes in British Barn Owls, *Tyto alba* with a discussion of aldrin-dieldrin poisoning. *Ibis* 133: 162-169.

Newton, I., Wyllie, I., Gray, A. and Eadsforth, C. V. 1994. The toxicity of the rodenticide flocoumafen to barn owls and its elimination via pellets. *Pesticide Science* 41: 187ï 193.

Newton, I., Wyllie I. and Dale L. 1999. Trends in the numbers and mortality paterns of sparrowhawks (*Accipiter nisus*) and kestrels (*Falco tinnunculus*) in Britain, as revealed by carcass analyses. *Journal Zoology Society* 248: 139ï 147

Noor Hisham, H., Hasber, S., Sukri, T. I. and Samsudin, A. 2007. Integrated approach and effective control measures of major pests and diseases in oil palm cultivation in FELDA-FASSB experiences Seminar APS Kumpulan Perladangan FELDA, Jerantut Pahang. Pp 45-57.

Noor Hisham, H., Mohd Rizuan, C. Z. A., Sukri, T. I., Mohd aswad, A, W. and Hafidzi, M. N. 2010. Kekunci pengenalan jantina pungguk jelapang (*Tyto alba javanica*) berdasarkan perbezaan morfologi. *Kemajuan Penyelidikan FASSB* 54: 6-12.

Norsham, R. (1988). Kajian pergerakkan burung pungguk dan tikus dengan menggunakan radio telemetri. Universiti Kebangsaan Malaysia. Master of Science thesis. Unpublished. 80 pp

Olsen, P.; Fuller, P. and Marples, T. G. 1993. Pesticide-related eggshell thinning in Australian raptors. *Emu*. 93: 1-11.

Otteni, L. C., Bolen, E. G. and Cottam, C. 1972. Predator-prey relationships and re-production of the Barn Owl in southern Texas. *Wilson Bulletin* 84(4): 434-448

Pank, L. F. and Hirata, D. N. 1976. Primary and secondary toxicity of anticoagulant rodenticides. In Joermann. 1998. A review of secondary-poisoning studies with rodenticides. *Bulletin OEPP/EPPO Bulletin* 28: 157-176.

Papworth, D. S. 1958. A review of the dangers of warfarin poisoning to animals other than rodents. *Research Society Health Journal.* 78: 52-60.

Parmar, G., Bratt, H. Moore, R. and Batten, P. L. 1987. Evidence for a common binding site *in vivo* for the retention of anticoagulants in rat liver. *Human Toxicology*. 6: 431ï 432.

Peakall, D. B., Jeffrey L. and Lincer, B. 1996. Do PCBs Cause Eggshell Thinning. *Environmental Pollution* 91 (1): 127-129.

Penteriani, V., Delgado, M. M., Maggio, C., Aradis, A. and Sergio, F. 2005. Development of chicks and predisperal behavior of young in the Eagle Owl (*bubo bubo*). *Ibis* 147: 155-168.

Pesticides Board, Malaysia 2012. Registered pesticide 2005ï 2012. 200 pp. Available at http://www.moa.gov.my/ registered pesticide

Petterino, C. and Paolo, B. 2001.Toxicology of various anticoagulant rodenticides in animals. *Veterinary and Human Toxicology* 43: 353-360.

Poche, R. M. 1988. Rodent tissue residue and secondary hazard studies with bromadiolone. *Bulletin OEPP/EPPO Bulletin* 18: 323-330.

Poche, R. M. 1986. The status of bromadiolone in the United States. Proceding. Vertebrate Pest Conference 12:6-15. Online version available at http://digitalcommons.unl.edu/vpc12/50/.

Pouliquen, H., Fauconnet, V., Morvan, M. L. and Pinault, L. 1997. Determination of Warfarin in the yolk and the white of hens eggs by reverse-phase high-performance liquid chromatography. *Journal of Chromatography* 702: 143-148.

Prakash, I. 1988. Rodent pest management. CRS Press, Inc. Folrida, USA. 480 pp

Priede, I. G. (1992) Wildlife Telemetry - Remote Monitoring and Tracking of Animals, Ellis Horwood, Chichester. 60 pp.

Primus, T. M., Eisemann, J. D., Matschke, G. H., Ramey, C and Johnston, J. J. 2001. Pesticides and Wildlife, ACS Symposium Series 771. American Chemical Society, Washington, DC.

Proulx, G. 2011. Field evidence of non-target and secondary poisoning by strychnine and chlorophacinone used to control Richardsonôs ground squirrels in southwest Saskatchewan. P Ninth Prairie Conservation Endanger Species C: Pp 128ï 134.

Puan, C. L, Goldizen, A. W., Zakaria, M, Hafidzi, M. N. and Baxter G. S. 2011. Relationships among rat numbers, abundance of oil palm fruit and damage levels to fruit in an oil palm plantation. *Integrative Zoology* 2011: 6: 130-139

Quarles, W. 2013. Protecting raptors from rodenticides. *Common Sense Pest Control* 27 (1-4): 1-16.

Radvanyi, A., Weaver, P., Massari, C., Birdt, D. and Broughton, E. 1988. Effects of chlorophacinone on captive kestrels. *Bulletin Environment Contaminant Toxicology* 41: 441-448.

Rahn, H., Paganelli, C. V. and Ar, A. 1975. Relation of avian egg weight to body weight. *Auk* 92: 750ï 765.

Ratner, B. A., Horak, K. E., Warner, S. E. and Johnston, J. J. 2010. Acute toxicity of diphacinone in Northern bobwhite: Effects on survival and blood clotting. *Ecotoxicology and Environmental Safety* 73: 1159-1164.

Renton, K. 2002. Influence of environmental variability on the growth of Lilac-crowned Parrot nestlings. *Ibis* 144: 331ï 339.

Ricklefs, R. E. 1967. A graphical method of fitting equations to growth curves. *Ecology* 48: 978-983.

Ricklefs, R. E. 1968. Patterns of growth in birds. *Ibis* 110: 419ï 451.

Riedel, M., Riedel, B. and Schlegelmilch, H. 1991. Risk of secondary intoxication for birds of prey and owls following use of chlorophacinone baits against common voles. In Joermann. 1998. A review of secondary-poisoning studies with rodenticides. *Bulletin OEPP/EPPO Bulletin* 28: 157-176.

Riley, S. P. D., Bromley, C., Poppenga, R. H., Whited, L. and Sauvajot, R. M. 2007. Anticoagulant exposure and notoedric mange in bobcats and mountain lions in urban Southern California. *Journal of Wildlife Management* 71(6): 1874-1884.

Robertson, H. A., Colbourne, R. M., Graham, P. J., Miller, P. J. and Pierce, R. J. 1999. Survival of brown kiwi (*Apteryx mantelli*) exposed to brodifacoum poison in Northland, New Zealand. *New Zealand Journal of Ecology* 23: 225-231.

Robinson, M. H, Twigg L. E. and Wheeler S. H. 2005. Effect of the anticoagulant, pindone, on the breeding performance and survival of merino sheep, *Ovis aries* 140(3): 465-73.

Sage, M. E., Fourel, I., Coeurdassiera, M. E., Barrat, J., Berny, P. and Giraudoux, P. 2010. Determination of bromadiolone residues in fox faeces by LC/ESI-MS in relationship with toxicological data and clinical signs after repeated exposure. *Environmental Research* 110: 664ï 674.

Sanchez-Barbudo, I. S., Camarero, P. R. and Mateo, R. 2012. Primary and Secondary poisoning by anticoagulant rodenticides of non-target animals in Spain. *Science of the Total Environment* 420: 280-288.

Schweitzer, A. 2011. Why Do Poisons Matter?. UrbanCarnivores.com. Available at: http://www.urbancarnivores.com/poisons/

Shamsiah, M. and Goh, N. S. 1991. The use of Barn owl (*Tyto alba*) to control ricefield rat. An experience in Seberang Perak. *MAPPS Newsletter* 15(2): 20-21.

Sheffield, S. 1997. Owls as biomonitors of environment contamination. 1997. 2nd Owl Symposium. Manitoba, Canada. 383- 398 pp.

Shawyer, C. R. 1985. *Rodenticides:* A review and assessment of their potential hazard to non-target wildlife with special reference to The Barn Owl (*Tyto alba*). The Hawk Trust. London. 29 pp.

Shawyer, C. R. 1987. The barn owl in the British Isles. The Hawk Trust, London, UK, 113 pp.

Shore, R. F., Malcolm, H. M., Wienburg, C. L, Turk, A., Horne, J. A., Dale, L., Wyllie, I. and Newton, I. 2001. Wildlife and pollution: 1999/2000 Annual report. *JNCC Report*, No. 321.

Shore, R. F., Birks J. D. S., Afsar, A., Wienburg C. L. and Kitchener, A. C. 2003. Spatial and temporal analysis of second-generation anticoagulant rodenticide residues in polecats (*Mustela putorius*) from throughout their range in Britain, 1992ï 1999. *Environmental Pollution* 122: 183ï 93.

Siikamaki, P. 1996. Nestling growth and mortality of pied flycatchers *Ficedula hypoleuca* in relation to weather and breeding effort. *Ibis* 138: 471ï 478.

Sipayung, A. 1992. Barn owl (*Tyto alba*) reproduction in oil palm plantations. *Bulletin Pusat Penelitian Perkebunan Marihat* 12(3): 44-51.

Smal, C. M. 1989. Barn owls (*Tyto alba*) for the control of rats in agricultural crops in the tropics. In Symp. Biological Control of Pests in Tropical agricultural Ecosystem, Bogor, Indonesia. (eds. Sosromarsono, S; Gabriel, B. P.; Mali, U.; Tjitrosomo, S. S.; Tjitroisemito, S. and Tohari, M.). *SEAMED-BIOTROP Special Publication* 36: 255-276.

Smal, C. M. 1990. Research on the use of barn owls (*Tyto alba*) for biological control of rats in oil palm plantations: 1986-1989. In *Proc. of the 1989 POROM International Palm Oil Congress. Module II (Agriculture).* Palm Oil Research Institute of Malaysia, Bangi. p 342-356.

Sparks, J. and Soper, T. 1995. Owls. David and Charles, UK. 239 pp.

Springer, A. S. 1980. Pesticide levels, egg and eggshell parameter of great Horned Owls. *Ohio Journal of Science* 80: 184-187.

Starck, J. M. and Ricklefs, R. E. 1998. Avian growth and development. Oxford Univ. Press, New York, New York, USA.

Sterner, W. 1978. Study on secondary-poisoning hazards of the rodenticide chlorophacinone in the system mouse-carrion crow. International Bio-Research, Walsrode. Unpubl. Report to BBA (DE). In Erickson, W. 2001. Chlorophacinone (067707): secondary hazard studies. United States Environmental Protection Agency. Office of Prevention, Pesticides and Toxic Substances. Available at http://www.epa.gov/opp00001.

Sterner, W. 1981. Study on secondary-poisoning hazards of Lepit-Feldmausköder to white storks. International Bio-Research, Walsrode. Unpubl. Report to Schering AG. In Erickson, W. 2001. Chlorophacinone (067707): secondary hazard studies. United States Environmental Protection Agency. Office of Prevention, Pesticides and Toxic Substances. Avaiable at http://www.epa.gov/opp00001/chem_search/cleared_reviews/csr_PC-067707_18 Apr-01_a.pdf.

Stone, W. B., Okoniewski, J. C., and Stedelin, J. R. 1999. Poisoning of wildlife with anticoagulant rodenticides in New York. *Journal of Wildlife Diseases* 35(2): 187ï 193

Stone, W. B., Okoniewski, J. C. and Stedelin. J. R. 2003. Anticoagulant Rodenticides and Raptors: Recent Findings from New York, 1998ï 2001. *Bulletin Environmental Contamination Toxicology* 70: 34ï 40.

Suárez, E., Fernández C., Pro J., Ramos C., Unamuno V., Ortiz J., Haro A. and Tarazona, J. V. 2008. Assessing the environmental risk for primary and secondary poisoning in birds and mammals of the rodenticide chlorophacinone. Annex to the Chlorophacinone Environmental Risk Assessment Report. 18 pp.

Sunde, M. L. 1971. Older birds produce thinner shells. Farm Technology. 20 pp

Swedish Chemicals Inspectorate. 2006. Bromadiolone, Active Substance in Biocidal Products, Product Type 14 (Rodenticides). Document II-A: Effects Assessment for the Active Substance. Member State Report: Sweden. Sundbyberg: Swedish Chemicals Inspectorate. In Coeurdassier, M., Poirosn, C., et al. (2012). The diet of migrant Red Kites (*Milvus milvus*) during a Water Vole (*Arvicola terrestris*) outbreak in eastern France and the associated risk of secondary poisoning by the rodenticide bromadiolone. *Ibis* 154: 136ï 146.

Sykes, A. H. 1955.Adrenaline excess inhibits shell formation. *Poultry Science* 34: 622-628

Talloen, W., Lens, l., Van Dongen, S. and Mathysen, E. 2008. Feather development under environment stress lead exposure effects on growth patterns in great tits (*Parus major*). *Bird study* 55: 108-117.

Taylor, T. G. 1970. How an eggshell is made. *Scientific American* 222: 88-95

Taylor, I. 1994. *Barn Owls:* Predator-prey relationships and conservation. Cambridge University Press. 304pp.

The Barn Owl Trust. 2010. Thinking of having a captive Barn Owl? Available at http://www.barnowltrust.org.uk/infopage.html?Id=51

Thomas, P. J., Mineau, P., Shore, R. F., Champoux, L., Martin, P. A., Wilson, L. K., Fitzgerald, G. and Elliott, J. E. 2011. Second generation anticoagulant rodenticides in predatory birds: Probabilistic characterization of toxic liver

concentrations and implications for predatory bird populations in Canada. *Environment International* 37: 914ï 920.

Toms, M. P., Crick, H. Q. P. and Shawyer, C. R. 2001. The status of breeding Barn Owls *Tyto alba* in the United Kingdom 1995-1997. *Bird Study* 48: 23-37.

Tosh, D. G., Mc Donald, R. A., Bearhop, S., Liiewellyn, N. R,, Fee, S. and Sharp, E. A. 2011a. Does small mammal prey guild affect the exposure of predators to anticoagulant rodenticides? *Environmental Pollution* 159(31): 6ï 12.

Tosh, D. G., Shore, R. F., Jess S, Withers, A., Bearhop, S. and Ian M. W. 2011b. User behavior best practice and the risks of non-target exposure associated with anticoagulant rodenticide use. *Journal Environmental Management* 92: 1503ï 8.

Tsachalidis, E. P., Liordos, V. and Goutner, V. 2005. Growth of White Stork (*Ciconia ciconia*) nestlings. *Ardea* 93(1): 133-137.

Tucker, R. K and Haegele, H. A. 1970. Neither egg weight nor shell thickness affected by 300 parts per million DDT in daily diet. *The Bulletin of Environmental Contamination* and *Toxicology* 5: 191-194.

Tucker, R. K. 1971. Effects of many chemicals on shell thickness. *Utah Science* 6: 47- 49.

Turner, P. D. and Gillbanks, R. A. 2003. Oil Palm Cultivation and Management ï 2nd Edition. *The Incorporated of Planters. Kuala Lumpur*, Malaysia. 915 pp.

Valchev, I., Binev, A. R., Yordanova, V., Ordanova. A. and Nikolov, Y. 2008. Anticoagulant Rodenticide Intoxication in Animals - A Review. Turkey Journal Veterinary. *Animal Science* 32(4): 237-243.

Vigo, G., Williams, M. and Brightsmith, D. J. 2011. Growth of Scarlet Macaw (Ara Macao) chicks in southern Peru. *Ornitologia Neotropical* 22: 143-153.

Vudathala, D., Cummings, M. and Murphy. L. 2010. Analysis of Multiple Anticoagulant Rodenticides in Animal Blood and Liver Tissue Using Principles of QuEChERS Method. *Journal of Analytical Toxicology* 34. 273-279.

Wakeley, J. S. 1978. Factors affecting the use of hunting sites by Ferruginous Hawks. *Condor* 80: 316-326.

Walker, L. A., Shore, R. F., Turk, A., Pereira, M. G. and Best, J. 2008a. The Predatory Bird Monitoring Scheme: Identifying chemical risks to top predators in Britain. *Ambio* 37: 466-471.

Walker, L. A., Turk, A., Long, S. M., Wienburg, C. L., Best, J. and Shore, R. F. 2008b. Second generation anticoagulant rodenticides in tawny owls (*Strix aluco*) from Great Britain. *Science Total Environment* 392: 93ï 98.

Walker, L. A., Llewellyn, N. R., Pereira M. G., Potter, E. D., Sainsbury, A. W. and Shore, R. F. 2012. Anticoagulant rodenticides in predatory birds 2010: a Predatory Bird Monitoring Scheme (PBMS) report. Centre for Ecology & Hydrology, Lancaster, UK. 17 pp.

Ward, D. J. 2008. An ecological assessment of secondary poisoning risk in the Australian sugarcane industry. Queensland University and Technology. Ph.D. Thesis.

Welty, C. J. 1982. The life of birds. W. B. Sunders Company, London. 25 pp

Wilson, R. T., Wolson, M. P. and Durkin, J. W. 1987. Growth of nestling barn owls *Tyto alba* in central Mali. *Ibis* 129: 305-318.

Win, G. A. and Brian, S. 2003. Practical Laboratory Skill Training Guides: High Performance Liquid Chromatography. UK: Royal Society of Chemistry. 124 pp.

Winters, A. M., Rumbeiha W. K., Winterstein, S. R., Fine, A. E., Munkhtsog, B. and Hickling, G J. 2010. Residues in Brandtôs voles (*Microtus brandti*) exposed to bromadiolone-impregnated baits in Mongolia. *Ecotoxicology and Environmental Safety* 73: 1071ï 1077.

Wong, Y. L. J. 2005. Screening on suspected secondary rodenticide poisoning by determination of coagulation times in Barn Owls (*Tyto alba*) in Tanjung Karang, Selangor. Universiti Putra Malaysia. Final Year project Of Doctor of Veterinary Medinie (D.V. M). 122 pp.

Wood, B. J. 1969. Population studies on the Malaysian wood Rat (*Rattus tiomanicus)* in oil palms, demonstrating an effective new control method and assessing some older ones. *The Planter* 45: 510-526.

Wood, B. J. 1976. Vertebrate pests. In Oil palm research. Edited by Corley, R. H. V., Hardon, J. J., and Wood, B. J. Elsevier Scientific Publishing Company. The Netherlands. pp 395-417.

Wood, B. J. 1994. Rodents in agriculture and forestry. In Rodent pests and their control. (EDS. A.P. Buckle and R.H. Smith) CAB International, Wallingford, Oxon, UK. p 45-83. 200 pp.

Wood, B. J. 2001. Rat control in oil palms and rice fields. *Pesticide Outlook* 4: 71-74.

Wood, B. J. and Chung, G. F. 2003. A critical review of the development of rat control in Malaysian agriculture since the 1960ôs. *Crop Protection* 22: 445ï 461.

Wyllie, I. 1995. Potential secondary poisoning of barn owls by rodenticides. *Pesticide Outlook* 6: 19-25.

Yoccoz, N. G., Bustnes, J. O., Bangjord, G. and Skaare, J. U. 2009. Reproduction and survival of tawny owls in relation to persistent organic pollutants. *Environment International* 35: 107ï 112.

Young, J. and De Lai, L. 1997. Population declines of predatory birds coincident with the introduction of Klerat rodenticide in North Queensland. *Australian Bird Watcher* 17: 160-167.