

**EDIBLE FROG HARVESTING IN INDONESIA:
EVALUATING ITS IMPACT AND ECOLOGICAL CONTEXT**

Thesis submitted by

Mirza Dikari KUSRINI BSc (IPB) MSc (IPB)

In February 2005

for the degree of Doctor of Philosophy
in Zoology and Tropical Ecology
within the School of Tropical Biology
James Cook University

ELECTRONIC COPY

I, the undersigned, the author of this work, declare that the electronic copy of this thesis provided to the James Cook University Library, is an accurate copy of the print thesis submitted, within the limits of the technology available.

Signature

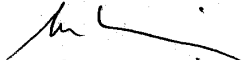
Date

STATEMENT OF ACCESS

I, the undersigned, the author of this thesis, understand that James Cook University will make it available for use within the University Library and, via the Australian Digital Theses network, for use elsewhere.

I understand that as an unpublished work, a thesis has significant protection under the Copyright Act and;

I do not wish to place any further restriction on access to this work.


MIRZA D. KUSRI
(Name)

26 FEBRUARY 2005
(Date)

ABSTRACT

Frogs are harvested in Indonesia for both domestic consumption and export. Concerns have been expressed about the extent of this harvest, but there have been no detailed studies on the edible frog trade in Indonesia, or on the status or population dynamics of the harvested species. To investigate the possible impact of this practise, I collected data on harvesting and trading of frog legs in Java, Indonesia. I also investigated the ecology and population dynamics of the three species that are most heavily harvested: *Fejervarya limnocharis-iskandari* complex, *F. cancrivora* and *Limnonectes macrodon*.

The first step of the study quantified the extent of the Indonesian edible frog leg trade for export and domestic purposes. Harvesting is an unskilled job and serves as livelihood for many people. There is no regulation of this harvest, and species taken and size limits are governed by market demand. The most harvested species in Java are *F. cancrivora* and *L. macrodon*. Harvests occur all year long. The number of frogs harvested fluctuates and is controlled by natural forces such as dry/wet seasons, moon phase, and planting seasons. Records of the international trade in Indonesian frog legs are available from 1969 to 2002; the mass of frozen frog legs exported has increased over the years. I used data on the relative weights of frogs and their legs to estimate how many frogs were represented by the export records. In 1999-2002 an average of 3,830,601 kg of frozen frog legs were exported annually; this represents an export harvest of approximately 28 to 142 million frogs, all with masses greater than 80 g, the minimum size of animals that have legs considered suitable for export. I used data collected by following frog hunters in the field to assess their capture rates and the numbers and sizes of frogs captured. I found that only about one-eighth of frogs

captured are of sizes acceptable for export, and therefore estimate that the domestic market is approximately 7 times as large as the export market.

In the second step of the study, I used field data on *F. limnocharis-iskandari* complex, *F. cancrivora* and *L. macrodon* to gain greater understanding of the population biology and dynamics of the harvested species. Populations of *F. limnocharis-iskandari* complex and *F. cancrivora* were studied in six rice fields in West Java during the planting seasons of 2002 and 2003. Both *F. limnocharis-iskandari* complex and *F. cancrivora* were abundant in the rice fields, with estimated overall mean densities of 193.71 and 39.76 per hectare. The mean density of *F. cancrivora* was very similar to that of unharvested populations in Malaysia (8.6 – 91.2 per hectare) (Jaafar, 1994) and was much higher than the mean density (0.7 frogs/ha) found for *Rana tigerina*, the larger species of edible Indian paddy field frog investigated by Dash and Mahanta (1993). These comparisons suggest that densities of *F. cancrivora* in Javan rice fields are relatively high, despite ongoing harvesting pressure. *F. limnocharis-iskandari* complex and *F. cancrivora* were able to breed continuously all year without an apparent season. Both species showed sexual size dimorphism, with females larger than males. Both appear to be short lived.

The population dynamics of *L. macrodon* were observed at two stream sites West Java: Cilember and Ciapus Leutik. The habitat at Ciapus Leutik is relatively heavily modified by human activity, while Cilember is in a nature reserve and is less disturbed. A mark-recapture study was conducted once a month between June 2002 and May 2003 (a continuous 12 month sampling period), and in January, April and July 2004. Skeletochronological analysis of phalanges removed during toe clipping suggests that this species lives longer than *F. cancrivora* or *F. limnocharis-iskandari* complex. Recapture rates of *L. macrodon* in both locations were low and more frogs were

observed during periods of higher rainfall. In this study, more *L. macrodon* were found at Cilember than at Ciapus Leutik stream. It is unclear whether the low number of frogs at Ciapus Leutik was caused by over-harvesting or by other factors. There is a need for further monitoring to obtain a greater understanding of the population dynamics of this species.

In conjunction with my field work, I measured a number of parameters to determine the type and extent of pesticide residues present in rice fields, and to attempt to determine whether those and another potential stressor, drought, might be affecting the morphology, body condition, or developmental stability of frogs. I also surveyed populations of the rice field frogs and *L. macrodon* for the emerging disease chytridiomycosis, which could strongly affect the population dynamics of the frogs. Two types of pesticide residues were detected in water and soil: organochlorine (lindane, aldrin, heptachlor, dieldrin and endosulfan) and organophosphate (chlorpyrifos and diazinon). Six organochlorines type (BHC, lindane, aldrin, heptachlor, dieldrin and endosulfan) and three organophosphates (propanofos, chlorpyrifos and diazinon) were detected in the livers and leg muscles of both frog species. Almost all pesticide residues were low compared to the Maximum Residue Limit set by WHO and the Government of Indonesia although a few individuals showed higher pesticide residues contents. Pesticide residue levels did not appear to be related to any measure of frog condition or stress. Both species of rice field frogs exhibited relatively low percentages of abnormalities, probably within the normal range. Only *F. limnocharis-iskandari* complex consistently exhibited levels of fluctuating asymmetry in excess of measurement error. Levels of asymmetry differed between characters. Higher limb asymmetries were elevated in 2002 compared to 2003, whilst body condition was lower in 2003. It is possible that the lower body condition in 2003 was caused by stress from

an environmental factor, in this case the drought in that year. It is clear that for both *F. limnocharis-iskandari* complex and *F. cancrivora*, fluctuating asymmetry is not a powerful indicator of stress. There was no sign of chytrid infection in any samples of the three species.

To assess the impact of harvesting, I used two approaches. I developed a model of the population dynamics of *F. cancrivora* and ran simulations for ranges of parameters including harvesting rate. The simulation indicated that current levels of harvest may be near the maximum level sustainable by the population. My second approach was to compare data on the population biology and distribution of both *Fejervarya* species to criteria for assessing the conservation status of the species, i.e. IUCN Red Categories and the CITES Res. Conf. 9.24 on the Criteria for Amendment of Appendices I and II.

My assessment using listing criteria showed that neither *F. limnocharis-iskandari* complex or *F. cancrivora* are qualified for inclusion into any IUCN Red List and CITES Appendices. On the other hand, more consideration needs to be given to *L. macrodon*. This frog is not qualified for inclusion in CITES Appendix I. At present, it is not possible to determine whether this species could be listed as vulnerable or in CITES Appendix II due to a lack of data, such as survivorship among stages, and habitat size, on the population biology of this species.

Recommendations for management of the harvest include: 1) regular monitoring of this trade especially in other islands such as Sumatra by the scientific authority of CITES (The Indonesian Institute of Science or Lembaga Ilmu Pengetahuan Indonesia, LIPI), 2) regular monitoring of the numbers of export companies and their middleman, 3) developing a simple identification key and distributing it to the middlemen to ensure correct identifications, 4) assessing the possibility of breeding local frogs for this trade

to replace the farming of the exotic frog *Rana catesbeiana*, and 5) ensuring that harvest is limited to species that are not adversely impacted.

ACKNOWLEDGMENTS

I thank Allah, God the Almighty that has guided me throughout my life, including this part of my life journey as student. More than 30 years ago as a toddler I stood watching buckets of frogs captured the night before from the neighbouring rice fields by my father and brother. Little did I know at that time that this personal fascination would result in this dissertation.

The project was made possible by various funding. The Australian Development Scholarship gave a scholarship for the author as part of a scholarship program for Indonesian Government Employees. Funding, mostly from the Wildlife Conservation Society, with additional funding from Indonesian Reptile Amphibian Trader Association, Research Office Institut Pertanian Bogor and James Cook University, made fieldwork possible. I thank all the funding agencies for their help.

Many people have supported my study, emotionally and scientifically. Without them, I doubt if I could have manage to finish my study on time, and for that I wish to give them all my sincerest thanks.

In Australia, I am grateful for the advice and assistance from my supervisor Assoc. Prof. Ross A. Alford, who has not only supported my research but also gave me valuable advice and comments on various matters. He has also inspired me to do more frog research in the future, so thank you very much Ross. I could not find better supervisor than you.

I also wish to thank my fellow students, some of them are now alumni's, Adam Felton, Kay Bradfield, Doug Woodhams, Jodi Rowley, Nicole Kenyon and Kim

Hauselberger and research assistants (Tracy Langkilde, Anthony Backer, Sara Townsend and Carryn Manicom) in the frog lab, who has shared the same passion for frog research while trying to maintain humour during the gruelling days as uni-fellows. I thank them for the companionship and insight on various matters. Jodi Rowley has opened her heart and her home during my last 2 weeks in Townsville. For this I thank her – your book collections also helped me a lot! Adam Felton and Richard Retallic prepared me for the rigours of skeletochronology analysis in tropical frogs, while Sara Townsend, Sue Reilly from the histological lab, and Kim Hauselberger helped me during my histology work. Kay Bradfield practically showed me step-by-step analysis for developmental stability analysis. I also want to thank my ALO during my study: Janelle Walsh and Alex Salvador. They both ensured that my transition as a student went smoothly. Special thanks for my editor; Tim Harvey who edited the grammatical works in this thesis.

I also wish to thank my fellow Indonesian friends and family for the companionship and joyful sharing of our country during my time in Townsville. A special thanks is given to Yeni Mulyani – who was in Darwin - who has been a great listener to my woes and joys even though she was practically in the same boat as I.

In Indonesia, my greatest thanks and appreciation is for Dr. Ani Mardiasuti and family. Not only has she encouraged me to further my study but also has fully supported my research by giving advice and also acting as host during my stay in Bogor. I thank her family (pak Agus Pakpahan, Angga, Andya and Mbah Mandi) for their hospitality. I am also deeply grateful for the help of my assistant Anisa Fitri, SHut. For more than three years Fitri had been invaluable in assisting me with her great administration skills and practicality. With great determination she managed all the dirty work of contacting

farmers, harvesters, traders and managing volunteers while ensuring that data taken met the requirement of her boss. Tackling this research would have been impossible without the help of volunteers, so I would like to thank Hijrah Utama (Aji), Mommad Dede Nasir (Dogen), Sumantri Radiansyah (Abenk), Ita Novita Sari, Vivien Lestari, Ian Budarto, Sudrajat, Reddy Rahmadi, Dadi Ardiansyah, Edi Sutrisno and many more who gave their time to help me. In 2001, Yoshiko Hikariati accompanied me sorting export data from the crumbling old books in the Statistical Office (BPS) in Pasar Baru, for this I thank you.

I would also like to thank Dr. Djoko T. Iskandar (ITB), Dr. Tonny Soehartono (CI-IP), Ibu Mumpuni (Museum Zoologicum Bogoriense), Bapak George Saputra (IRATA), Bapak Frank B. Yuwono and Dr. Damayanti Buchari (WT-IP) who gave me advice before and during this research, and Dr. Asep Nugraha, MS from Agribio in Bogor who assisted me with the pesticide work. Dr. Ibrahim Jaafar from Malaysia has kindly sent me a copy of his thesis and for this I thank him. I thank Jurusan Konservasi Sumberdaya Hutan (JKSH), Fakultas Kehutanan IPB for cooperation during my stay in Bogor. I also thank my colleagues in JKSH, especially Dr. Lilik B. Prasetjo and his lab who helped me with the mapping, and Arzyana Sunkar, MSc who not only joyfully volunteered in the field but also reminded me how to operate Powersim. I would also thank the farmers who have given me access to their rice fields, especially to Kang Ade (Subang), Kang Karmo (Karawang) and the people of Ciptarasa (Sukabumi). Special thanks are also given to the harvesters and traders especially Wanto in Bogor, who has given me an insight into their world.

Last but not least, I thank my family for their support during my study. My Mother, Zaghleila Azizah has supported me – not only financially but mostly emotionally

during all my years as a student (it is a long way from my kindergarten days!). I also thank my sisters and brother (Etoy, Mia, Latifah and Ai) and the in-laws. Wanda Wirianata assisted me during preliminary work in Ciptarasa and for this I am grateful. My mother in law and Latifah opened their house for me to use during my stay in Jakarta and I thank them for their hospitality.

Huge appreciation and thanks go to my husband, Ramadin Wahono Subekti, who stopped all his work and took care of our children while I was away in the fields, busy in lab or writing, which has practically been most of the time during our stay in Townsville. I thank my children, Benz Satrio Utomo Ramadin and Adinda Sri Yuani Ramadin for their understanding and support. I love you and I have been blessed. **Terima kasih.**

TABLE OF CONTENTS

Title	i
Statement of Access	ii
Abstract	iii
Acknowledgment	viii
Table of Contents	xii
List of figures	xvii
List of tables	xxiii
Statement of Sources	xxvii
CHAPTER 1. GENERAL INTRODUCTION	1
1.1 Harvest from the wild	1
1.2 Frogs for human use with the emphasize of Indonesian frogs and threats to their existence	3
1.3 The sustainability of wildlife harvest	7
1.4 Research focus	10
1.5 Research aims	10
1.6 Thesis outline	11
CHAPTER 2. INTERNATIONAL TRADE IN INDONESIAN FROG LEGS ..	12
2.1 Introduction	12
2.2 Methods	13
2.2.1 <i>Harvest estimation</i>	13
2.2.2 <i>Exporter profiles</i>	15
2.3 Results	16
2.3.1 <i>Species exported</i>	16
2.3.2 <i>The volume and value of Indonesian frog leg exports</i>	17
2.3.3 <i>Destinations of exported frog legs</i>	19
2.3.4 <i>Frog Export Profile</i>	20
2.3.5 <i>The sources of exported frog legs</i>	23
2.3.6 <i>Number harvested for export</i>	24
2.4 Discussion	25

CHAPTER 3. EDIBLE FROG HARVESTING AND THE STRUCTURE OF THE DOMESTIC MARKET	29
3.1 Introduction	29
3.2 Methods	29
3.3 Results	32
3.3.1 <i>Species harvested</i>	32
<i>a. Species in trade</i>	32
<i>b. Frog sizes</i>	34
3.3.2 <i>The process of harvesting frog and the characteristics of harvester</i>	34
<i>a. Profiles of harvesters, middle men and traders</i>	34
<i>b. Harvesting Techniques</i>	36
<i>c. Harvesting effort</i>	37
3.3.3 <i>Market structure</i>	38
<i>a. Price</i>	40
<i>b. Levels of income and profit</i>	41
<i>c. Sustainability</i>	45
<i>d. Number of frogs sold in local market</i>	46
3.4. Discussion	48
CHAPTER 4. STUDY SPECIES AND SITES	55
4.1 Introduction	55
4.2 Description and distribution of the common edible frogs	55
4.2.1 <i>Paddy field frog, <u>Fejervarya limnocharis</u></i>	56
4.2.2 <i>The crab eating frog, <u>Fejervarya cancrivora</u></i>	62
4.2.3 <i>The Giant Javanese Frog, <u>Limnonectes macrodon</u></i>	65
4.3 The locations	69
4.3.1 <i>Rice fields</i>	71
<i>a. Location</i>	71
<i>b. Rice planting method and management</i>	77
4.3.2 <i>Streams</i>	82

CHAPTER 5. POPULATION DYNAMICS OF <i>F. LIMNOCHARIS</i> AND <i>F.</i>	
<i>CANCRIVORA</i>	85
5.1 Introduction	85
5.2 Methods	87
5.2.1 Population study	87
5.2.2 Determination of sex	89
5.2.3 Skeletochronology analysis	90
5.2.4 Sampling bias	91
5.2.5 Movement of <i>F. cancrivora</i>	91
5.3 Data analysis	92
5.4 Results	94
5.4.1 Traits of <i>F. limnocharis</i> and <i>F. cancrivora</i>	94
5.4.2 Demographic analysis	100
5.4.3 Sampling effects	113
5.4.4 Population estimates	114
5.4.5 <i>F. cancrivora</i> movement	119
5.5 Discussion	120
CHAPTER 6. THE POPULATION BIOLOGY OF <i>LIMNONECTES</i>	
<i>MACRODON</i>	128
6.1 Introduction	128
6.2 Methods	128
6.2.1 Location	128
6.2.2 Sampling	131
6.2.3 Data analysis	133
6.3 Results	135
6.3.1 Microclimate	135
6.3.2 Captures	136
6.3.3 Traits of <i>L. macrodon</i>	140
6.3.4 The biology of <i>L. macrodon</i>	145
6.3.5 Population dynamic and population structure	147
6.3.6 Microhabitat use	154
6.3.7 Movement	154
6.4 Discussions	156

CHAPTER 7. ENVIRONMENT STRESS	161
7.1 Introduction	161
7. 2. Methods	164
7.2.1. <i>Study area</i>	164
7.2.2 <i>Morphological abnormalities</i>	164
7.2.3. <i>Pesticide analysis in rice fields</i>	165
a. <i>Sample collection</i>	165
b. <i>Pesticide residue analysis</i>	166
c. <i>Statistical analysis</i>	167
7.2.4 <i>Developmental Stability Analysis</i>	168
7.2.5 <i>Chytridiomycosis</i>	170
7.3 Results	171
7.3.1 <i>Morphological abnormalities</i>	171
7.3.2 <i>Pesticide levels</i>	177
7.3.3 <i>Fluctuating Asymmetry</i>	189
7.3.4 <i>Chytridiomycosis</i>	197
7.4 Discussion	197
CHAPTER 8. CONSERVATION STATUS OF THE EDIBLE FROGS	205
8.1 Introduction	205
8.2 Methods	207
8.2.1 <i>Modelling the impact of frog harvest</i>	207
a. <i>General model description</i>	207
b. <i>Harvesting simulation model</i>	208
8.2.2. <i>Conservation status</i>	211
8.3 Result	213
8.3.1 <i>Harvesting modelling</i>	213
a. <i>The simulation</i>	213
b. <i>Model limitation</i>	213
8.3.2 <i>Conservation status</i>	221
8.4 Discussions	225
CHAPTER 9. GENERAL DISCUSSIONS AND CONCLUSION	228
9.1 Introduction	228
9.2 The extent of the Indonesian edible frog leg trade	228

9.3 The population status of the harvested species	230
9.4 Environment stressor	232
9.5 The sustainability of harvest and the conservation status of the edible frogs	234
9.6 Recommendations	238
REFERENCES	240

LIST OF FIGURES

Figure 2-1.	The correlation between leg mass (g) and body mass (g) of <i>F. cancrivora</i> and <i>L. macrodon</i> based on captured frogs from harvesters	15
Figure 2-2.	Volume of frog legs exported by Indonesia from 1969 – 2002. 3 Moving average: A sequence of averages that are computed from the every three data series to smoothes the fluctuations in data, thus showing the pattern or trend more clearly	18
Figure 2-3.	Value of frog legs exported by Indonesia from 1969 – 2002. FOB value: value of export which still included shipping costs and the insurance costs) from the point of manufacture to a specified destination	18
Figure 2-4.	Processing frog legs for export (top) and box of skinless frog leg ready to be shipped (centre and below)	22
Figure 2-5.	The volume of frog legs exported out of ports in four main islands in Indonesia	24
Figure 2-6.	Total rice field area in several main islands in Indonesia 1983 to 1999. Data taken from Indonesian Statistical Bureau	27
Figure 3-1.	Frogs sold in the markets, either alive (centre) or as skinless legs (top). Below, a costumer buy frog legs in Madiun, East Java	33
Figure 3-2.	Equipment used to capture frogs include lamps, bags and bamboo pole with net in West Java (left) or three headed spears in East Java (right)	39
Figure 3-3.	Rejected frog legs with bruised marks	39
Figure 3-4.	The web of frog leg supply from harvesters to consumers usually consist of hunters, middle men, supplier and then the costumer itself either an export company that will distributed the legs to overseas or local consumers in the market	40
Figure 3-5.	<i>Rana catesbeiana</i> (top) and abandoned frog farm in Malang, East Java (below)	47
Figure 4-1.	Differences in webbing between the toes of <i>F. limnocharis</i> , <i>F. cancrivora</i> and <i>L. macrodon</i>	58
Figure 4-2.	The distribution of <i>F. limnocharis</i> in Indonesia. Points were made based on specimens stored at MZB and additional survey	61
Figure 4-3.	The distribution of <i>F. cancrivora</i> in Indonesia. Points are based on localities of specimens stored at MZB and additional surveys	63

Figure 4-4.	Various type of habitat for <i>Limnonectes macrodon</i> : A – stream with fast flowing water and boulder in Caringin (Bogor), B – stream flowing across rice fields in Cilengkong (Sukabumi) , C - Small stream in Cilabruk (Sukabumi) with closed canopy; D – irrigation tributaries in Situ Gunung (Sukabumi)	67
Figure 4-5.	The distribution of <i>L. macrodon</i> in Indonesia. Points were made based on specimens stored at MZB and additional surveys	68
Figure 4-6.	Monthly rainfall in Caringin and Darmaga from January 2002 to December 2003. Data from Caringin is taken from Ciawi Station, whilst data for Darmaga is from Darmaga Bogor station. Data source: Stasiun Klimatologi Darmaga Bogor, Badan Meteorologi dan Geofisika Balai Wilayah II)	72
Figure 4-7.	Monthly rainfall in Karawang and Subang from January 2002 to December 2003. Data is the same for both locations, since it was only served by Cilamaya Karawang station. Data source: Stasiun Klimatologi Darmaga Bogor, Badan Meteorologi dan Geofisika Balai Wilayah II	73
Figure 4-8.	Sampling sites in paddy fields in West Java	76
Figure 4-9.	Various stages of rice fields. A and B are rice fields in Caringin during the second and sixth weeks after planting. Fallow periods in Karawang (C) and Sukabumi (D). Rice plants ready to be harvested in Subang (E) and terrace rice fields during the sowing period in Mount Halimun National Park enclave (F)	80
Figure 4-10.	Sampling sites in streams	84
Figure 5-1.	Snout vent length of <i>F. limnochari-iskandari</i> complex and <i>F. cancrivora</i>	96
Figure 5-2.	Body mass of <i>F. limnocharis-iskandari</i> complex and <i>F. cancrivora</i>	97
Figure 5-3.	Relationship between snout vent length (mm) and mass (gram) of <i>F. limnocharis-iskandari</i> complex and <i>F. cancrivora</i>	99
Figure 5-4A.	Female <i>F. limnocharis-iskandari</i> complex (SVL = 41.5 mm, mass = 5 g), 1 LAG (arrow): scale 40 μ m	101
Figure 5-4B.	Male <i>F. limnocharis-iskandari</i> complex, no LAGs, SVL = 43 mm, mass = 6.4 g. (MC = Marrow cavity; EB = Endosteal Bone; PM = Periosteal Bone)	101
Figure 5-4C.	Female <i>F. cancrivora</i> (SVL = 42 mm, mass = 4.6 g); LAG (arrow) = 1	102
Figure 5-5.	Relationships between number of lines of arrested growth and snout vent length for <i>F. limnocharis-iskandari</i> complex and <i>F. cancrivora</i> . Samples were taken from West Java during September 2001	103

Figure 5-6.	Population structure of <i>F. limnocharis-iskandari</i> complex in Caringin and Darmaga for 4 sampling times (2002 and 2003) based on snout vent length (mm) of individuals at first capture in a sampling episode	104
Figure 5-7.	Population structure of <i>F. limnocharis-iskandari</i> complex in Karawang-1 and Karawang-2 for 4 sampling times (2002 and 2003) based on snout vent length (mm) of individuals at first capture in a sampling episode	105
Figure 5-8.	Population structure of <i>F. limnocharis-iskandari</i> complex in Subang-1 and Subang-2 for 4 sampling times (2002 and 2003) based on snout vent length (mm) of individuals at first capture in a sampling episode	106
Figure 5-9.	Population structure of <i>F. cancrivora</i> in Caringin and Darmaga for 4 sampling times (2002 and 2003) based on snout vent length (mm) of individuals at first capture in a sampling episode	107
Figure 5-10.	Population structure of <i>F. cancrivora</i> in Karawang-1 and Karawang-2 for 4 sampling times (2002 and 2003) based on snout vent length (mm) of individuals at first capture in a sampling episode	108
Figure 5-11.	Population structure of <i>F. cancrivora</i> in Subang-1 and Subang-2 for 4 sampling times (2002 and 2003) based on snout vent length (mm) of individuals at first capture in a sampling episode	109
Figure 5-12.	Mean size of <i>F. limnocharis-iskandari</i> complex and <i>F. cancrivora</i> in different stages of planting (top) and water level (bottom)	111
Figure 5-13.	Density of <i>F. limnocharis-iskandari</i> complex (top) and <i>F. cancrivora</i> (bottom) captured in three regions (1 = Bogor, 2 = Karawang; 3 = Subang)	112
Figure 5-14.	Density of <i>F. limnocharis-iskandari</i> complex (top) and <i>F. cancrivora</i> (bottom) captured in various stages of planting and water level during 2002 and 2003	113
Figure 5-15.	Mean rate of recapture for <i>F. limnocharis-iskandari</i> complex and <i>F. cancrivora</i> in different planting sites and water level	115
Figure 6-1.	The Ciapus Leutik stream (left) and the Cilember stream (right)	130
Figure 6-2.	Mean relative humidity (%), air and water temperature (°C) in the Cilember and the Ciapus Leutik Stream during sampling	137
Figure 6-3.	Proportion of <i>L. macrodon</i> captured in the Cilember stream	138
Figure 6-4.	Number of <i>L. macrodon</i> found in Cilember stream	138
Figure 6-5.	Proportion of <i>L. macrodon</i> captured in the Ciapus Leutik stream	139
Figure 6-6.	Number of <i>L. macrodon</i> found in the Ciapus Leutik stream ...	139

Figure 6-7.	Mean frogs found (observed and captured) in the Cilember and the Ciapus Leutik streams during 4-monthly periods in the continuous period between June 2002 and May 2003	140
Figure 6-8.	Size and body mass of <i>L. macrodon</i> in the Cilember and the Ciapus Leutik	141
Figure 6-9.	Relationship between snout vent length (mm) and mass (gram) of <i>L. macrodon</i>	142
Figure 6-10.	SVL and mass gain of five <i>L. macrodon</i> in the Cilember stream. Months 1–12 are June 2002 to May 2003 respectively. Trendlines are shown only for frogs recaptured more than 3 times	144
Figure 6-11.	Growth rate (mm SVL per month) as a function of snout vent length (SVL) for <i>L. macrodon</i> in the Cilember stream	145
Figure 6-12.	Percentages of reproductive female <i>L. macrodon</i> harvested in Caringin (n = 49)	146
Figure 6-13.	Relationship between body mass of <i>L. macrodon</i> female versus mass of eggs	147
Figure 6-14.	The proportion of frogs caught and time in months since first capture, in the Cilember stream	148
Figure 6-15.	Estimated number of <i>L. macrodon</i> population in the Cilember stream (mean \pm SE) during July 2002 to March 2003	149
Figure 6-16.	Estimated number of <i>L. macrodon</i> population in the Cilember stream (mean \pm SE) in September to November 2002 and December 2002 to February 2003	149
Figure 6-17A.	<i>Limnonectes macrodon</i> from the Cilember stream with 5 LAGs; (SVL 77.86 mm, mass = 61 g)	151
Figure 6-17B.	<i>Limnonectes macrodon</i> from the Cilember stream with 3 LAGs; (SVL 101.74 mm, mass = 126.5 g)	151
Figure 6-18.	Snout vent length (mm) versus number of line arrested growth (LAGs) for <i>Limnonectes macrodon</i>	152
Figure 6-19.	Population structure of <i>L. macrodon</i> in the Cilember (A) and the Ciapus Leutik (B) stream during three-monthly periods (June-August 2002; September- November 2002, December 2002-February 2003 and March-May 2003) based on the frequency of snout vent lengths category	153
Figure 6-20.	The position of <i>L. macrodon</i> along transect in the Cilember stream (top) and the Ciapus Leutik stream (bottom). Month 1 – 12 is for June 2002 until May 2003. Month 13 = January 2004, month 14 = April 2004, month 15 = July 2004. No <i>L. macrodon</i> were found in	

	month 15 in the Cilember stream	154
Figure 6-21.	The percentage of <i>L. macrodon</i> found in four types of microhabitat	155
Figure 6-22.	Pool like area in the Ciapus Leutik Stream where <i>L. macrodon</i> was sometimes found	159
Figure 7-1.	Measurement of hind limb and front limb characters of <i>F. limnocharis</i> and <i>F. cancrivora</i>	169
Figure 7-2.	Anophthalmy (no eye) in <i>Rana chalconota</i> found in Situ Gunung in 2003(top); Trauma – limb amputation in <i>F. cancrivora</i> (left, bottom) and Developmental abnormality – Amelia in <i>F. cancrivora</i> (right, bottom)	173
Figure 7-3.	Prevalence of <i>F. limnocharis-iskandari</i> complex abnormalities per site and sampling occasions. Total sampling occasions: 29. Total sampling occasions with abnormalities = 25	175
Figure 7-4.	Prevalence of <i>F. cancrivora</i> abnormalities per site and sampling occasions. Total sampling occasions: 24. Total sampling occasions with abnormalities = 11	176
Figure 7-5.	Mean pesticide residues (ppm) in water, soil, livers and leg muscles of <i>F. limnocharis-iskandari</i> complex and <i>F. cancrivora</i> in Caringin	186
Figure 7-6.	Mean pesticide residues (ppm) in water, soil, livers and leg muscles of <i>F. limnocharis-iskandari</i> complex and <i>F. cancrivora</i> in Darmaga	186
Figure 7-7.	Mean pesticide residues (ppm) in water, soil, livers and leg muscles of <i>F. limnocharis-iskandari</i> complex and <i>F. cancrivora</i> in Karawang NP	187
Figure 7-8.	Mean pesticide residues (ppm) in water, soil, livers and leg muscles of <i>F. limnocharis-iskandari</i> complex and <i>F. cancrivora</i> in Karawang P	187
Figure 7-9.	Mean pesticide residues (ppm) in water, soil, livers and leg muscles of <i>F. limnocharis-iskandari</i> complex and <i>F. cancrivora</i> in Subang NP	188
Figure 7-10.	Mean pesticide residues (ppm) in water, soil, livers and leg muscles of <i>F. limnocharis-iskandari</i> complex and <i>F. cancrivora</i> in Subang P	188
Figure 7-11.	Percent asymmetry of female <i>F. limnocharis-iskandari</i> complex during 2002 and 2003	193
Figure 7-12.	Percent of asymmetry of male <i>F. limnocharis-iskandari</i> complex during 2002 and 2003	194
Figure 7-13.	Pesticide and insecticide use (kg/ha)in rice fields in Indonesia	201

Figure 7-14.	Mean annual rainfall in Caringin and Darmaga and Karawang and Subang regions.	202
Figure 8-1.	Flowchart of frog population dynamics	207
Figure 8-2.	Diagram of systems that influence the population of frog	208
Figure 8-3.	Model of population dynamic of <i>Fejervarya cancrivora</i> in rice field habitat using program Powersim	214
Figure 8-4.	Tadpole population dynamics with level of harvesting 200 million, number of reproductive episodes per female = 4, with 1000 eggs per episode, and juvenile survival 0.72	215
Figure 8-5.	Dynamics of juveniles and mature frogs with level of harvesting = 200 million, number of reproductive episodes per female = 4, with 1000 eggs per episode, and juvenile survival 0.72	215

LIST OF TABLES

Table 2-1.	The proportion of whole body mass accounted for by leg mass in <i>F. cancrivora</i> and <i>L. macrodon</i>	14
Table 2-2.	Annual mean volume of frog legs exported and predicted number of frogs taken. A is for SVL between 89 – 162 mm, mean 101.43 mm and B is for SVL between 100 – 150 mm, mean 125 mm	17
Table 3-1.	Number of people interviewed during 2001-2003	30
Table 3-2.	Size and mass of frogs captured by harvesters	34
Table 3-3.	The average trip length and catch/effort per hour and per km of harvester	38
Table 3-4.	Price of frogs (in Indonesian Rupiah) in Jakarta and West Java	43
Table 3-5.	Price of skinless frog legs in East Java (in Rupiah) unless stated as other form	44
Table 3-6.	Comparative price of frogs sold from harvester to local consumer in Indonesian Rupiah, based on the maximum price available for each stakeholder	45
Table 3-7.	Harvester daily wages assuming that transportation is nil, food and price of frogs were constant	45
Table 3-8.	Percentage of frogs captured in category A (mass>80 grams), number in brackets refers to actual number	48
Table 3-9.	Indonesian's edible frog species and their endangered status adapted from Schmuck (2002)	51
Table 4-1.	Mean size of specimens stored in Museum Zoologi Bogor basaed on island group	59
Table 4-2.	Mean size of specimens stored in Museum Zoologi Bogor	59
Table 4-3.	Essential statistics of the six administrative areas of Java (BPS, 2002)	69
Table 4-4.	Microclimate in the paddy fields of Bogor, Karawang and Subang. Data were recorded at 21.00 – 24.00 hours	75
Table 4-5.	Rice field sites surveyed for <i>F. limnocharis-iskandari</i> complex and <i>F. cancrivora</i> in West Java, Indonesia	78
Table 4-6.	Streams and ponds surveyed for <i>L. macrodon</i>	83
Table 5-1.	The location and size of sampling area	88
Table 5-2.	T-tests for sexual dimorphism in snout vent length	95
Table 5-3.	Traits of <i>F. limnocharis-iskandari</i> complex by site (2002 and 2003)	99

Table 5-4.	Traits of <i>F. cancrivora</i> by site (2002 and 2003)	98
Table 5-5.	Densities of frogs captured inside bocks of paddy field and in the border. Numbers in brackets indicate the actual number captured	114
Table 5-6.	Range and mean of the two recapture rates (number of recaptures/total frogs captured the day before) estimated for each combination of location and sampling period	116
Table 5-7.	<i>F. limnocharis-iskandari</i> complex population estimates based on the Schnabel method	118
Table 5-8.	<i>F. cancrivora</i> population estimates based on the Schnabel method	119
Table 5-9.	Summary of capture rates and movement of <i>F. cancrivora</i> (\pm SD)	120
Table 5-10.	Comparison of density (frogs/ha) of <i>F. limnocharis-iskandari</i> complex in Java estimated in my study using mark-recapture data with estimates from Dash and Mahanta (1993) in India and Jaafar (1994) in Malaysia	125
Table 5-11.	Comparison of density (frogs/ha) of <i>F. cancrivora</i> in Java estimated in my study using mark-recapture data with estimates from Dash and Mahanta (1993) in India and Jaafar (1994) in Malaysia	125
Table 6-1.	Summary descriptions of study sites	129
Table 6-2.	Microclimates at the Cilember and Ciapus Leutik stream sites	135
Table 6-3.	Traits of <i>L. macrodon</i> in the Cilember and Ciapus Leutik streams	142
Table 6-4.	Snout vent length (mm) and mass (gram) gains of <i>L. macrodon</i> at Cilember during June 2002 to May 2003	143
Table 6-5.	Traits of <i>L. macrodon</i> captured by harvester in Caringin (West Java)	146
Table 6-6.	Summary of movement of <i>L. macrodon</i> at the Cilember stream	155
Table 7-1.	Data on individual frogs analysed for pesticide residues in 6 rice fields	166
Table 7-2.	Maximum Residue Limits Based on the WHO Codex Alimentarius and the Indonesia Ministry of Health Decree 1996 for meat products ..	167
Table 7-3.	Numbers of frogs measured for developmental stability analysis	168
Table 7-4.	Types of abnormalities found in frogs of West Java	172
Table 7-5.	Numbers of frogs showing abnormalities captured by professional frog hunters. Number in brackets is the actual number of frogs exhibiting this type of abnormality. Several frogs showed multiple types of abnormalities (*)	172

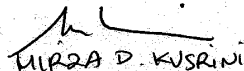
Table 7-6.	Type of morphological abnormalities found in specimens of <i>F. limnocharis-iskandari</i> complex and <i>F. cancrivora</i> stored in Museum Zoologi Bogor (MZB)	177
Table 7-7.	Pesticide residue in water and soil in 6 locations	178
Table 7-8.	Mean organochlorine (\pm standard deviation) residue in <i>F. limnocharis-iskandari</i> complex	181
Table 7-9.	Mean Organophosphate residue (\pm standard deviation) in <i>F. limnocharis-iskandari</i> complex	182
Table 7-10.	Mean Organochlorine pesticide residue (\pm standard deviation) in <i>F. cancrivora</i>	184
Table 7-11.	Mean organophosphate pesticide residue (\pm standard deviation) in <i>F. cancrivora</i>	184
Table 7-12.	Differences of pesticide residues between pair of location	185
Table 7-13.	Differences of pesticide residues between pair of region	185
Table 7-14.	Palmer and Strobeck (2003) Fluctuating Asymmetry (FA10A), measurement error (ME2), tests for significance of directional asymmetry (DA) and FA + Antisymmetry for each character of <i>F. limnocharis-iskandari</i> complex. Measurements not transformed	190
Table 7-15.	Palmer and Strobeck (2003) Fluctuating Asymmetry (FA10A), measurement error (ME2), tests for significance of directional asymmetry (DA) and FA + Antisymmetry for each character of <i>F. limnocharis-iskandari</i> complex. Measurements log transformed ...	190
Table 7-16.	Palmer and Strobeck (2003) Fluctuating Asymmetry (FA10A), measurement error (ME2), tests for significance of directional asymmetry (DA) and FA + Antisymmetry for each character of <i>F. cancrivora</i> . Measurements not transformed	191
Table 7-17.	Palmer and Strobeck (2003) Fluctuating Asymmetry (FA10A), measurement error (ME2), tests for significance of directional asymmetry (DA) and FA + Antisymmetry for each character of <i>F. cancrivora</i> . Measurements log transformed	191
Table 7-18.	Analysis of variances (ANOVA) for differences of asymmetry among sex in <i>F. limnocharis-iskandari</i> complex	192
Table 7-19.	Results of Kruskal Wallis test for significance of differences between asymmetry of fore- and hindlimbs in each class of individuals of <i>F. limnocharis-iskandari</i> complex in 2002 and 2003	192
Table 7-20.	The F-value for one-way test of means differences of mean asymmetry of <i>F. limnocharis-iskandari</i> complex between year 2002 and 2003 ...	192

Table 7-21.	Results of tests for differences in mean asymmetry of <i>F. limnocharis-iskandari</i> complex between the Bogor region and combined Karawang/Subang region	195
Table 7-22.	Results of Kruskal-Wallis tests, for differences in body condition among males, females, and juveniles of <i>F. limnocharis-iskandari</i> complex in 6 locations at one or two sampling times	196
Table 7-23.	Results of Kruskal-Wallis tests for differences of in body condition index of <i>F. limnocharis-iskandari</i> complex among sites	197
Table 7-24.	Mean pesticide residues in water and soil, and in the livers of frogs and water birds in Subang. Data for water birds taken from Ginoga's (1999) research in Sukamandi rice fields; Data on water, soil and frogs from the Subang P rice field site	199
Table 8-1.	The equations and numbers used in the simulation	212
Table 8-2.	Result of 20 year simulations using different combinations of total harvest, number of major reproductive episodes per female, and fecundity per reproductive episode. Juvenile survival to reproduction in this set of simulations is constant at the level (0.72) estimated by Wood et al. (1998) for <i>Rana grylio</i>	219
Table 8-3.	Result of 20 year simulations using different combinations of total harvest, number of major reproductive episodes per female, and fecundity per reproductive episode. Juvenile survival rate to reproduction in this set of simulations is reduced to 0.5 and 0.3	220
Table 8-4.	Assessment of biological criteria of <i>F. cancrivora</i> and <i>L. macrodon</i> against guidelines for inclusion in the IUCN Red List	222
Table 8-5.	Assessment of biological criteria of <i>F. cancrivora</i> and <i>L. macrodon</i> against guidelines for inclusion in CITES Appendix I	223
Table 8-6.	Assessment of biological criteria of <i>F. cancrivora</i> and <i>L. macrodon</i> against guidelines for inclusion in CITES Appendix II in accordance with Article II, paragraph 2 (a) of the CITES Convention	224
Table 8-7.	Assessment of biological criteria of <i>F. cancrivora</i> and <i>L. macrodon</i> against guidelines for inclusion in CITES Appendix II in accordance with Article II, paragraph 2 (b) of the CITES Convention	224

STATEMENT OF SOURCES

DECLARATION

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given


KIRZA D. KUSRINI
(Name)

26 FEBRUARY 2005
(Date)