Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

ECOLOGY AND POPULATION TRENDS IN NEW CALEDONIAN *PLACOSTYLUS* SNAILS (MOLLUSCA: GASTROPODA: BULIMULIDAE)

A thesis presented in partial fulfilment of the requirements
for the degree of

Doctor of Philosophy
in Zoology

at Massey University, Palmerston North,
New Zealand

Placostylus fibratus

Placostylus porphyrostomus

Fabrice Brescia

2011

Abstract

This study focuses on two endemic New Caledonian land snails: *Placostylus fibratus* and *Placostylus porphyrostomus* (known locally as bulimes) which are in decline and listed as vulnerable by the IUCN. On the Isle of Pines, both species are highly-valued commercially and traditionally harvested species suffering from exploitation for human consumption. In the dry forests of the New Caledonian mainland, *P. porphyrostomus*, especially, is threatened due to habitat degradation and loss, and rodent predation. Prior to this study, the life histories, impact of human harvest, and population trends remained largely unknown for the New Caledonian *Placostylus* species and restoration trials for their conservation had not been undertaken. Addressing these deficiencies forms the foundation for the thesis, and the findings are used to formulate recommendations for management and conservation.

On Isle of Pines, the extent and densities of *P. fibratus* are greater than the scattered and isolated populations of *P. porphyrostomus* found on the island and in the dry forests of the Mainland. *Placostylus* snails are long-lived (estimated at 19 to 39 years for *P. fibratus* in this study) and relatively slow growing, taking up to four years to reach sexual maturity (aperture lip ≥3.5 mm). Non-exploitative mortality factors impinge disproportionately on juveniles. Consequently, the age-structure of populations is changing, with juveniles becoming increasingly rare. Annual survival rates for *P. fibratus* are estimated as 59.0% for juveniles and 70.0% for adults.

The major cause of mortality of juveniles was predation by introduced rodents (the ship rat *Rattus rattus*, the Polynesian rat *Rattus exulans* and the mouse *Mus musculus*) that are present in very high densities compared with those reported elsewhere where *Placostylus* occurs, such as New Zealand. I found density estimates of 25.4 rats ha^{-1} in the rainforest (23.0 – 34.6 rats ha^{-1}, 95% confidence intervals) and 19.1 rats ha^{-1} in the dry forest (18.9 – 23.6 rats ha^{-1}, 95% confidence intervals).

In the dry forest, 87.6% of all of the empty juvenile shells found for *P. porphyrostomus* appeared to have died from rodent predation and 73.2% for *P. fibratus* on Isle of Pines. The introduced little fire ant *Wasmannia auropunctata* had a negative impact on *Placostylus* growth but not on mortality under semi-natural conditions.

I showed evidence for a decline in the total population of *P. fibratus* snails on the Isle of Pines between 1993 and 2008, with a particularly sharp decline in the

population of juveniles from 2001 to 2008. About 60,000 adult snails are collected annually from the wild for sale, and an additional 69,000 snails are estimated to be eaten annually by Kuniés (the local people of the Isle of Pines). Thus, the actual annual harvest represents approximately 6% of the estimated wild adult stock (ca. 2.5 million snails on average over the period 2001-2008).

A stage-structured population dynamics model developed here showed that if the harvest rate is maintained as it is (ca. 120,000 adult snails per year), then the population is likely to decline to very low numbers within the next 50 years. If the harvest rate increases, the rate of decline is accelerated. Sustainable exploitation is predicted to be attained at a 3% annual harvest rate (c.a. 70, 000 snails per annum), which would preclude collection for commercial purpose since the daily consumption by locals on Isle of Pines would account for most or all of this number. The model is very sensitive to rodent predation rates and predicts that the *Placostylus* population would likely recover if rodent predation was decreased even slightly.

Restoration trials were undertaken for *P. porphyrostomus* populations on the mainland. I successfully controlled rodent populations for 22 months by continuous poisoning in 5 ha of dry forest. After 15 months, the poisoning was sufficient to reduce and maintain rodent activity at low levels but I was unable to conclusively demonstrate a significant benefit to snail populations in the poisoned areas during this period, probably due to the specific life history traits of these snails and the flow-on effects of poisoning also reducing the density of rodents in non-poisoned areas. A trial release of 21 captive-bred *P. porphyrostomus* snails was conducted in an isolated patch of dry forest including two release procedures (soft- vs. hard-release). Twenty five months after the release the trial was deemed a success. The mean survival rate over this period was 100% for hard-released snails, which was significantly higher than the 70% survivorship for soft-release snails. No differences in snail growth (weight and aperture lip thickness) existed between the two release-procedures. Soft-released snails travelled shorter distances from the release point than hard-released snails, and showed significantly higher site fidelity. Supplementation with captive-bred snails appeared viable as a conservation strategy for New Caledonian *Placostylus* in dry forests.

The key findings of the thesis have direct implications for the conservation and management of New Caledonian *Placostylus*; recovery plans highlighting urgent

actions that need to be undertaken for each species of New Caledonian *Placostylus* have been proposed to provide guidance for both managers and local people.

Ecologie et évolution des populations des escargots du genre *Placostylus* (Mollusca: Gastropoda: Bulimulidae) de la Nouvelle-Calédonie

Resume

Le présent travail porte sur deux escargots terrestres endémiques de la Nouvelle-Calédonie, *Placostylus fibratus* et *Placostylus porphyrostomus* (localement appelés bulimes), listés comme Vulnérables par l'IUCN, et dont les populations sont en déclin. Sur l'Ile des Pins, les deux espèces présentent un intérêt commercial et/ou sont aussi collectées de manière traditionnelle ; elles sont aujourd'hui menacées par leur exploitation pour la consommation humaine. En forêt sèche, sur la Grande-Terre, *P. porphyrostomus* est menacé par la perte et la dégradation de l'habitat et la prédation par les rongeurs introduits. Avant la présente étude, les traits d'Histoire de Vie, l'impact de la collecte par l'Homme et l'évolution des populations avaient été très peu étudiés chez les *Placostylus* calédoniens; aussi, des opérations de restauration des populations dans un but de conservation n'avaient jamais encore été initiées. Combler ces lacunes constitue les bases de la thèse dont les résultats contribuent à établir des recommandations pour la gestion et la conservation des espèces.

A l'Ile des Pins, les densités de *P. fibratus* sont plus importantes que celles de *P. porphyrostomus* sur l'île mais aussi en forêts sèches sur la Grande-Terre où les populations de cette dernière espèce apparaissent disséminées et très isolées. Les *Placostylus* présentent une durée de vie longue (estimée ici à 19-39 ans pour *P. fibratus*) et une croissance très lente nécessitant au moins 4 années pour atteindre la maturité sexuelle (une lèvre coquillère épaisse de 3.5 mm). Les facteurs de mortalité (autre que l'exploitation par l'Homme) affectent de manière disproportionnée le stock de juvéniles ; en conséquence, la structure de population s'en trouve modifiée, avec un nombre de jeunes se raréfiant de plus en plus. Le taux de survie annuel pour les juvéniles de *P. fibratus* est estimé à 59.0% ; il est de 70.0% pour les adultes. La principale cause de mortalité des escargots juvéniles identifiée a été la prédation par les rongeurs introduits (rat noir *Rattus rattus*, rat Polynésien *Rattus* exulans et la souris domestique *Mus musculus*) qui se rencontrent sous de très fortes densités comparées à celles reportées ailleurs où le genre *Placostylus* est présent (en Nouvelle-Zélande notamment). Les densités estimées ici ont été de 25,4 rats.ha^{-1} en forêt humide (23,0 – 34,6 rats ha^{-1}, 95% IC) et 19,1 rats ha^{-1} en forêt sèche (18,9 – 23,6 rats ha^{-1}, 95% IC).

En forêt sèche, 87.6% des coquilles vides de juvéniles ont été endommagées par la prédation par les rats, et 73.2% pour *P. fibratus* à l'Ile des Pins. La fourmi électrique *Wasmannia auropunctata* a un effet négatif sur la croissance des escargots mais sa présence n'a pas affecté la survie en conditions semi-naturelles.

Il a été mis en évidence un déclin de la population totale de *P. fibratus* entre 1993 et 2008, avec en particulier, entre 2001 et 2008, un déclin de la population de juvéniles. Environ 60 000 bulimes adultes sont collectés en forêt annuellement pour alimenter le marché, tandis que de manière additionnelle environ 69 000 individus sont consommés chaque année par les foyers Kuniés au quotidien. Ainsi le nombre d'animaux collectés annuellement en forêt représente environ 6% du stock actuel estimé (évalué à 2,5 millions d'escargots en moyenne pour la période 2001-2008).

Le modèle de dynamique de population basé sur les stades de croissance développé ici afin de prédire l'évolution des populations pour *P. fibratus*, indique que si le niveau de prélèvement actuel est maintenu (environ 120 000 escargots adultes par an), les populations présentent un risque de fort déclin au cours des 50 prochaines années. Si le taux de collecte est augmenté, le déclin est accéléré. Le modèle prédit que l'exploitation durable de la ressource serait atteinte pour un taux de collecte de 3% (environ 70 000 escargots par an). Ce quota correspond à la consommation actuelle des seuls ménages Kuniés, et n'est ainsi pas compatible avec une collecte à des fins commerciales. Le modèle est très sensible à la prédation par les rongeurs introduits et prédit que la population de bulimes pourrait être rétablie si la prédation par les rongeurs était réduite même très légèrement.

Des opérations de restauration des populations de *Placostylus porphyrostomus* de forêt sèche sur la Grande-Terre ont été initiées. Nous sommes parvenus à réguler les populations de rongeurs introduits par empoisonnement continu pendant 22 mois sur 5 ha de forêt. Après 15 mois, l'empoisonnement a été suffisant pour réduire et maintenir l'activité des rongeurs à des niveaux très bas, mais nous n'avons pas pu mettre en évidence un rétablissement significatif des effectifs dans les zones empoisonnées au cours de la période écoulée probablement à cause des traits d'histoire de vie très particuliers de ces escargots, mais aussi du fait que les zones non-empoisonnées contigües ont également été affectées légèrement par l'empoisonnement, y réduisant aussi les densités de rats.

Egalement, une opération de renforcement des populations à partir d'individus nés en captivité a été réalisée dans un lambeau isolé de forêt sèche. Les escargots, au nombre de 21, ont été relâchés selon deux procédures (avec (soft) et sans adaptation préalable au milieu (hard release)). Après 25 mois de suivi, l'opération a été couronnée de succès. Le taux de survie moyen a été significativement plus élevé pour les escargots non adaptés (100%) contre 70% pour ceux ayant subis un conditionnement pré-lâcher. Aucune différence de croissance n'a été mise en évidence selon la catégorie de lâcher. Les pré-adaptés ont présenté des distances de dispersion au point de lâcher moindres que celles des escargots lâchés tels quels, et une fidélité au site plus importante. Le renforcement des populations à partir d'individus captifs apparait comme une solution réalisable dans le cadre d'opérations de conservation pour les escargots du genre *Placostylus* en forêt sèche.

Au final, les principaux résultats obtenus au cours du présent travail de thèse présentent des applications directes pour la conservation et la gestion des *Placostylus* de la Nouvelle-Calédonie à court et moyen terme. Les plans de sauvegarde proposés pour chacun des taxons calédoniens, soulignant les actions qui seraient à mettre en œuvre de manière urgente pour la sauvegarde des espèces, constituent de précieux outils pour les gestionnaires et la population locale.

To my family

who have always encouraged me

in my choices despite the distance between New Caledonia and France.

Thank you

and in memory of Théodore Koteureu called Dolly

ACKNOWLEDGEMENTS

Primarily I would like to thank my Supervisor Assoc. Prof. Murray Potter and my co-Supervisor Assoc. Prof. Alastair Robertson for their advice on experimental design and methods, encouragement and support at all stages of the PhD, and their valuable comments on manuscript that greatly improved the English of the thesis. Also my gratitudes are also towards my local co-Supervisor Christine Pöllabauer for her friendship and her unconditional support teaching me to always think positive by repeating her favourite diction "where there is a will there is a way".

Thanks to Dr Michel Salas (CIRAD, Fr) and Dr Ian Stringer (Department of Conservation, NZ) who firstly discussed about the possibility of doing a PhD on New Caledonian *Placostylus* snails. Without their collaborative work in 1997 this research would probably have never been possible.

Also thanks to everybody met at the Massey University Ecology Group and in Palmerston North when I came to meet my Supervisors once a year, and in particular Erica, Masha and Kevanne.

This research was supported by funding from the Ministère Français des Affaires Etrangères and the Agence Française de Développement (AFD) with a grant enabling an efficient supervision by six-monthly travels of my Supervisors into New Caledonia and the support of the expenses to my stays at Massey University. Thanks also to the Institut Agronomique néo-Calédonien (IAC) for the additional financial support and to have allow me to realize a PhD during my other duties during my employment at IAC. The work on Isle of Pines was also funded by the Direction de l'Environnement de la Province Sud (DENV) and the work on dry forest by the Programme de Conservation des Forêts Sèches (PCFS); I am particularly grateful for their support and involvement into the conservation of *Placostylus* snails to Anne-Claire Goarant and Cendrine Meresse (DENV) and Christian Papineau and Stéphane Hénocque (PCFS).

I would like to thank Jean-Claude Hurlin, Antoine Mai Viet Toa and Hipolyte Lenoir technicians at IAC for their valuable help on field work and data collection. Also I appreciated the friendship and help of Thérèse Mekenese in the finalization of the

manuscript and her support all along the PhD and during periods when I felt discouraged.

I am really grateful to the Grand Chief of Isle of Pines M. Hilarion Vandegou who accepted that a work was conducted on *Placostylus* of Isle of Pines, and thanks to all the clans to have accepted that surveys were done on their forests. I am particularly grateful to the Koteureu Family in Gadgi district for their friendship and their help on field work: thanks to Catherine, Théodore, Stéphanie, Vincent, Etienne and Véronique. In Kéré district, thanks to Charlotte and Paul Vama and Miguel Vama for their help in fieldwork. In Youaty district, thanks to the Touatsira family for giving us access to their forest.

Many thanks to all the team of the "Gîte Nataiwatch" for their welcome. Thanks to Guillaume and Eulalie Kouathe, Ines Kouathé, Marie-Paule Kouathé, Nicolas Zerathe, Sylvie Vakié and Thérèse Vakoumé for their friendship, happiness and all the funny discussions and laughs we had during my monthly trips on Isle of Pines.

Thanks to Mr Jonhston and Mr Metzdorf to have accepted to open us their domain to access to the remnant patches of dry forest in Nékoro and Mépouiri in Poya. Thanks also to Bokoé-Gowe Aristide, Olivier and Igor, Nedia Raphael and Nedia Pierre-Louis and Daye Samuel for their help in fieldwork in dry forests of Poya.

I am also really grateful to Mauricette Cognard for her valuable help in moments of doubt and all she did for me. Thanks also to Mike Williams for his friendship and his support.

Finally, I address all my thanks to Stanley Poarairoua for his presence and voluntary help in fieldwork in Poya each time it was necessary because the guides forgot to wake up…, but also for his support and for all the good time we spent.

Foreword

The research for this PhD thesis was conducted during my work at Institut Agronomique néo-Calédonien (IAC) where my employer agreed that I could spend a part of my time working on the thesis meanwhile conducting other actions on conservation of New Caledonian Wildlife. Thus in parallel I developed a programme for conservation and management of native flying-foxes, overhunted for consumption by different communities of the country.

Assoc. Prof Murray Potter and Assoc. Prof. Alastair Robertson, Massey University, supervised me through regular mailing and annual visits to New Caledonia. I also spent a week every six month in Massey University to discuss about progression of the research and analysis.

Fieldwork was conducted from 2003 to 2009 and consisted of intensive work surveying snails on the whole Isle of Pines and dry forests of New Caledonia. This required working closely with local population to obtain the necessary traditional authorization of Tribes to work in their forests on Isle of Pines (Kanak customs), to explain the aims of the study, to share their traditional knowledge and perceptions on snails and to discuss in return about the scientific information we gained all along the study. Only once it was more difficult like when I was pursue by an isolated “in trance” person equipped with an axe (!) after several previous damaged on my car. I had never thought that conserving a land snail would have been so perilous!

During the study, about thirty young adults accompanied me in the forests of Isle of Pines and ten others on the Grande-Terre in Poya in search of snails.

TABLE OF CONTENTS

	Page
Title page	i
Abstract	iii
Résumé	vii
Dedication	xi
Acknowledgements	xiii
Foreword	xv
Chapter 1. Introduction	**1**
1.1 Study background	3
1.2 Contribution of the research	5
1.3 Study area	5
1.4 Thesis structure	7
1.5 Contribution of co-authors	9
1.6 References	10
Chapter 2. A review of the ecology and conservation of *Placostylus* (Mollusca: Gastropoda: Bulimulidae) in New Caledonia	**13**
Abstract	15
Résumé	17
2.1 Introduction	19
2.2 General state of knowledge	22
2.2.1 Life history	22
2.2.2 Distribution, habitat and diet	22
2.2.3 Activity	24
2.2.4 Dispersal	26
2.2.5 Life span and growth	26
2.2.6. Reproduction	28
2.2.7 Population structure and population decline	29
2.2.8 Reasons for the decline of New Caledonian *Placostylus*	31
2.2.8.1 Habitat modification and destruction	31
2.2.8.2 Over-collection for human consumption	32
2.2.8.3 Pig and rodent predation	34
2.2.8.4 Other threats	36
2.3 Conservation	37
2.3.1 Legal aspects	37
2.3.2 Captive breeding	38
2.3.3 Utility for conservation	39
2.3.4 Research needs and conservation recommendations	40
2.4 Acknowledgements	42
2.5 References	43

Chapter 3. The influence of human harvest of the endemic New Caledonia Snails *Placostylus fibratus* (Mollusca: Gastropoda: Bulimulidae) on population trends **51**
Abstract 53
Résumé 55
3.1 Introduction 57
3.2 Methods 59
3.2.1 Study area 59
3.2.2 Survey of snail stock and sampling design 59
3.2.2.1 1993 to 2004 59
3.2.2.2 2006 to 2008 60
3.2.2.3 Information collected during snail surveys 60
3.2.2.4 Social survey: number of snails collected on Isle of Pines for consumption 61
3.2.2.5 Survey of the number of snails collected for daily consumption by Kuniés 61
3.2.2.6 Survey of the numbers of snails collected for commercial marketing 61
3.3 Results 62
3.3.1 Snail population trends 62
3.3.2 Human harvest of snails 70
3.3.2.1 Snails collected for marketed 70
3.3.2.2 Snails collected for personal consumption 72
3.3.2.3 Total annual harvest 72
3.4 Discussion 74
3.4.1 Population changes through time 74
3.4.2 Prospects for management 75
3.4.2.1 Continue monitoring population trends 75
3.4.2.2 Involve the local people 76
3.4.2.3 Establish a systematic harvesting plan 76
3.4.2.4 Organisation of the snail industry 76
3.4.2.5 Exploited snails from captivity 77
3.4.2.6 Sustainable use of the resource 77
3.5 Acknowledgements 78
3.6 References 79

Chapter 4. Population structure, growth, longevity and mortality in two species of *Placostylus* snails (Mollusca: Gastropoda: Bulimulidae) in evergreen and dry forests in New Caledonia **83**
Abstract 85
Résumé 87
4.1 Introduction 89
4.2 Methods 90
4.2.1 Study areas 90
4.2.2 Mark recapture study 92
4.2.3 Survey of snail stock from 2006 to 2008 on the Isle of Pines 93
4.2.4 Caged rodent trial 93
4.2.5 Data analysis 94
4.3 Results 95
4.3.1 Snail abundance 95
4.3.2 Snail population structure from the survey of stock on the Isle of Pines 97
4.3.3 Empty shell accumulation 102
4.3.4 Causes of mortality 104
4.3.5 Snail rodent vulnerability 107
4.3.6 Survival and fecundity 108
4.3.7 Growth and lifespan 111
4.4 Discussion 115
4.4.1 Snail density and population structure 115
4.4.2 Growth rate 117
4.4.3 Lifespan 118
4.4.4 Survival, fecundity and mortality 119
4.4.5 Relevance to conservation management 120
4.5 Acknowledgements 121
4.6 References 122
4.7 Appendix 125

Chapter 5. The abundance of introduced rodents (*Rattus* spp. and *Mus musculus*), and the evaluation of two abundance index techniques in wet and dry forests of New Caledonia: application to the conservation of an endemic land snail of the genus *Placostylus* (Gastropoda: Bulimulidae) **129**
Abstract 131
Résumé 133
5.1 Introduction 134
5.2 Methods 135
5.2.1 Study areas 135
5.2.2 Grid trapping and tracking experiment 136
5.3 Results 138
5.4 Discussion 144
5.4.1 Species and abundance 144
5.4.2 Tunnels and snap-trap captures 146
5.4.3 Tracking tunnels and wax blocks 146
5.4.4 Applicability of the rodent indices and recommendations for their use in New Caledonian forests 147
5.5 Acknowledgements 148
5.6 References 149

Chapter 6. Impact of the invasive little fire ant (*Wasmannia auropunctata*) on New Caledonian *Placostylus* (Mollusca: Gastropoda: Bulimulidae) in semi-natural conditions **153**
Abstract 155
Résumé 157
6.1 Introduction 159
6.2 Methods 161
6.2.1 Study area 161
6.2.2 Sampling and experimental design 161
6.2.3 Abundance of ants 162
6.2.4 Survival and growth of snails 162
6.2.5 Analysis 162
6.3 Results 163
6.3.1 Abundance of little fire ants 163
6.3.2 Growth of snails 163
6.3.3 Survival 166
6.4 Discussion 167
6.5 Acknowledgments 169
6.6 References 170

Chapter 7. Exploring plausible strategies for avoiding disaster: a population dynamic model for the exploited New Caledonian endemic land snail *Placostylus fibratus* (Mollusca: Gastropoda: Bulimulidae) **173**
Abstract 175
Résumé 177
7.1 Introduction 179
7.2 Methods 181
7.2.1 Study area and species 181
7.2.2 Model description 181
7.2.3 Historic data on *Placostylus fibratus* harvest rates and population trends 182
7.2.4 *Placostylus fibratus* life history 182
7.2.5 Parameters and model construction 184
7.2.6 Equations 185
7.3 Results 188
7.3.1 Calibration of the model 188
7.3.2 Population trends 189
7.3.3.1 The effect of human collection 189
7.3.3.2 Significance of rodent predation 191
7.4 Discussion 193
7.4.1 A first simple simulation model for *P. fibratus* 193
7.4.2 Assumptions and validity of the model 193
7.4.3 Fate and persistence of populations 193
7.4.4 Suggestions for management 194
7.4.4.1 Limit the harvest by reinforcement of control measure 194
7.4.4.2 Continue monitoring population trends 195
7.4.4.3 Involvement of locals 195
7.4.4.4 Rodent control 195
7.4.4.5 Recommended research 196
7.5 Acknowledgements 196
7.6 Appendix A- Parameters used for the calibration of the *Placostylus* model 197
7.7 References 198

Chapter 8. A landsnail restoration attempt: rodent poisoning in a remnant dry forest patch in New Caledonia **203**
Abstract 205
Résumé 207
8.1 Introduction 209
8.2 Methods 211
8.2.1 Study area 211
8.2.2 The rodent poisoning design 211
8.2.3 Information collected on snails 213
8.3 Results 214
8.3.1 Impact of poisoning on rodent abundance 214
8.3.2 Snail mortality 215
8.3.3 Changes in the population of live *P. porphyrostomus* and *A. fulica* 219
8.4 Discussion 221
8.4.1 Effectiveness of rodent control 221
8.4.2 Costs 222
8.4.3 Impact of poisoning on snail populations 223
8.4.4 Conclusion and prospects 225
8.5 Acknowledgements 226
8.6 References 227

Chapter 9. Trial release of the endemic land snail *Placostylus porphyrostomus* (Mollusca: Gastropoda: Bulimulidae) in a remnant patch of dry forest of New Caledonia **231**
Abstract 233
Résumé 235
9.1 Introduction 237
9.2 Methods 238
9.2.1 Study area and release site 238
9.2.2 Captive breeding and individual selection 239
9.2.3 Preparation before release 240
9.2.4 Release procedure and monitoring 241
9.2.5 Analyses 241
9.2.5.1 Survival 241
9.2.5.2 Growth 242
9.2.5.3 Movement distances and direction between surveys 242
9.3 Results 242
9.3.1 Fate of released snails 242
9.3.2 Survival 244
9.3.3 Changes in body mass and growth 245
9.3.4 Distances travelled and dispersal movements 247
9.3.5 Behaviour patterns 249
9.4 Discussion 249
9.5 Acknowledgements 252
9.6 References 253

Chapter 10. General conclusions and management recommendations **257**
10.1 Overview 259
10.2 Main ecological findings and fate of New Caledonian *Placostylus* populations 260
10.3 Opportunity and feasibility of restoration trials 264
10.3.1 A rodent control programme by continuous poisoning 264
10.3.2 A captive-bred snail supplementation programme 266
10.4 Recommendations for management 267
10.4.1 Recovery Plan for *Placostylus fibratus fibratus* on Isle of Pine 267
10.4.2 Recovery Plan for *Placostylus porphyrostomus* on dry forests 271
10.4.3 Recovery Plan for poorly-known *Placostylus* 275
10.5 Research prospects 279
10.5.1 Some aspects of the life history traits 279
10.5.2 Feasibility of restoration trials 280
10.5.3 Interactions with introduced species 280
10.5.4 Knowledge on genetic differentiation between populations 280
10.6 Conclusion 281
10.7 References 282

Appendices **285**

Appendix 1. Diversity and phylogeny of New Caledonian *Placostylus* land snails 287
Appendix 2. A rearing method for *Placostylus (Research note)* 317
Appendix 3. Two posters presented at the World Congress of Malacology-Perth 2004 325